Sustainable Urban Energy Planning: Development of a District Energy Business Model in Canada

by

Adlar Gross

Supervised by

Jose Etcheverry

A Major Paper submitted to the Faculty of Environmental Studies in partial fulfillment of the requirements for the degree of Master in Environmental Studies

York University, Toronto, Ontario, Canada

November 30, 2018

I. Abstract

District energy is widely regarded as an integral part of the sustainable energy transition for its ability to utilize sources of low-carbon heating and cooling, provide energy security, resiliency, and integrate high shares of renewable energy into the energy system. In the absence of clear provincial and national policy and regulatory frameworks in Canada business models have struggled to get off the ground and compete with other more institutionalized energy production technologies. Although many successful models for district energy system implementation can be found around the world, Canada has seen limited uptake and has been unable to achieve larger scale buildout to realize economies of scale and capture the full benefits of district energy. With shifts to energy market liberalization and increasing reliance on private capital to provide public infrastructure the business model for district energy must adapt. This paper seeks to define the business model and identify the barriers and challenges to larger-scale adoption in the context of energy liberalization. The development of DE in four European countries are reviewed to understand the different contexts and key factors that can be adapted to Canada. Interviews with customers of district energy systems in Canada are analyzed to better understand stakeholder decision-making processes and values in relation to energy to inform the business model. The paper concludes with a literature review and discussion of the components of the business model and different methods in which risks can be mitigated. This study finds that under market liberalization district energy business models become more complex and difficult to implement especially at a larger-scale, although not impossible. Clear targets and supports from federal and provincial governments for city-scale district energy systems are needed to legitimize its use and level the playing field with alternatives. Institutional barriers need to be addressed and adequate

carbon price is needed to allow district energy to be competitive with conventional sources of thermal energy.

II. Foreword

This major paper is the culmination of a two-year plan of study (POS) that began with the desire to investigate the linkages between land use planning and renewable energy. This led to my discovery of the field of sustainable energy planning and a semester abroad in the Sustainable Energy Planning and Management Program at Aalborg University and the Folkecenter for Renewable Energy in Denmark. As Denmark offered a wealth of experiences and examples on district energy, through these experiential learning opportunities it became clear that district energy was the important link between land use planning and energy that I was looking for, and my focus and interests began to be drawn more to the field of energy planning than to land use planning, while still recognizing the intersections of the two fields.

At its core, this paper is an analysis of a locally embedded process (district energy planning), within the shifting landscapes of energy market liberalization, and provincial and federal level policy. It seeks to explore how, under these conditions, locally embedded actors can bring about the energy transition in their cities and towns.

This paper will examine the two major components of my POS: land use planning and sustainable energy planning and management. Due to the many intersections between the components, they will not be examined in turn, but will be studied through the lens of the business model. The business model in combination with institutional economics will act as a theoretical framework to understand how the land use planning and energy planning intersect and affect implementation of district energy.

This research has played a major role in meeting the learning objectives of my POS. District energy is local infrastructure and studying it therefore requires a thorough understanding of land use planning due to the important role that local authorities and actors play in its implementation, and the need to coordinate and negotiate between multiple parties and interests. The sustainable energy planning component is necessary to understand the combined technical, economic and social aspects of energy supply, and to understand the place of decentralized energy within national and sub-national energy system planning and policy.

Outside of this research paper, experiential learning undertaken through field experiences, work placements, attending conferences and workshops have played a large role in meeting my learning objectives.

III. Table of Contents

IV. List of Acronyms

BCUC	British Columbia Utilities Commission
CEP	Community Energy Planning
CHP	Combined Heat and Power
COP	Coefficient of Performance
CPCN	Certificate of Public Necessity
DE	District Energy
DES	District Energy System
ESA	Energy Service Agreement
ESCO	Energy Service Company
ETS	Energy Transfer Station
GHG	Greenhouse Gas
GHGI	Greenhouse Gas Intensity
GIB	Green Investment Bank
IRR	Internal Rate of return
KWh	Kilowatt Hour
KWt	Kilowatt Thermal
MSW	Municipal Solid Waste
MWe	Megawatt Electric
MWh	Megawatt Hour
PM	Property Manager
REIT	Real Estate Investment Trust
ROE	Return on Equity
ROI	Return on Investment
ROR	Rate of Return
RNG	Renewable Natural Gas
TEDI	Thermal Energy Demand Intensity
TES	Thermal Energy System

V. List of Figures and Tables

1. Introduction

As the saliency and urgency of climate change and climate change action continues to grow, urban areas have a crucial role to play in influencing and shaping the transition to a low-carbon society. While much attention has been focused on achieving emission targets set by national governments, urban centres, as sites of these transitions have often been absent from analysis (Bolton & Foxon, 2013). However, in more recent years, municipalities have been taking more of a leading role in climate action through development of their own city-wide climate action plans, sometimes in response to the absence of effective climate policy at the national or sub-national level. Commonly called community energy planning (CEP), municipalities, recognizing the impact of energy use on carbon emissions, have begun to focus on reducing greenhouse gas (GHG) emissions from energy production and energy within their borders. District Energy, simply defined as a network of underground pipes that distributes thermal energy generated at a centrally located energy plant to local users, is regaining attention as a major component of CEP due to its ability to decarbonize the heating sector, as well as meet a number of local economic development and resiliency objectives.

1.1 Background

1.1.1 Community Energy Planning

Jaccard et al. (1997) is credited with developing one of the first formal definitions of CEP or community energy management, defining it as “a planning and management process that focuses on energy strategies that can be implemented at the neighbourhood, municipal or regional level” (p.1066). This is an expansion of the traditional approach to energy planning that focuses on technology substitution of individual buildings, equipment and processes, and a restructuring of the economy, rather than the relationship between the design of human settlements and energy throughput (Jaccard et al., 1997). This approach to energy planning and policy has recently become more mainstream, with over 200 communities across Canada that have developed a CEP (QUEST, 2016). This rise in activity can be seen as a manifestation of alternative technology activists from the 1970s that advocated for local, small-scale, collective approaches to sustainable energy generation (Smith, 2005). As Walker and Devine-Wright (2008), point out in the UK, the emergence of community renewables initiatives in energy policy may suggest a movement away from large-scale centralised energy systems that have been the dominant paradigm in the mid to late 20^{th} century. The current CEP trend in Canada also indicates a movement in this direction.

Concurrent with this notion of decentralization and soft energy paths is the shift of control over energy planning and management away from the regional approaches dominated by experts that required little community-involvement, to one of local participation that aligns with "local needs, values and resources" (Hoffman & High-Pippert, 2005). This more participatory system that engages citizens as active stakeholders and incorporates their ideas and opinions into the decision-making process, has been enabled by developments in the 1970s that gave communities access to the tools, knowledge and technology that has allowed them to plan their energy systems themselves (Lerch, 2007). In this way, CEP can meet the triple bottom line goals of environment, society and economy for a community by "establishing a clear link between local generation and local consumption" (Hoffman & High-Pippert, 2005, p.393). This is based on the idea that "people will want to make choices that do the least harm to themselves, their families and their communities" (Hoffman & High-Pippert, 2005, p.393).

The main motivation for the recent trend in CEP is the desire to reduce local GHG emissions, protect against rising prices from centralized electricity generation and the creation of more self-sufficient and resilient energy systems (St. Denis & Parker, 2008; Tozer, 2013). This shift to more local control of and participation in the energy system is driven by the recognition that municipalities have direct or indirect control of approximately 44% of GHG emissions in Canada (Federation of Canadian Municipalities [FCM], 2009). Jaccard et al. (1997) have shown through a comparison of business-as-usual to a community energy management (CEM) scenario over 15 years in four different case studies, that CEM measures can generate a 15-30% decrease in energy service costs, and energy consumption, a 30-45% reduction in air emissions

CEP can also act as a local economic stimulus, which also plays a large role in a communities' decision to implement a CEP. Local economic benefits can be generated from recirculating energy spending within the local economy, cost savings from energy conservation and demand management, and the creation of local energy-related jobs (QUEST, 2016).

1.1.2 District Energy

District Energy (DE) refers to the supply of thermal energy from a central plant in order to meet local heating and cooling demands by using a distribution network of underground pipes as a marketplace and delivery system. A major advantage of DE is its ability to use virtually any fuel available, particularly its ability to use local fuel or heat sources that would otherwise be wasted (Werner, 2017). A DE system (DES) can be understood as consisting of three parts: the centralized energy plant, which utilizes heat sources, such as combined heat and power (CHP) units, boilers, heat pumps, industrial waste heat, or a combination thereof; a thermal network or distribution network which consists of the pipes, that delivers the heat to the customers through an energy carrier such as steam or water; and the building which includes the energy transfer station (ETS) in the mechanical room (**Figure 1)**.

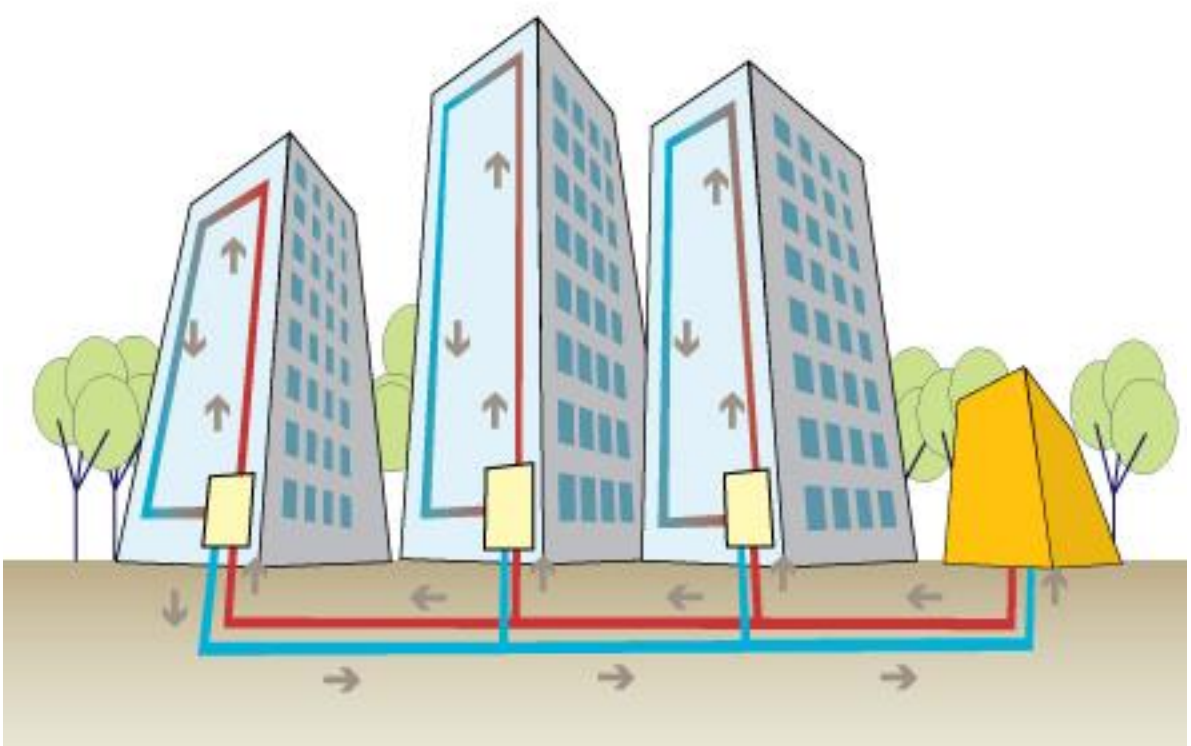

Figure 1. Simplified diagram of a district energy system. Heating and cooling is supplied from the energy plant on the right through the thermal network to the energy transfer stations in the mechanical rooms of the building (City of Surrey, 2018).

The thermal network is a loop of piping that consists of a supply and return side that connects buildings to the energy plant. Each ETS is equipped with a heat exchanger which extracts the heat from the supply side of the loop and then deposits the lower temperature energy carrier to the return side where it flows back to the energy plant to be heated again. The temperature of the heat carrier in the pipes is of key importance. Low supply temperatures increase electrical output from CHP, increases heat recovery from industrial waste heat and geothermal heat and increases the efficiency of heat pumps (Gadd & Werner, 2014). Low return temperatures increase heat recovery from flue gas condensation and lowers the heat losses to the ground as the heat is being distributed (Ibid). Achieving low distribution temperatures allows DES to use lower temperature sources of heat which is important for the role DE is to play in future sustainable energy systems where increasingly efficient buildings with low heat demands can be supplied by low temperature sources.

DE is widely regarded as an integral part of the transition to future sustainable energy systems and the only way to decarbonize the heating sector (Connolly et al., 2014; Lund et al., 2014). It has emerged as a major component of CEP due to its ability to offer a wide range of benefits to communities including the reduction of GHGs, reducing air pollution, improving resilience, stimulating local and green economies, improving energy efficiency, as well as aiding in the integration of high shares of renewable energy sources into the energy system (Lund, Möller, Mathiesen & Dyrelund, 2010; Riahi, 2015). Due to its ability to allow economies of scale in energy provision it can take advantage of virtually any available thermal energy source providing energy security by insulating communities from rising fuel prices and enabling the use of low-carbon and renewable sources of heat that may not be economically or technically viable for individual households such as industrial waste heat, geothermal, and solar thermal (Thornton, 2005). DE can increase energy efficiency by capturing waste heat sources, by aggregating the varying energy demands of different types of buildings into a steady thermal load that can be managed efficiently (Gilmour & Warren, 2008). DE offers resilience as underground pipes are protected from extreme weather events, and decentralized energy plants that utilize CHP can continue to provide power in the event of grid failure as well as reduce peak electricity demand. DE stimulates local economies by keeping local energy dollars circulating in the local economy and creating demand for skilled labour (Gilmour & Warren, 2008). For building owners and property managers DE offers value by reducing the size of the building mechanical room, therefore opening up more saleable floor space, avoiding the costs associated with boiler maintenance and replacement, simplifying building operations, and providing a reliable energy supply (Thornton, 2005).

DE represents an important connection between the electricity sector and the heating sector. Because electricity is more difficult to store than thermal energy, DE offers a solution by being able to convert electricity to thermal energy through the use of electric heat pumps and boilers (See Components of the Business Model: Heat Pump Based Systems). Since when the wind blows, or the sun shines cannot be controlled, energy systems with high shares of renewable energy sources such as wind turbines and solar panels frequently have times of excess electricity production. Rather than sell the electricity to another jurisdiction at a loss, which is often the case, converting the electricity to thermal energy to be used in a DES is an opportunity to provide low-cost, carbon free heating, while avoiding the losses associated with long-distance electricity transmission (Lund et al., 2010).

1.1.3 Combined Heat and Power

A key benefit of DE is enabling more widespread use of CHP. CHP or cogen refers to the capture of waste heat from the generation of electricity, usually in a gas turbine, resulting in the simultaneous production of heat and electricity (**Figure 2)**. CHP can have an overall fuel efficiency of between 60-90% by capturing and utilizing the waste heat, which decreases fuel consumption by 20-30% compared to conventional production through separate technologies (Lund & Andersen, 2005; US EPA, 2017). Because of the requirement that heat and electricity are produced at the same time, CHP in conjunction with DE has been mainly used in supply of large urban areas in order to allow for efficient use of the heat (Lund & Andersen, 2005). Industrial applications in particular have demonstrated positive results with the use of standalone CHP system. Industry often has high energy consumption needs, making a case for self-generation, of electricity and the heat can be used in industrial processes, to heat company buildings, or can be sold to a nearby DES. On the electricity side CHP improves resilience of the industrial operations in the event of power outages, lowers electricity costs and protects against market spikes (Simchak & Davis, 2013).

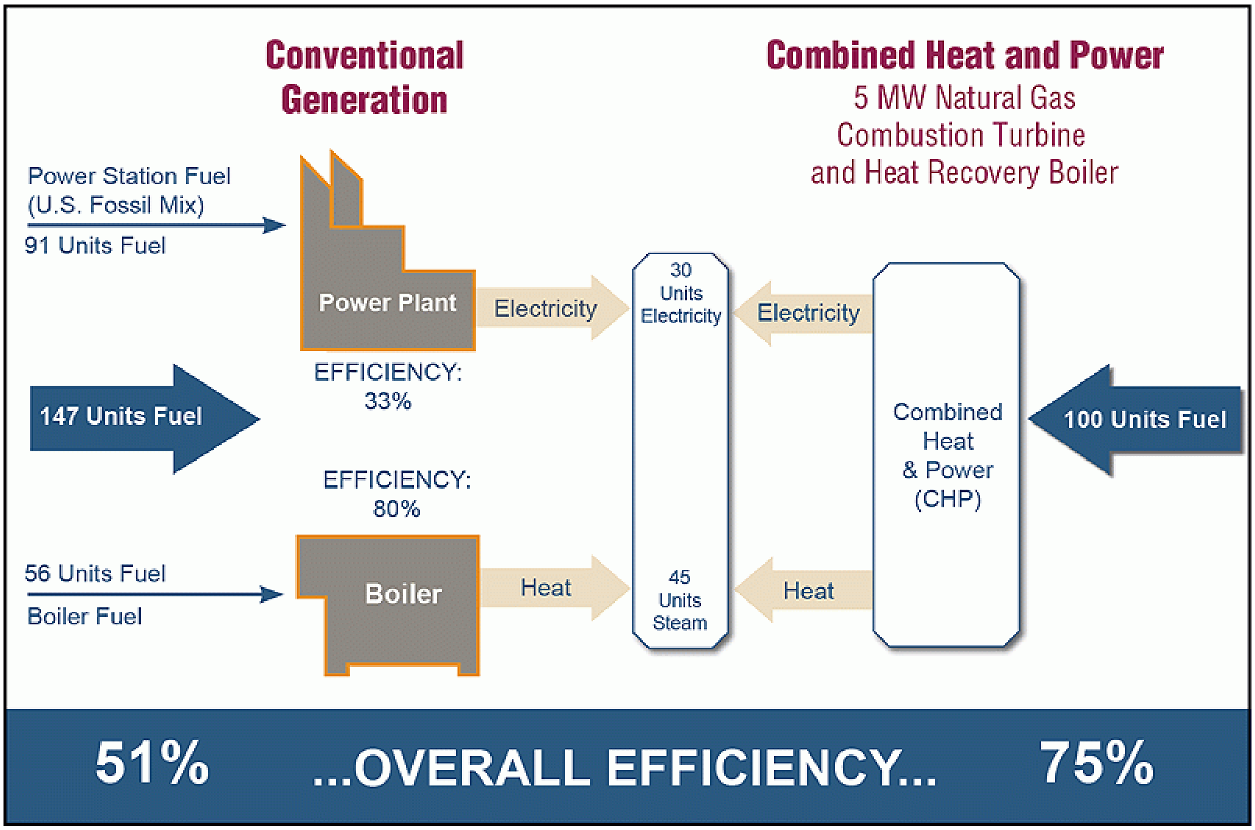

Figure 2. The efficiency of CHP compared to separate heat and power generation (US EPA, 2017).

1.1.4 The Evolution of District Energy

DE is not a new technology, with the earliest system being attributed to the French village of Chaudes-Aigues Cantal, where wooden pipes were used to distribute warm water (Werner, 2017). The first commercial DES was built in Lockport, New York in 1877, and throughout the 1880's DE began to be used in several cities throughout North America with the first Canadian system built in 1880 in London, Ontario (Thornton, 2005). DE remains relatively underutilized in North America but has become an important and well-established energy source throughout Europe (Ibid).

To better understand the history and evolution of DE, Lund et al. (2014) identifies four generations of DE (**Figure 3**). The first generation is characterized by using steam as the heat carrier. These were the systems first introduced in North America in the 1880s and almost all were of this type until the 1930s. Because steam was used as the heat carrier it required the use of very high temperatures which resulted in considerable heat losses and resulted in some accidents from steam explosions. The return pipes were often subject to corrosion which gave less condensate returns and lowered the energy efficiency. The main motivation for building these systems were to replace individual boilers in apartments to reduce risk of boiler explosion and to improve comfort. These older systems are still in operation today, for example Downtown Vancouver is still served by a steam system and are often termed 'legacy' systems. Due to the inefficiencies of these systems replacement programs in some jurisdictions are upgrading to the more modern hydronic (water-based) systems.

The second generation used pressurized hot water as the heat carrier with supply temperatures over 100°C. These systems were the dominant type from the 1930s to the 1970s and were mainly motivated by a need for fuel savings which was obtained by using CHP.

The third generation still uses water as the heat carrier, but the supply temperatures are lowered to below 100°C. These systems were introduced in the 1970s and were largely driven by a need for energy efficiency and fuel switching in response to the two Oil Crises. Third generation DE is still the predominant type of system used in the new construction or expansion of all systems through North America, Europe, and Asia.

Throughout these generations the trend has been a lowering of distribution temperatures, the increased use of prefabricated materials and a minimizing of complicated components thereby reducing construction costs and time and improving energy efficiency. Therefore, Lund et al. (2014) defines the future fourth generation as consisting of even lower distribution temperatures and the increased use of materials that are easy to assemble and construct. Furthermore, future DES are motivated by the need for a transition to a sustainable energy system and therefore should be designed to minimize carbon pollution through the use of renewable or recycled sources of heat and to act as an integrator of renewable energy supply. These systems are also often called low-temperature district energy systems and use supply temperatures of 50°C and return temperatures of 30°C, allowing them to recycle low-temperature heat sources that were too low for previous generations, and achieve lower heat losses from the thermal network (Lund et al., 2014).

Fourth generation systems should also allow the use of smart thermal grids and intelligent control of building operations. Smart thermal grids are similar to the idea of smart electricity grids in that they allow the integration of heating and cooling production from decentralized sites such as from individual buildings with excess heating or cooling in addition to central energy plants. Intelligent control refers to the use of weather forecasts to calculate heating demand in each room of a building allowing for more efficient operation of the system and more accurate prediction of peak loading. Some examples of low-temperature DES can be found in operation but are still in pilot project phase or exist at smaller-scales. Another class of DES has also emerged in recent years which utilize very low or ambient temperatures between 18°C and 30°C. Sometimes termed ambient temperature DE, these systems typically use heat pumps to upgrade heat to useable levels for building applications, as well as for cooling. These systems will be discussed in further detail under the Heat Pump Based Systems section

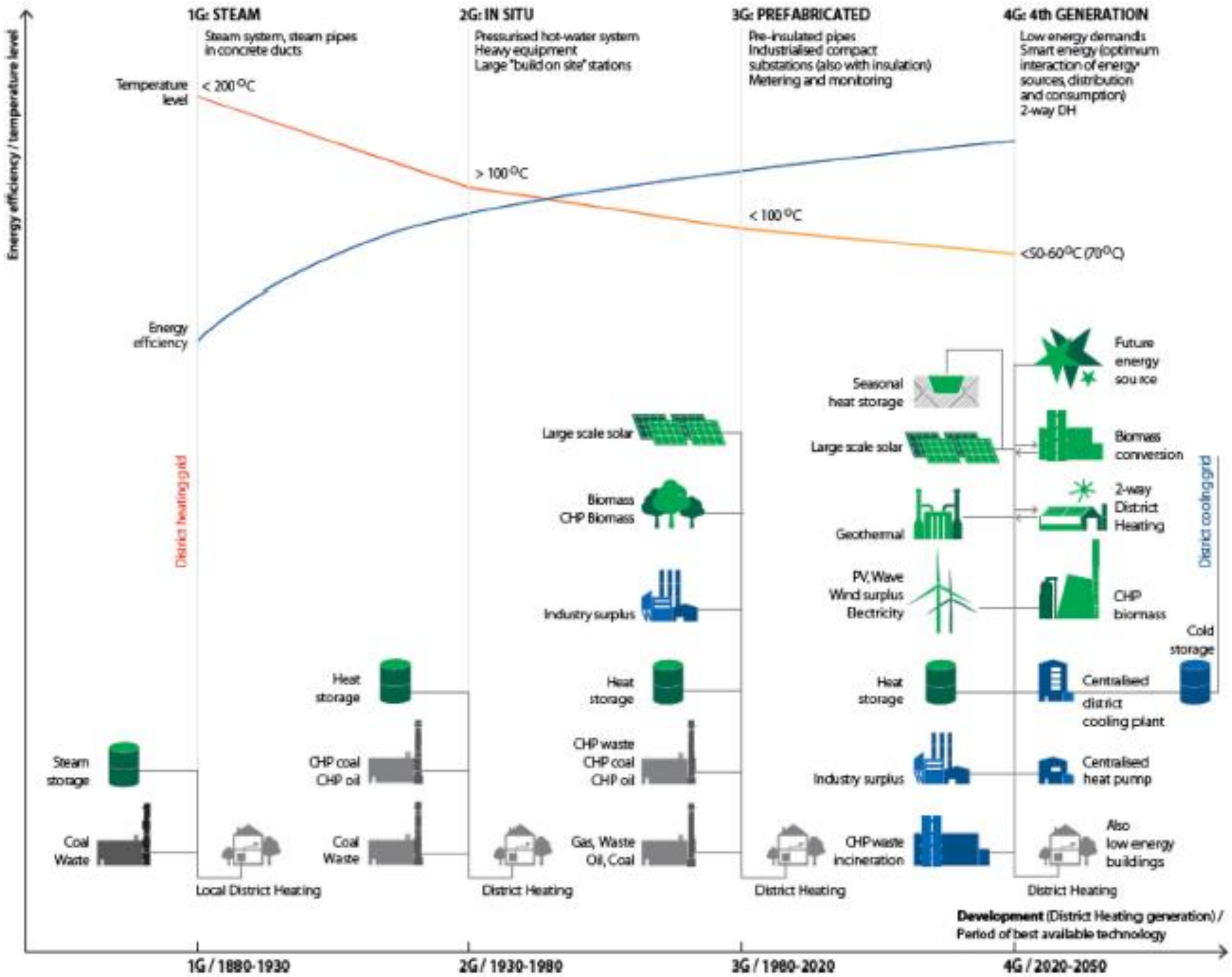

Figure 3. The four generations of district energy 1880-2050. (Lund et al.,2014)

1.1.5 Challenges to the Business Model

DE has a number of unique challenges that must be overcome by the business model. If a DES is to be economically viable it requires a monopoly on the thermal energy supply in the area it is serving in order to be operate efficiently and generate sufficient financial returns (See Components of the Business Model: The Distribution Network). A large portion of the DE value proposition is also hard to monetize or assign an economic value. For example, what is the monetary value to an individual of resilience to outages as a result of extreme weather or what is the value of sustainability to an individual? For an industry or business this might be calculated by determining the loss of economic output as a result of the outage or through carbon pricing. For a residential customer this value is harder to determine. In addition, customers may not be willing to pay more to reduce environmental impact.

Another issue that must be addressed is the timing of development. DE requires long-planning horizons as full buildout can take ten to twenty years (King, 2012). This introduces a high degree of uncertainty as to the willingness or ability of customers to connect to the system. However, the system must be sized to the correct capacity from initial construction to avoid costly replacements in the future. This will be discussed further in Components of the Business Model: The Distribution Network.

A further potential challenge to the business model is the increasing efficiency of new buildings, which lowers heat demand and therefore reduces revenue for the utility. Yet, at the same time lowering heat demand opens up capacity in the DES to connect more buildings, provided the density is sufficient to justify laying more pipes in the ground. This is where government support through capital grants can be important to reduce the capital costs of connecting lower density neighbourhoods.

Some view the increasing efficiency of low-energy building designs such as passive house and net-zero as removing the need for DE (Lund et al., 2010). On the other hand, reducing heat demands in such a way involves significant investment cost while low cost waste heat sources are readily available in combination with heat pumps that can help integrate renewable energy into the energy system. In addition, DE is typically connected to new buildings, as old buildings must undergo costly retrofits to be compatible. Recognizing this need to reduce energy demand in new and old buildings while integrating waste heat and renewable energy, Mathiesen et al., (2016) propose an approach to this problem that identifies the most cost-effective solution as the point where marginal investments in building energy efficiency exceed the marginal cost of heat production in a DES. The grey circle in **Figure 4** indicates where energy efficiency retrofits in old buildings are no longer cost-effective and the red circle indicates point where in new buildings.

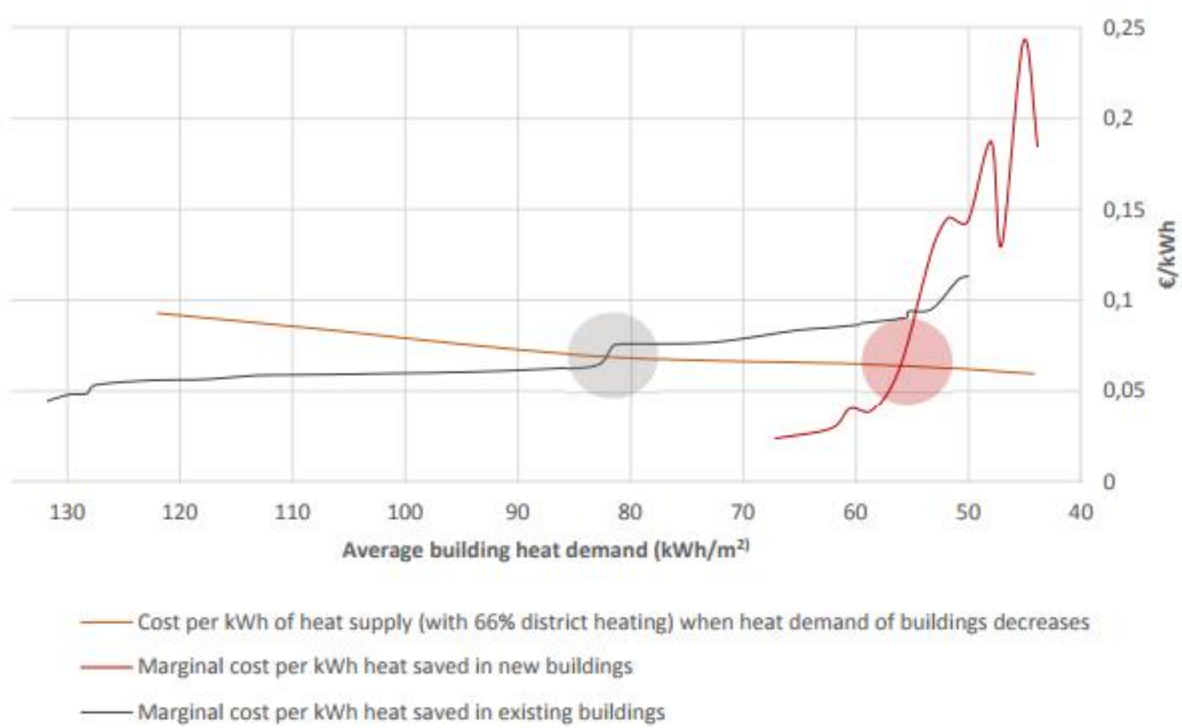

Figure 4. Marginal cost of reducing heat demand in existing buildings and new buildings compared to marginal cost of heat production in Denmark (Mathiesen et al., 2016).

1.1.6 A Note on Terminology and Scope of the Study

In the past, DE was mainly used to meet heat demands and is therefore commonly referred to as district heating (DH) (Mikler, 2018). However, DE can also be used for cooling, so DE is a term that encompasses both heating and cooling applications. For clarity, the term DE will be used throughout this paper to refer to DE generally, whereas DES will be used to refer the physical system consisting of the central energy plant, and the distribution network.

Due to time and space constraints this paper will focus primarily on the heating aspect of the business model. This approach is also justifiable in that heating forms the basis of most DE business models due to the requirement of heating year-round, as in the summer months domestic hot water is still required and industrial and/or commercial applications have steadier heat demands. It should be noted that particularly in North America where air conditioning is much more common than in Europe, providing district cooling could be a profitable endeavour for a DES. However, because cooling is only needed a few months per year, investments in the infrastructure to provide it are harder to justify than for heating. Exceptions of course include building uses that have steady cooling demands such as ice rinks and data centres. In these situations, the heat ejected as a result of the cooling process can be used in a DES (See Components of the Business Model: Heat Pump Based Systems).

1.2 Study Rationale

With the electricity sector in many provinces in Canada are already relatively decarbonized due to high shares of hydropower and nuclear, DE has a large role to play in further decarbonizing the building and industrial sectors. In Ontario, for example, the building and industrial sectors are now the second biggest emitters after the transportation sector (Environmental Commissioner of Ontario, 2016). Significant potential exists for DE, but it has seen limited uptake in Canada due to a lack of clear provincial policy and regulatory frameworks in Canada for the implementation of DE systems with the exception of B.C. (Mcvey, Farbridge, & Calvert, 2017). This has created uncertainty around business cases, which leads to high risk, or perceptions of risk for investors, consumers and municipalities. With no clear business model municipalities are also not taking advantage of existing land use planning tools and powers available to them in the establishment of DE networks (Mcvey et al., 2017). Drawing on the experiences of jurisdiction in Europe, this research seeks to understand why Canada has seen limited DE diffusion, as well as explore and define potential DE business models in the absence of provincial policy frameworks. As the viability of a business model is closely linked to government regulations and policies, this research will also contemplate what institutional and policy frameworks are needed to enable business models that allow for economically feasible utilization of sustainable energy sources.

1.3 Research Questions

1.) What is the experience of other jurisdictions (Denmark, Sweden, Netherlands, U.K.)?

2.) What is the business architecture for DE?

   a. What is the value of DE?

   b. Supply chain: What are the strengths and weaknesses of different supply options?

   c. How do different governance models distribute risks, responsibilities, and benefits to stakeholders?

      i. What are the roles of the, municipalities, developers, consumers, private enterprise, and others?

      ii. What are the strengths and weaknesses of different governance models

   d. How should rates be designed, costs be recovered and how does rate design impact consumers, and suppliers?

   e. What are the decision-making processes of property owners, developers and managers in relation to connecting to DE?

3.) How should the industry be regulated? What consumer protection measures can be used?

4.) What provincial level policy frameworks are needed?

5.) What other factors influence the economic viability of DE development and how can these barriers be overcome?

2. Theoretical Framework

2.1 Energy Liberalization

Over the last 35 years most developed countries have undergone privatization, restructuring, and deregulation in sectors that had previously been regulated monopolies or state-owned such as energy, telecommunications, mail, airlines and trucking (Joskow, 2008). Based in neo-liberal ideology, this trend in government policy has focused on creating market competition on the grounds that it is able to secure short-term cost efficiencies (Hawkey & Webb, 2014). Despite these policies being contested or not delivering expected results in many cases, public policy has generally continued to follow this trend of liberalization over the years (Ibid).

Policies to liberalize the energy sector usually take the form of an unbundling of the transmission, distribution, generation, and retail sectors from vertically integrated utilities into separate entities. The stated goals of the reforms have been to reduce electricity costs and retail prices, and secure short-term cost efficiencies, generally being motivated as a result of high operating costs, construction cost overruns, high retail prices, falling cost of production from low prices, and the development of more efficient generation technologies (Hawkey & Webb, 2014; Joskow, 2008). For example, in Ontario, the construction cost overruns, and debt incurred by Ontario Hydro, combined with times of skyrocketing electricity retail prices in the early 2000s played no small role in the unbundling of Ontario Hydro into separate entities and the creation of a wholesale electricity market.

As policies have sought to disaggregate transmission and distribution from generation and retail and introduce competition in wholesale and retail markets in pursuit of economic efficiency and commercial goals the result has been a limitation on social obligations and more of an orientation of policy towards profitable returns on private capital (Rutherford, 2008; Mitchell, 2008). Hawkey and Webb (2014) identify energy market liberalization as part of a larger shift from ‘government to governance’, where activities and responsibilities once carried out by governments are being contracted out to private, public and civil society organizations, which has been associated with increased fragmentation in services and a decline in the ability for coordinated planning. This poses a problem for DE, as in order for it to provide sustainability benefits DE relies on establishing long-term benefits between locally-embedded actors and resources, as well as external financial and technical expertise (Hawkey & Webb, 2014). Due to the requirement for high upfront costs in DE in return for the ability to exploit a low-cost energy source, economic viability also requires long-term user commitments to take the energy. Historically, governments have played important roles in coordinating the multiple interdependencies between the generators, network operators, the users and the investors, as well as providing strong supports and institutional frameworks for spatially and socially optimized DE networks (Hawkey & Webb, 2014). With the shift towards energy liberalization, a lack of support, policy and planning from higher levels of government, and an increasing reliance on private capital for public infrastructure projects, new business models and institutional structures must be established to allow for successful deployment of DE under this new context.

2.2 Business Model Concepts

2.2.1 Business Model Definition and Analysis

The development of a DE business model will be based on the heat energy business model concept constructed by Okkonen & Suhonen (2010), from the experiences of heat entrepreneurship in Finland**.** Okkonen & Suhonen (2010) draw mainly on the Business Model Concept developed by Osterwalder (2004). In this concept, a business model is defined as an abstract representation of the business logic of a company. That is, how the company makes money through what it offers, to whom it offers it, and how this is accomplished. Osterwalder (2004) adopts a framework that includes four areas a business model must address, each with their respective elements and sub-elements. A simplified outline of this framework is provided below:

1.) Product: All aspects of what the firm offers to customers
    a. Value Proposition: Statement of benefits
        i. Offering: Part of a firm's bundle of products and services
2.) Customer interface: How and to whom the product/service is delivered.
    a. Target Customers
        i. Distribution Channel
    b. Relationship a company establishes with a target customer
3.) Infrastructure Management: How a company creates value
    a. Capability: Ability to execute a repeatable pattern of actions
    b. Resources: Inputs into the value-creation process
    c. Value Configuration: The arrangement of activities to provide the value proposition

i. Value Chain

d. Activities: Actions performed by a company to achieve its goals and create value

e. Partnerships: cooperative agreement between two independent companies to carry out a project or specific activity jointly

4.) Financial Aspects

a. Revenue Model

i. Revenue Streams

ii. Pricing

b. Cost Structure

2.2.2 Business Architecture

The business architecture is a description and characterization of the components of a business model, their linkages and sequencing (Okkonen & Suhonen, 2010). Identifying the architecture for product/service flows can be done through deconstructing the value chain to identify its elements. In the first conceptualization of the value chain by Porter & Miller (1985), a value chain is broken into five elements:

1.) Inbound Logistics

2.) Operations

3.) Outbound Logistics

4.) Marketing and Sales

5.) Service

Analyzing the value chain seeks to answer two questions: 1.) What activities should a firm perform and 2.) what is the configuration of the firm that would allow it to add value to the product and to compete in its industry? Value chain analysis then has four steps:

1.) Defining the strategic business unit
2.) Identifying critical activities
3.) Defining products
4.) Determining the value of an activity

Amit & Zott (2001), expand on this conceptualization of how value is created, through transaction cost economics, focusing on the transaction as the unit of analysis and point of value creation. They define a business model as depicting "the content, structure, and governance of transactions so as to create value through the exploitation of business opportunities." Content is the goods being exchanged, and the resources and capabilities required to do so (i.e. source of heat, distribution network, heat exchangers, finances, technical know-how, etc.). Structure is the parties involved in the exchange, how the parties are linked, the sequencing of the exchange and adopted exchange mechanism (i.e. supplier-customer contracts, loan agreements). Governance is how the company is organized and determines how risks are allocated between parties (i.e municipally-owned, privately-owned or hybrid ownership).

A business model can therefore be seen as a description of the architecture of the firm and its network of partners for creating, marketing and delivering value to generate a profit (Okkonen & Suhonen, 2010). In terms of DE the crucial parts of the business architecture that will focused on here are:

    a. Establishment of the DE plant and distribution network
    b. Organization of the fuel supply chains
    c. Defining ownership and responsibilities between all stakeholders involved (governance models)
2.) Establishment of the earning logics (strategies to generate and maintain profitable and sustainable business operations).

(Adapted from Okkonen & Suhonen, 2010)

2.3 Institutional Economics

This paper takes an expanded view of the business model based on institutional economics outlined in Hvelplund (2013), not viewing it isolation but seeing it as “embedded in an artificial, concrete institutional setting that can be modified” (p.12). This is called the concrete institutional approach and is in contrast to the neo-classical approach which seeks to maintain a ‘free-market’ where technologies should only enter the market when they are ready to be competitive (**Figure 5)**. Under a neo-classical regime, climate policy takes the form of internalizing the market externalities created by GHG emissions through carbon taxes or cap and trade systems. If implemented, societal goals are thought to be achieved in an economically optimal way. It is clear from recent provincial and federal policy developments that this is the approach prevalent in Canada. However, this approach ignores the character of technological change by assuming that all companies behave identically in the market and have the same motivations for developing new technologies.

Hvelpund finds the concrete institutional approach lacking in that it assumes that at a certain stage of development all companies will implement renewable energy technologies because it has become a sound business decision.

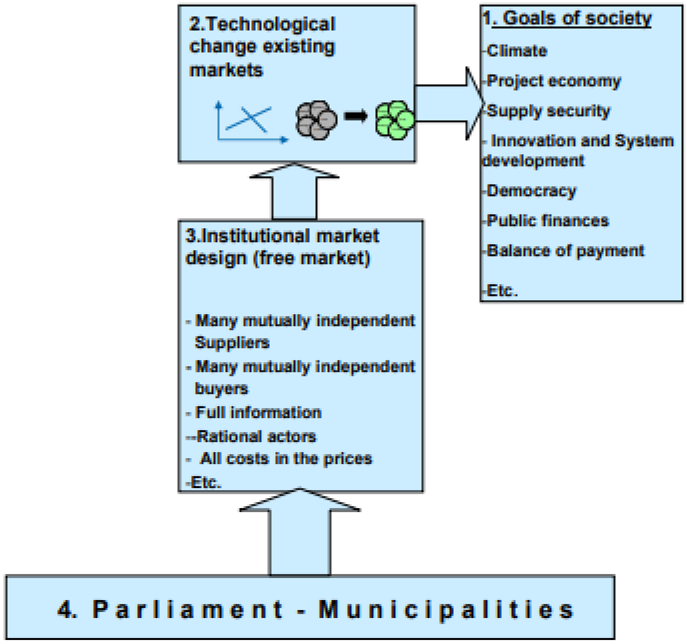

Figure 5. Neo-classical approach to market design. (Hvelplund, 2013)

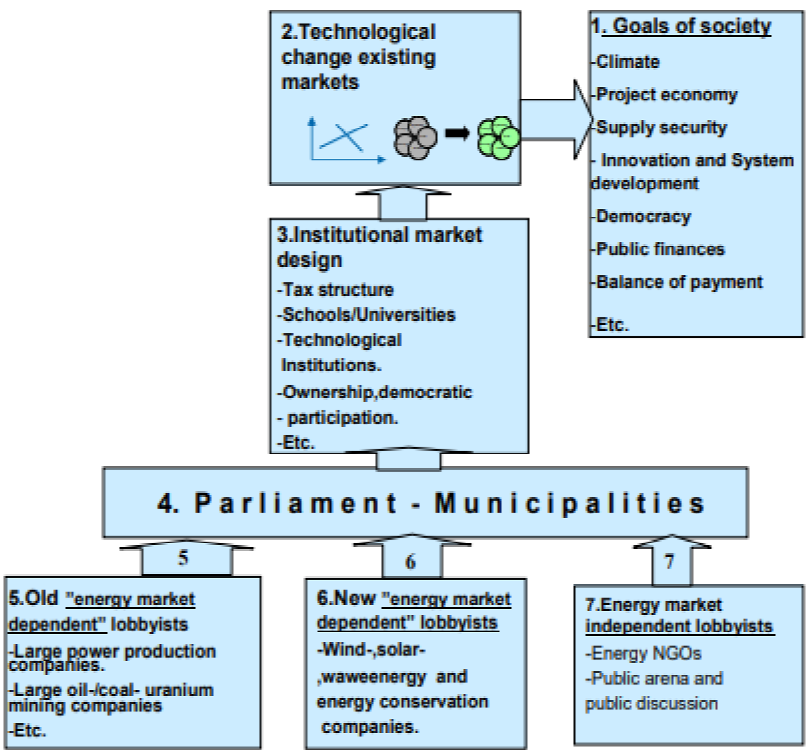

Figure 6. Innovative democracy approach to market design. (Hvelplund, 2013)

This approach therefore does not support changes in the political process and redesign of the market and results in the same type of public regulation tools as the neo-classical approach. Hvelplund therefore adds the innovative democracy approach which recognizes that market rules are designed in a political process and that this process must be redesigned in order to pull society from the fossil fuel path dependency that is propagated by current market conditions. **Figure 6** therefore adds to the neo-classical paradigm seen in **figure 5** the political process. Innovative democracy seeks to establish alternative goals from the political process in an unbiased manner by giving influence from independent lobbyists at least the same weight as the dependent lobbyist; the difference between the two being that independent lobbyists have no direct economical interest in the technological alternatives. In practice, this means granting funds to independent lobbyists to establish prototypes and pilot projects for new technologies and to develop well-designed policy suggestions, therefore creating a level playing field by granting an equal voice and equal economic means to all actors.

3. Methodology

This report uses a qualitative approach to understand the factors that contribute to a successful DE business model and why DE has not reached higher penetration in North America. A qualitative approach is more interpretative and exploratory which allows for data generation which is more flexible and sensitive to the social context in which it is produced, in contrast to more rigidly standardized quantitative methods (Denzin & Lincoln, 2000; Mason, 2002). Furthermore, qualitative research is multimethod in focus and takes a “naturalistic approach to its subject matter” (Denzin & Lincoln, 2000), meaning that theories are grounded in the day-to-day realities and experiences of people. Qualitative researchers study things in their natural settings and attempt to interpret phenomena in terms of the meaning people bring to them (Denzin & Lincoln, 2000).

Qualitative methods were identified as the best approach to address the research questions as implementation of DE requires a high degree of social interaction between different organizations and levels of government. A qualitative approach is also well suited to this research as it seeks to understand the experiences of people that interact with DE as owners, operators and customers so as to identify best practices and where certain practices may be improved. The barriers to successful implementation of DE are not technical; many technically sound examples of operation can be found around the world including in North America. Rather, the barriers are institutional and therefore require an analysis of the rules, norms and routines that establish the authoritative guidelines for social behavior (Scott, 2008). The qualitative methods of literature review, semi-structured interview and case study are well-suited to identifying these aspects of the problem.

While a mixed methods approach that combines qualitative and quantitative methods is well-suited to the field of energy planning due to the interactions between technology, economics, societal factors, and policy, a quantitative approach to this research would be of limited value due to the very site-specific nature of DE. Site-specific variables of DE include available heat sources, length of the piping, number and size of heat loads as well as local regulations, policies and access to financing, which vary widely according to the context, making a quantitative analysis only beneficial to a specific site. Therefore, this research will focus on the qualitative and institutional aspects of the business model in order to produce outcomes and recommendations that will be of more generalizable use.

3.1 Triangulation

Triangulation is "the use of multiple methods or data sources in qualitative research to develop a comprehensive understanding of phenomena" (Patton, 1999). By using multiple-methods triangulation seeks to create validity and credibility in the research by "circumvent(ing) the potential inadequacies of a single data source" (Hoggart, Lees, & Davies, 2002). The idea being that through cross validation, two or more distinct methods are found to be congruent and yield comparable data" (Jick, 1979). This research will employ the "between (or across) methods" (Jick, 1979) type of triangulation, using literature review, semi-structured interview and case-study comparative research.

3.2 Literature Review and Comparative Research

A literature review is the synthesis of the accumulated knowledge relevant to the research questions. Neuman (2011) identifies six types of literature review that vary in their scope and depth, each suited to achieving different objectives. This research will use context review, historical review and self-study review. Context review serves the purpose of situating this research within the existing larger body of knowledge and demonstrates how it will contribute or build upon this foundation. This type of review is used throughout the Introduction and in the Theoretical framework and District Energy in Canada sections. In the Jurisdictional Scan section historical review is used to trace the development of DE in selected countries over time in order to understand the contributing factors that have either led to successful diffusion of the technology or have failed to do so. This component of the research will also include a type of comparative research: case-study comparative research. Self-study review is used in the Components of the Business Model section to demonstrate the researcher's knowledge of DE business models.

3.3.1 Comparative Research

Comparative research seeks to "reveal aspects of social life that operate across units" by "focusing on similarities and differences between units (Neuman, 2011, p.486). Case-study comparative research, as one type of comparative research, compares particular societies or cultural units with the aim of identifying "factors that are constant or vary across multiple cases" (Neuman, 2011, p.487). In this case nation states and the municipalities within them are used as the unit of investigation in order to illustrate how the interactions between different levels of government as well as external economic, political and social landscape shifts impact local level energy planning.

Denmark and Sweden were initially selected as the first two countries for the comparative research due to their well-developed industries and high shares of DE in their energy systems. As the research progressed it became evident that in order to draw more applicable lessons for Canada, countries that are more similar to the liberalized energy policy context Canada where has developed DE in the absence of strong national support should also be included in the study (i.e. Netherlands and the United Kingdom)..

3.3 Interviews

Qualitative research interviewing is a form of data collection that involves asking targeted questions of a 'key informant' or someone who has specialist knowledge about other people, processes or happenings that is more extensive, detailed or privileged than ordinary people and is relevant to the research question (Payne & Payne, 2004). Wengraf (2001), defines the objective of a research interview as "having to do with getting a better understanding of reality" and being "designed for the purpose of improving knowledge". Qualitative research interviews are a useful method for accessing individuals' attitudes and values and therefore are well suited to this research as it seeks to understand the values and decision-making processes behind consumers decisions to connect to a DE.

Silverman (2006) outlines three ontological approaches typically taken by social scientists as positivism, emotionalism, and constructionism. Positivists view data gained from interviews as potentially giving access to facts about the world. Emotionalism sees interviewees as subjects who actively construct their social worlds and researchers seek to generate data to gain insight into their experiences. Constructionism sees the interviewer and interviewee as both participating in the construction of meaning and seeks to understand how meaning is mutually constructed. The research approach taken here lies between positivism and emotionalism as the research questions require factual information about events that took place, and technical questions about DES, as well as gaining insight into participants personal experiences with, and attitudes towards DE and their values in relation to energy supply. Therefore, the semi-structured interview format was selected for this research due to its flexibility in asking both standardized questions about technical information and participant's roles in relation to DES and being able to follow up on answers that lead to further insights and questions not originally contemplated by the researcher.

3.3.1 Semi-Structured Interview

A semi-structured interview contains structured and unstructured sections and consists of both standardized and open format questions (Walliman, 2006). Using an interview guide that contains a list of questions and topics to be covered, the researcher asks questions of the interviewee leaving flexibility for follow up questions or to follow a different order than outlined in the guide, the objective being to bring out how the interviewee themselves interprets events and issues (Bryman, Teevan, & Bell, 2009). This research follows the steps outlined by Bryman et al. (2009) for the formulation of the interview guide:

1. General research area
2. Specific research questions
3. Interview topics
4. Formulate interview questions
5. Review/revise interview questions
6. Pilot guide
7. Identify novel issues
8. Revise interview questions
9. Finalize guide

Interviews were conducted over the phone and in person and were recorded and transcribed by the researcher.

3.3.2 Interview Participant Selection Rationale

Interview participants were selected to provide a cross-section of the DE industry and included participants from the supply side of the business model (DE managers/operators, energy consultants, city planners) and from the customer side (Property developers, building owners, property managers; **Table 1)**. The intent of this section of the research was to identify the decision-making processes and values of DE customers and therefore takes a more in-depth focus on this topic which is reflected in the higher number of interviews undertaken with customer side. Participants who were property developers were further categorized according to what sector of the development industry they primarily operated in.

Category of Participant	**Number of Participants**
Building Owner/Property Manager	1
Property Developers	5
Developer/Property Manager	3
Developer-owned Utility	2
Developer/Property Manager/Developer-owned Utility	1
District Energy Manager	3
Energy Consultant	2
Community Energy Planner	1

Table 1. Interview Participants

Many participants filled multiple roles, and this is reflected in the category they are assigned to. **Table 2** provides the key for the assigned codes. Interviews with participants on the supply side were undertaken to provide context and to further knowledge of the researcher. An additional category also emerged from the interviews which was developer-owned DE utilities, as some developers that were contacted were developing their own onsite DES for their multi-building developments.

3.3.3 Interview Analysis

Analysis of the transcribed interviews follows the process of coding whereby raw interview data is organized into conceptual categories or codes, tags or labels that assign meaning to a "chunk" of data, and then further refined into specific themes and concepts (Neuman, 2011). The organization of the data in this way allows the researcher to begin to draw connections and threads between categories and begin to see emergent patterns that lead to broader generalizations or theory (Ibid). This research draws on the coding processes outlined by Strauss (1987) in Neuman (2011) and in Seidman's (2006) method of analyzing thematic connections.

Category of Participant	**Assigned Code**
Building Owner	BO
High-rise Developer	HR
Mid-rise Developer	MR
Community Scale Residential	CSresi
Mixed-use Developer	MU
Property Manager	PM
Real Estate Investment Trust	REIT
Developer-owned utility	DOU
District Energy Manager	DEM

Table 2. Codes assigned to interview participants

In this approach the data goes through three stages of coding: open coding, axial coding, and selective coding. Open coding is the first pass through the data where passages of interest are marked, thematic labels are assigned that place that passage in a category based on the research questions and concepts in the literature review. Assigned labels are kept tentative as categories change as the process continues. Axial coding, the second pass through the data focuses on the already assigned code labels and themes to begin drawing connections between them and look for concepts or categories that can be further clustered together. Categories are divided into new ones or merged together. Selective coding is the third pass through the data after conceptual categories have been well-defined and involves scanning all the data and previous codes for cases that illustrate the emergent themes. The results of this process are presented in **Table 3.**

Conceptual Categories	Specific Themes
Project Drivers and Developer/Property Manager Value	1) Economics 2) Marketing 3) Sustainability 4) Reliability 5) Resiliency
Knowledge Gaps	1) Perceptions 2) Technical Knowledge 3) Institutional Barriers 4) Communication Barriers
Barriers	1) Availability of Capital 2) Real Estate Market 3) Internal Champions 4) Regulatory barriers
Government and Regulation	1) Mandatory Connection 2) Role of national and sub-national governments

Table 3. Conceptual categories and themes

4. District Energy in Canada Overview

While DE is becoming more recognized for the advantages it can provide, especially in meeting decarbonization goals, approaches in Canada have not resulted in significant uptake. Statistics taken from the Canadian Industrial Energy End-use Data and Analysis Centre (CIEEDAC) District Energy Inventory show that DE systems account for approximately 1% of the thermal energy market share, with 159 DE systems in Canada in 2016 delivering annually 5.9 million MWh. However, construction of DE facilities has been increasing, with half of all facilities commissioned since 2000. 51% of the DE systems are in large population centres with over 100,000 people, with most common customers of DE systems being commercial and institutional buildings, community and recreational facilities, government offices and educational facilities.

British Columbia (BC) and Ontario together account for the construction of almost 60% of all DE systems, as well as the most amount of connected floor space. Ontario has the highest installed capacity of heating and cooling, however, interestingly Alberta is second in installed capacity as a result of having a small number of large systems. Investments in DE have been driven primarily by utilities, municipal, provincial, and federal governments, as well as institutions. Most have received some type of funding from senior or local levels of government. Institutions such as academia, and healthcare own the majority of systems, followed by private corporations, municipal government, then provincial and federal governments. While a variety of fuel sources are used in Canadian DE facilities (biomass, geoexchange, electricity, industrial waste heat, sewer waste heat, sea and lake water cooling, municipal solid waste, solar energy), natural gas (NG) is the primary fuel source in 88% of systems. The most common renewable energy source is biomass (4%), followed by geoexchange and solar (2%).

4.1 Federal Polices

Currently, Canada lacks a national energy strategy that includes legislative support or a clear planning framework for DE. Support has taken the form of grant funding for pilot projects or public-sector led projects that are tied to low-carbon, net-zero, or energy efficiency objectives. Canmet Energy, a division of Natural Resources Canada (NRCan), oversees and initiates DE research and pilot projects at the federal level.

4.2 Provincial Policies

Provinces have jurisdiction over their own energy systems and determine the planning powers available to municipalities, therefore provincial policy has more direct influence over implementation of DE than federal policy. With the exception of BC, provincial policies generally mirror the federal situation, as in most provinces DE is either not mentioned in the legislation or lacks clear direction and a supporting framework that legitimizes and guides municipal action to implement DE. Due to time and space constraints this paper does intend to provide an overview of DE developments in all of the provinces but will rather focus on notable examples from BC and Ontario as these cases offer a contrast in their approaches, account for the majority of DE in Canada as well as hold the majority of the population, and major population centres.

4.2.1 British Columbia

BC has supported DE development through a range of policy mechanisms. Broader policies aimed at a shift to a low carbon economy have included GHG emission reduction targets and introduction of a carbon tax. Development of DE is promoted through alignment with BC's energy objectives outlined in the Clean Energy Act, including fuel switching, encouraging communities to reduce GHG emissions and increase energy efficiency, as well as reduce waste by using waste heat, biogas and biomass. The province also provides supports through subsidies and low interest loans and supports the use of biomass in DES through funding and the creation of the Bioenergy Network. The Transfer of Federal Gas Tax Agreement provides funding for municipalities undertaking projects that reduce GHG emissions, and BC Hydro has offered funding for DE prefeasibility and feasibility assessments as well as capital incentives based on expected electricity savings.

Provincial policy has also provided incentives and the necessary tools to municipalities to undertake effective CEP. Central to this was the Local Government Act which established a core legislative framework to enable CEP by requiring GHG targets, policies, and actions to be included in official community plans. Parallel to this is the Climate Action Charter which is a voluntary commitment to achieve carbon neutral government operations and measuring and reporting on community GHG emissions, which has been signed by the majority of BC municipalities. The Climate Action Incentive Revenue Program incentives signing the charter by providing a 100% rebate of the carbon tax to signatories. While not directly impacting DE, as discussed above DE has become an important component of many CEPs. Where municipally-owned DES do exist, mandatory connections bylaws have been implemented that require new buildings or buildings subject to rezoning to connect to the system if located in the service area. BC legislation has also clarified that municipalities in BC can also use density bonusing and exemptions from development cost charges to incentive connection to DES.

4.2.1.1 Thermal Energy Regulatory Framework

BC offers the only example of a clearly established regulatory framework for DE in Canada. DES are considered public utilities and are therefore currently regulated by the BC Utilities Commission (BCUC), the province's independent regulatory tribunal that oversees all electric, gas and DE utilities, under the Thermal Energy System (TES) Regulatory Framework. Municipally-owned utilities are exempt from this regulation, as well as Micro TES (capital costs less than $500,00), and TES owned by a Strata that exclusively serves the Strata (BCUC, 2015). BCUC's stated mission is to ensure that ratepayers receive safe, reliable energy at fair rates from regulated businesses, and that energy service providers receive fair rates of return (BCUC, 2018). Certificates of Public Convenience and Necessity (CPCN) are issued by the regulator as their approval to construct the utility or utility expansion. TES regulation is divided into two stream A and B. Stream A TES are systems with a capital cost of between $500,000 and $15,000,000 and are exempt from rate regulation and the requirement to have a CPCN. However, the Stream A TES must have the thermal generation and distribution equipment located on the same site as the thermal load and must have long-term energy service contracts with its customer already in place in order to qualify. Stream B TES are all other systems that don't fall into the other categories and are subject to full regulatory review process. In this process, thermal utilities must submit a revenue requirement application that forecasts the revenue needed from rates in order to meet expenses and a target return on equity (ROE), as well as outline the development plan for the system. The revenue requirement is then tested in a public process and a rate design is decided on which determines how rates should be structured among customer classes and consumption levels. Target ROE is set by adding a utility specific risk premium to a benchmark rate of return based on long-term Canada bond yields (Ostergarrd, 2012).

While BC's regulatory framework is aimed at protecting consumers and ensuring fair rates of return for utilities these regulations have acted to disincentivize investment and connection to DE in many cases. The regulatory process is an expensive endeavour that adds a large amount of time and uncertainty to projects which is a disincentive to private DE companies to make big investments (DEM1). It also acts a disincentive to developers or building owners to connect to the system due to the increased uncertainties around the timeline of the construction of the system, and if the system will meet the building code requirements (DEM1). Some disincentive to smaller systems exist as well, as the regulatory costs are disproportionate to the capital costs. In one example, the application process cost $1 million for a system with a total capital cost of $10 million (DEM1). At the same time the regulation incentives the Micro-TES and small Stream A systems where a DES serves a cluster of buildings owned by a single-owner. As one DE manager put it, "we are going to see a lot more Stream A type developments coming forward, but I don't think we are going to see very much Stream B activity in this province I think the BCUC has made it pretty much impossible" (DEM1). This type of DE development essentially bypasses the economic and social benefits offered by achieving economies of scale, and misses opportunities for larger-scale growth in the industry.

4.2.2 Ontario

DE in Ontario has been relatively unsupported by the provincial government and has been left primarily to municipal or private initiative. DE is specifically mentioned once in the Provincial Policy Statement in relation to promoting energy conservation and the development of renewable energy systems including DE and is briefly mentioned in most recent long-term energy plan. DE has been supported more indirectly through climate change policy and grants for clean energy projects. The Municipal Energy Plan Program, for example, provides funds to aid in the development of comprehensive municipal energy plans. The Municipal GHG Challenge Fund bankrolled by proceeds from the Cap and Trade program also provided funding to a number of low carbon DES. However, with the recent change to a Conservative government and the cancellation of these programs all funding has been removed for these projects drastically impeding the business cases (Langer, 2018).

Although Ontario lacks the same clarity in the available tools municipalities can use to implement climate change action plans and/or CEP, including DE, municipalities can still utilize land use planning powers to do so. No instances of mandatory connection appear in Ontario as it does not appear to hold up legally (CEP2). The approach in Ontario municipalities has rather been to opt for a more voluntary approach to securing customer bases. Municipalities such as Guelph and Toronto require new buildings or those subject to rezoning to assess the feasibility of connecting to DES in zones designated for DE or where a system is available for connection. Similarly, East Gwillimbury requires feasibility studies where large developments or secondary plans propose higher densities. Connection is generally encouraged by the municipality and standardized construction guidelines and technical standards for building design to be compatible with the DES are published. Although the legislation does not clarify this, other tools such as density bonusing, and development charge refunds can be used by municipalities. The Toronto Green Standard is one example, where developers who voluntary exceed the Tier 1 energy efficiency standard by implementing green building initiatives such as connecting to a DES are eligible for a development charge refund. As in BC, the Federal Gas Tax Fund has also been used, for example, by Markham to finance their DES (Bradford, 2012).

4.2.3 Building Codes

Building codes are under provincial jurisdiction and can be a powerful tool that can determine how energy is used in buildings. Over the years building energy efficiency has improved greatly as a result of more stringent energy efficiency requirements. However, building codes have also presented some barriers to adequate and fair consideration of DE. As the compliance pathways are based on the National Building Code and the ASHRAE standard, offsite measures, such as DE, are not recognized (QUEST, 2017). In ASHRAE, for example, onsite renewable energy sources or heat recovery are treated as free energy by the building performance rating method (ASHRAE, 2004). However, the same technology at an off-site DE plant would be considered purchased energy. As the ASHRAE energy modelling method is based on the cost of energy, this leads to on-site measures being favoured over the same measure that are located off-site.

Cost of energy based models also fail to incorporate other performance measures such as carbon emissions and thermal energy demand. A more effective approach is the use of performance metrics such as greenhouse gas intensity (GHGI) and thermal energy demand intensity (TEDI). TEDI is an internationally recognized best practice used in building performance requirements in Switzerland, Denmark and other European nations, and is used in Canada in some voluntary and municipal building standards such as the Canadian Green Building Council's Zero Carbon Building Standard, Vancouver's Zero Emission Building Plan, and Toronto Green Standard. TEDI measures the total amount of energy required to heat a building after all sources of heat loss and passive heat gain are accounted for (King, Purcell, & Lysenko, 2017). In order to meet a TEDI requirement, this approach requires that designers optimize building characteristics around heating through passive design measures such as orientation, solar access and building envelope before implementing mechanical solutions (Ibid). While a focus on reducing TEDI may not seem beneficial to a DE business, as it essentially means a reduction in revenue, using TEDI shifts the more common focus on electricity efficiency to also include thermal energy. Readily available TEDI metrics can also allows easier assessment of heat demands in an area to determine if DE is a viable option.

5. Jurisdictional Scan

5.1 Denmark

Denmark has a long history of community ownership both in the agriculture and energy sector, in particular with wind and DH co-operatives. This experience with bottom-up approaches to planning and renewable energy development and clear national policy direction and support have played an essential role in the growth of the Danish DE industry, as well as laying a foundation for a decentralized and sustainable energy system.

5.1.1 Historical Development

The first CHP plant connected to a DE network was established in Denmark in 1902- a waste incineration plant in Frederiksberg, to deal with the growing waste problem in the municipality (Danish Board of District Heating [DBDH], 2017). This idea then began to catch on with many communities in the 1920's who established small to medium sized diesel-powered electricity generating plants that supplied nearby buildings with waste heat (DBDH, 2017). DE continued to expand in Denmark, but diesel oil shortages during the second World War, forced many operators to switch from CHP to solid fuel heat-only boilers. After the fuel supply returned, an excess of capacity incentivized the expansion of even more DE networks (DBDH, 2017).

However, between 1950 and 1974 typical residential homes still employed individual fossil fuel burners for space and water heating, which were problematic due to their expense, pollution, and requirement for maintenance on a regular basis (Maegaard & Avis, 2001). DE provided a cost-effective, and efficient solution for communities, eliminating the need for individual maintenance, and reducing costs. Furthermore, most of the DE systems were owned by the consumers, ensuring fair prices, and allowing any efficiency savings to be reinvested back into the communities (Maegaard & Avis, 2001).

By the 1970's DE had expanded in the larger cities, supplying 30% of all homes (Energistyrelsen, 2017b). Due to the high dependence on oil (Denmark imported almost 100% of its fossil fuels), the 1973/74 oil crisis spurred even more expansion of CHPs not only to the large cities, but also to the small and medium sized cities (Energistyrelsen, 2017b).

5.1.2 CHP Policy

Integral to the successful expansion of DE and CHP in Denmark were two key pieces of national government legislation: The *Electricity Supply Act of 1976*, which required all new electricity production to be CHP, and the *Heat Supply Act of 1979* that required municipalities to make heat plans, and provided the municipality with the option of mandating connection to a DE system (Chittum & Østergaard, 2014; Energistyrelsen, 2017; Parajuli, 2012). An important piece of legislation that contributed to expansion in smaller cities was the "co-generation agreement" of 1986 between government and national utilities that required the establishment of at least 450 MW of small-scale CHP (Energistyrelsen, 2017).

These policies led to a second wave of decentralized CHP development in the 90's where many new plants were built in small towns and villages (Andersen & Lund, 2004). The government also introduced various taxes and subsidies to increase the price advantage of DE and to direct decisions on fuel and technology to more sustainable uses (Hawkey et al., 2015). For example, since the 1970's and 80's biomass and biogas have been exempt from heat taxes, and currently they receive an add on of DKK 150 (20 Euro) per MWh on top of the spot market price (Energistyrelsen, 2017). In 1993 use of biomass in centralized plants was facilitated through a requirement to use 1.2 million tons of straw and 0.2 million tons of wood chips annually by the end of 2000 (Energistyrelsen, 2017).

Up until 1989 CHP received a fixed tariff for electricity, as well as a grant subsidy (Andersen & Lund, 2004). In 1989 the government introduced a triple-tariff scheme with tariffs for low, medium and peak load operation, to reflect the higher price of electricity during times of high demand and introduced a premium per kWh of 0.013 Euro to encourage the building of local, consumer owned CHP (Andersen & Lund, 2004; Maegaard & Avis, 2001). The triple-tariff variations in accordance with demand were known ahead of time, therefore minimizing uncertainty and risk to the energy producer (Andersen & Lund, 2004). The impact of the triple-tariff led to CHP plants investing in over-capacity of the CHP units combined with thermal storage capacity, which allowed the plants to increase their performance during higher paid periods, therefore increasing their revenues (Andersen & Lund, 2004). The heat storages allowed the CHP plants to optimize co-generation in accordance with electricity demand, or decrease production when there was low electricity demand, and still supply heat when it is needed (Energistyrelsen, 2017).

In the current model CHPs sell electricity at the fluctuating market price. Because the market price is based on short-term marginal costs in the NordPool electricity market, which can become very low due to high shares of wind in the system and depending on the level of water in Norwegian hydro dam storages, market prices have been much lower than the long-term marginal costs (Sievers & Stadler, 2005). As a result, decentralized CHP faced economic losses, and a production independent allowance was created, which is paid on an annual basis according to changes in the electricity price (Sievers & Stadler, 2005). After 2018, only CHP using renewable energy sources will receive an add-on to the spot market price (Energistyrelsen, 2017).

5.1.3 Municipal Heat Planning

The Danish municipal heat plans established under the *Heat Supply Act* were locally developed plans that identified and mapped existing and future building heat demands, as well as potential heat sources, and included a cost-effectiveness and local appropriateness assessment of heat supply options (Chittum & Østergaard, 2014). The heat plans would establish zones that defined what areas would be supplied by DH or natural gas, and building owners were required to pay standing charges even if not drawing heat from the system (Energistyrelsen, 2017; Hawkey et al., 2016). With DE companies having an average connection rate of 82%, these plans have created a stable investment environment, and long-term confidence in DE, reducing risks and perceived risks to consumers, municipalities, suppliers and owners (Chittum & Østergaard, 2014).

Although mandatory heat plan legislation has been removed today, municipalities are still empowered at a local level by the *Heat Supply Act* to develop heat plans that maximize use of CHP, socio-economic benefit, and reduce fossil fuel dependence. Municipalities hold the primary authority in heat planning decisions, and are responsible for preparing, and updating municipal heat plans, and approving projects, with the final decision power lying with the city council (Energistyrelsen, 2017). They still decide which new DE components shall be built, or altered, may still require heat suppliers to undertake a project or use certain fuels/technologies, and can mandate connection to a DE system (Chittum & Østergaard, 2014).

Larger DE plants are typically owned by energy companies, while smaller ones are owned by companies, municipalities or consumer co-operatives (Energistyrelsen, 2017). The municipality acts as a regulator of the heat companies, which are often independent companies controlled by the municipality, or are answerable to them (Chittum & Østergaard, 2014).

In the Danish co-operative ownership model, a co-operative is established by the consumers and a board of directors is elected. The municipality also sits on the board of the co-operative and the city council retains the power to issue approvals and require heat cooperatives to make proposals for connecting new developments (Chittum & Østergaard, 2014). Each consumer gets an equal share and vote in the co-operative. The municipality acts as a guarantor for the loan, thus securing low-interest rates for the project (Chittum & Østergaard, 2014).

State regulations in Denmark also prohibit heat companies from making any profit. While the business model of the company does turn a profit, this profit, by law, must be returned to the consumers (Chittum & Østergaard, 2014). Whether municipally or cooperatively owned, in both cases the owner of the heat company is also the consumer, therefore creating an incentive to keep costs down. The public/consumer owned models also allow for lower rates of return, and longer pay back times than privately owned companies. While these measures protect against monopoly powers, to ensure efficiency, DH companies are voluntarily benchmarked against each other, and prices paid by consumers in different areas are publicly ranked online (Energistyrelsen, 2017).

5.1.4 Current Status

DE currently supplies 63% of all households in Denmark. CHP produced 66.8% of heat in DES supplied by coal (20.6%), natural gas (7%), biomass (18.3%), and waste (19.6%). Units that produced district heating alone used biomass (14.4%), and natural gas (18.3%). Solar thermal, geothermal, and heat pumps are in use but supply very little of the heat demand (Danish Energy Agency, 2017). In the long-term the national government aims to eliminate fossil fuels for electricity and heat by 2035 with heat pumps expected to provide a major input to DE in the future and waste to heat is predicted to provide a stable baseload to 2050 (Euroheat and Power, 2017a).

5.2 Sweden

In contrast to Denmark, DE in Sweden was driven more from municipal interest in CHP as an alternative to purchasing electricity from major suppliers, rather than being driven by national policies and mandates to undertake CHP and municipal heat planning as in Denmark. National policies followed by incentivized DE more indirectly through incentives and disincentives for particular fuel sources, and more directly through subsidies and loans to DE utilities.

5.2.1 Historical Development

The first DE system in Sweden was a thermal power station converted to CHP to supply an industrial facility in 1948 (Werner, 2017). Following this, DE developed from nine major municipalities that introduced DE in the 1950's, to every major city or town now with their own DE system, with about 500 systems currently in operation (Ibid). Up until 1990 all systems were municipally owned and operated, only later being transferred to municipally owned subsidiary companies (Ericsson, 2009). The important role municipalities played in DE development was natural considering they could benefit from synergies it provided: they already owned electricity distribution networks and other municipal infrastructure as well as large housing companies and could integrate DE alongside these services as well as take on long-term financial risk because of their income from a municipal tax (Ericsson, 2009; Werner, 2017). Furthermore, strong local government and development powers allowed for coordinated development of buildings and infrastructure, as well as financial resources due to the ability to tax inhabitants (Ericsson, 2009). Municipalities were able to secure initial customer bases from publicly owned buildings and multi-dwelling buildings owned by municipal housing companies aided by formal and informal networks between municipal officials/employees, municipal housing companies and cooperative housing associations. Johnson et al. (2002), outlines some of the primary drivers of municipal investment in DE as:

- Cheap and efficient electricity production in CHP plants
- Economy and Fuel flexibility (Cheap heavy oil could be used instead of light oil, as well as waste heat sources. Economies of scale could also be achieved.)
- Efficiency (Centralized maintenance and technological scale effects)
- Environment (Economies of scale in emissions control)

For consumers, DE was and still is attractive due to its convenience and competitive prices (Ericsson, 2009) While there is only one DE supplier for a particular area, customers do have the option of disconnecting and switching to a different individual heat source (Ibid).

Post Second World War, growth of DE systems was facilitated by a shift to hydronic centralized heating systems in buildings, which are more compatible with DE connection (Ibid). CHP was also a motive for DE development in the 50's and 60's when hydropower was thought to be insufficient to meet future electricity demand, however CHP development halted when the political decision to pursue nuclear was made (Ibid). Nevertheless, the market for DE grew substantially throughout the 1960's and 70's, driven by air quality concerns and the building of a million new single-family homes and apartments as part of the Million Homes Program, many of which were immediately connected to DE systems (Ericsson, 2009; Werner, 2017). National policies initially supported DE through access to low cost finance for housing corporations to support connection to heat networks (Hawkey et al., 2015)

In the 1970's and 80's with the growing awareness of Sweden's reliance on imported oil, reducing oil dependence became a priority. The Swedish government acted to reduce investment uncertainty and created pressure at a municipal level to develop heat networks through a series of acts that clearly laid out the role of the municipality in energy conservation, as well as establishing low-cost, long-term loans for DE systems (Hawkey et al., 2015). DE was also supported through an oil substitution program due to DE's ability to switch from oil to a wide variety of other heat sources including coal, biomass and municipal solid waste (MSW) incineration (Ericsson, 2009; Hawkey et al., 2015). However, the program also led to an expansion in electric heating for buildings which made nuclear power the main competitor to DE as a result of the lower rates it could provide (Ibid). Major power suppliers saw municipal interest in decentralized CHP and DE solutions as a threat to their business and as competition to the Swedish nuclear power policy and would offer lower price electricity supply contracts to municipalities that promised not to use CHP (Werner, 2017). Nevertheless, between 1985-2000 DE increased steadily and multi-fuel boilers and heat pumps in combination with other heat sources became popular (Ericsson, 2009).

In 1977, similar to Denmark's approach, the national government mandated municipalities to create municipal energy plans to clarify their role in national energy policy (Ericsson, 2009). However, these plans were less prescriptive in their approach than Denmark requiring municipalities only to address energy efficiency and energy security in their plans, and form oil reduction plans, while not requiring DE planning specifically (Hawkey et al., 2015). However, by 2006 27% of municipalities lacked a municipal energy plan, while others were quite outdated and the legislation was criticized for not making clear sanctions or requirements of what the plans should include and did not give any authority to influence energy decisions of other actors, and so the effectiveness of these plans was limited (Ericsson, 2009). While municipalities do have full control over land use planning, they are not allowed to require connection to DE systems or any other source of heating. Although they may be able to require connection if municipal land is sold for a new development, they cannot require the use of it, opting instead to market or suggest connection where it makes sense (Ibid).

In the 90’s, policy objectives shifted to climate change mitigation and obtaining a secure and competitive energy supply. This led to the implementation of a carbon tax in 1991 and an investment subsidy for biomass CHP, which also incentivized DE development (Ericsson, 2009; Werner, 2017). Out of the 16 CHP plants that received the biomass subsidy 12 were part of a DES (Ericsson, 2009).

As focus began to shift more to market solutions and deregulation of national electricity markets with market liberalization occurring in 1996, non-municipal owners began to acquire ownership of DES with many being sold to national or international energy companies (Werner, 2017). The decision to sell was for some a result of political difficulties in now having to run the utility as a for-profit business, while for others it was more driven by financial difficulties experience by many municipalities in the 90’s (Ibid). Local companies also began to expand to regional companies by acquiring and merging systems together, a trend which continued today for the advantages it offers in economies of scale, as well as increasing the potential for electricity production from CHP (Ibid). By 2004 municipal ownership had dropped to 60% (Werner, 2017).

5.2.2 National Polices

Two investment subsidies have been provided to DE by the Swedish government: The Local Investment Programmes (LIP) and the Climate Investment Programmes (Klimp). The LIP subsidy, administered in 1998, aimed to strengthen local environmental initiatives and increase employment (Ericsson, 2009). Municipalities received support for collaborating with local industry and organizations. (Ericsson, 2009). Of the 6.2 billion SEK set aside, DE received about 1 billion which was used for new construction, expansion, and retrofitting (Ibid). In particular, the subsidy increased the use of industrial waste heat by making longer connections between industry and the DES economically viable, as well as increasing the connection of one- and two-story dwellings (Ibid). LIP was replaced by Klimp in 2002, with a similar objective of encouraging cooperation between municipalities and local industry (Ibid).

In 2003, Tradable Renewable Energy Certificates were introduced which has indirectly incentivized DE production as biomass CHP has been very competitive under this scheme (Ericsson, 2009). While the certificates are only for electricity production, it has been successful in attracting investment into biomass CHP DES (Ibid).

Waste management legislation and taxes has also played a role in incentivizing DE by providing a fuel source. Combustible and organic waste is banned from landfills and is instead incinerated for CHP production (Ericsson, 2009). While waste incinerators have high capital costs, the sale of heat from the incinerators has made it possible to charge low gate fees for the waste (Ibid). Furthermore, heat production from MSW in CHP is exempt from the energy tax and is levied a lower carbon tax (Ibid).

While municipalities have played a leading role in DE development, aided by indirect incentivization by the national government, national policies have also more recently provided direct subsidies to support DE development (Ericsson, 2007). In 2006 a subsidy was provided for the replacement of oil heating in one- and two-story buildings and direct electric heating in all residential buildings with either DE or heat pumps. The program was successful in attracting applicants with most who switched from oil boiler opting for heating pumps (43%), while DE and biofuel boilers accounted for 20% and 37% respectively (Ibid)

5.2.3 Regulation

Up until market liberalization DES had been regulated by the Local Authority Act which regulates municipal businesses though three principles that governed municipal business actions: 1.) The principle of equal treatment; 2.) the principle of locality, and 3.) the principle of cost-based pricing. These principles ensured that all citizens were treated equally, business was not engaged in other municipalities, and that the DES was operated on a non-profit basis. In order to ensure competitiveness with private companies after market liberalization these principles were lifted from municipalities (Ericsson, 2009). As more DES were bought by national/international companies local heat markets began to interact with the larger markets for gas and electricity which raised concerns around cross-subsidization and has prompted discussion on regulation of DES in Sweden (Ibid). As a result, the Energy Market Inspectorate now monitors the DE sector to ensure that the dominant position of the DE supplier is not abused (Ibid).

In order to deal with ownership issues and to act as an industry coordinator, the Swedish District Heating Association was founded in 1949. The association played a key role in knowledge sharing and introduced in 1970 a quality assurance system for distribution pipes to identify early in the development process bad pipe installations (Werner, 2017). The Association also developed technical standards that have shaped the market for equipment suppliers to increase compatibility between different components of the system and has reduced the risk of utilities being locked-in to equipment that is no longer supplied on the market (Ericsson, 2009).

Initially, municipally-owned systems were operated on a non-profit basis, however when systems began to be bought by private companies no basic pricing principle was in place for this new arrangement, which triggered price discussions (Ibid). In 1996, with electricity market deregulation it was decided that both electricity and heating should have equal pricing principles and to be based on market pricing, which led to price increases in certain jurisdiction (Ibid). In response, separate legislation for DE was called for, as up until then the legislative framework for DE had fallen under the Municipal Act (Ibid). The District Heating Act was introduced in 2008 after deliberation by the purpose established District Heating Commission. The act focused on transparency, requiring publishing of annual balance sheets with profit and loss statements, and established a District Heating Board to handle complaints over prices and heat delivery (Ibid).

5.2.4 Current Status

Currently, DE is the market leader in the heating sector providing 55% of heating demands. While in the past DE replaced fuel boilers, now the main competitor is individual heat pumps, which have a market share of 25% (Werner, 2017). CHP has seen a renewed interest due to increased electricity prices as a result of market liberalisation, higher prices on the Nordic electricity market and the Swedish renewable energy tradable certificate scheme. CHP now makes up and currently supplies the majority of heat to DES constituting 42% of the supply (16% recycled CHP; 6% fossil CHP; 20% renewable CHP) (Ericsson, 2009; Werner, 2017). The remainder is made up of 32% recycled heat; 20% renewable boilers; 2% fossil boilers; 3% electricity input (Werner, 2017). However, CHP supply of heat is still lower than other countries such as Denmark, Austria and Germany, due to the taxation of the heat output in the same way as heat-only boilers neglecting the heat recovery ability of CHP, therefore DES operators opted to use other heat supply methods when oil taxes were raised in the 1980's (Werner, 2017).

Currently low electricity prices do not favour DE and has increased the competitiveness of individual heat pumps (Euroheat and Power, 2017b). Similar to Canada, further DE expansion is also hindered by building regulation that favour individual heating solutions by using purchased energy to the building as the demand cap, and until recently did not use primary energy factors (Werner, 2017).

5.3 Netherlands

Like other countries, DE development in the Netherlands was spurred by the oil crisis and national policies that sought to address it. Most DE development in the Netherlands occurred before market liberalization when CHP was attractive due to government financial support and high electricity prices (Hawkey et al., 2015). However, since heat network planning and development is a local process in the Netherlands the extent of national policy in DE has been only to protect consumers from the potential abuse of monopoly powers through regulations that cap prices at the cost of the alternative to DE, which is individual gas heating (Hawkey et al., 2015). Therefore, DE development is more like the Swedish experience where municipalities took a leading role.

5.3.1 Historical Development

In 1974 the Dutch government created the Committee on District Heating to investigate the prospects of DE and to support municipal and regional decision-making (Raven & Verbong, 2007). However, the Netherlands differs from the Scandinavian countries in that DE did not see widespread expansion as a result of these policies, with only 16 out of 50 feasibility studies making it to implementation (Hawkey et al., 2015). This is in large part due to the discovery of extensive natural gas reserves in 1959 that resulted in the establishment of an extensive natural gas distribution network and a strong institutional embeddedness. Schaeffer and Struker (1994; cited in Raven and Verbong 2007) identify three more specific reasons why DE did not see more widespread adoption in the Netherlands. First, because gas distribution companies were owned by municipalities, they often opposed DE development as this was an important source of revenue used to finance municipal facilities, leaving little for gas companies to invest in capital intensive DE infrastructure. Instead, the regioanlly owned electricity companies established DE companies, which led to competition with and opposition from the natural gas companies. Second, Dutch consumers showed a preference for the already established and reliable individual gas heating systems. With a switch to DE, customers were also forced to switch to electricity for cooking as having gas, electricity and heat all delivered to a building would be cost prohibitive. However, customers were not familiar with electric cooking and opposed it. Furthermore, there was a general aversion to collective services that were associated with communist practices. Third, the tariff structure was problematic, as it was decided to copy the structure for gas which had a low fixed cost and a larger variable charge. However, this did not reflect the cost structure of heat supply, which typically has high fixed costs and lower variable charges. Lastly, heat demand was lower than expected due to a national programme for house isolation that resulted in smaller houses. Lower heat demand was exacerbated by construction delays. In response to the failing DE companies the government provided 45 million in financial aid to companies to prevent their closure, but no new DE plants would be constructed until the mid-1990’s. On the other hand, CHP had more success, with 85 units installed between 1968 and 1988, the majority of which were built by the chemical industry.

5.3.2 CHP Diffusion

CHP saw rapid diffusion by the end of the 1990's and is considered to be a success story, although the majority of this was led by the industrial sector and therefore saw limited DE buildout as a result, in addition to the institutional reasons stated above (Hekkert, Harmsen, & Jong, 2007). While industry had already established its internal market for heat electricity based on CHP by 1970, government support for CHP contributed greatly to its continued expansion starting in 1979 with acknowledgment of its energy cost and efficiency saving with the establishment of the Commission on Cogeneration, which created further legitimacy for the technology (Hekkert et al., 2007) . The Commission played an important role, bringing together actors, providing investment grants and offering lower natural gas prices for CHP production, as well as identifying barriers and making recommendations to government for further cogen diffusion (Hekkert et al., 2007; Raven & Verbong, 2007). With the separation of the electricity production and distribution according to the Electricity Act in 1989 distribution companies also became interested in CHP as they could either buy from the cheapest producer or produce electricity themselves with cogen (Hekkert et al., 2007).

In 1991 environmental action plans were created to expand CHP, supported by an environmental tax on consumer energy bills, and in 1994 heat plans were created particularly for residential areas, which resulted in 1250MWe of CHP, half of which was allocated for DE project (Ibid). With a fixed feed-in tariff for CHP, plants could be sized according to the heat demand, which was typically larger than the electricity demand, therefore increasing the profitability of CHP plants and contributing to their expansion. Despite removing subsidies and lowering the feed-in tariff, CHP constituted about half of electricity production in the Netherlands by 1994 (Ibid).

In 1989 a new electricity law was introduced to increase competition and improve economic efficiency, that required electricity companies to separate production and distribution activities leading to a merger of electricity production companies into four regional companies, as well as a merger of the distribution companies (Hekkert et al., 2007) These mergers led to horizontal integration of electricity and gas distribution companies, which resulted in further expansion of CHP in DES as the competition with the gas companies no longer existed (Ibid).

5.3.3 Rotterdam

Without any clear supports or direction from the national government DE development was driven more from the local level, the main example being Rotterdam. Development of a DE system here was led by the harbor industries which saw the dumping of waste heat into the river as an environmental problem which they wished to collaborate on, seeing opportunities for industrial ecology (Hawkey et al., 2015). A company was formed, Warmtebedrijf, which would deliver waste heat from industry to domestic and commercial building in Rotterdam, the municipality only becoming involved in the project when climate politics began to be more prominent (Ibid). The system plan was developed jointly by the municipality, the port authority, the regional government, three energy companies, and two companies from the harbor that would supply the heat. Warmtebedrijf itself was a joint-venture between the municipality, the port authority, the regional government, and the housing corporation, which was responsible for constructing and operating the heat transmission network (Ibid). The DE areas were divided up into concession zones for competitive tendering which two of three energy companies were awarded contracts (Ibid). The municipality played an important role here in developing the heat market by using its building control powers to grow the user base (Ibid). Furthermore, Dutch energy labelling does not value DE in the same way renewables are, so the municipality the national authority to improve DE valuation in energy labelling schemes which incentivized housing corporations to connect as this increased their property values and allowed them to charge higher rents (Lenhart, Vliet, & Mol, 2015).

However, after all this was established one of main heat suppliers, an oil refinery owned by shell, refused to sign on for the 25 years of operation that was laid out in the original business model, wishing only to sign on for 15 years, fearing that the DE system might not at times be able to take all the waste heat, therefore interfering with the operations of the oil refinery (Lenhart et al., 2015). With the withdrawal of Shell, the system instead relied on waste incinerators to supply the heat, and the heat company was reorganized into two parts: a public sector company that would develop and the maintain the system, and a joint venture between one of the energy companies and the municipality responsible for the purchase and sale of energy across the system (Hawkey et al., 2015). However, as the contract with the waste companies required them to make heat available from the collected waste a second waste incinerator had to be built, which the municipality stepped into finance increasing its share of equity and underwriting of commercial loans (Ibid).

5.3.4 Current Status

Currently, only 4.4% of dwellings are connected to DE. 80% of this is supplied by excess heat from CHP production and industrial waste heat, and a fraction from renewable heat sources (Euroheat and Power, 2015a). There are thirteen large-scale grids that are supplied by major power producers such as Eneco, Essent, and Nuon, as well as 6,600 smaller scale grids that are owned and operated by housing corporations, owners associations, project developers and other such parties (CE Delft, 2009). As the government seeks to reduce its gas dependence with its policy to remove gas as a source of heating and cooking in all residential buildings, DE is seeing increased attention today (Morris, 2017). However, recent changes to the Dutch Heat Act have created some uncertainties as to its impact on the business case as the act seeks to balance two objectives: the facilitation of the energy transition, and the protection the position of heat users (CMS Netherlands, 2017).

5.4 United Kingdom

The DE sector in the United Kingdom (UK) is very underdeveloped and perhaps draws the most similarities with the Canadian context. Only in 2012 did national policy begin to institutionalize the supply of low carbon heat, heretofore only mentioned as an add-on in biomass or thermal efficiency policy (Hawkey et al., 2015). While government has attempted to stimulate DE development, it has not seen widespread adoption. Hawkey et al. (2015) characterize the policy approach as relying on voluntarism of local actors and authorities to set objectives and identify opportunities. This has led to objectives and opportunities tending to focus on small groups of buildings often owned by a single organization, as opposed to other European cities where DE is situated as a solution to critical local problems. There are currently less than 2,000 DES in operation and around three quarters of these supply less than a hundred buildings (Wang, 2018). Furthermore, more reliance is placed on commercial actors to spearhead development, creating tension with social and environmental goals (Hawkey et al., 2015). Polices that do exist have created uncertainty and unpredictability in the DE industry and are subject changes with shifts in politics. The aid that government does provide is in the form of knowledge and skills to municipalities, which does not address local capacity to recruit and coordinate large user bases, which is a crucial factor for the buildout of DES.

5.4.1 Historical Development and National Policies

Hawkey et al. (2015) outline the major national policy initiatives that have attempted to stimulate DE development in the UK. In response to the 1973-1974 oil crisis, a state entity was planned to be created to oversee the development of city-scale heat networks based on CHP, however, state participation in the economy was seen as unacceptable at the time and the program would instead become a competition between local authorities for grant funding based on their ability to attract private investment. Three cities received funding and three others decided to build without the grant, however success was varied across the cities with some building sizeable networks and others building nothing. The government's objectives for this program were also problematic, focusing solely on the short-term financial returns that the technology could provide rather than the energy security and efficiency benefits.

15 years later the Community Energy Programme was launched, which provided £50 million in grants for technical studies and capital grants up to 40% of the costs. Funding was provided to public sector organizations and some successful projects were built, but the program was abruptly cancelled in 2006, with the belief that the program's targets would not be met. The deadlines the applicants were required to meet also did not reflect the timescales needed to properly organize and plan a heat network, and many applicants dropped out of the program with the complexities being too large to handle within the timeframe of the program. Importantly, the timescales imposed by the program forced the schemes to be small scale proposals, thereby missing the benefits of DE provided by reaching economies of scale. On the positive side the program did shift its accounting method to assess the option that would be the least cost solution over the lifetime of the project, which produced more favourable results for many systems.

In 2009, a Low Carbon Infrastructure Fund was created in response to the 2008 financial crisis, which was to support 10 heat networks, and then in 2012 the Green Investment Bank was established with aim to support commercial financing of a range of technologies, including heat networks. A key difference between these programs was that the objectives of the Community Energy Programme and the Infrastructure Fund were to provide emergency stimulus, whereas the GIB's aim was to establish self-sustaining commercial investment markets; the result being that GIB projects must show higher rates of return than previous programs. This hindered expansion of DE projects as the initial large heat demand anchor loads provided steady revenue and showed good returns, however, further expansion later to smaller loads is likely not to show higher financial returns.

In 2012 the UK government, recognizing the failure of past programs to recruit a broader user base, allowed local authorities to use their land use planning powers to require new developments to connect. However, this resulted in limited uptake due to lack of clarity on how decentralized energy related to other planning objectives.

As of 2013 Scottish and UK governments have established support services for local authorities working on DE, providing grants to cover consultancy work needed to complete plans and assessments. The UK Heat Networks Delivery Unit provides a team of specialists to guide the local authority through the development process, including feasibility studies, development of local plans and engagement with contractors or other partners. The Scottish Heat Networks Partnership helps organization gain access to external funding. The governments have also undertaken heat mapping at the national-scale after attempts at the municipal scale did not produce desirable results.

Hawkey et al. (2015) conclude that the structure of programs that aimed to support DE expansion failed to structure the programs in a way that allowed the full benefits of DE to be realized through reaching economies of scale and failed to provide tools that allowed municipalities to recruit a larger user-baser. This has resulted in a fragmentation of the DE supply into smaller systems that connect specific groups of building often with a common owner. The unrealistic time frames and sudden changes in policy also did not allow time for the industry to prepare for policy changes or to properly establish itself.

5.4.2 Current Status

DE currently supplies 2% of the heat demand in the UK supplied primarily by natural gas CHP at 80% followed by energy from waste, oil and biomass (Euroheat and Power, 2015b). Going forward electricity revenue from CHP may be an important driver of DE as 5.8% of total national electricity production was supplied by CHP as of 2015 (Ibid). Significant potential for growth exists with the national government putting the economic potential at 14% of heat demand by 2030 (Ibid). The government has also recognized the importance of DE in their energy and climate objectives with expansion of heat networks as a key part of the Clean Growth Strategy (Wang, 2018). UK building regulation also requires new building to consider DE as well as heat pumps (Ibid), highlighting the uncertainty in the future competition between these two heat supply options.

5.5 Lessons Learned from the European Experience

The growth of the DE industry in many European nations was stimulated by the oil crisis, however each country saw the growth or lack of growth of their industries play out in vastly different ways. This can be attributed to the variety of local, cultural, political, social, institutional, technological, and economic factors that led to different pathways that can be drawn on to inform the Canadian experience. While this external stimulus of the oil crisis does not currently exist in Canada in the same way, other external stimuli such as the need for climate action and climate resilience are applying pressure towards an increase in DE. The European examples also illustrate how different interactions between municipal and national governments have given rise to different models of DE development. Because Canadian provinces have jurisdiction over their own energy systems, examples of national policies of European countries for the most part are applicable to the provincial governments in Canada.

5.5.1 Municipal Leadership and National Policies

Denmark and Sweden are examples where strong municipal leadership was enabled and supported by national policy over the long-term, Sweden taking a more ground-up approach from municipal initiative and national policy then following, while Denmark took a more top-down approach with clear mandates that municipalities implement heat plans and CHP plants. While the development of the DE sector in these countries occurred under a more state-controlled market regime, these experiences can still offer some lessons on the range of policies available to incentivize the DE sector in Canada. However, it should also be recognized that DE development didn't just occur because it was nationally mandated. An often-circulated assumption is that the success of European DE models is because it was centrally mandated, and Europeans are generally more socially-minded (EC1). While national mandates may have been the initial impetus in some cases it should be recognized that DE continued to be pursued because it was demonstrated to be the best option for cities in terms of generating revenue for the municipality and providing a reliable and cost-effective service that could attract business and industry (EC1). National polices created the institutional support necessary to demonstrate successful business models. The experience of Sweden also counters this ‘myth’ in that municipalities pursued DE first of their own volition, with national support coming only later.

In all the country cases CHP has played an integral role in the development of the DE sector, and the establishment of clear policies and targets from higher levels of government such as a tariff scheme, fuel taxes and capital grants fostered widespread adoption and created a foundation for it to be a profitable investment. Although in Sweden competition with nuclear electricity has hindered its development, the ability for CHP to either produce cheap electricity locally or sell it on the electricity market, as well as sell the heat has improved the business case for DE. In all cases one of the key factors in growth was the clear benefit to the municipality and the consumers of CHP and its ability to deliver competitive heat prices by taking advantage of waste heat. Positioning waste heat as a pollution problem by the community or in legislation also stimulates DE development.

A large share of municipal ownership in both countries also improved their ability to coordinate development with the DES and allowed access to financial resources and low-interest financing. In Sweden, this was a particularly important factor as the municipalities themselves owned many of the buildings and housing development companies. As market liberalization began to take place in Sweden and the municipal DE companies began to be sold to the private sector it is interesting to note that prices began to rise after the legislation changed to remove the requirement that DES operate on a non-profit basis. Furthermore, it was necessary for the regulations to change to ensure protection of the customers as concerns were raised over cross-subsidization taking place by international energy companies that also operate in the electricity and gas markets.

In Denmark, market liberalization has affected DE in a different way, as CHP plants must now compete on the open market rather than using the previous triple tariff scheme, which has hindered their profitability and is beginning to result in DE plants switching to heat only biomass or natural gas boilers, as electricity is still too expensive to be used for DE. Due to the high share of clean electricity in Denmark's grid and more frequent times of excess electricity production from wind turbines, many organizations in Denmark are pushing for lower electricity prices through mechanisms such as a tax incentive for heat pumps in DES in order to decarbonize the heating sector and create a better business case for heat pumps. This may offer an example of a way Canada can leap frog over having to build conventional DES that still rely on natural gas, particularly in provinces that already have lower carbon electricity grids. In the absence of provincial or federal policies this is happening to some extent with borehole geoexchange DES with heat pumps proposed in Toronto, and some already in operation in BC.

While national policy in Denmark provided a clear municipal planning framework and powers from the beginning, national policy in Sweden quickly followed the initial municipal impetus, updating legislation with more clearly defined roles of the municipality in energy efficiency and energy security. These clear heat planning frameworks were a key factor of success in these countries as the municipalities could clearly delineate areas where DE would make sense and grant monopoly power so as the ensure no competition would take place between heat providers. Strong principles of equal treatment to all citizens and cost-based pricing prevented abuse of such monopoly powers, with Denmark providing municipalities with a methodology for undertaking local appropriateness cost-effectiveness studies that had to show positive social benefit, as well as requiring that heat companies must be operated on a non-profit basis.

The development of industry standards and DE associations in Demark and Sweden also enhanced quality assurance and streamlined the construction process lowering uncertainty and risk associated with selecting equipment and the construction process, which ultimately improves the performance of the systems and therefore its credibility to the consumers. Furthermore, the DE associations have played an integral role in constantly improving the systems through research and innovation as well as providing a voice of the DE industry to government.

While strong municipalities were the driver in Sweden, in both Sweden and Denmark national policies recognized the ability of DE and CHP to meet national energy policy objectives and national policy clearly played a large role in the long-term growth of the DE sector through mechanisms that removed market barriers and incentivized the use of lower carbon fuels. These supports have allowed the DE industry in these countries to be self-sufficient, although supports do continue to be provided mostly around the role of DE in decarbonization.

5.5.2 DE in Liberalized Markets

The development of DES in countries that have already had gone through a good deal of liberalization more closely resembles the Canadian situation and can perhaps offer some more useful lessons. Under these regimes public authorities have less power to build their own energy systems and instead focus on strategies that create conditions for other, usually private sector actors, to manage energy supply and delivery (Hawkey et al., 2015). With liberalization we are seeing less municipal ownership and more third-party control of the DES, which reduces the ability of the municipality to coordinate the expansion of the systems or to act for the greater social and environmental good though decarbonizing the systems. While these models may be more complex in this situation, they are still viable, although the barriers that have arose out of literature on the Netherlands and the UK are more institutional in nature.

In the Netherlands a strong institutional embeddedness of individual boilers supplied by a natural gas grid has prevented more widespread adoption of DE, despite the proliferation of CHP. Instead, DE projects have been the result of collaboration and cooperation between municipalities, industry and energy companies taking more of an industrial ecology approach. As the example of Rotterdam illustrates large scale DE projects have had trouble getting off the ground due to the complexities involved in negotiations between the multiple parties and actors. This situation seems to be present as well in the UK although for different reasons, where DE is driven more by commercial interests and larger-scale projects have also failed to get off the ground due to a lack of tools to recruit a larger user base.

The UK case closely mirrors the context in Canada where the commercial sector is being turned to for finance or partnership, and larger scale, city-wide systems have failed to materialize. DE development is also of a fragmented nature with the majority of users being universities, public sector organizations or other groups of buildings with a single-owner. National and provincial approaches in Canada resemble UK policy approaches as well in that support is only provided through grant funding, and guidance or support tools. UK policy has taken a more targeted approach to developing a DE industry, however, the approaches were subject to sudden changes in political will, ignored the time dimension of DE and focused too much on achieving high rates of return, rather than on the GHG reduction and societal benefits.

As these examples have illustrated DE development under energy market liberalization policies leads to a much riskier and complex development process, which often results in costlier, and/or smaller systems that have difficulty expanding. As the main benefit of DE is achieved through reaching economies of scale this can be considered a failure of the business model to achieve its outcome.

6. Marketing and Stakeholder Engagement: Understanding DE Customer Values and Decision-making processes

Even though a wealth of DE best practices, case studies and lessons can be found in many countries with burgeoning DE industries and successful systems in place, the North American industry still struggles to see mainstream adoption despite the success of various pilot projects and smaller scale systems throughout the continent. As outlined above, a key challenge in a successful business model under a liberalized market regime is the ability to attract a broader user-base across multiple types of owners and building types. This section therefore seeks to understand the challenge of market development in the DE sector in Canada by analyzing the needs, perspectives and decision-making processes of property developers, building owners and property managers in relation to energy and connection to DES.

This research was conducted in partnership with Quality Urban Energy Systems of Tomorrow and consisted of carrying out fifteen semi-structured interviews with developers, property managers, and building owners of mid-rise, high-rise, commercial and mixed-use developments across Canada.

Developers and building owners/property managers (PM) have different values and priorities due to their different responsibilities and approaches to the building industry, and therefore were initially treated as distinct categories. However, some participants were both developers and property managers/building owners, and thus have overlapping values. Most participants were also involved in more than one building market segment of mid-rise, high-rise, commercial and mixed-use. Furthermore, many of the participants also had roles as managers of DE systems in addition to their developer or building owner role/ PM. This is a result of many deciding to develop small scale, onsite DE systems for their larger community-scale developments. An important finding of this study has been that many developers are choosing to develop their own onsite DE systems where existing municipal scale systems are not in place.

The Findings are divided into five sections: 1) Stakeholder Values and Market Drivers; 2) Knowledge and Expertise Gaps 3) Regulations; 4) Mandatory Connection; 5) Energy Service Agreements; and 6) Role of Government.

6.1 Stakeholder Values and Market Drivers

Developers, building owners, and property managers have a wide variety of views, experiences, perception, knowledge, and values, as well as varying motivations for their initial interest in DE projects. In places with mandatory connection bylaws this was stated as the primary reason for connecting. For one developer/PM the decision behind connection to the municipal DE system was a show of good will towards the municipality in order to maintain a good relationship. For others, development of onsite DE systems, or connection to external systems was more of a pilot project to explore different value propositions and revenue streams. Existing heating systems reaching the end of their lifetime was also a stated reason for interest in DE arising.

While, interest in DE may be driven by a wide range of motivations or factors, the primary decision-making criteria that arose across all interviews was the importance of having a good business case for DE. Given a good business case, DE was seen as being able to deliver other values such as sustainability, resiliency, cost stability, and operational savings. However, some emphasized the importance of DE being able to deliver a combination of these values and improve on them:

> "It needs to be cheaper, greener and better, more reliable, less [operation and maintenance) costs." (REIT1)

These benefits also have potential to be marketed to customers of DE utilities (DEU). Although this depends on if such values are in demand in local market conditions, as well as the future price of carbon in each province.

The common values that emerged from the interviews are categorized into primary factors that motivated developer and PM/building owner decision-making in relation to energy and DE:

- Financial
- Reliability & stability of the system
- Timing of development, and developer independence and control
- Sustainability

A number of other secondary factors were not key in the decision-making process but were recognized for their potential value to DE customers. These were often referred to as *soft* or *ancillary* benefits, and included:

- Cost Stability
- Resiliency
- Sustainability

Sustainability is categorized as both a primary and a secondary factor due to the varying motivations and goals of participants; for some the opportunity DE provided to meet sustainability goals was a primary decision-making factor, whereas others did not have sustainability goals and saw it more as an added benefit.

The following section will discuss the findings of this research. For a more in-depth discussion of the primary and secondary factors, varying perspectives on them, as well as, knowledge gaps, views on regulation and the role of government, and preferences for energy service agreements and supporting interview quotes see Appendix A.

6.2 Findings

As may be expected, the main decision-making criteria for developers and PMs is that the cost of connecting to a DE system must be at least equal to putting in conventional natural gas boilers. However, it was revealed that cost alone is not enough, DES must provide reliability and stability as well. If one of these factors is missing, then the usefulness of the system is dramatically reduced. Nevertheless, cost is typically the first criteria that must be met before the value of other factors is considered. Sustainability also emerged as a powerful driving factor behind decisions to connect to systems or to develop onsite systems and DE is helping developers meet voluntary building code standards that use TEDI or GHGI. DE was able to reduce occupancy costs or provide a cost-effective approach to meeting a sustainability goal in some cases, but more widespread adoption and decarbonization was not seen as likely as gas prices continue to be low and most did not see high customer demand for sustainability or a willingness to pay a premium for it. The value of DE was seen as increasing as carbon prices begin to rise or if natural gas prices start to escalate, but uncertainty around what level carbon will be priced at hinders development in this area. Perspectives on resiliency followed a similar pattern. Value was seen in being able to have heat during severe weather or outages, but this had not become a big enough value that customers would pay a premium for it yet. Marketing the resiliency, cost stability and sustainability aspects of DE arose as ways to attract customers to the system even if costs are slightly higher.

Often cited capex and opex savings were not realized by many developers and PM's. Although a few did cite positive savings from DE or at least recognized the potential for them, these savings were often seen as being insignificant in the current real estate market. Saving money on housing is always important to consumers, especially with prices very high, but high demand, scarcity, and low interest rates, make capex and opex savings from DE not significant factors in the eyes of developers and PMs. Furthermore, savings realized on the developer's side may not be passed on to customers. If prices begin to drop, then DE may become more of a factor in decisions to develop in an area or to buy or rent units. In the current market, provision of cooling may have a better value proposition for DE since it would be cutting out a portion of the electricity bill, which is typically higher than gas bills.

One problem, more general to sustainability and energy improvements, that requires a solution is the division in value between developers' and PM's. Benefits of such projects typically accrue to the building owner or tenant in the form of operating cost savings, however, the developer has little incentive to invest in the extra capital required to fund these upgrades, as selling prices must then be increased to recover the extra capital costs. This adds more risk as the developer must then market these savings and hope customers are willing to pay a premium.

Many DE systems were also found to be not performing as expected. Although further research is needed in this area, one of the causes behind this that emerged from this study is the lack of knowledge and expertise around DE in the development community as well as in municipal and senior levels of government. Lack of communication and cooperation between building engineers and DE engineers leads to incompatible or sub-optimal building designs, which make achieving expected performance difficult. Without support from other levels of government DE systems can also have difficulty achieving sufficient heat density to be cost-effective further affecting their performance.

Lack of knowledge was also a big part of the perception that DE is just an added layer of complexity to the development process that creates uncertainty and risk to the developer due to the introduction of new and unfamiliar concepts and equipment, as well as the lack of well-established relationships and routines that characterize the use of standalone heating systems. Getting developments ready for occupancy on time is of great importance to developers and therefore anything that is perceived to endanger that is seen as a risk. Lack of knowledge and understanding of DE combined with the value that developers' place on control and independence in the development process creates further pushback on such things as mandatory connection bylaws. Therefore, it appears that it is not enough that DE is cost neutral in comparison to business as usual but must be able to provide a small competitive advantage and/or be able to provide other marketable benefits like increased resiliency, cost stability and sustainability. But even if DE can provide a range of benefits to developers, PMs and end-users, stakeholders must first be educated on DE and how it can provide these things.

All levels of government were called upon to provide more funding, education, tools and guidance to municipalities and end-users on DE. While some regulation and oversight could be useful in helping to provide clarity in how heat prices are structured and create more confidence in DE systems, these things could also be achieved by using guarantees in well written and transparent energy contracts.

7. Components of the Business Model

This section of the paper will outline the components of the DE business model as conceptualized by Okkonen & Suhonen (2010) and Osterwalder (2004) drawing on the results of the above jurisdictional scan and semi-structured interviews. This section will also include a synthesis of the literature on governance models and relies as well on experiential learning undertaken by the researcher at the Folkecentre for Renewable Energy in Denmark, and through a field experience at the City of Toronto.

7.1 District Energy Infrastructure:

7.1.1 The Distribution Network

DE is characterized by high upfront capital costs with the distribution network accounting for the majority of the costs due to the use of highly insulated piping and digging of trenches to lay the pipe. Costs of laying piping vary depending on the location and can often be hard to predict if subterranean infrastructure is not well mapped out. Soft dig sites are less expensive than digging under streets (Hawkey et al., 2015). The diameter and routing of the pipes are also important cost variables. The shortest path between two connection points may not always be available increasing the length of the piping and therefore the cost. Rights-of-way may have to be granted by the local authority, or by-laws passed that allow piping to pass underneath parks for example. In Canada, the immaturity of the DE industry is also impacting the distribution capital cost. In comparison to Europe, standard DE components are much higher priced and a lack of contractors that have experience laying DE piping has also increased construction costs in some projects (EC1). For example, experienced contractors in Europe can lay 100m of pipe per day, compared to 2m per day in Canada (EC1). In one case, contractors in Canada over complicated the process using concrete tunnels and adding in expansion loops where they weren't necessary (EC1)

Due to the high upfront capital costs of the distribution network, the business model is highly dependent on how much thermal energy can be delivered per unit of piping and is dependent on three factors outlined by King & Shaw (2010): density of development, load diversity, and anchor loads. First, the higher the density of development, the higher the heat loads will be per unit of piping, therefore increasing the amount of revenue that can be recovered per dollar spent on the pipes. This factor is also defined as heat density, or the total heat demand of a land area (Persson & Werner, 2011). Lower heat densities also result in higher heat losses in the network and can therefore can also increase the overall cost of the system as more heat must be produced to meet the same demand (Ibid). By utilizing waste heat, higher distribution costs may be accepted as this heat may be available to the system for free or lower cost than alternative sources (Ibid). In order to meet environmental or social objectives governments may choose to subsidize lower density connections, as was done in Sweden (See Jurisdictional Scan)

Second, load diversity refers to the diversity in the load profiles of different building types. Residential load profiles will spike in the morning, and evening during the week when residents prepare for and come home from work, and on weekends. Commercial load profiles tend to use energy at opposite times as residential load profiles, and industrial load profiles are more constant. Having a mix of uses connected to a DE smoothes out the aggregate load profile and minimizes spikes in demand. This is important for DE as energy plants must be sized to meet at least the peak load and are often sized above this amount to increase resiliency. Having this excess of capacity that is only used for a short-period of time per day during peak demand is an inefficient use and increases the costs of the system without increasing revenues. Furthermore, smooth load profiles increase the efficiency of boilers or electricity generating engines such as CHP.

Third, anchor loads refer to buildings or customers with large, stable heat loads that provide stable sources of revenue over the long-term for the DES such as hospitals, social housing, prisons, data or tech companies, swimming pools and ice rinks. Anchor loads are often the first buildings to be connected to the system as they provide a stable cash flow on which to build the rest of the business model. A common approach once the DES is established with anchor loads and the concept has proven is to then expand the system to smaller users. However, in order to for successful expansion to occur the system must be future-proofed. Future proofing refers to designing the system from the beginning to be expanded by ensuring sufficient capacity is built into the pipes. Future-proofing adds costs to a project but is generally cheaper than replacing a pipe with one of greater capacity (Hawkey et al., 2015). Future-proofing becomes a challenge when the future connection of buildings is uncertain. This becomes a 'chicken and egg' problem as customers may not agree to connect until the system is built, but it may not be financially justifiable to build a system at the required capacity if it is not certain that the required user-base will connect.

Other external factors such as changes in the housing market, stock market crashes, fluctuating electricity prices, and shifts in politic leadership also act to increase uncertainty. This is where provincial and municipal policy and planning are essential to give powers to the municipality to mandate connection to DES in designated areas through a legitimized planning process, or to level the playing for DE by incentiving connection to DE through other mechanisms such as fuel taxes or building codes.

7.1.2 Supply Chain

The supply chain of a DE system consists of the sources of heat that are fed into the system. The high costs of the distribution system can be offset by DE's ability to take advantage of the lowest cost heat source available (Hawkey et al., 2015). A single plant often utilizes multiple heat sources such as CHP, natural gas boilers, electric boilers, and/or waste heat in order to capture this advantage. This section will describe the most commonly employed range of heat sources available to DE.

7.1.2.1 Natural Gas

Natural gas is the most commonly used fuel supply in DE systems today due to its availability and current low price (Nyboer & Griffin, 2016). It is used to fuel boilers to produce steam or hot water. Extensive natural gas pipe networks in Canada allow easy delivery to the point of combustion and in many cases natural gas is the primary fuel supplying energy to a DES. Regardless of the primary energy source used by the system most DE plants have natural gas boilers as backup or for peak load. Due to its low price many systems are built to use only natural gas at first with the intention of later switching to more sustainable sources. However, the well-established natural gas infrastructure and industry, as well as the continuation of low market prices makes it difficult for alternative sources of energy to be competitive.

7.1.2.2 Biomass

Despite an abundance of biomass resources in Canada use of biomass for heating or bio-heat in DES is very low compared to Scandinavian countries where biomass is one of the primary sources of heat, although its use has been growing with 14% of DE facilities using biomass as their primary fuel and another 10% using it in combination with natural gas or oil (Nyboer & Griffin, 2016). Government support has aided in the growth of the industry at the federal level through initiatives and programs targeting research & development and innovation, GHG reductions, energy efficiency and tax incentives, as well through supporting the development of bioheat and power, and bio-fuel from waste products (Bradburn, 2014). At the provincial level fuel content mandates, infrastructure grants, carbon pricing, and in Ontario the feed-in tariff and coal phase-out having acted to stimulate growth (Ibid). From 2000 to 2013 bio-heat installations connected to DES grew from 5 to 74 installations, with a total of 581 buildings connected with the majority located in BC and the Northwest Territories (NWT) (Ibid). Provincial policies in BC, NWT, Quebec and PEI have targeted the development of bio-heat DES through energy strategies, tax incentives, and funding (Ibid).

The biomass fuel supply can come from wood harvested from forests, purpose-grown energy crops or from by-product flows such as timber processing, crop residue, manure, and municipal solid waste (Bradburn, 2014). The stages of the biomass supply chain include: harvesting, transport, storage, and processing (NRCan, 2017). The harvesting and transport stages require most of the investment for labor and equipment (Okkonen & Suhonen, 2010). Processing varies depending on the type of biomass. Wood biomass can either be chipped or made into pellets. Crop residue such as wheat straw is typically delivered in bales.

The supply chain can be organized in various ways, which is determined by a contract between the biomass supplier and the DE Raw biomass materials are either bought as a standing sale or sale on delivery (Okkonen & Suhonen, 2010). In a standing sale the purchaser harvests the material themselves, whereas in a sale on delivery the purchaser buys the already harvested material. The various stages of harvesting and transportation can also be subcontracted out (Ibid).

7.1.2.2.1 Biogas

Biogas follows a slightly different supply chain and can create energy from a variety of waste streams including onsite farm waste as well as institutional, commercial and industrial waste streams such as food processing plants, slaughterhouses, schools and hospitals, however manure is the main feedstock (Bradburn, 2014). Biogas is produced through the process of anaerobic digestion whereby organic material is broken down in an oxygen-free environment to produce biogas which is a combination of methane and carbon dioxide. After delivery to biogas production facility biogas can be used to fuel CHP plants, it can be upgraded to RNG for injection into the natural gas grid, or it can be compressed for use as transportation fuel (Bradburn, 2014).

In Denmark, biogas production and sale to DE companies have been an important business for farmers as the residue from the biogas production process increases manure’s effectiveness as a fertilizer and has been a main driver in the development of cooperatively owned biogas facilities that provide biogas for heating to nearby municipalities. In Canada, Ontario is the leader in biogas production due to provincial financial assistance and feed-in tariff programs that made a strong business case for on-farm biogas plants. No examples of biogas use in DE connected CHP could be found in Canada.

7.1.2.2.2 Sustainability

From a climate change perspective, over the course of its lifetime a plant sequesters carbon and using that plant for biomass energy releases that carbon to the atmosphere with no net change in the carbon balance (Field, Campbell, & Lobell, 2008). For this reason, it is often regarded as carbon neutral in carbon accounting methods because those carbon emissions would be released anyway regardless of human interference. However, the sequestration of that carbon took place over many years, whereas combustion of the biomass releases the emissions instantaneously. Furthermore, fossil fuels are almost always involved throughout the production process, and deforestation releases tree and soil carbon content to the atmosphere as well (Field et al., 2008). However, establishing high-diversity grassland for biomass energy production on land degraded from former agricultural uses has been shown to sequester more carbon in the roots and soil than was delivered by the biomass energy harvested from it.

Due to conflicts with other uses of biomass for food production or timber, using by-product flows is the more sustainable approach and more cost-effective as it adds value to what would otherwise be a waste product. For farmers, crop residue can be sold to a DE company and the ash returned to the farmer to be spread on the field as fertilizer. Truck transportation and burning of biomass for DE in urban centres has raised concerns over local air quality in some jurisdictions such as Vancouver, which has acted as an obstacle to the development of some of these systems (DEM2).

7.2.2.3 Solar Thermal

Sørensen et al., (2012) outlines the primary types of DE connected solar thermal as being either centralized or distributed and ground-mounted or rood-mounted. Centralized systems typically consist of ground mounted solar collectors or roof-mounted collectors in an apartment block for example, located close to the heating plant. Hot water storage tanks are used to increase the share of heat supplied by solar to meet demand (the solar fraction) by allowing surplus heat produced during sunny periods to be stored for later use. These systems are typically owned by the DE company themselves. Distributed systems have solar collectors that feed-in to the DE grid at any point in the system. Ground mounted is the more common approach as it is easier to deploy and is the cheaper solution, whereas roof mounted is more labour intensive and requires more piping for connection. While roof mounted avoids the land cost the structural integrity of the building must be sufficient to install it, or higher costs may need to be incurred for reinforcements.

Solar thermal for DE has only been used in a few pilot projects in Canada and has seen limited uptake so far in other jurisdictions. The high capital costs and high-space requirements for ground-mounted solar fields, especially when needing to meet high heat demands are likely factors in this. However, Denmark has developed a burgeoning solar thermal industry and a strong business case for solar thermal in DE plants that can offer some lessons.

7.2.2.3.1 Solar Thermal Development in Denmark

Denmark has emerged as a leader in solar thermal DE through a long history of experimentation with solar thermal DE with the first large-scale plant built in 1988. Wanting to offset the use of natural gas boilers in their plants steady growth in the industry was fostered by numerous pilot projects subsidized by the national government that allowed a strong business case to be built, that was also aided by the establishment of its own manufacturing industry. The main constraint on increasing the share of solar in the overall heat supply is that the times of greatest solar radiation in the summer corresponds to times of lowest heat demand, allowing only for solar fractions of 10-20% (Andersen, Bødker, & Jensen, 2013). Therefore, Denmark also embarked on a number of seasonal storage pilot projects in order to increase the solar share, by preserving the solar energy until it can be discharged in winter (Ibid). Pilot projects such as these have provided the experience and know-how necessary in the design and operation of solar thermal and long-term energy storage (LTES) in DE systems, that have formed the foundation for future investments.

Having a 20% solar share has become a very straightforward business case in Denmark, particularly for natural gas boiler DE plants which are more expensive than the cheaper untaxed biomass plants (PlanEnergi, 2017). While the use of solar thermal did not lower the heat cost substantially, it did provide heat price stability as it is known that heat prices will be 20% lower for at least the 25-year lifetime of the asset (PlanEnergi, 2017).

Up until 2005 solar thermal had only been used to offset the use of natural gas boiler DES. A number of factors combined to create the impetus to explore the business case for CHP in conjunction with solar thermal. First, with the new rule that CHP plants would have to compete in the Nordpool spot market, low electricity prices in the summer for the electricity produced from CHP made it not as economical to run as natural gas boilers. Second, certain natural gas designated areas were mandated by law to use natural gas and therefore could not switch to the cheaper biomass fuels. Subsidized pilot projects were initiated that resulted in positive socio-economic outcomes. The success of these pilot projects drove the interest of the other heat companies, along with feasibility studies showing positive results without the aid of subsidies (Sørensen & Trier, 2012; PlanEnergi, 2017). Following this, efforts were made to share experiences through, site visits, telephone support, and the establishment of knowledge-sharing networks: The Solar Heat Group for tilities, established by the District Heating Association with two meetings per year, and a network for large scale solar heating plants, utilities, and suppliers, which meets one every year (Sørensen & Trier, 2012). Spread of knowledge and innovative ideas was also advanced through the non-profit model, as this removes the business case for keeping ideas inhouse (Sørensen, 2016).

7.2.2.4 Heat Pump Based Systems

Heat pumps are electrical devices that extract heat from one area and transfers it to another by circulating refrigerant through cycles of evaporation and condensation (NRCan, 2017). Heat normally flows from hotter mediums to colder ones; however, heat pumps allow this basic physical law to be reversed through the addition of electrical energy that extracts heat from a low temperature source as the refrigerant evaporates under low pressure, and then releases the heat to the heating area as it is condenses in the compressor under high pressure (Phetteplace, 2007). When this process is reversed the heat pump extracts heat from an area and ejects it to a heatsink producing cooling. Heat pumps deliver more heat output than the equivalent electric input it uses, therefore giving it an efficiency of usually between 250% to 400% (Centre for Energy Advancement Through Technological Innovation [CEATI], n.d.). While it is confusing to refer to efficiencies higher than 100%, heat pump efficiency is usually referred as the coefficient of performance (COP). Heat pumps with a COP four therefore would produce four units of heat for every unit of electrical input.

Heat pumps can be airsource, watersource or groundsource. Heat pumps that serve a single household or unit are referred to as individual heat pumps. Individual household heat pumps, especially air source heat pumps have emerged as one of the main competitors with DE in some jurisdictions (Werner, 2017). For use in DES large-scale groundsource or watersource heat pumps are used most commonly as part of geothermal or geoexchange systems. Heat Pumps in conjunction with DES are commonly used in two types of applications: geoexchange and geothermal.

7.2.2.4.5 Geoexchange

Geoexchange systems are referred to by various names (earth energy systems, ambient loops, cold district heating) however, the basic principle remains the same: a thermal energy circuit which circulates and stores thermal energy in a water/ethanol mix and acts as a heat sink or heat source for connected buildings that deposit or removes thermal energy from the circuit though the use of a heat pump, thereby meeting both heating and cooling demands. Buildings connected to a geoexchange system also act as thermal sources and sinks.

Geoexchange systems take advantage of the relatively constant ground temperatures that occur at shallow depths and can range from the individual house scale to the district scale (NRCan, 2002). A key characteristic of district scale geoexchange systems is allowing for thermal energy sharing between buildings. When simultaneous heating and cooling demands exist in a system, the rejected heat, for example from a location with a consistent cooling demand such as a data centre or ice rink, can be taken by the DE system and either be used to meet a heat load elsewhere in the system or can be stored for later use either in the pipes or a in a separate thermal storage unit.

As described by Vaughan & Lundquist (2012), most networks have a two-pipe circuit consisting of two separate and parallel closed loops of piping: one warm and one cool, or supply and return, which serve to transfer and store thermal energy between sources and sinks. The conduits are fluidly interconnected only at the building through the energy transfer station (ETS) and at the energy centre. The ETS extracts heat from the warm conduit using heat exchangers and heat pumps to heat the building, and then deposits the cooled water into the cool conduit. Or, it extracts heat from the building and deposits it into the warm conduit.

The circuit is also connected to at least one energy centre that is thermally coupled to at least one external heat source or sink and can contain the backup or peaking boilers. In closed loop systems vertical borehole fields or horizontally lain pipes are commonly used as the source/sink. In an open loop system, the thermal source/sink is often a free-flowing underground aquifer. The function of the energy centre is to maintain thermal balance within the system by adding or removing thermal energy. If a net amount of thermal energy is removed, the energy centre deposits more energy from a connected thermal source. If a net amount is added by the buildings, the energy centre stores the excess energy in a connected heat sink such as a geoexchange field or must release it as waste through cooling towers. Although, it is possible to maintain balance within the circuit if connected buildings collectively remove and return about the same amount of thermal energy.

Many different configurations exist of geoexchange systems, but the main distinction is between centralized and distributed systems. Centralized systems are configured with the heat pumps located in the energy centre. The low temperature heat extracted from the thermal source is upgraded by a heat pump and distributed to the ETS in individual buildings through the thermal network. The Southeast False Creek Neighbourhood Energy System in Vancouver is an example of such a system where lower temperatures from waste sewer heat is upgraded at the energy centre with heat pumps and then distributed to heating loads (City of Vancouver, n.d.).

In a distributed system the heat pumps are located in the ETS of the individual buildings. Since low temperature heat is being distributed through the pipes, distribution heat loss is less, and uninsulated piping can be used which lowers costs. However, having the heat pumps and heat exchangers located in the ETS increases the footprint of the mechanical room and can increase maintenance costs reducing potential cost savings that may be attractive to DE users.

Trade-offs

Some trade-offs exist between distributed and centralized systems. Distributed systems have the ability to share energy between buildings by using onsite heat pumps to reject heat into the loop when cooling is desired, and extract heat when heating is required. This has the benefit of only needing two pipes in the ground (supply and return) for heating and cooling rather than four and gives each building the ability to adjust temperatures (Bünning et al., 2017). However, these systems depend on perfectly balancing heating and cooling demands between buildings to maintain the temperature balance in the distribution grid. To maintain balance these types of systems must be integrated with heat rejecters (cooling towers, geoexchange) or heat adders (boilers, geoexchange; Pellegrini & Bianchini, 2018). Because distributed systems operate at low supply and return temperatures, they can use cheaper, uninsulated distribution pipes making them particularly useful where linear energy density is low (Compass Resource Management, 2012)

Distributed systems also require more equipment in the building's mechanical room. For example, the Cheakamus Crossing NES in Whistler, B.C., which captures sewer waste heat, requires a heat exchanger, a heat pump, a domestic hot water tank and a space heating tank (City of Whistler, 2017). This may increase maintenance costs for the building owner as DHW tanks and buffer tanks have eight to ten-year lifespans. To overcome this Whistler implemented an Upgrade and Maintenance Program that provides up to $1000 for issues that require parts replacement or flushing and facilitates bulk pricing for annual maintenance of the home heating system.

In contrast, centralized systems only require a heat exchanger along with the necessary control systems and pumping equipment. On the other hand, centralized systems may still require insulated pipes, as the heat is upgraded to a higher temperature before distribution to the consumers, as in the case of the Southeast False Creek system. While having a centralized system with four pipes to deliver heating and cooling will add to capital cost, pipes have longer lifetimes than the additional mechanical room equipment needed in a distributed system. Therefore, on a lifecycle basis centralized system may be more cost-effective as the pipes will not have to be replaced for at least 50 years, whereas mechanical room equipment may need replacement after 10 years.

Other benefits of a centralized system are similar to the benefits already attributed to converting from individual heating systems to DE systems, including reduced maintenance costs, reduced capacity requirements, more reliability, and space savings in the mechanical room.

7.2.2.4.6 Geothermal

Geothermal energy is defined as the energy contained as heat in the Earth's interior, the origin of which is linked to the internal structures and processes of the planet (Barbier, 2002). While there is natural flow of heat from the core as it dissipates to the surface, local geological processes can lead to high temperature sources being located within economic drilling depths (Grasby et al., 2012). For clarity, while geoexchange does take advantage of heat naturally stored in the earth, geothermal refers to heat extracted at 150C or less at 1000m for low temperature geothermal, or not less than 200C at 1000m for high temperature geothermal in the form of naturally occurring steam or hot water that can be directly used in DES (Gunlaugsson, 2004). Low, medium and high temperature geothermal resources can be used for space heating, while high temperatures are more favourable for electricity production (Grasby, 2012). Although not as efficient, electricity can be economically generated at temperatures as low as 80C (Ibid).

Geothermal DE consists of three components: heat production, transmission/distribution, and central pumping stations and in-building equipment (Ibid). Heat production requires drilling of production wells and a submersible pump that pumps the hot water or steam to a heat exchanger on the surface that is connected to the distribution grid. The cooled water is then injected back into the geothermal reservoir through the use of an injection well and injection pump. Geothermal resources have to be located at an economically viable drilling depth and must have sufficient surrounding permeable rock that allows surface water to accumulate and be heated (Grasby et al., 2012).

The potential of Canada's geothermal resource is equal to 1 million times the current electricity consumption, however much of it lies beyond economical drilling ranges, far from load centres or outside of areas served by transmission lines (Grasby et al., 2012). While the resources are widely distributed across Canada most of the potential lies in Western Canada and the Northwest Territories presenting a potential opportunity to provide heating for remote communities (**Figure 7**).

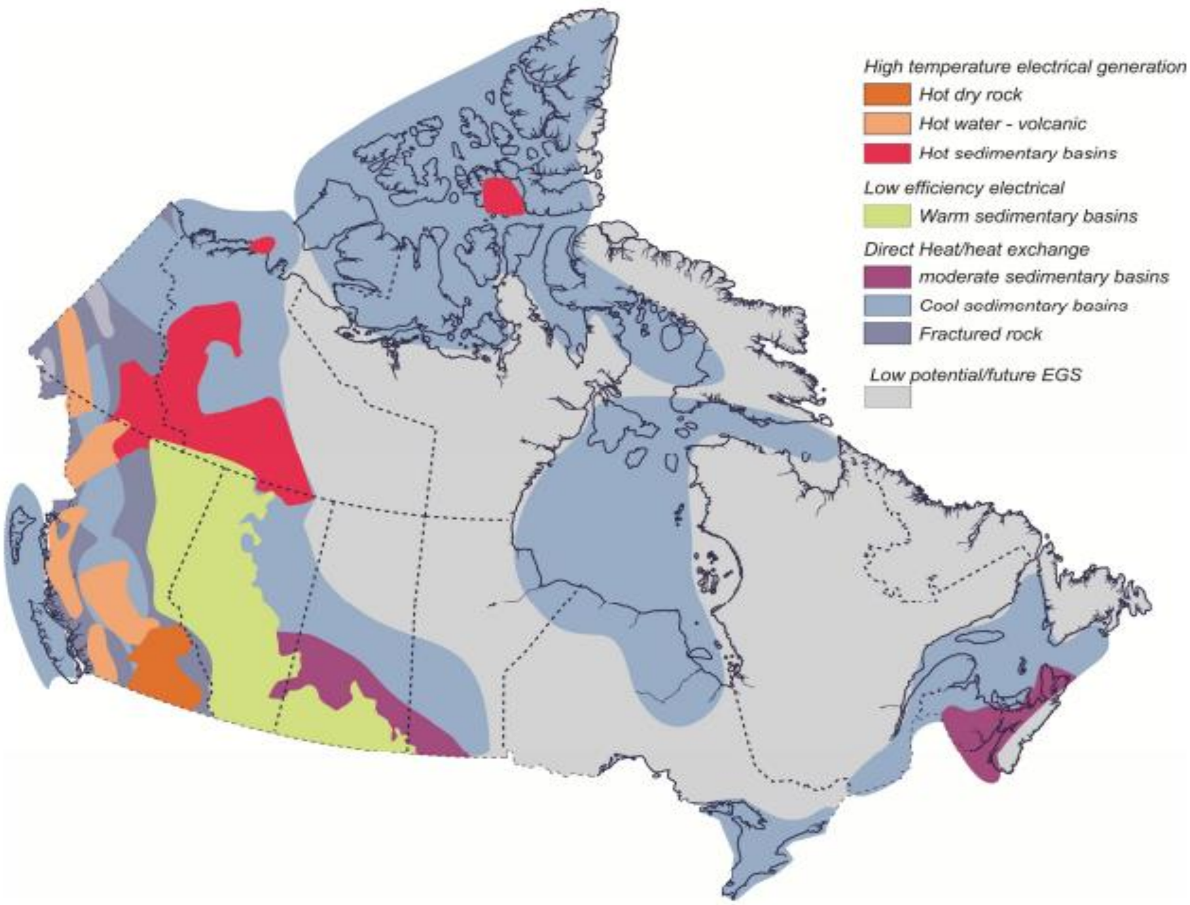

Figure 7. Geothermal resource potential of Canada (Grasby et al., 2012).

7.2 Financial Considerations

The lifetime of DE networks can be over 40 years before any replacement is needed, therefore how costs and benefits are calculated in feasibility studies and which performance metrics chosen by organization that measure the profitability of an investment are crucial factors in deciding to build or not build a DES. Financial models and feasibility studies tend to use 15-25 years as the lifetime of the asset (Hawkey et al., 2015), however this may negatively impact economic assessments of DE and could affect the perceived viability of the project due to the longer payback periods and high upfront capital costs of characteristic of DE. Assessing the project over its full life-cycle, including future avoided costs from rising fuel prices, for example, can improve the business case for DE (King, 2012).

Different organization will use different financial indicators to determine if investments should be made which include the payback period, net present value (NPV), internal rate of return (IRR) and return on investment (ROI). The payback period is the period of time before the investment begins to generate net positive cashflows and is an important indicator for organizations that have limited capital or do not wish to take on long-term debt as they may wish to free-up capital for other projects (Hawkey et al., 2015). However, due to the high upfront capital costs and longer durations of planning and development, short payback periods are difficult to achieve for DES.

NPV calculates the net cash inflows and outflows of the project over its lifetime in present day dollars. If the revenues from thermal energy sales are not enough to generate sufficient profit over the lifetime of the asset, then the NPV will be negative or too low to be attractive to project proponents.

IRR is a metric often used to estimate and compare the profitability of potential investments. It is defined as the discount rate that results in the NPV being equal to 0 and ultimately tells investors what their annual rate of return will be. The discount rate represents the time value of money; a dollar today is worth more than a dollar tomorrow, or ten years from now. Discount rates are subjective, and each organization will have different preferences for which discount rate to use, with higher discount rates placing less value on costs and benefits in the future resulting in higher IRR (Hawkey et al., 2015). The chosen discount rate has a large impact on the outcome of feasibility assessments of DE because of the longer payback periods associated with it and the fact that benefits may not be realized until later in the lifetime of the asset.

ROI is a simpler investment performance metric that measures the percentage increase of an investment over a period of time by taking the difference between the cash flow and the costs of the investment and dividing it by the costs of the investment. However, ROI does not take into account the time-value of money as represented by the discount rate in the IRR, and therefore is not as suitable for longer investment horizons. Because each organization uses different metrics ROI and IRR will be referred to generally as rates of return (ROR) throughout this paper unless specifically referring to one of the above-mentioned metrics.

7.3 Governance Models

The different governance models for DE can be seen as occupying a spectrum between wholly publicly-owned and wholly privately-owned. In the middle exists different degrees of split or shared ownership that result in different allocations of responsibility and risk. Governance models affect every aspect in the development of DES including project schedule, allocation of capital costs, financing costs, access to financing, grant availability, capital and operating efficiency, customer rates, capacity for growth and innovation, flexibility and adaptability, regulatory requirements, transparency, administrative complexity and strategic alignment (Cleveland, 2013). As with other aspects of DE, the choice of governance model depends on the specific local context such as the available energy sources, regulations, type of financing, and expertise that is available.

The majority of governance models involve the public sector in some way due to the important role local governments play in many aspects of DE development such as planning approvals, access to municipal rights-of-way, regulation, policy, financing, providing stability as a consumer, as a coordinator between multiple city-wide projects, and the ability to focus on long-term planning to meet social and environmental objectives. Even if a project is led by the private sector, they will look to the public sector to underwrite the project (Poyry Energy & Faber Maunsell, 2009) Municipalities are also able to accept longer payback times and lower RORs. However, the public sector does not usually have the in-house expertise to carry a project through every phase of development themselves. Therefore, DE governance models typically involve both the public and private sector to some degree. The ROR, risk appetite, and availability of capital project investors and proponents are crucial deciding factors in the type of governance model that should be chosen and the degree of the public or private sector involvement. Private sector involvement usually occurs if the project gives a sufficient ROR, or through trying to meet a particular building regulation (Hawkey et al., 2015; Riahi, 2015). Because of the longer payback times, private investment usually comes from companies that have a long-term view or already have energy utility investments, such as already existing energy companies, or utilities. However, in Canada many property developers are pursuing smaller, campus scale DES to serve their own community scale developments. In this model the

DES are either owned and operated by the company or are outsourced to a third-party company for operation.

7.3.1 Public Ownership Models

Full public ownership of the DES has the benefit of giving the municipality complete control over the future of the system, making it possible to deliver broader social benefits and align with city goals particularly relating to sustainability, fuel poverty, and resiliency, and to include these benefits in socio-economic cost-benefit analyses (Riahi, 2015). Strategic alignment with other municipal policies, programs and projects can also be easier under full municipal control as coordination can occur internally and the number of stakeholders to coordinate is reduced. However, the municipality must also take on all the risk of the project and must finance the project on their own.

A municipally-owned DE utility also has the ability to choose technologies with low-environmental impact and have control over rates and how the utility expands to achieve further environmental and economic benefit (Baber et al., 2006). Municipal control over rates can also allow for a more equitable approach, for example setting rates based on customer groups (i.e. residential, commercial) rather than on their location in the network and work to connect customers that may not be prioritized by a privately-owned utility, such as social housing, or those with a low connection capacity (Riahi, 2015). Municipalities are more inclined to have longer-term outlooks and therefore may be more willing and able to take on projects with longer payback times and lower ROR, due as well to their access to low-interest financing and grant funding, and exemptions from income and property taxes (Baber, 2006). In terms of rates, the impact of lower financing costs and debt interest rates, as well as acceptance of lower ROR can be passed on to customers in the form of lower service rates. The municipality also receives all profits from the DES and can reinvest this back into the project to make upgrades or lower rates for customers, or use it to fund other projects (Riahi, 2014).

A high degree of flexibility and adaptability is also maintained by a public ownership model as the municipality can choose to maintain the business or exit by selling it to the private sector in order to release funds for other projects, increase returns, or expand the system by allowing private sector partners to own or partially own the system (Riahi, 2015). Municipalities may also be exempt from certain regulations that affect DE. For example, in BC municipally-owned DE utilities are exempt from rate regulation by BCUC. In such cases, municipalities may wish to establish advisory panels, or review boards to ensure transparency and fairness to customers.

Operation of the system typically occurs through a city department, similar to other public infrastructure, or by establishing an arm's length subsidiary. Existing municipally-owned utilities are also often well positioned to develop and operate a DES, such as already existing electricity or gas utilities, due to their experience in making infrastructure investments and familiarity with rate structures (CEP1).

Developing and operating from a city department is typically financed from the public balance sheet (Rao et al., 2017). However, if the project ROR is low, this can be a way to lower administrative costs, as the transaction costs of establishing a new entity are avoided and administrative efficiencies can be gained by integrating new responsibilities with existing staff and departments. Under this model the city council has direct control over staffing, operating and capital budgets and utility rates (Baber et al., 2006).

If the project has a higher ROR the municipality may choose to own, operate and maintain the DES by establishing a subsidiary or special purpose vehicle (Riahi, 2014). The subsidiary is typically established as a company limited by guarantee, with the possibility of other public sector organizations owning shares in it (Rao et al., 2017). This model can be costlier and more difficult to implement as it requires the establishment of formal agreements that dictate the relationship between the city and the subsidiary (i.e. funding arrangements, risk transfer, access to infrastructure) (Baber et al., 2006). At the same time, it can reduce the administrative burden on the municipality as a board of directors is typically established to oversee governance (Riahi, 2014). Subsidiary ownership has the benefit of reducing the financial liability of the municipality and can also increase the speed and flexibility of decision-making and allow for more a commercially-minded operation as every decision does not have to go through council. The system is operated more as a business rather than as a public service, and is controlled by an independent board of directors, which provides an arms-length approach to governance that is more separated from the politics of municipal councils (Ibid). However, city councils can still maintain control over the subsidiary by passing by-laws that determine how rates are set, and through appointments to the board of directors (Baber et al., 2006).

Establishing a subsidiary corporation comes with its own set of regulations under national and sub-national regulatory frameworks and can also increase transparency by requiring certain internal reporting and accounting standards. If the DES is planned to be sold to the private sector, having it already owned by a subsidiary corporation allows for easier transfer of the assets, otherwise a company limited by shares would likely have to be established and the assets transferred to it before being sold (Riahi, 2014).

Municipalities also often maintain ownership of the DES as part of a city department or through a subsidiary but contract out for the different stages in DE development. This typically involves a competitive bidding process in which companies are selected for the design, construction and/or operation, maintenance and administration of the system. This model still allows the municipality to retain control over things like rates and capital decisions but can also transfer some business risk to the third-party operator depending on the contract, although this may come with a higher cost to contract operations (Baber et al., 2006). Issuing a tender and negotiating a contract also adds complexity, and contracts could put constraints on changes to operating policies and exit strategies (Ibid).

7.1.3.2 Public-Private Hybrid Ownership Models

Public-private models may be chosen when the ROR is sufficient to attract private investment, and when the local authority wishes to transfer some risk but wants to maintain some control over the project, but also wants private sector expertise and financing. (Riahi, 2014). A wider range of governance structures fall under this category. In this section joint-ventures, concession contracts, service agreements, and strategic partnerships will be discussed.

7.1.3.2.1 Joint-ventures

Joint-ventures typically refer to the creation of a subsidiary corporation limited by guarantee with split public-private ownership. The split in ownership is based on the equity contributions of each partner, which can take the form of cash, land, expertise or skills (Rao et al., 2017). They are pooled asset models where skillsets, resources and risks are shared according to the expertise of the parties under one company or utility (Riahi, 2015). Municipalities can underwrite the loan and/or the sales risk, commit to long-term service contracts, deal with regulatory and planning barriers, and provide land. The private sector can take responsibility for the risk associated with the design, construction and operation of the system, and can provide skills and expertise (Ibid). The shares of equity contributions are defined through agreements, which also include the division of risks, decision-making (including growth and technology decisions), as well as exit or buy-out provisions (Compass, 2012).

Joint-ventures are more complex than wholly-owned models and can be administratively costly as legal agreements and contracts must be negotiated (Rao et al., 2017). However, they allow access to municipal sources of financing, and maintain a degree of municipal control over projects, while benefiting from access to private capital and expertise. Governance usually occurs through a board of directors that reflects how the ownership is split. In terms of flexibility and adaptability, the municipality can decide to maintain the status quo, sell to the partner or other private interest, or buy from the partner to create full municipal control (Riahi, 2014).

7.1.3.2.2 Split-Asset Models

Split asset model involves an ownership split across the assets with contractual obligations between parties, instead of having all assets under one company with shares divided between stakeholders (Compass, 2012). Parties are typically responsible for financing the asset that they control (Riahi, 2014). A typical asset split in a DES is between the distribution system and the generation assets, where the owner of the distribution system is responsible for customer connection, and retail sales, and the owner of the generation assets is responsible for the generation of heating and cooling (Compass, 2012). Split-asset models allow each party to focus on the part of the business that they are experts in, however it can also hinder growth of the system as the parties must engage with each other to expand and their goals must be well-aligned.

7.1.3.2.3 Concession contracts

In a concession contract, the local authority usually develops a feasibility study and then tenders it to the private sector to be financed, designed, built and/or operated for a specified term (Riahi, 2014). The private sector entity is usually an energy service company (ESCO) or a utility who also bears all the risks of designing, building, and operating the system (Ibid). The municipality still owns the assets and therefore still bears some risk as they must buy back the system at the end of the contract or contract for another term (Ibid). The business case for the commercial energy company can be made more viable by the municipality by guaranteeing long-term thermal loads by connecting their own buildings, or through mandatory connection bylaws (Rao et al, 2017). A high-degree of control can still be maintained by the municipality through the concession contracts, which can include how tariffs should be charged and the length of the contract. For example, in Paris, the contract sets a maximum price for delivered heat, and requires a lower price for social housing (Rao et al., 2017).

7.1.3.2.4 Strategic Partnerships

Strategic partnerships are a relatively new model that doesn’t involve public sector ownership of assets but does involve close collaboration with a private sector partner to deliver DE (Compass, 2012). This model goes beyond more passive roles of the municipality in terms of policies or providing franchise rights to deliver heat in an area. Instead, the municipality takes a much more proactive and collaborative approach, engaging in joint infrastructure and land use planning, joint marketing, and providing support through methods such as granting land rights, tax exemptions or grants (Ibid). Partnerships may be formalized in agreements and the public sector may impose requirements on the private partner to meet environmental or social objectives (Ibid). Profit sharing can also be stipulated in the contract.

Cofely in the UK is often cited as pioneering this model in Southampton and Birmingham. In this case the municipality did not want to take on ownership and financing responsibilities, and therefore partnered with Cofely after being selected through a competitive bidding process. The relationship was formalized through a joint-cooperation agreement (Ibid).

Similarly, recognizing the need for private sector expertise and resources in order to advance the low-carbon thermal network objective of the City of Toronto's climate change plan, the City partnered with Enwave, a utility with existing DE assets in Toronto. The City and Enwave entered into a joint-partnership agreement for the development of four thermal network nodes, with the City playing an important role in the coordination of land use and infrastructure planning. The capital requirements are split roughly 50-50 between the parties, with the municipal share coming from provincial grants.

7.1.3.3 Private Ownership Models

In the private ownership model, the private sector fully owns, operates and controls the DES and finances it through debt and/or equity (Rao et al., 2017). All risk lies with the private sector, but local governments can still play a strong role in mitigating risk and facilitating DE development through formal or informal agreements, such as strategic partnerships, or more indirectly through permitting, zoning bylaws, and granting municipal street access (Riahi, 2014). The company that owns and operates the system may also offer a position for the local government on the board, but otherwise has full control over the rates and direction of the DES. In some jurisdictions such as BC, rates for private DE companies are regulated by an independent regulatory tribunal. This can be seen as a strength to some customers who value independent oversight, rather than rates that are set more politically by a local government council or municipally-owned company (BO/PM1). Many privately-owned DES also take the form of a campus DES that serves the companies own buildings on a property, connects several blocks owned by the same company, or developers building at the community-scale.

Other strengths of this model are the access to private sector capital, leveraging of expertise and best practice, and shorter development times. Weaknesses include potentially higher rates charged to customers and inability to access low-interest loans or municipal grants (Rao et al., 2017). It is also more difficult for local governments to steer the system towards meeting social and environmental objectives.

7.1.3.4 Cooperative Models

A cooperative model refers to shared ownership of the DES by the consumers of heating and/or cooling. Each consumer typically has an equal share in the company, or more shares may be given to those who have larger heat demands. Governance is conducted by an elected board of directors, and the municipality is usually given a seat on the board. Members can also vote on issues at general assemblies. Cooperatives are typically not-for-profit, so any profits are reinvested in the system for upgrades or to lower rates. Financing is commonly done through loans that are based on security provided from contracts for heat loads from the members of the cooperative. Municipalities may also underwrite loans, which can allow for lower interest, or provide revenue bonds which are secured against long-term customers. In the early days of DE cooperatives in Denmark, individuals were responsible for raising their share of the capital to finance the system through personal equity or individual bank loans. While this shifted more risk to the consumer, it allowed the DE company to focus solely on efficient operation of the system (EC2). Currently, municipalities commonly underwrite loans for the cooperatives however the DE industry is perceived by the banks as a very stable investment environment so low-interest loans are more easily procured even without municipal support (Chittum & Østergaard, 2014).

7.1.3.5 Energy Service Company Models

In the context of policies continuing to incentive energy efficiency and renewable energy generation, concurrent with the move towards liberalized energy markets, ESCOs have emerged to meet the demand for a wide range of energy services for end-users. ESCOs are similar to more conventional energy providers in that they supply and install energy efficient equipment, retrofit buildings, provide O&M, facility management, and supply heat/electricity. However, ESCOs also provide financing for an energy system, and guarantee the energy savings or performance against their remuneration for their services (Pantaleo, 2013). ESCOs therefore risk their payment on the performance of the system. ESCOs play an important role in the energy transition by pooling smaller-scale energy efficiency projects and/or distributed generation assets together. This has the effect of reducing investment costs through economies of scale, decreased operational costs from centralized plant maintenance, fuel supply savings through bulk purchases, and ability to qualify for support measures that require certain thresholds (Pantaleo, 2013). In terms of DE, ESCOs can be organized in a variety of ways in terms of responsibilities, ownership of assets and relationship with the consumer and the local government, which determines how risks are distributed (**Table 4)**.

ESCO Arrangement	**Description**	**Governance model**
ESCO provides equity/debt	• ESCO assumes risk • End-user pays for consumption under contract • Option for end-user to receive ownership after payback period	Private
End-user provides equity/debt	• End-user owns plant, ESCO operates and guarantees performance	Private
ESCO and end-user share investment risk	• Reduces billing charge for end-user • Decreases debt/equity ratio for ESCO	Private Partnership
Public Sector provides equity/debt	• Public sector owns and sells energy to end-user • ESCO operates according to contract	Public
Public Sector and ESCO share equity/debt	• Public sector receives invested money back through capacity charges and plays facilitation role	Public-private partnership

Table 4. ESCO organizational structures (Pantaleo et al., 2013).

Public Sector Models			
Type	Strengths	Weaknesses	Opportunities
Internal Municipal Department	• Access to low cost financing and grants • Control over social and environmental objectives • Control over network growth • Generates revenue for municipality • Administratively simple	• Amount of debt may be limited • Internal budgets take the risk • Need to develop internal skills and capacity • Longer municipal procurement process	• Longer-term investment perspective and acceptance of lower ROR allows more projects to move forward

Type	Strengths	Weaknesses	Opportunities
Municipal Subsidiary	• Access to low cost financing and grants • Financial and technical risks are shifted away from municipality • More transparency in operations • Insulated from municipal council politics	• More administratively complex • Longer municipal procurement process • Advantages over city department model may be limited	• Allows for easier transfer to private sector • Council still has a degree of control over system to reach social and environmental objectives
Municipal ownership, third-party Operator	• Business and operational risk transferred to private sector • Allows access to private sector expertise	• Negotiating contracts and issuing tenders adds complexity • Contracts may constrain certain decisions or exit strategies	• Outsourcing to experts can result in a more efficient and higher quality service • Can maintain municipal control over rates and policies through bylaws

Hybrid Models			
Type	Strengths	Weaknesses	Opportunities
Joint-Venture	• Allows access to both public and private sector sources of funding • Risk is shared between partners • Sharing of assets and expertise • Provides certainty that municipality will support project	• More complex and costly than wholly owned models	• Flexibility can be maintained through different potential exit strategies for either party • Municipality still has a degree of control over objectives
Split Assets	• Allows each party to focus on their specialization	• Parties must cooperate to achieve system growth or social/environmental goals • Contractual relationships between parties adds complexity	
Concession Contracts	• Leverages third-party financing • Technical and commercial risk transferred to third-party • Expertise provided by third-party operator • Shorter private sector procurement process	• Reduced control for public partner • Subject to higher private sector rates of return	

Type	Strengths	Weaknesses	Opportunities
Strategic Partnerships	• Leverages private sector expertise and financing • Leverages municipal support and leadership • Joint agreements clearly define roles for partners • Offers high degree of flexibility in how risks and responsibilities are shared • Does not require creation of a subsidiary corporation	• Requires strong cooperation and aligned goals between public and private partners • Subject to higher private sector rates of return • Social and environmental goals are subject to negotiation • Requires active and involved municipal participation	
Private Models			
Wholly-owned	• Access to capital • Private sector expertise • Shorter procurement times	• Higher expected rates of return • No municipal control over social/environmental objectives • Higher financing rates	
Cooperative	• Non-profit allows lower tariffs • Greater control over objectives, and network growth	• Access to capital • Must outsource expertise	□ Profit can be reinvested in system or used to lower tariffs

Table 5. Summary of Governance Model Strengths and Weaknesses

7.4 Earning Logics

Earning logics are a range of strategies to maintain profitable and sustainable business operations. This section will therefore discuss some of the strategies for overcoming challenges unique to the DE business model including the key factors than need to be in place to attract a customer base and secure investments. Thermal energy rate structures and energy service agreements and the roles they play in mitigating risk between the DE owner and the consumer.

7.4.1 Attracting a User-Base

In order to make a successful business case that can attract users and investment and withstand shifting political winds planning for DE needs to include the following factors (Adapted and modified from EC1):

1. Clearly defined areas where DE is viable and is identified as the preferred option
2. Clear technical guidelines and building standards for DE-ready buildings
3. Multi-decadal commitments and plans
4. Monopoly over the heat-supply to ensure ability to offer competitive pricing
5. Energy Service Agreements that clearly define the roles and responsibilities of the user and the DE utility
6. “Election-proof” governance including:
    a. Supply continuity, quality and environmental goals
    b. Strategic business plan that has been fulfilled
    c. High quality of management
    d. Financial and ethical obligations met

7.4.2 Rate Structures

Rate structures refer to how DE companies recover capital and operating costs by charging customers for connection to the service and for the amount of heat consumed. How rate structures are designed play a large role in how risks to the DE owner are mitigated.

7.4.2.1 Two-Part Rate Structures

Two-part rate structures refer to a fixed charge component and a variable charge component and is the most common approach in the industry (King, 2012). The fixed charge recovers the fixed costs of the energy plant and the distribution network including debt payments, rent, wages and overheads. It can also be called a capacity charge and is related to the amount of peak heating capacity required by the customer (Ibid). Fixed capacity charges are often based on the avoided operation and maintenance costs of a conventional stand-alone heating system. These costs can include all equipment costs, engineering and consulting fees, natural gas and electrical services, ongoing maintenance contracts, risks of ownership, and boiler replacement reserve funds (Bradford, 2012).

The variable component or consumption charges corresponds to the amount of metered consumption per month in $ per MWh and covers all variable costs including fuel costs, electricity, and water consumption, as well as any other consumables (King, 2012). Having a variable charge protects the DES owner from fluctuations in cash flows due to changes in volume of sales or energy prices. No profit or loss is earned on the sale of energy itself thereby insulating returns on equity from external factors such as energy prices and weather. Instead, profit is earned through the fixed capacity charges, which provides a much more stable revenue and can make lower ROIs typical of DES more viable to a prospective company. This model resembles electricity utility rate structures, which is another reason why companies choose this model as the structure is already familiar to them (CEP1). In contrast, if a single charge is used that covers all costs the DE company runs the risk of not receiving sufficient cash flows if due to events out of their control, for instance milder weather than expected, if occupancy is reduced or if energy efficiency measures reduce demand.

Two-part rate structures also provide the benefit of sending price signals to customers. On the fixed capacity charge side customers are incentivized to reduce the amount of capacity they need. On the variable side customers are incentivized to reduce their energy consumption as this will also reduce their monthly bill.

7.4.2.2 Cost-Reflective Pricing vs. Avoided-Cost Pricing

Rates can be either linked to the input costs of the DES (cost-reflective pricing) or the input costs of the customer (avoided-cost or market-based pricing) which is typically natural gas boilers (Hawkey et al., 2015). In cost-reflective pricing rates are sometimes set approximately equal to the avoided costs anyway with consumption charges equal to the fuel cost for heating or the electricity cost for cooling, and the capacity charge equal to the non-fuel costs per KWt per month in order to ensure competitiveness with conventional heating and cooling systems (EC2). Essentially, the amount of heat consumed by the customer is converted into the amount of natural gas they would have used if they had a conventional boiler or furnace.

Cost-reflective pricing typically has higher fixed charges and lower variable charges reflecting the higher capital costs of DE and the usually lower fuel costs. These higher fixed charges can act to discourage energy efficiency objectives as customers have little incentive to reduce energy consumption as their activities will only marginally impact their overall heat bill. This is the case in Denmark where cost-reflective pricing is mandated by law (Chittum & Østergaard, 2014). Cost-reflective pricing is important for DE utilities because higher fixed capacity charges reduce financial risk (Ostergarrd, 2012). On the other hand the users of the system bear the risk that their heat bills will be higher than the alternative (Hawkey et al., 2015).

If using the avoided-cost approach, the DES operator bears the risk that the rates will be too low to sustain the business or are too high and cannot attract customers. Regulatory regimes in some jurisdictions deal with this by capping rates at the equivalent costs for alternative technologies, such as in the Netherlands (Hawkey et al., 2015). Heat charges will be similar to the DES costs but will vary depending on different utility rates and different customer load profiles. For cooling loads the amount of consumption is converted in to the amount of electricity they would have used in a chiller plant. A challenge with this approach is determining the appropriate efficiency to use in the calculation, as it is not possible to know exactly what the coefficient of performance (COP) of the chiller would have been in the real-world vs the manufacturer's nameplate COP (EC2). Similarly, thermal energy produced by a conventional boilers plant is generally not metered making the actual seasonal efficiency of the boiler unknown. This is a challenge for the DE utility because customers will argue that their COP is higher and therefore would have used less electricity, or that their boiler efficiency is equal to the nameplate efficiency, even though real-world chiller and boiler efficiencies are lower (EC2).

Another challenge of the avoided-cost approach is that it may produce higher variable charges and lower fixed charges as the variable charges will be tied to the market prices of the alternative fuel. This presents an added risk to the DES operator, as they will be receiving less revenue from the more stable fixed capacity charges. However, higher variable charges and lower fixed charges more closely resembles a typical electricity utility bill and therefore is more familiar to the customer. One problem with having higher fixed charges is that customers often do not understand why their bill is so high even though their consumption may be low and they can become dissatisfied with the service (DEM2). This problem can be overcome through sufficient marketing, education and customer engagement on the part of the DES operator.

7.4.2.3 Connection fees

Connection fees are upfront charges to the customer for the initial connection to the system that are set close to the avoided cost of hot and chilled water plants that no longer need to be installed (King, 2012). Connection fees are often charged to the building developer and help to ensure that the end user pays a competitive price. If a connection fee is not charged then the capacity charge must be set higher to recover the costs, which is passed on to the final customer, and the developer saves the money that would have been spent on hot and chilled water plants (MR/PM1). This presents a challenge as developers may be reluctant to pay a connection fee in the absence of mandatory connection policies or argue for a lower connection fee, and the capacity charges must be set to recover all ongoing fixed costs, amortization and any additional capital investments in the DES. This also highlights the developer-building owner-tenant value split where cost savings realized by the developer during the construction phase are not passed onto the customer, and end users may be dissatisfied with the higher rates they have to pay as they may not account for the avoided future equipment replacement costs. From the perspective of the DE owner the downside of connection fees is that this revenue stream will eventually cease as full buildout of the system is reached.

7.4.2.4 Deferral Accounts

Another risk inherent to DE is the timing of development. When dealing with new developments the DE system must be ready to connect new buildings as any delays in the opening of the building will deter developers and building owners from connecting. Likewise, buildings must be ready for connection on time, so the DE utility can start generating revenue.

Deferral accounts are sometimes used by DE utilities to deal with the issue of insufficient revenue streams during the initial stages of development. Deferral accounts essentially allows the costs of developing the DES to be amortized over an agreed upon period, which is commonly set at when full buildout is expected to be achieved, which is often 20-years. This approach is also known as a rate stabilization account, as the rates are kept stable over time. In this way initial customers do not have to pay more in the early years of development when the customer base is not sufficient to recover the costs of service because cost of service shortfalls are captured in a deferral account which is set be fully recovered by the year of full buildout.

7.4.3 Energy Service Agreements

In the absence of a regulatory framework or a mandatory connection bylaw, DE utilities must negotiate Energy Service Agreements (ESA) with individual customers that dictate the terms of service. This represents a significant risk that critical mass in the customer base may not be obtained to meet cost of service requirements if customers cannot be persuaded to connect, and ESAs must be designed to mitigate this risk.

Energy service agreements are the contractual terms that govern the relationship between the heat supplier and the customer. Besides outlining the rate structure and contracted capacity, the ESA is particularly important in the absence of a regulatory framework in order to protect both the customer and the DE utility and to mitigate risk.

On the customer side, the primary mechanisms that are desired by consumers in the ESA are:

- Guarantees- benchmarking of prices back to market, and periodic review to ensure fairness
- Transparency of the rate structures
- Insurance that the system will deliver a reliable heat. i.e. a certain amount and quality of heat when it is needed

A typical term for an ESA is 20 years with two additional terms of 10 years at the customers option. In effect this is then a 40-year contract which is important for the customer since the buildings will not have standalone heating and/or cooling systems of their own and the customer does not want to be left in a position where the contract is expired and the they have no choice but accept the price the utility wishes to charge (EC2).

For the DE utility, the contract must ensure that the customer purchases all of its thermal energy from the utility in order to ensure sufficient revenue is generated to meet cost of service. Furthermore, the ESA should also include a clause that the ESA is not valid until it has been approved by a board of directors. This allows the supplier to negotiate ESA's with potential customers up until a certain date so as to be able to decide if there are sufficient customers for the proposed DES to be economically viable (EC2).

8. Conclusion

Despite the growing awareness that DE is one of the only viable and cost-effective ways to decarbonize the heating sector it has failed to see widespread adoption or to reach city-wide scales in Canada. This lack of diffusion can be attributed to a number of institutional barriers that prevent economic competitiveness with other energy technologies. Energy policy at the federal and provincial level has offered many subsidies for low carbon projects but has failed to offer the appropriate tools and support to allow these systems to reach larger scales. Energy policy tends to focus primarily on the electricity sector, often to the exclusion of thermal energy. Energy solutions focused on optimization of individual building heating designs and solutions are the norm, and the use of natural gas fired furnaces and boilers connected to the gas distribution network has become the conventional approach. DE and other multi-building alternative energy solutions are an emerging market that must compete with well-established individual building approaches. Many building codes also prioritize the efficiency of the building envelope over other approaches that could provide larger carbon reductions. Furthermore, building codes do not adequately account for offsite sources of renewable or low carbon energy which results in unequal consideration of DE. Lack of targeted provincial or federal policies have also created uncertainty for municipalities, developers and consumers looking to DE for its energy and sustainability benefits. Although, there is disagreement in the industry on whether, or how, DE should be regulated it is clear from the European cases that strong direction and/or support for municipal initiatives from higher levels of government creates legitimacy around the technology and gives municipalities the tools needed to enact proper system planning and coordinate between the multiple actors required to implement city-wide systems. Where stronger provincial policy and direction does exist, such as in BC, we are seeing more activity in the DE sector, yet these systems have yet to reach city-scale buildout and still face a number of regulatory, economic, and social barriers.

Similar to the U.K. and the Netherlands the shift to liberalized energy markets in Canada has constrained DE development with its focus on achieving short-term cost efficiencies at the expense of longer-term social, energy, financial and sustainability benefits. While implementing DE in this situation is not impossible, it becomes more complex and more difficult to reach larger-scale buildout as the public-sector is asked to turn to commercial finance and partnership, therefore limiting projects to ones that achieve higher ROIs, which can hinder further expansions of the network. However, at the same time the attraction of the private sector also opens up access to new sources of capital as well as expertise and market knowledge that otherwise might not be available to municipalities. From the perspective of climate change mitigation municipally owned systems are better suited to building systems that achieve wider societal benefit. Yet with the proper institutional support public-private hybrid models that can draw on private sector capital and expertise may be the way forward. The low-carbon electricity-based thermal networks planned Toronto, while still smaller scale are an example of how these systems can begin to be built out.

8.1 Recommendations for Successful Business Models

Federal and provincial governments have a large facilitation role to play in creating the institutional support for municipal-scale DE, including providing guidance, leadership, funding, best practices, education, and developing a planning and development process that municipalities can adopt and adapt. At the federal level and provincial level, it is recommended that thermal energy is given equal attention with electricity in national and provincial energy strategies and that explicit policy goals are set for the increased diffusion of city-scale DES, in order to raise awareness and increase legitimacy of DE. A national heat mapping initiative should be undertaken to identify areas where the potential for DE is high. This will also remove the need for already resource constrained municipalities to pay consultants to complete this. Similar to the approach in other countries, the establishment of a commission dedicated to DE research and development that can act as an industry liaison and networking hub could also play a large role in increasing legitimacy and stimulating growth in the industry. Key tasks of the commission should be to provide a catalogue of technology options and data on the costs of different heating options, their carbon abatement potential, and the carbon abatement costs of each option The DE industry in Canada has a long way to go to reach maturity and have construction costs competitive with other well-established industries. Taking such actions sends clear signals to industry and the private sector that DE will become an area of stable investment and growth.

At the provincial level, planning frameworks should clearly define the role of municipalities in climate action generally, and in the planning of heat networks specifically. Clarifying how municipal planning powers can be used to develop DES can also help to reduce uncertainty in projects. However, clearly delineating what municipalities can and cannot do may have the danger of excluding certain powers from being used. The current context in Canada of no clear planning and regulatory frameworks means that virtually anything is possible. Municipalities and DE companies can experiment with different approaches that work for them. To avoid a situation, like in the UK where national policy was not matched to the local needs and realities of DE, or in BC where regulation has acted to incentive only small-scale systems, provincial policy approaches can follow something similar to the Swedish experience where policy acts to support and enhance municipal initiatives. This will require a close relationship with municipalities, industry and energy companies to identify what type of regulation and planning powers are needed. This may be carried out, for example, by the previously recommended district energy commission. Use of building codes that have TEDI and GHGI requirements can also incentivize DE connection.

It is important to note that while countries like Denmark have conferred the ability to mandate connection, it is rarely used. DE should attract customers on its own merits because it offers an attractive value proposition including high service quality, reliability and competitiveness in pricing. As one interviewee put it “mandatory connection is a two-way path to ruin” (CEP2), meaning that if a building is mandated to connect to a system and the performance is not as expected because of any one of the institutional barriers outlined in this paper then both the customer and the DE utility will suffer; the customer because they are not receiving the service they were promised, and the utility because no more customers will want to connect. This reinforces the need for creating the institutional conditions that allow DE to be attractive rather than forcing customers to connect. If mandatory connection is to be used, connection should only be required if a feasibility study has generated positive results. Municipalities should instead focus on clearly delineating areas where DE is the preferred option based on well formulated and vetted studies.

Although regulation can offer certainty to consumers by ensuring fair pricing it is generally viewed as increasing the costs and length of the development process and is something that can be replaced by standard ESAs. Regulation should rather focus on proper thermal metering practices to ensure more accurate billing and allow for better energy use data collection. Once the DE industry has reached a more mature stage further regulations may be necessary.

In order to ensure that DES do not become reliant on natural gas as the sole fuel source it is clear that carbon pricing must be implemented at the correct level to make DE based on low carbon sources economically competitive. Natural gas CHP has often acted as the backbone of the DE industry due to the additional revenues from electricity sales, and its ability to insulate against rises in electricity prices in self-generation applications. In the short-term, natural gas CHP may be a necessary ‘evil’ in that displacing individual gas boilers and natural gas power plants with decentralized CHP will result in more efficient fuel use and therefore achieve lower GHG emissions. Furthermore, in the current political reality natural gas may be the only option to establish economically competitive heat networks. However, it is clear that in the long run the continued widespread use of natural gas is not sustainable. In a future sustainable energy system CHP will operate on biogas, and the primary heating source in DES should be heat pumps fed by renewably generated electricity. Rather than repeat the path of countries like Denmark which are slowly transitioning from natural gas and biomass-based DES to heat pump-based systems, from a climate change perspective it is necessary to leap frog directly to heat pumps. This approach only makes sense in provinces that already have relatively decarbonized electricity systems. It also presents a number of challenges as electricity prices must be low enough for this approach to be economically and socially acceptable and any large increase in electricity demand will have a significant impact on electricity supply planning. Nevertheless, electricity systems based on renewable energy have the potential to offer low electricity prices as they have no fuel costs, and once capital costs have been recovered renewable energy sources have very low operation and maintenance costs. Additionally, times of excess electricity production in energy systems with high shares of renewable energy offer further opportunities for a low-cost supply of electricity.

Provincial and federal governments also have large roles to play in bridging the knowledge gaps in the industry, that municipalities simply do not have the resources to undertake. Higher levels of government have the ability to establish trade agreements for DE components or create knowledge transfer programs for best practices in DE construction. Adoption of Canada-wide standards based on widely-accepted standards used in already established DE markets would also act to streamline the construction process. Curriculums in engineering schools must also be updated to teach proper building design for connection to DE and to move away from individual building optimization approaches to community-scale approaches.

In the current landscape of liberalized energy markets, such approaches that seem to favour one technology may not be well-accepted by policymakers and pundits. However, it should be recognized that DE itself is not technology but is infrastructure that can take advantage of a wide variety of fuels and technologies. From the perspective of institutional economics, it also follows that while it may seem that policies are unfairly favouring one approach, rather than letting competitive markets decide, in actuality policy is creating fairness by leveling the playing field between options.

9. References

Amit, R., & Zott, C. (2001). Value creation in e-business. *Strategic Management Journal*, *22*(6–7), 493–520.

Andersen, D. J., Bødker, L., & Jensen, M. V. (2013). Large Thermal Energy Storage at Marstal District Heating. *18th International Conference on Soil Mechanics and Geotechnical Engineering 2013*, 3351–3354.

Andersen, A., & Lund, H. (2004). Decentralized CHP in Competitive Markets. *News from Danish Board of Distrct Heating*.

ASHRAE. (2004). ASHRAE 90.1 Appendix G. Building Performance Rating Method.

Bradford, B. M. (2012). *Planning for District Energy: Broad recommendations for Ontario municipalities to help facilitate the development of community based energy solutions*. Unpublished Thesis. University of Waterloo.

Barbier, E. (2002). Geothermal energy technology and current status: an overview. *Renewable and Sustainable Energy Reviews*, *6*, 3–65.

BCUC. (2015). Thermal Energy Systems Regulatory Framework. Retrieved from: https://www.bcuc.com/Documents/Proceedings/2013/DOC_34697_05-09-2013_TES-Regulatory-Framework-Strawman.pdf

BCUC. (2018). About the BCUC. Retrieved from https://www.bcuc.com/about/

Bolton, R., & Foxon, T. J. (2013). Urban infrastructure dynamics: Market regulation and the shaping of district energy in UK cities. *Environment and Planning A*, *45*(9), 2194–2211.

Bradburn, K. (2014). 2014 CanBio Report on the Status of Bioenergy. CanBio. Retrievd from: http://www.fpac.ca/publications/2014_CanBio_Report.pdf

Bryman, A., Teevan, J. J., & Bell, E. (2009). *Social Research Methods* (2nd ed.). Don Mills: Oxford University Press.

Bünning, F., Wetter, M., Fuchs, M., & Müller, D. (2018). Bidirectional low temperature district energy systems with agent-based control: Performance comparison and operation optimization. *Applied Energy*, *209*, 502-515.

CE Delft. (2009). District heat in the Netherlands. Retrieved from: https://www.cedelft.eu/en/publications/980/district-heat-in-the-netherlands

CEATI. (n.d.). Heat Pumps: Energy Efficiency Reference Guide. Retrieved from https://www.ceati.com/freepublications/7018_guide_web.pdf

Chittum, A., & Østergaard, P. A. (2014). How Danish communal heat planning empowers municipalities and benefits individual consumers. *Energy Policy*, *74*(C), 465–474.

City of Vancouver. (n.d.). Neighbourhood Energy Utility Fact Sheet. Retrieved from: https://vancouver.ca/docs/planning/renewable-energy-neighbourhood-utility-factsheet.pdf

City of Whistler. (2017). Cheakamus Crossing DES Recommendations. Retrieved from https://www.whistler.ca/sites/default/files/2017/Oct/news/files/24219/2017-10-03_des-report.pdf

Connolly, D., Lund, H., Mathiesen, B. V., Werner, S., Möller, B., Persson, U. Boermans, T., Trier, D., Østergaard, P. A., and Nielsen, S. (2014). Heat roadmap Europe: Combining district heating with heat savings to decarbonise the EU energy system. *Energy Policy, 65*, 475–489.

CMS Netherlands. (2017). Bill to amend to the Dutch Heat Act. Retrieved from: https://www.lexology.com/library/detail.aspx?g=918c728a-83b1-4cf4-9416-9410f148f153

Danish Board of District Heating. (2017). District heating history. Retrieved from http://dbdh.dk/district-heating-history/

Danish Energy Agency. (2017). *Energy statistics 2016*. Retrieved from: https://ens.dk/sites/ens.dk/files/Statistik/energy_statistics_2016.pdf

Denzin, N. K., & Lincoln, Y. S. (2000). *Handbook of Qualitative Research*. Thousand Oaks, Calif: Sage Publications.

Energistyrelsen. (2009). *The Danish Example*. Retrieved from http://stateofgreen.com/files/fact-sheet---the-danish-example

Energistyrelsen. (2017a). Danish Experiences on District Heating. Retrieved from https://ens.dk/en/our-responsibilities/global-cooperation/experiences-district-heating

Energistyrelsen. (2017b). *District Heating- Danish Experiences*. Retrieved from https://ens.dk/sites/ens.dk/files/Globalcooperation/dh_danish_experiences180915.pdf

Energistyrelsen. (2017c). *Regulation and Planning of District Heating in Denmark*. Retrieved from https://ens.dk/sites/ens.dk/files/Globalcooperation/regulation_and_planning_of_district_heating_in_denmark.pdf

Environmental Commissioner of Ontario. (2016). *Facing Climate Change: Greenhouse Gas Progress Report 2016*. Retrieved from: https://eco.on.ca/reports/2016-facing-climate-change/

Ericsson, K. (2009). *Introduction and development of the Swedish district heating systems-Critical factors and lessons learned*. Policy development for improving RES-H/C penetration in European Member States. European Commission. Retrieved from: http://lup.lub.lu.se/record/1384351/file/1384353.pdf

Euroheat and Power. (2015a). District Energy in the Netherlands. Retrieved from: https://www.euroheat.org/knowledge-centre/district-energy-netherlands/

Euroheat and Power. (2015b). District Energy in the United Kingdom. Retrieved from: https://www.euroheat.org/knowledge-centre/district-energy-united-kingdom/
Euroheat and Power. (2017a). District Energy in Denmark. Retrieved from: https://www.euroheat.org/knowledge-centre/district-energy-denmark/

Euroheat and Power. (2017b). District Energy in Sweden. Retrieved from: https://www.euroheat.org/knowledge-centre/district-energy-sweden/

Federation of Canadian Municipalities. (2009). Act locally: The municipal role in fighting climate change. Retrieved from: http://www.fcm.ca/Documents/reports/Act_Locally_The_Municipal_Role_in_Fighting_Climate_Change_EN.pdf

Field, C. B., Campbell, J. E., & Lobell, D. B. (2008). Biomass Energy: the scale of the potential resource. *Trends in Ecology and Evolution*, *23*(2), 65–72.
Gadd, H., and Werner, S. (2014). Achieving low return temperatures from district heating substations. *Applied Energy, 136*, 59-67.

Gilmour, B., & Warren, J. (2008). The New District Energy: Building Blocks for Sustainable Community Development. Canadian District Energy Association.

Grasby, S. E., Allen, D. M., Bell, S., Chen, Z., Fergusin, G., Jessop, A., Kelman, M., Ko, M., Majorowocz, J., Moore, M., Raymond, J., and Therrien, R. (2012). Geothermal Energy Resource Potential of Canada. NRCan.

Gunnlaugsson, E. (2004). Geothermal District Heating in Reykjavik, Iceland. International Geothermal Days Poland. International Course on Low Enthalpy Geothermal Resources. Retrieved from: https://orkustofnun.is/gogn/unu-gtp-report/UNU-GTP-2003-01-06.pdf

Hawkey, D., & Webb, J. (2014). District energy development in liberalised markets: situating UK heat network development in comparison with Dutch and Norwegian case studies. *Technology Analysis & Strategic Management*, *26*(10), 1228–1241.

Hawkey, D., Webb, J., Lovell, H., M, M., Tingey, M., & Winskel, M. (2015). *Sustainable Urban Energy Policy: Heat and the City*. New York: Routledge.

Hekkert, M. P., Harmsen, R., & Jong, A. D. (2007). Explaining the rapid diffusion of Dutch cogeneration by innovation system functioning. *Energy Policy*, *35,* 4677–4687.

Hoffman, S.M., & High-Pippert, A. (2005). Community energy: A social architecture for an alternative energy future. *Bulletin of Sci, Tech, and Soc*, *25*(5). 387-401.

Hoggart, K., Lees, L., & Davies, A. (2002). *Researching Human Geographies*. London : New York: Arnold.

Hvelplund, F. (2013). Innovative Democracy, Political Economy, and Renewable Energy: A full-scale experiemnt in Denmark 1976-2013. *Environmental Research, Engineering and Management*, *4*(66), 5–21.

Jaccard, M., Failing, L., & Berry, T. (1997). From equipment to infrastructure: community energy management and greenhouse gas emission reduction. *Energy Policy*, *25*(13), 1065–1074.

Jick, T. D. (1979). Mixing Qualitative and Quantitative Methods: Triangulation in Action. *Administrative Science Quarterly*, *24*(4), 602–611.

Johansson, B., Börjesson, P., Ericsson, K., Nilsson, L. J. and Svenningsson, P. (2002) The Use of Biomass for Energy in Sweden - Critical Factors and Lessons Learned. Report 35 Lund, Department of Energy and Environmental System Studies, Lund University.

Joskow, P. L. (2008). Lessons learned from electricity market liberalization. *The Energy Journal*, *29*, 9–42.

King, L., Purcell, B., & Lysenko, N. (2017). The City of Toronto Zero Emissions Building Framework. City of Toronto.

King, M. (2012). *Community Energy: Planning, Development, and Delivery*. International District Energy Association. Retrieved from: https://www.bloomingtonmn.gov/sites/default/files/USCommunityEnergyGuide.pdf

King, M., & Shaw, R. (2010). Community Energy: Planning, Development and Delivery. Town and Country Planning Association. Retrieved from: https://www.lda-design.co.uk/wp-content/uploads/2013/08/LDA-Comm_Energy_PlanDevDel.pdf

Langer, J. (2018). *What's in, what's out? TAF reviews Ontario's climate policy cancellations*. Toronto Atmospheric Fund. Retrieved from http://taf.ca/whats-taf-reviews-ontarios-climate-policy-cancellations/

Lerch, D. (2007). Post Carbon Cities: Planning for Energy and Climate Uncertainty. Post Carbon Institute. Retrieved from: https://www.scribd.com/document/240726935/Post-Carbon-Cities-Planning-for-Energy-and-Climate-Uncertainty.

Lenhart, J., Vliet, B. V., & Mol, A. P.(2015). New roles for local authorities in a time of climate change: the Rotterdam Energy Approach and planning as a case of urban symbiosis. *Journal of Clenar Production*, *107*, 593–601.

Lund, H., & Andersen, A. N. (2005). Optimal designs of small CHP plants in a market with fluctuating electricity prices. *Energy Conversion and Management*, *46*(6), 893–904.

Lund, H., Möller, B., Mathiesen, B. V, & Dyrelund, A. (2010). The role of district heating in future renewable energy systems. *Energy*, *35*, 1381–1390.

Lund, H., Werner, S., Wiltshire, R., Svendsen, S., Thorsen, J. E., Hvelplund, F., & Mathiesen, B. V. (2014). 4th Generation District Heating (4GDH). Integrating smart thermal grids into future sustainable energy systems. *Energy*, *68*, 1–11.

Maegaard, P., & Avis, R. (2001). *Transition to Energy Efficient Supply of Heat and Power*.

Mason, J. (2002). *Qualitative Researching* (2nd ed.). London: sage.

Mathiesen, B. V., Drysdale, D. W., Lund, H., Paardekooper, S., Skov, I. R., Connolly, D., … Jensen, J. S. (2016). Future Green Buildings: A Key to Cost-Effective Sustainable Energy Systems. Department of Development and Planning, Aalborg University.

Mcvey, I., Farbridge, K., & Calvert, K. (2017). *On the path to net-zero communities: Integrating land use and energy planning in Ontario municipalities*.

Mikler, V. (2018). District Energy 101. Integral Group. Retrieved from: https://www.integralgroup.com/wp-content/uploads/2017/06/IntegralGroup_District-Energy-101.pdf

Morandin, M., Hackl, R., & Harvey, S. (2014). Economic feasibility of district heating delivery from industrial excess heat: A case study of a Swedish petrochemical cluster. *Energy*, *65*, 209–220.

Morris, C. (2017). *The Dutch go district heat.* Energy Transition: The Global Energiewende. Retrieved from: https://energytransition.org/2017/03/the-dutch-go-district-heat/

Neuman, W. L. (2011). *Social Research Methods: Qualitative and Quantitative Approaches* (7th Ed.). Boston: Pearson.

NRCan. (2017). Innovative Biomass Supply Chain Solutions for Commercial and Institutional Heating Plants Used in the Forestry Sector. Retrieved from: https://www.nrcan.gc.ca/energy/funding/current-funding-programs/eii/16047

NRCan. (2017). What is a heat pump and how does it work? Retrieved from https://www.nrcan.gc.ca/energy/publications/efficiency/heating-heat-pump/6827

NRCan. (2002). Commercial Earth Energy Systems: A Buyer's Guide. Retrieved from; http://publications.gc.ca/collections/Collection/M92-251-2002E.pdf

Nyboer, J., & Griffin, B. (2016). District Energy Inventory for Canada, 2014 About CIEEDAC. Retrieved from http://www.sfu.ca/content/dam/sfu/cieedac/publications/facilities/District Energy Inventory Report 2016.pdf

Okkonen, L., & Suhonen, N. (2010). Business models of heat entrepreneurship in Finland. *Energy Policy*, *38*(7), 3443–3452.

Ostergarrd, P. (2012). The Regulation of District Energy Systems. Pacific Institute for Climate Solutions. Retrieved from: https://pics.uvic.ca/research-pages/publications/white-paper/regulation-district-energy-systems

Osterwalder, A. (2004). *The Business Model Ontology: A Proposition in a Design Science Approach*. Unpublished Thesis. l'Université de Lausanne. Retrieved from: http://www.hec.unil.ch/aosterwa/PhD/Osterwalder_PhD_BM_Ontology.pdf

Parajuli, R. (2012). Looking into the Danish energy system: Lessons to be learned by other communities. *Renewable and Sustainable Energy Reviews*, *16*(4), 2191–2199.

Patton, M. Q. (1999). Enhancing the quality and credibility of qualitative research. *Health Services Research*, *34*(5).

Payne, G., & Payne, J. (2004). *Key Concepts in Social Research*. London: Sage Publications.

Pellegrini, M., & Bianchini, A. (2018). The innovative concept of cold district heating networks: a literature review. *Energies*, *11*(1), 236.

Persson, U., & Werner, S. (2011). Heat distribution and the future competitiveness of district heating. *Applied Energy*, *88*(3), 568–576.

Phetteplace, G. (2007). Geothermal heat pumps. *Journal of Energy Engineering*, *133*(1), 32-38.

PlanEnergi. (2019, August 8). Personal Interview.

Porter, M. E., & Millar, V. E. (1985). How Information Gives You a Competitive Advantage. *Harvard Business Review*, *63*(4), 149–160. Retrieved from https://hbr.org/1985/07/how-information-gives-you-competitive-advantage[28/11/2016

Poyry Energy, & Maunsell, F. (2009). The Potential and Costs of District Heating Networks. Retrieved from: https://webarchive.nationalarchives.gov.uk/20121205193015/http://www.decc.gov.uk/assets/decc/what we do/uk energy supply/energy mix/distributed energy heat/1467-potential-costs-district-heating-network.pdf

QUEST. (2017). District Energy Working Group: Codes and Standards Working Paper.

Quality Urban Energy Systems of Tomorrow [QUEST]. (2016). Community energy planning: The value proposition: Environmental, health and economic benefits. Retrieved from: http://gettingtoimplementation.ca/wp-content/uploads/2016/02/Full-Report_ValueProposition_OnlineVersionFeb92016.pdf

Raven, R., & Verbong, G. (2007). Multi-Regime Interactions in the Dutch Energy Sector: The Case of Combined Heat and Power Technologies in the Netherlands 1970–2000. *Technology Analysis & Strategic Management*, *19*(4), 491–507.

Riahi, L. (2015). *District Energy In Cities: Unlocking the Potential of Energy Efficiency and Renewable Energy*. Retrieved from http://www.unep.org/energy/districtenergyincities

Scott, W. R. (2008). *Institutions and Organizations*. London: Sage.

Seidman, I. (2006). *Interviewing as Qualitative Research: A Guide for Researchers in Education and Social Science*. New York: Columbia University.

Silverman, D. (2006). *Interpreting qualitative Data: Methods for Analyzing Talk, text and Interaction*. London : New York: Sage.

Simchak, T., & Davis, S. (2013). Combined Heat and Power for Industrial Revitalization. Centre for Clean Air Policy. Retrieved from http://ccap.org/assets/White-Paper_Combined-Heat-and-Power-for-Industrial-Revitalization_CCAP_July-20131.pdf

Smith, A. (2005). The alternative technology movement: an analysis of its framing and negotiation of technology development. *Human Ecology Review, 12* (2), p.106-119

Sørensen, P. A., & Trier, D. (2012). *Danish model for implementation of SDH in CHP-systems*.

Sørensen, P. A., Nielsen, J. E., Battisti, R., Schmidt, T., & Trier, D. (2012). *Solar district heating guidelines: Collection of fact sheets*. Retrieved from www.solar-district-heating.eu

St. Denis, G., & Parker, P. (2009). Community energy planning in Canada: The role of renewable energy. *Renewable and Sustainable Energy Reviews, 13.* 2088-2095.

Thornton, R. P. (2005). IDEA Report: The District Energy Industry. International District Energy Association.

Tozer, L. (2013). Community energy plans in Canadian cities: Success and barriers in implementation. *Local Environment, 18*(1). 20-35.

US EPA. (2017). CHP Benefits. Retrieved July 26, 2017, from https://www.epa.gov/chp/chp-benefits

Vaughan, W. T., & Lindquist, E. D. (2012). *U.S. Patent Application No. 13/378,035*.

Walker, G., and Devine-wright, P. (2008). Community renewable energy: what should it mean. *Energy Policy, 36*(2), p.497-500.

Walliman, N. (2006). Data Collection Methods. In *Social Research Methods*. London: Sage.

Wang, Z. (2018). Heat pumps with district heating for the UK's domestic heating: individual versus district level. *Energy Procedia, 149* , 354-362.

Wengraf, T. (2001). *Qualitative Research Interviewing*. London: Sage Publications.

Werner, S. (2017). International review of district heating and cooling. *Energy*, *137*(15), 617–631.

Werner, S. (2017). District heating and cooling in Sweden. *Energy*, *126*, 419–429.

10. Appendix- DE Stakeholder Value and Decision-Making Processes: Semi-Structured Interview Results

Financial Factors

All interview participants expressed that cost, and bottom line is the number one priority of developers and property managers (PM)/building owners when deciding to connect to a DE system or to develop their own system. For developers, the focus is on capital expenditures (capex) while PM/building owners are more concerned with operating expenditures (opex). From the developer's perspective, connecting to a DE system must have equal if not lower capex than the alternative: usually on-site natural gas boilers. For the PM/building owner, opex must be equal to or lower than the alternative. Given a good business case, potential exists then to market opex savings to customers.

> "As a condo developer the focus is on the capital cost or the capex and the operating cost of our developments or the opex, is not really a focus or a concern because we sell that opex to someone else, it's their responsibility now to operate and maintain their home or their condo or whatever so it's not only just DE but all upgrades that have impacts on the operating cost of our developments are not really that important to a developer who's focused maybe on only upfront capital costs, so energy unfortunately falls mostly into that operating cost bucket." (MR/PM1)

> "It would have to reduce overall costs, it's got to provide value to the customer. Either the cap[ital] costs or the hook up and tie in is deferred and members carrying that capital get a return on that capital or the overall costs of operating is lower than the building next to it. The end-user has to see value in it. If I own the building and I'm going to lease it out, then my operating costs need to be lower than my competitors for that building so that becomes a big thing." (MUD/PM1)

> "Number one, it's got to meet a business performance goal, the business case has to be sound and that worst case has to be cost neutral compared to business as usual. And after that, if the business case can be met then [we can] be pursuing energy improvements to improve that business case whether it be directly to the bottom line or if it's cost neutral and we can get that marketing piece out of it to try and increase interest and therefore sales in the development." (MR/PM1)

> **"**The developer should have the opportunity to mitigate their capital requirements by not having boilers on site or having cost advantage over the grid prices of

> electricity and essentially let me just rephrase that, the developers should have a significant cost advantage capital or operating when it comes to energy. By energy I mean both electrical and thermal. So, can a DE solution provide that if the answer is yes, they should [connect].” (DOU1)

Opex savings are more difficult for a developer to realize as those savings must be sold off to the customer, as one mid-rise developer/PM put it:

> “It costs more on the capital to put in energy efficient measures and technologies and you don’t realize the benefits until you operate it for 10 years. But as a condo developer or home developer the developer doesn’t realize those savings because they sell them off, so the only way to recoup your costs is to increase your selling price and try and sell those operating savings to your future customers…” (MR/PM1).

Developers must then work to market those opex savings to customers, the risk of which depends on the target demographic:

> “…we’re not going to be interested in spending a lot of capex to make savings on the opex because we’re not going to be there to realize them and it’s as simple as that… unless we can raise the prices of the units and that means we would have to then market our developments with that in mind to attract a different type of buyer to pay a premium for their property, but that would be a completely different business model and I think it depends on the location and the target demographic that we’re looking to sell to that would determine whether or not that would be risky play or a good play.” (MR/PM1)

> “…any capex that’s going to make the price of the home not as competitive then that’s going to become a challenge to sell the homes … the homeowner if they know they’re going pay more to live in a house they won’t buy it. So, for us it’s both, but directly for us it’s the capex that’s going to impact us financially in that short term. The operating cost would affect or impact the attractiveness of that development to the purchaser.” (CSResi1)

However, opex is still of importance to the developer in being able to ultimately sell. In rentals, tenants compare operating costs and base rental rates to other buildings when looking for places to live. Similarly, condo buyers will compare the condo fees of different prospective buildings. A mixed-use developer that also develops and operates office buildings outlined this difference in value from a developer’s perspective and as building owner:

> "… in an office building you are in more of a buy hold strategy so those op[erating] costs are really important in terms of getting your lease rate right because even though you're going to pass those operating costs onto your tenants when you're trying to attract a tenant it's a combination of operating costs and base rent that their comparing to other buildings. So, if I can reduce my operating costs then I can generally increase my rental rate because the combined cost is what's being compared building to building. Somebody might pay twenty-two bucks a foot in a building if the op[erating] costs are lower than another building they might only pay twenty bucks a square foot because the op[erating] costs are higher, so it is absolutely a factor. In a condo it is also important in that you're trying to sell condos and they have operating costs and those operating costs are compared building to building in your condo fees, so you do consider it, I think in a straight up condo it's probably considered less than it is in any kind of office play, or buy and hold rental pay, or anything like that." (MUD1)

Developers may have different motivations or different cost metrics depending on sources of funding as well. For example, investment from pension funds are more likely to have a triple bottom line goal, although cost may still be the primary determining factor:

> "Cost [is the main decision-making criteria]. It depends again on the type of developer. Generally, it's not triple [bottom line] unless you're a pension fund probably or certain developers. It's probably more of those who are owned by pension funds perhaps there is a triple bottom line but that's a falsehood, it's really going to be cost. Like dollar per cost of capital cost of the trade-offs between connecting versus doing it your own in building solutions." (HR/MR/PM/MUD1).

One developer/property manager of a commercial/institutional property made the decision to connect based on a lifecycle analysis, which showed positive results:

> "The determination that the cost of purchasing for that building would be less than the alternative of building the conventional physical plant boilers and chillers in the building and comparing that cost of capital and operating costs. So again, all in lifecycle cost was better using the DE and geoexchange approach than it was using conventional boilers and chillers." (MUD/PM1)

When speaking about an acceptable heat price one developer knowledgeable about DE also indicated they would consider it on a lifecycle basis. Furthermore, they recognized that DE could offer other benefits such as sustainability and resiliency and therefore prices did not need to be much lower than business as usual:

> "… negotiating to a price that is slightly better than it would be for me to operate my own and that's in a full cost accounting sense, like you do have to consider long-term replacement like the lifecycle costs the O&M costs and things and compare those to the rates that you're going to pay for the DE but it just needs to be competitive it doesn't have to be a ton better because I think there's other benefits but it has to be competitive." (MUD1)

However, the effectiveness of a business case on a lifecycle basis was brought into question by another developer/PM who recognized the benefits of lifecycle costing however still questioned whether or not it would show positive economics due to DE having to compete with already established infrastructure:

> "…everybody talks about lifecycle costs and I agree that from a lifecycle point of view there's probably some benefit, but the fact of the matter is this is new infrastructure so you're competing with new (not to say that I don't agree with it but you're competing with new) infrastructure, so you can't say that it's cheaper even on a lifecycle basis" (HR/MR/MUD/PM1)

Capex Savings

Most developers had come into ownership of buildings after they had been connected, and many were involved with developing their own on-site systems. Therefore, many did not have experience with capex savings from connecting to an offsite DE. However, stakeholders did recognize the potential for capex savings, for example from space savings in the mechanical room:

> "… as the developer I can reduce my capital costs because I can reduce my chiller and boiler plant in the building, I can save the real estate associated with having the chiller and boiler plant in the building, I can eliminate cooling towers or dry coolers on my roof which gives me potentially more saleable real estate or at least keeps noise and issues away from penthouse buyers and things because cooling towers aren't the nicest thing when you have a penthouse patio or something up top. So, I get to reduce the capital cost basically as a developer which is nice, I might pay a connection fee to a DE company but its lower." (MUD1)

> "I could still see a developer saying yes to be connected to an existing system even if they were mandated to because now I reduce my capital costs on installing, because now I don't have to put a centralized heating system in my

> building anymore I can just put in an energy transfer station like a heat exchanger system and the pipes come in and I just save myself all of the capital costs of a mechanical room in my condo so to be honest if I'm building a condo and nothing is going to change in my pricing structure of my business case except I can remove one or two capital cost expenditures I'm in… I'm not concerned, I think it would be a great idea because yeah I get to reduce the capital cost and the fuel cost, or the energy costs are going to be downloaded onto the users." (MR/PM1)

For those that did have experience with DE connection two developers realized capex savings, while another did not:

> "I think the capital cost is still cheaper to do just conventional gas lines, these are insulated water lines to a heat exchanger kind of thing at each property line, and I don't think there was any saving on the mechanical system. I think it was a higher capital cost for the municipality… so part of the premise is that you're saving on your heating appliances but you've still got to put heat exchangers and metering type equipment in and things like that and my impression is that it's not any cheaper to connect heat exchangers and metering equipment at the property line than it would have been to put in our own proprietary heating and cooling appliances" (MR/PM2)
>
> "… for the developer that makes the decisions it's not cheaper." (HR/MR/MUD/PM1)

For two DE managers, capex financial benefits helped to ease developer's concerns with connecting to a DE, as well as free up space on rooftops for green roofs:

> "I think one of the things that really convinced them was generally costs, they financially benefitted from connecting to a DES. It's not as expensive as building your own internal system obviously while there is some offsetting, ongoing capital costs that they still have to contribute because the plant is still supplying them with energy. I think overall net they've benefitted so I think when they looked at the numbers, they realized they were plus under that situation". (HR/MR/PM/DEM1).
>
> "They don't have to spend money on heating equipment, boilers and hot water tanks… it frees up space both in the parkade where equipment might be located, but also on the rooftops where you need things like flues for boiler and often boilers and equipment do go on the rooftops so it has cleared up a lot of rooftop space for amenities and… from the air you see a lot of green space on those rooftops and that wouldn't be possible without the utility to connect to." (DEM1)
>
> "… there's definitely some savings on the hard cost on your development cost as a developer upfront, you know as since we are both the developer and the DE utility, I would say that those numbers all kind of balance out. But in the case

> where I separate myself and I'm just a developer, yes those costs are cheaper." (DOU1)

Capex savings were also seen by developers as not significant enough to incentivize connection or be a determining factor in the decision to develop, especially with real estate market prices so high. When making a decision to develop, developers normally assess all costs including land, consultants, development, permit fees, consultancies for architects and engineers and the cost of constructing and commissioning the building, plus the cost of financing and funding the project. The profit margin of developing in one area is then compared to other areas. The cost of energy and energy equipment is a few line items in the developer's cost analysis, and therefore cost decreases or increases from DE were not identified as being significant enough to be a critical factor in whether or not someone chooses to develop on a particular site, to buy a unit in a building, or to rent a unit; it was seen as more of an added benefit. However, according to one developer/PM only smaller developers would gain any cost advantage:

> "… no developer's going to go unless they're looking for money, like some developers may say they see the cost of the plant taking that off their books, if they're a smaller developer, as an advantage, but then they're usually at a disservice to the end-user because they're looking to make a profit probably on the sale of that equipment… it's like you have to build a plant anyway - $500,000 say the plant is, oh maybe I don't have to do it and its 500 off my book, well how much are you going to pay me to do that sort of thing. But those are small developers and it has not been a game buster business is all I have to say." (HR/MR/MUD/PM1)

> "[Space saving] is noticeable but I wouldn't call it a gamechanger. I don't think anyone would say yes or no to deciding to do something like this based off of space, I think it's the cherry on top, it's a bonus, so you know instead of having a rooftop mechanical room maybe I can get an extra penthouse suite or two out of it and pad my financial performer for my development or I could get a couple more parking spaces out of the basement which would also help increase sales and revenue you know but it's not going to make or break the project at all. It's just a bonus." (MR/PM1)

Cost savings or additional revenue from space savings in the mechanical room had a range of views on its value to developers, from high to low. A mid-rise developer/PM did not realize any financial benefits from the space saved and put cost savings in the mechanical room at 10-20%

> "… the mechanical room's a little bit smaller and probably located a little bit differently. They're still going to have, like I said, heat exchangers and you're still going to have heating equipment and things like that and you've still got to have make-up air systems for ventilation in the hallways, whether you use a rooftop system or some type of a furnace in a boiler room. So, if your trying to quantify it you know you might save ten or twenty percent on your mechanical rooms so it's not a huge it's not a budgetary item that we identified or broke out." (MR/PM2)

> "It's a factor but it's not really that significant. It depends, if it's a tower maybe, if it's a house maybe not as much. Again, it depends what systems you're looking at and because we build large scale and really unique markets, DE or community energy does not always mean there's no equipment in the house or you're reducing the number, or the space allocated for the systems." (CSResi1)

Location of mechanical rooms in commercial spaces such as the parkade also mitigates space saving value depending on how the parking is priced:

> "In most cases it's 10,000 dollars per 300 square foot, so it's like thirty bucks a foot so it's not a huge capital cost saving I don't believe for the district heating for reducing the size of the boiler or furnace room, boiler room, mechanical room." (MR/PM2)

The cost savings that were achievable from reducing the mechanical room was again seen as insignificant in the current real estate market, particularly due to low interest rates:

> "… maybe the mechanical room might be twenty by twenty just to pick a number out of the air and you might have been able to reduce it by ten to twenty percent, so 400 feet your saving forty feet at thirty bucks a foot saleable you know you're talking about thirty times forty not very much money, 1,200 bucks is that what it works out to? Insignificant particularly in a low interest rate environment you know. Yeah so no it doesn't save much on space I think a lot of those presumed attributes we didn't realize." (MR/PM2)

However, another developer of sustainable mixed-use developments saw more value in the space saving aspects, and therefore opportunities for additional revenue:

> "I think it's a fairly big factor… if you took a 100,000 square foot building, you're going to reduce your construction costs by somewhere between four dollars and six dollars a square foot by eliminating that plant equipment. You still have circulation pumps, you still have ventilation air, all that kind of stuff but getting rid of your chillers and boilers and the plant and works associated with those is going to save you somewhere between three and six maybe four and six dollars a square foot which is a huge savings, and then on top of that for a 100,000 square foot building I probably need about, give or take 3,000 square feet of area for a mechanical room plus space on the roof and so depending on what markets you're in you either don't build that space and save your 230 to 240 bucks a square foot because you haven't had to build it at all or you turn that into saleable space and you're able to gain profit on that space because you can sell that space as a condo or lease that space as an office because you don't have mechanical equipment in it. So, it is a significant advantage for the developer and it's one of the main reasons that if there is DE available it makes a lot of sense for market developers to connect." (MUD1)

It was also brought to attention that space saving benefits can be limited by zoning bylaws and restrictions that would prevent adding additional units. This problem could be overcome through municipal incentives such as density bonusing where DE is implemented.

> "…if your saving on the space or your freeing up more space it's unlikely you're going to be able to build additional residential units that you can sell because of the height restrictions and the zoning, so there's no incentives with cities or municipalities where if you let's say if you move with a geothermal system and you eliminate the cooling towers and the boilers they won't incentive you by allowing you to build more, so there's no real savings and then typically when you move away from the traditional boiler cooling tower systems you're paying more, at least for the first few years you're paying more for the new systems so I don't think that's going to be… if it becomes a wash they'll be lucky but it's unlikely, there's always a premium." (CSresi1)

Depending on location, provision of cooling was recognized as being able to improve capex savings for developers:

> "I'm looking for both heating and cooling… because getting rid of the cooling plant is probably a bigger advantage to me than getting rid of the heating plant in my building so I want both cooling and heating…" (MUD1)

Opex Savings

Opex savings were generally not realized by building owners and property managers connected to offsite DE systems, with only one developer/property manager realizing operating cost savings:

> "… it's reduced energy costs, reduced O&M costs, reduced the need for equipment, increased reliability…" (REIT1)

> "I don't think we've realized any cost advantages or operating efficiency advantages." (MR/PM2)

> "For the end-user, no its not cheaper. For the end-users: it's actually more expensive for the end-user…" (HR/MR/MUD/PM1)

When opex savings were recognized a developer-owned utility was able to market these savings to condo boards:

> "It's marketed generally to condo boards in terms of when they're selling the units that they're overall costs are lower so tenants, people who are buying the units I think become aware of it, but I think soon after they don't really remember." (HR/MR/PM/DEM1)

A property manager with two similar buildings located close to each other found the building with standalone natural gas to have a lower operating cost than the DE connected one.

> "… the natural gas operates at a lower cost if you combine the maintenance and the energy cost combined because I know you have to take into consideration the maintenance side of it which you on the DE side of it course you're not having to pay for the boilers yourself whereas in the other buildings we have that infrastructure that we have to look after. So, on an annual operating cost I certainly do not see there to be an economic advantage going DE." (BO/CPM1)

Another developer/PM of residential, commercial and mixed-use developments connected to municipally owned systems found similar results, but the impact of higher operation costs did not affect sales due to the state of the real estate market.

> "They've made energy generation higher when you compare it to traditional utilities. So, for example the dollar per KWh number for generation is higher than if you had natural gas and that's usually the measurement that developers use to see the cost. It hasn't really affected sales I would say it's because the market place." (HR/MR/MUD1)

A developer-owned utility has also been struggling with higher opex costs being passed down to customers, however this has largely been a function of not having reached full build-out yet:

> "… the way our DE is just by virtue of the current number of customers we do get a lot of complaints from the strata companies that the biggest line item in their budget is the DE utility costs right and so obviously those costs include the cost of transferring some of those capital costs on to the district side and the system side and until we get a customer base of where it's around eight million square feet of connected density that's when you start to realize your gains and that's what we're forecasting." (DOU1)

One developer/PM remarked that the lack of achieving performance goals in DE systems has also to do with the modelling assumptions used in the feasibility analysis:

> "… well there are efficiency and cost lifecycle cost benefits to doing it they may not be as dramatic as they appear on the outside and a critical factor is building into your modelling the best possible assumptions about the alternative costs so you have to assume certain economics of the increase in the price of electricity versus the increase in the price of gas or the lack thereof for example and typically in a project sometimes you have this tendency to build in assumptions that are a little too optimistic in order to generate a favourable business case for the project, you have to be really careful about that." (MUD/PM1).

In addition, as noted earlier by the development community, heat is a minor component of building owner's operating costs due to the current low prices of natural gas. In addition, developer/PMs don't consider energy costs in isolation:

> "I don't break down into components and live and die by every one of those components you know but I would look at the overall envelope the overall mechanical systems all the different utilities you know heat power water communications and then I'd look at some of the urban design things… when you're designing a development and you're carrying through the cost of operating and capital to the consumer it's not about one component you've got to look at all the components and you've got to value for short term and long term and then hook them all together." (MR/PM2)

The cost of heating therefore is not a significant deciding factor in the decision-making process. One property manager estimated that heating makes up 6% to 8% of operating costs.

> "It would not be the reason to develop or not develop in an area because real estate opportunities particular in this market are so scarce, so hard to come by, DE or not. DE would not be the decision to go or no go on the major investment decision. It's a relatively minor piece on the overall costs in a building. I should qualify that we're in the office industry so if you're more energy hungry than we are then obviously it could become a bigger cost input, whereas for us it's not a

major component of our annual operating costs but that on its own would not be a decision to go or no go on an investment (BO/PM1).

> "... on the senior's buildings typical operating costs will vary from about 75 to 90 cents per square foot per month. That's all costs including some staffing and things so probably pre-taxes, utilities and of that the utility component you know heat, water, power would be about 21-24 cents per foot and maybe power is 13-15 cents and heats maybe 6 or 7 and waters maybe 2 or 3. So the biggest utility cost is power." (MR/PM2)

Instead, more potential for savings was again found to be on the cooling side, as cooling is mainly electricity based and is therefore costlier in most jurisdictions than heating:

> "… there are a lot of buildings here, apartment buildings that are done with heating and if they do use air conditioning it's pretty well some sort of electric based system condenser and chiller, so I think there's benefits on the cooling and I don't think on the heating. It would be highly speculative if there was any efficiencies or savings on the heating side of the formula." (MR/PM2)

One developer/PM also identified that sub-metering could reduce opex by removing the transaction between the PM and the utility, and instead moving the responsibility of the heating bill to the individual tenants:

> "… as the building owner I would love to have a DES because all of my tenants are going to be actually paying their own heating bills directly to that DE utility and as a building owner, I'm only going to have to maintain the central heat transfer unit in the basement which is almost like a zero-maintenance piece of equipment." (MR/PM1)

The complexity of bulk metering as opposed to sub-metering, was exemplified by an experience in a mixed-use development where the DE utility installed one house meter, and PM's became responsible for having to check meters that weren't revenue grade and then bill the different areas and tenants of the development themselves:

> "… what we found was you have to do essentially separate heat exchangers or separate ETS's (energy transfer stations) so the cost of that is not practical and so typically what we'll do is we'll throw onto a PM company we'll do one essentially house meter and then they'll need to have other checked meters that aren't revenue grade and go around buildings and do all the math and then subsequently bill different areas whether they be retail units or different stratas or

> etc. and so that's been like an annoyance or a nuisance for PM companies, they become more the face of the energy cost and manage it… " (DOU1)

At the same time, a different developer/PM preferred bulk purchasing of heat instead of individual metering as the differences from unit to unit were negligible and did not warrant installing separate meters. However, this may be specific to this PM's case as they own and operate senior's buildings where residents are more aware of their energy usage due to reliance on fixed incomes.

External market factors also had an impact on effective operation of a DE plant. The operation of an on-site DE system for a multi-building community scale development was hindered by the 2008 market crash, which delayed the build out of the development causing the central plant to run less efficiently due to the lower than expected loads.

However, in cases where DE systems have not been performing as expected, developers have often been protected by contract clauses that guarantee heat prices would not increase above a certain level.

Stability, Reliability and Resiliency

Reliability, stability and resiliency are grouped in one section here due to linkages participants made between them. Views and understandings of these words varied. Reliability was often linked to resiliency and thought of as the ability to minimize outages during extreme weather events. One developer of residential community scale projects said reliability and stability "… mean basically systems not breaking down and in the aftermath of a severe weather event … the homes and communities are resilient, that you'll still be able to live in a house." (CSresi1).

Another developer of large sustainable, mixed-use developments defined reliability as the heat supply and a certain amount of contracted-for peak energy always being there whenever it's asked for. Stability was defined as the DE system being able to supply the heat in the correct temperature range depending on the season to ensure proper functioning of the building's heat exchangers.

> "My building side equipment is going to be designed to have a certain temperature and a certain temperature range so it will be a certain temperature in the heating season a certain temperature in cooling season and I need that DE to be provided within that temperature range and that's really important or my heat exchangers are not going to work properly and I'm not going to get enough heating or cooling into the spaces and that is a challenge for some district systems because it's hard to design when you don't exactly know how people's buildings are going to behave. So that's the stability issue and it would be very, very important." (MUD1)

Most participants listed reliability and stability as secondary to the financial aspects or did not list reliability and stability when asked about why they did connect to a DE system or what they are looking for a DE system to provide. A participant from a REIT rated the decision to connect to a DE system as 80% or 90% towards financial return, and the remaining 10-20% consisting of environmental benefits, space savings, and reliability. Generally, stability and reliability were important, but would not be paid more for.

> I: **"**And on the stability and reliability aspects how big of issues are those for you when connecting to a system?"
>
> P: Well as the developer it's all about the bottom line so until that carbon tax starts to really have some teeth or cap and trade has some teeth it's not going to affect the bottom line of a developer and a constructor. When it does start to affect the bottom line, that's when you're going to see movement in the market, guaranteed. (MR/PM1)
>
> "It always comes down to cost I would say. I would say reliability second to that, but you look at your costs because you know that you will have to either absorb that or you'd need to convey that to the end-user or you'd need to tell a story around it." (DOU1)

This lack of emphasis on stability and reliability may be because it is rarely an issue - as one developer put it:

> "… in a typical building today with the way technology are, heating plants failing that's a pretty low occurrence. Most buildings are designed with some redundancy around heating so there's backup boilers and … there's backup pump systems, so it's pretty rare for a building to get cold." (MUD1)

However, resiliency and reliability, as in the ability for service to continue in the event of an outage elsewhere, were identified as areas that would be of benefit, but would not be a significant decision-making criterion as blackouts and brownouts are not that common, and it is not something that has gained enough traction that customers would pay extra for it. However, one developer recognized that DE systems would likely have their own backup generators and would therefore be of value to buildings that did not have them. Resiliency was seen as an area that may gain more value in the future, specifically in areas where severe weather can cause outages of heat and power:

> "Yes [resiliency] would be an advantage, I would say it doesn't happen a lot, but I think it's happening more and I think there's more awareness, like people are going because of our societies are all so connected they go what happens if this breaks down or that breaks down what's the redundancy in the system, yep that resiliency has got some value yep. I don't think the consumer is out paying me for that right now…" (MR/PM2)

> "You can still design a building today under a certain height that wouldn't need any kind of backup generator and so in the event of a power failure you can have no heat because either the pumps aren't working or fans can't work and things that distribute the heat can't get there even if your gas boilers can still fire you may not be able to distribute that heat to the building, whereas a DE plant is going to have a backup emergency generator for the scale of the business that it's in and so your almost always going to have the ability to have heat to the building so I like that idea. Also, district systems tend to be underground so they're less affected by weather… it's not like a big decision factor for me because buildings don't go down much our electricity grids are pretty stable in our major cities, you know barring big ice storms, so that's yeah… in terms of benefits of district I would count that one as kind of low." (MUD1)

> "… the big hurricane that came into New York a few years ago, oh, it will never flood, the streets of New York will never be under water. Well they were, and a

> lot of people went for a long time without electricity and heating and cooling depending on their climate and there were a few pockets that did have their lights on and they were on microgrids and so the people without lights were noticing the people with lights and were asking questions like how come their lights are still on how come their still comfortable and you know well they have a microgrid so there's a lot of talk in the states, a little bit here, but mostly in the states because of the hurricane of municipalities looking at microgrids and DES from a security perspective." (MR/PM1)
>
> "… there's some buildings that have connected to our system and there's some buildings that have not so the moment something happens, and their building is no longer functional while the surrounding buildings are functional, I think that's where people are really going to start to pay attention to umm the advantage of this type of environment." (HR/MR/PM/DEM1)

However, one developer/PM indicated that customers may be willing to accept slightly higher costs in return for insurance that the heating and power systems will not go out, especially in the current real estate market:

> "People need places to live and if they need to pay like a little bit of a premium on their energy bill, I don't think people would really care and that's when you get to the other selling features. It's like when a storm happens and the other building that was cheaper doesn't have electricity and you do, you're going to be really happy that you payed a slight premium on your energy." (MR/PM2)

A suggestion, from this developer/PM, to better market the added value of resiliency was to frame it as more of an insurance policy.

A CEO of a developer-owned energy service company (ESCO) also saw opportunity for DE to allow developers and property managers to meet reliability, cost and sustainability goals, seeing these three factors as interdependent:

> "Yes, we have had phenomenal reliability in the past but if we can add to that reliability without sacrificing the cost advantage and have a sustainability goal met, then why not.
> …
>
> We just have to ensure that all solutions are on the table to achieve three objectives: A high degree of reliability, affordability, and sustainability. We can't sacrifice reliability for instance, you talked about comfort, if this DES is not

> providing reliability then it is no good for me. The design has to take into account higher reliability than what I have today.
>
> …
>
> It is a balancing act: affordability, sustainability, and reliability have all got to be balanced it's not easy, but it's got to be balanced." (DOU1)

Another developer also expressed how stability, reliability and cost cannot really be looked at in isolation, as all are needed equally:

> "I don't know that I would rank them, those things have to work together like if its super cheap and unreliable it doesn't help me, if its super reliable but more expensive than market energy then I'm not going to be able to sell it, so those things have to come in to balance not one way over the other… if I'm just looking to connect what I'm looking for is stability, I want reliability to make sure that I never have a situation where I don't have heating or cooling and then I'm looking for the cost like the whole rolled up cost to be better than a stand-alone, it doesn't have to be drastically better, the same or better but I'm not going to pay more for it." (MUD1)

Two participants reported that stability was an issue to those who were connected to DE systems. Both situations stemmed from lack of knowledge and expertise that resulted in the wrong kinds of equipment being installed in the buildings. These knowledge gaps will be discussed further below. Reliability arose only as an issue in one developer-owned DE utility still being built out where use of temporary boilers was resulting in some outages.

However, two developers knowledgeable about DE brought attention to the challenge some DE systems are facing in providing the needed temperature range to the building due to difficulty in knowing how buildings are going to behave once they are built.

Sustainability and Cost Stability

Participants had a wide range of company sustainability goals ranging from harder targets to general interest in increasing sustainable or energy efficient projects, to targets reflecting an eco-efficiency approach where sustainability improvements go hand in hand with cost savings from energy efficiency initiatives.

Goals and targets included:

- 5-year energy strategy with goal of 20-30% ROI per project
- 10% energy efficiency increase across portfolio
- Striving for higher levels of sustainability
- Looking at energy innovation
- Become the leading sustainable home developer in North America
- Develop carbon neutral communities

Sustainability arose as one of the driving factors behind the decision of some developers and building owners to connect to or develop their own on-site DE systems, and DE was identified as one of the means to achieving their sustainability goals. In one case a connection to a DE system that was fed by a geoexchange field contributed to obtaining LEED certification. Sustainability was generally associated with carbon reductions, however some interviewees talked about storm resiliency when asked about sustainability.

> "We are sort of committed to trying to make low or zero carbon developments, it's just what we do, it's our thing and so in order to do that the economics are very, very difficult at the building scale." (MUD1)
>
> "Yes, it's helped us with sustainability as well. Once the CHPs are fully operational in the event of a major power outage anybody connected to basically the system will basically still be able to receive their heating and cooling as well as electricity until the grid is restored which is a significant component just because the ice storm that hit us a few years ago." (HR/MR/PM/DEM1)
>
> "Some of the discussions last year started to look at what's going to be the cost of carbon next year or five years from now, so it makes good business sense to be ahead of that curve." (REIT1)

For one developer renewable energy fueled DE systems are the most cost-effective way build carbon neutral communities, as opposed to a net-zero approach, due to the ability of DE to share energy between buildings and use waste heat:

> "… it's a very peaky climate, it has really, really, really hot humid summers and really, really, really cold winters so it makes it very difficult to get market for sale condominiums and things to have an envelope that you can afford in order to get down to net-zero at the density that we're building. … the renewables available to you don't really work once you get up to 10, 12, 20 stories high, so a combination of market factors and, cost factors really drive you to look at solutions that are bigger than a standalone building, so that pushes you towards being able to do some kind of district system where you get the advantages of sharing energy so you have some buildings that are exothermic and so they're rejecting heat in the winter and you can use that to feed into the system and in our case we have a large industrial business adjacent to us and they have a lot of waste and so we developed our DES around recovering waste heat from them so that we could bring it over, so the drivers for us are really about carbon and then cost. (MUD1)

The ability for projects to deliver combined cost savings and sustainability benefits were recognized, but sustainability was also seen as an added benefit to the initial goal of achieving savings through improving energy efficiency:

> "… I would say it's a kind of a balanced approach to that, you can't be green at any cost because then you'll do a lot less green work. I don't really look at it either or, I think they tend to go hand in hand if they're good projects. I mean it can get tricky to, because sometimes being energy or economically efficient might not be carbon efficient, but it's some kind of waste reduction thing. It's not always clear cut. The green goal would be what's driving it too." (HR/MR1).

> "It really is about two things: supporting the brand of sustainability that's of big value to us and helping to keep occupancy costs down for our customers which also allows us to be more competitive in the market place if you will. I mean the bonus is the fact that not only is it supporting the brand image but there is a reality to it in terms of contributing to sustainability." (MUD/PM1).

> "Well I think the overall initiative about moving towards DE was the fact that when we looked at the individual buildings, the number of buildings that we were going to put in and the energy output of those buildings versus a DE component we found that we would be more efficient if we put in a DE environment. I think that was the entire premise behind the initialization. There was an intended GHG reduction… so basically we're basically producing energy at a more efficient rate than all of the buildings could do themselves in combination." (HR/MR/DEM1)

> "The primary focus is always the financial numbers so what's the operating cost, what's the capital cost, what's the risk of different options. There is always these ancillary benefits around green energy and carbon reduction targets things like that, sustainability goals. Those are important, but you've got to wrestle the financial numbers to the ground and that's typically how stuff gets past go." (REIT1)

Cost stability was often linked with sustainability as participants saw value in being able to switch to renewable fuels as carbon and/or NG prices increase. As carbon prices rise the business case for DE was identified as being able to improve, as the renewable or waste energy sources that DE can take advantage of becoming more economically attractive than NG.

> "… the biggest thing that we are comfortable marketing even though we're not even there yet is the fact that it has an ability to switch fuel sources should the market be subject to some volatility and other fuel source like gas or carbon taxes are imposed to a level where DE makes more sense with the fuel switch option." (DOU1)

> "I don't think energy will be a deciding factor until carbon is priced at a reasonable level. It's got to affect the bottom line and right now with cap and trade coming in and the price that carbon will be taxed at it's not at a level that will have any meaningful impact on the market. (MR/PM1)

> "I think cost stability is huge in an escalating market so you know if your somewhere that heats with electricity and electricity is escalating fast and your able to offer some district energy option that is not tied to electricity I think that could be a big advantage, it will be interesting to see what goes on in Ontario with you know gas prices have been at historic lows for 5, 6 years now, if the carbon tax is added to escalated gas prices the way its modelled to do then you could very well see some other options of DE having less escalation in cost overtime. So that's very market specific like where you are what the tax structures are and what your inputs to your DES are, but depending on the system that could absolutely be a good advertising point to say connect to us and your energy escalation is going to be good you know, I think that could play up very well." (MUD21)

Another developer saw cost stability alone to be the best-selling feature as energy prices are what end-users are more concerned about on a day to basis:

> "This may be controversial to say but people don't care about energy: most people, they don't. Everyone loves the idea of a net-zero house, but they won't pay for it… the cost of energy - you know that is something that the everyday consumer is worried about. You know, every two weeks I feel like there is an article about electricity prices going up and how outraged people are… I would be

> marketing it not as an energy related marketing scheme, but I would be talking about this as a fuel neutral or fuel flexible place regardless of what the energy prices are the community could relatively easily switch to a cheaper fuel if it needed to." (MR/PM1)

Where GHG intensity requirements for buildings are already place, DE was identified as having potential to help meet these goals:

> "… our DE utility helps in the sense that it's a little bit easier to offer our developments a low carbon source once we switch and so we don't have as much prescriptive building envelope requirements and we're meeting code requirements for GHG emissions so it kind of helps there I guess." (DOU1)

However, the potential for stakeholders to invest early in this is hindered by uncertainty around what future prices of carbon will be. In addition, connecting to natural gas DE now with the promise of switching to a renewable fuel in the future was seen as having to pay prices close to what a low carbon system would cost but without the low carbon benefits:

> "… it's costs certainty, it's not knowing what the cost is going to be… in a lot of cases the connecting to DE you're saying you are going to be low carbon in the future but you're not, you're paying basically close to low carbon costs now but you're not getting a low-carbon solution. How is this better than in-building options that I can actually install to meet the GHG targets that you say you're going to achieve in 5, 10, 15 years?" (HR/MR/PM/MUD1)

The motivation to pursue sustainability goals is also customer driven. Depending on the customer, sustainability can be important or not in a tenant's decision to rent. For the most part it was perceived that customers are not willing to pay more for sustainability in their homes, although, all prices being equal a consumer given a choice between a sustainable design or a conventional design would opt for the sustainable one.

> "For us it is not the type of tenant that we attract in our buildings they're worried about a whole bunch of other things not that piece they don't really care about the energy piece they care about umm having real estate in the right location that attracts staff that can help retain staff that is easy to transit that is close to the customers that has a competitive rate structure like all of those things they rank way higher like for example I do a lot of leasing tours in our building people never ask me about energy people never ask me about is this building LEED Gold

> or not they don’t care they care about its location the price structure the amenity levels.” (BO/CPM1)

> **“**So, I don’t think it is news to anyone to say that even though the benefit to the environment is very clear people are not happy with the prices. So, the developers are the same way, they are not going to be even more under pressure to keep the costs low, so the short answer is I don’t think we will be able to give DE the sort of boost that we need to give if we don’t prove that there is a significant cost advantage. When we have maybe a few developers who would say we want sustainability minded people to come to our developments, yeah, there is proof of that I think in BC, but I don’t know if you’re going to find distributed and district energy successful if it is not meeting the other two goals (affordability and reliability).” (DOU2)

> “You’re going have a hard time finding customers that are willing to pay a steep premium for an energy related unit. Like they want granite counter tops, you know, that’s a much easier sell than net-zero.” (MR/PM1)

> “.. in ‘08 sustainability was ratcheting up in the priorities for Canadians, it is not a big factor right now for Canadians we don’t see anyone, I shouldn’t say anyone, we see a very low percentage of the population willing to spend more money to do something sustainably. If the two things are equal, they will choose the sustainable one like equal in cost equal in value they will choose the sustainable one but they will very rarely spend more for the sustainable option so I would say I have a relatively bleak outlook in terms of a proper consumer change towards sustainability.” (MUD/DE2)

> “I think people right now aren’t willing to pay a premium on green technology, but I think at some point we’re all headed there and whether it’s being taxed being imposed and people realizing benefits on the financial end or people are just more coming around to paying a premium for sustainable initiatives.” (DOU1)

Government or institutional projects were seen as more likely to be sustainability minded or driven by a sustainability corporate mandate. As one developer/PM of an institutional/commercial space put it:

> “I think it’s still for our customers or our tenants it’s still something that’s quite important to them when they make their decisions about space and renting their space, so we see it as a strong marketing feature for us if you will, and we are seeing we are being well received by our customers.” (MUD/PM1)

Where incomes were higher, a developer/PM saw that as driving interest in green initiatives;

> “I think there’s a disproportionate interest because there are higher incomes there, so it adds a sort of Maslow’s hierarchy of needs to want to be perceived to be green and progressive.” (MR/PM2)

Generally, sustainability was seen as having a larger and larger impact on the building industry going forward, both through building code changes, through carbon pricing, and as more awareness around the need for sustainable solutions grows. The focus on building envelope efficiency was seen by some as a threat to DE systems as thermal energy demand could become lower in the future.

> "Some of the discussions last year started to look at what's going to be the cost of carbon next year or five years from now, so it makes good business sense to be ahead of that curve. There might not be a cost of carbon in 2017 but that doesn't stop us from doing projects that could be driven by some environmental stuff too… there is suddenly an awareness that being green is actually good for business. And it's pretty much it's going to be mandatory. I think it's a definite kind of background push that's happening I can't pinpoint it one particular thing. So very important." (REIT1)

> "The code changes that are being imposed at the national level right now are going to have us building our buildings 70-80% more energy efficient than they are today. And that's going to obviously dramatically reduce the need for heating and cooling. So, we're looking at how our building are going to change from an envelope perspective and that's where our focus is right now. And we are looking at what point the mechanical is going to change, because at some point the mechanical is going to change entirely." (MUD1)

Development Timing, Developer Independence, and Added Complexity

Some developers brought up the importance of development timing as being at least equally important as the financial aspects of connection to a DE. Concerns raised were that the DE system might not align with the timeline of the developer, or that problems with the system might delay the development process.

> "… I want my development to be up and running in two to three years, if you have a viable DE up and running which is based on geothermal, or RNG (renewable natural gas) or some other clean technology up and running in that time and be cost effective by a significant amount; I don't have the answers to that, but I'm posing that question maybe somebodies done that work." (DOU2)

Developers also value independence and control over the development process. As it is already a complicated process anything new adds another variable into the mix that adds some uncertainty.

> "… a lot of it is going to be speed by which you are going to be available to connect. One of the challenges is that developers don't like to have anything that's outside of their control so a lot of times they're like I'm not going to do that because I can't control what they're doing so I would rather just do it myself." (HR/MR/MUD/PM1).

> "… most buildings are very independent, so you know they want to run their own show and being reliant on a central system is not something that they contemplated originally when they came into this thing." (HR/MR/PM/DEM1)

> "There is also a lot of people that like to have their own empires too. The guy at the hospital I remember he didn't want anything to do with it and he wanted to run his own boiler plant and his own chiller and didn't want anything to do with DE. Just thinking about keeping the light on his own buildings so there is a lot of that kind of mentality too." (REIT1)

> "… we have a general contracting arm and so as a developer that arm is very risk averse when it comes to new systems. They like doing things they know, they like certainty, they like schedule they're very much so control freaks. DEU presents a little bit of gray to an otherwise black and white scenario that they like to live in and so there is some push back there when DE connectivity is discussed." (DOU1)

There was the perception that DE is an added layer of complexity to an already difficult development process as DE introduces new parties, concepts, and equipment to navigate. This also ties into the knowledge gaps around DE, which emphasizes the need for some regulations to improve clarity in the process. Perceptions on regulations will be discussed in further detail in a section below.

> "I think it would be more complicated because you're dealing with a bigger mechanical system or more expensive consultants and service contractors. I think the conventional systems of distribution are much cheaper and much more cost effective partly because the general consumer and the retail consumer buys those same services, so they have to be kept low. When you do a standalone or you create systems that are one-off or never been done before you get abused by consultants and service contractors and it's all brand new and there's no precedent and the regulations aren't written to serve it. So, I find it's a complete boat anchor, it's a complete problem. It's not a benefit, it's a distinct disadvantage." (MR/PM2)

> "So one thing that I mentioned is there's multiple parties now so rather than just dealing with your mechanical consultant and your plumbing contractor, which is sometimes already hard enough to coordinate, you now have two other parties on the district side that you're working together with so your DE utility engineers or your ETS engineers as well as your ETS contractor and so they all have to work together during the design and commissioning phases which adds a layer of complexity and has resulted in some issues with getting to a resolution. It's just a bit different, you're required to go hydronic and with hydronic you know you're looking at hydronic base boards or in-floor and in-floor is a little bit more expensive but in-floor in our experience or a builder's experience is more reliable when connecting to a DEU." (DOU1)

Complexity is also added to PM duties:

> "If your PM is accustomed to dealing with the boiler and calling in their plumber or whatever now they've got to deal with another party so you've got screaming residents and your trying to resolve the situation yet its connected to an ETS that you don't own and you need their collaboration to sort an issue, it inevitably takes more time resolve an issue because you have more parties so that would be the biggest one I would say." (DOU1)

Developer Owned Systems: Resiliency and Cost Stability

It was found that many developers are looking to develop their own centralized energy solutions for larger multi-building developments. Out of the twelve developers and PMs interviewed, 6 had developed or were in the process of developing onsite DE systems. Another two were looking to acquire such systems. Interest has been in developing, owning, and operating the systems themselves, as well as in outsourcing the operation to an energy service company. Interviewees conveyed their primary decision-making criteria to be finding a favourable business case for their on-site projects, as well as the ability to increase energy efficiency and share energy between buildings:

> "Well there's a value out there, it's an annuity. There's a reason why utilities do it, it's a long-term annuity that diversifies the business, so if they do it right it's another business, it's another revenue stream and that's the advantage." (HR/MR/PM/MUD1)

> "I think the overall initiative about moving towards DE was the fact that when we looked at the individual buildings the number of buildings that we were going to put in, the energy output of those buildings versus a DE component we found that we would be more efficient if we put in a DE environment, I think that was the entire premise behind the initialization." (HR/MR/DEM1)

On developer was also motivated by sustainability goals recognizing that DE is the most cost-effective means to achieving carbon reductions in their buildings:

> "a combination of market factors and cost factors really drive you to looking at solutions that are bigger than a standalone building so that pushes you towards being able to do some kind of district system where you get the advantages of sharing energy so you have you know some buildings that are exothermic and so they're rejecting heat in the winter and you can use that to feed into the system and in our case we have a large industrial business adjacent to us and they have a lot of waste and so we developed our DES around recovering waste heat from them so that we could bring it over, so the drivers for us are really about carbon and then cost." (MUD2)

Another developer, also interested in DE for their community-scale developments, was motivated more by the need to reduce complexity for homeowners as energy systems become more sophisticated and require more expertise to optimize:

> "Well I mean there are a couple of reasons, one of them is the costs, so when your adding systems to the house that means the homeowner has to pay for all of the new sophisticated systems whereas if you have a utility model then the utility can own and operate and amortize the infrastructure and equipment and just charge the homeowner a fee for the service and then you get the operational side. So, the equipment is becoming more sophisticated compared to what's typically installed in a traditional house and the homeowner is not qualified to you know optimize and operate and run this equipment, so we need a professional entity which in this case would be a utility to optimize and run and maintain this equipment over the long term." (CSresi1)

Value to the developer and the end-user is also increased by the use of CHP in the onsite system. As electricity is more expensive in jurisdictions such as Alberta and Ontario centralized CHP systems for multi-building developments have a good business case. Use of CHP also strengthens the resiliency aspect as customers have access to both heat and power in the event of an outage.

Main challenges developers of onsite systems experienced were unexpected technical issues, finding local equipment providers, utility regulation requirements, and getting municipal right-of-way approvals.

This movement towards ownership of on-site DE systems may be a reflection of what one developer/property manager brought forward as a need for a new definition of DE, which constitutes a move towards smaller more nodal DE systems:

> "… their (the municipality) definition of DE does need to change… it is a part of a toolbox and really looks at what DE means today and it's not going to be the same as it was yesterday so what should it look like in order to make it competitive… but it's going to be a smaller role and you have to make it more cost competitive to make it a better solution than in building solutions like air source heat pumps. So, I believe in DE it's just that it needs to be considered differently, it's not going to be... we're not going to be using the Copenhagen model anymore." (HR/MR/MUD1)

However, this emerging prevalence of developer-owned DE systems may be one the factors that are preventing it from reaching larger-scale buildout. Developers generally operate on timescales of one to two decades in terms of their financial risk, financial value, operating dynamics, whereas DE owners have to have a multi-decadal perspective, and "confusing those two creates a conflict of interest" (EC1). In Canada, this conflict only resolves itself when the building owner or the property developer and the DE owner operate on the timescale which results in the majority of DES being owned by institutions such as hospitals, academic campuses, or military bases (EC1). This situation closely resembles the UK case where expansion of small privately-owned single-owner systems is hindered due to commercial interest's need for short-term financial gains and higher ROR. In this sense, by attempting to start DE small to see if it works, failure or less than expected performance is likely the result either because it fails to capture the benefits of economies of scale, or because of a misalignment between developer timescales and motivations, and the realities of DE infrastructure.

Knowledge and Expertise Gaps

A major barrier that emerged from the interviews is the lack of knowledge, expertise and understanding in the development community, but also in municipalities and utilities around what DE is and how to properly analyze its potential, design buildings to be compatible with DE, and how to optimize systems:

> "… it's a bit different. The business model is very new in Atlantic Canada, so nobody really knows what they are talking about because there are no hard path proposals or what that would mean." (REIT1)
>
> "Why don't they connect? Part of this is, they don't have that experience that people have in Scandinavia where this is pretty common." (DOU21)
>
> "I'm now venturing into the private sector to find third party investors because I'm trying to find people interested in funding the due diligence work with feasibility studies and so I have been talking with these people for the last two and half three months and the I need to go to basics about the technology what it is what its capable of and also just as importantly what it's not and I'm talking like utilities, cities you name it, they just have no clue… because they didn't learn it in school and none of the consultants that they've had work for them in the past know anything about this stuff and they've never had any project like that ever in their jurisdiction in their career so like why… they don't even think to ask" (MR/PM1)

It was emphasized that knowledge around DE should evolve to a point where it becomes just another tool that a municipality can use to reach specific goals:

> "It goes back to the toolbox and really understanding what are the tools that will help achieve the goals depending on the location, so again DE is not the be all end all its really more of what are the levers in this area that make the most sense and in some cases DE may make sense…" (HR/MR/MUD/PM1)
>
> "… if they are aware of DE and its advantages and disadvantages then the DE should be added into the mix of options that they look at when they make these decisions." (MR/PM1)

Development projects that included on-site DE systems required an internal champion with the experience, and knowledge around DE. Interviewees remarked that the projects would never have got off the ground had they not been there to get it started:

> "… one of my big motivators to get myself involved with this project was I saw that they had an interest in CHP, but they didn't have any capabilities in realizing that interest in any way. So, I thought as an opportunity, because they had the interest which normally is half the battle, is just getting people interested in pursuing something like this. But I saw the risk that it was going to be pushed aside because they didn't have any in house expertise to take the torch and carry it forward and they wouldn't have the budget to go out and hire expensive experts to do it for them, so the idea would probably stagnate and get brushed off; they would put a typical heating system in." (MR/PM1)

Gaps in knowledge, and communication problems in the consulting community and municipalities, was also raised as a challenge to proper consideration of DE. This problem appears to stem from a lack of understanding of the building engineers on the technical requirements of DE, and of DE providers on how buildings are typically designed. In addition, designing for compatibility and optimal performance of DE systems is not something taught in engineering schools, and therefore consulting engineers are very unfamiliar with this process and may build in redundancies and design to conventional standards even though the building is to be connected to a DE system:

> "…they don't understand the development process… a lot of it is the interface between developers and the utility companies and also the consulting community and the utility companies. There's a lot of conflict between them and the goal is to really get the consulting community who is basically the people advising these people to understand in more detail what DE means. In areas where DE is mandatory, they're good but in other areas less so, and also get developers to determine whether or not there is an advantage for their end-users, their purchasers etc." (HR/MR/MUD/PM1)

> "The other thing that I often see is that because the consulting community, they don't understand the requirements of DE from a technical point of view, a lot of the issue is they get past mandatory connection but then there's technical issues and the technical issues are due to the fact that from a design point of view DE providers they don't understand buildings and building consultants don't understand DE so when you actually get to a technical point trigger that there

> might actually be issues in the building or their might be issues going back to the DES because they don't talk properly." (HR/MR/MUD/PM1)
>
> "… between the consultants and the DE consultants there are barriers like they don't necessarily see eye to eye for multiple amount of reasons one of the things you have to understand consulting engineers get paid on a percentage by capital so if they're not installing boilers in their buildings that's a hit to their bottom line so they're not necessarily going to help you not on purpose but that's the reality of it." (HR/MR/MUD/PM1)
>
> "… the biggest sort of gap between them are that building engineers… they have learned from the school of hard knocks to be extremely conservative and they are used to having a lot of redundancy and things so when you get a DE situation and you tell the building engineer that you're going to use DE they're still trying to add boilers and add chillers at the building level to give you redundancy they're still they don't necessarily believe that the temperature from the DES is going to meet this profile so then they make their equipment able to do a larger profile and so I think that actually a continuing battle between the DE engineers and the building engineers to just get people to sort of trust each other and get the design as efficient as they can instead of having a bunch of redundancy. The other thing that really messes up the district side too if you design a building and you say that you're going to deliver a certain delta T… if you don't get that change in temperature then your heat exchanger is not necessarily going to work and your inputs and outputs from your district loop aren't going to work, so if the building engineer messes up and overdesigns or the systems in the building are sort of bigger than they need to be and they never kind of deliver that delta T then it's very hard on the district system so that is an area that needs to continually improve I think." (MUD2)

These knowledge gaps also appear to be behind problems experienced by managers of developer-owned DE utilities with connections to other privately-owned buildings when incorrect equipment is chosen:

> "We faced a few challenges in terms of people's buildings who have chosen to choose a different or chose the size of their heat exchanger or chose their side of the distribution system and maybe they didn't consider the all the impacts before they've done it and so they've been challenged with some of the decisions that they've made overall." (HR/MR/PM/DEM1)
>
> "We got one building where we are the developer and we've been, just since we've connected to them, we've been going back and forth trying to resolve an issue and the issue is that their construction team value engineered some baseboards heater that weren't the originally approved ones by our DE engineers and so the heat isn't emitting the way it should be, so the system, the heat exchangers and all the set points around that are functioning as designed, the heat just isn't getting out into areas of the suite based on the swapping of the

> baseboards, so that created a lot of discomfort with developers now hooking in because of this one building that we've had an issue with the residence complaining so I would say that is still a valid risk." (DOU1)

For those looking to develop their own onsite DE systems lack of local maintenance options was also an issue that drove up the operating costs of the system:

> "We haven't gotten over the maintenance aspect of it yet, we need to find somebody that is readily available that makes sure the [CHP] is operating all the time. I think those challenges will continue… It's not a mature… and it's because there are so many different types of machines… each of them seems to have their own service guy that knows... So, for them to have one unit operating in Calgary that's expensive."
>
> "… ability to service equipment locally was one of the main criteria in [a procurement study for CHP]." (MR/PM1)

Linked to gaps in knowledge and expertise around DE solutions is the dominant focus on single building solutions to achieve sustainability goals through, for example, net-zero buildings. One developer pointed out that the more mainstream attention net-zero is getting would only be a threat to further DE development if architects and developers continue to work at an individual building level:

> "I only see it as a threat if architects and developers are looking at individual buildings which unfortunately is the status quo… this goes back to the lack of expertise and knowledge and awareness. That means the architects without looking at, they don't even know this is a thing that you could connect to them or if they do they think oh that's just a special Europe thing and so they'll just try and engineer the hell out of that one building to be net-zero whereas you might be able to achieve that more cost effectively if you looked at a centralized system and then instead of using gas fired CHPs in your central system maybe you could do biomass at a centralized system because biomass sure isn't going to work at the individual building level but it becomes a lot more viable with a centralized system where you scale it up, or if you have some land you can look at solar thermal you know when you have these DE systems the amount of energy sources available to you opens up tremendously, so again if they're thinking multi-building I do think net-zero could hurt DE but if they are aware of DE and its advantages and disadvantages then the DE should be added into the mix of options that they look at when they make these decisions." (MR/PM1)

This kind of competition between net-zero and DE was also echoed by a developer and a developer/PM:

> "I can build a passive house standard or a net-zero standard building for the amount of money you want to pay and I'm going to come out ahead." (MUD1)
>
> "… there's a bit of thinking within the business if you will that DE that uses gas fired boilers is less sustainable than the net zero electrical approach. That's the challenge we are facing right now with the next project is whether or not we connect to the DES or do a standalone net-zero electrical." (MUD/PM1)

Regulations

Developers and building owners/property managers generally agreed that some regulations are needed to improve clarity, certainty and streamline some aspects of the process. For example, regulation of thermal metering was raised as important for consumers to ensure accurate measurement. However, some felt the market was not ready for regulations yet, particularly developers that were also DE providers. Implementing a regulatory framework now was seen as adding another lengthy approval process that would discourage developers and building owners already unfamiliar with DE. Regulation was valued where it ensured fairness or provided some oversight in a monopoly situation, but the need for this could potentially be reduced through guarantees and other mechanisms in the energy contracts.

> "… but then comes the question who is going to regulate that DE service provider, so they don't use their monopoly position because now its mandatory." (DOU2)
>
> **"…** it's one of these things is that it does provide certainty, it does help developers understand that there is going to be a mechanism for their end-users to make sure that the costs are fair. So, I think that's a good thing. I think the barrier is the fact that it is a regulatory body and it takes time, so you cannot say that it will. You know, again because of the speed at which developers and again this is one small, small item on a list of many if it's a new system and they don't know what it is, that can be a challenge." (HR/MR/MUD/PM1)
>
> "Well I think as a consumer I would say we probably do need to regulate the metering of thermal energy, so you know no different than a hydro meter but if I want to bill you for electricity consumption then I need to use a meter that is

> certified by Measurement Canada. Right now, you can use whatever you can get away with for metering thermal energy. As a DE provider I'm not in a hurry for more legislation but as a consumer probably interested in that." (MUD2)

One developer/DE provider saw regulation as only needing to extend to mandatory connection:

> "… at the municipal level I think it does make sense to take parcels of land that are well positioned for DE and make mandatory connection. I would like to see that, I would like to see the growth of it because even if you're going to use traditional inputs even if you're going to burn gas there are still benefits to having a DE plant burning gas, it's still better environmentally you just get better options by putting a variety of loads together, so I think mandatory connection is a great idea so I would like to see that at the municipal level and then after that I don't know that that I feel that there should be a ton of regulation." (MUD2)

Another developer raised the issue of having proper independent regulatory oversight in place for DE utilities. In this view, municipalities creating bylaws to mandate connection to a municipally owned system was seen as a conflict of interest. While other participants did not express this concern, when questioned about it they did feel that some regulatory oversight was a good idea.

> "So I think that is a major piece of it that there is true independent oversight over DE and I don't think that is the case because most of the DES or a few of the DES are owned by the municipalities and those are the same municipalities that regulate through their zoning bylaws what you must and must not do… but if you have a true independent regulator out there like a utilities commission that verifies that the amounts that are being proposed to be charged for the use of that energy is a reasonable number and there's not unnecessary profit margins built in to it and people making use of the monopoly that they have in those systems or in those markets. Then I think it could work, an independently owned DE company and city government that regulates the use of the city like land use and those things and then combined with an energy regulator that provides oversight to all the situation. But that's not what's happening." (BO/PM1)

> "I mean as a consumer probably. I know there are things out there that are certainly ripe for abuse but I'm not a fan of too much red tape because I wear both hats is probably why I'm not a huge fan. There will be some bad apples out there for sure that tie you in to a contract that you can't get out of that is escalating unfairly and maybe the developer gets some benefit of that so maybe they get a signing bonus but then the condo that is connected to it ends up paying that signing bonus many times over because of the escalation clauses in the contract. You know there's games that can be played and there probably does need to be oversight." (MUD2)

Mandatory Connection

Perceptions on mandatory connection also ranged from positive to negative. Those with more experience and knowledge with DE tended to have more positive perceptions. For those positive towards it an important stipulation that arose was the role of the energy purchase agreements in clarifying and ensuring sound economics of the project for the customer of the DE.

> "Personally, I think that's a good idea… I mean there is a high first cost capital that hast to be borne by somebody, but if it's in the public interest I don't see any reason why there shouldn't be mandatory connection." (REIT1)

> "I don't see a problem with it at all as long as everybody goes in eyes wide open, so when the developer starts or whoever or if they're retrofitting a number of buildings as long as everybody understands what they're getting into upfront and they just hold to that then you're fine, as long as again you're not exceeding market conditions nobody has a complaint because you're not losing anything." (HR/MR/PM/DEM1)

> "…in principle the only thing would be the economics of it. Mandatory connection to municipal infrastructure sometimes doesn't provide you the best economics for providing energy to your tenants, that may or may not be true in any given case I guess." (MUD/PM1)

> "… it's not a bad idea as long as the developer has a chance to prove that that is you know beyond affordability, in other words the developer is saying look your forcing me to connect to this system I don't mind connecting to this system if it was in my tolerance, so let's say If I was going to have cost per unit of energy as X it shouldn't be 2X it should be X + something, but nothing beyond a certain ceiling." (DOU2)

> "Well because I know a lot about that business and what it is, I would just welcome it. I'd be very happy for a mandatory connection." (MUD2)

A few developers and property managers perceived mandatory connections as being a risk because it would eliminate choice, or it was perceived as being too expensive:

> "I wouldn't buy the land. We would be out. We would go build somewhere else… I could take the cost that I'm going to be charged and invest that cost into a better building and then pass on those savings to the purchasers through lower energy bills… Plus if I am a land developer let's say and my proposition is I have this DE system, that's fantastic but you are required to tie into then you got me, a vertical builder let's say, and I look at my nearest competitor in another community and

> he says hey you can do whatever you want here and I'm not going to charge you this. You build whatever you want. Where am I going to build?" (MUD1)

> "I'll tell you what my concern is with it and that's what the city of Vancouver is doing is the single sourcing of it that's what worries me about it. I mean I'm also supportive of DE but I'm not supportive if you or government policy mandates you to single source and you must hook up to DE because then we as owners are starting to lose some of the competitive advantage of being able to choose what is the energy source that we want to choose for our building." (BO/PM1)

One PM saw the risk of mandatory connection to be great enough to consider installing conventional NG boilers in the building in addition to a DE connection in order to increase their personal choice options:

> "I think it is generally speaking it could be a competitive advantage to have DE because its yet another choice who knows maybe at one point I want to have the option to have two different fuel sources and we may so I see it as a positive for as long as you maintain the choice it becomes a negative when you start to mandate that you shall and you must and you only have this choice for heating in your building." (BO/PM1)

The risk of mandatory connection was also linked to issues of ensuring regulatory independence by two participants i.e. if the municipality owns the system, they should not have the power to mandate connection to their own system.

> "At least from my perspective it comes to creating choice for building owners so that you don't create this monopoly and particularly not create a monopoly where you have absolutely no confidence in how independently run it really is." (BO/PM1)

> "… but then comes the question who is going to regulate that DE service provider, so they don't use their monopoly position because now its mandatory." (DOU2)

However, they were not opposed to building to DE ready designs:

> "I think the way you deal with that is basically say okay we would like you to be ready to be hooked up to DE so that when you build a building provide that connection to that system if you want… and you don't have to dig up the roads later if you wanted to connect it, so fine provide a future connection but don't do it to the exclusion of other fuel sources like NG and I think then at least we still always have the choice between choosing between system a and system b." (BO/PM1)

As can be seen in the above passage some of the reasons for perceiving mandatory connection as a risk relates back to knowledge gaps. Because DE is new to most developers and PMs there is uncertainty around the cost and a fear that being forced to connect to the system will take away their independence and control, or ability to choose a different fuel source. This shows a lack of understanding of the ability of DE to fuel switch to a cheaper fuel source. One developer/PM more experienced with DE commented on the perceived risk of mandatory connection: "I don't think they understand what the ramifications of connection truly are." (MR/PM1)

Another developer emphasized knowledge gaps as a fundamental reason for resistance to mandatory connection:

> "Because development is hard and development is risky and there are a lot of moving parts and if I have built buildings for twenty years and I have always put a central plant in them why do I want to change that, I know what I'm doing my consultants know what they're doing and I don't need to add any risk and any change is risk… it is a very difficult business and so anything that is different is adding risk and you've got to be educated on it and you've got to be educated on what the benefits are for the developer and as I'm sure you know most developers don't care environmentally like they're not focused on trying to build something green so that's not registering in to them as any advantage or anything and if they're offloading it so the op[erating] costs fully belong to the condo or the op[erating] costs are being transferred to tenants then they don't care that much about that so you know it's just different. If you go to a European developer and you tell them listen, there's no DE available you're going to have to put in boilers and chillers in your building they're going to look at you like you have two heads. So, it's just what your used to." (MUD2)

One developer/PM recognized that while there may be some push back against mandatory connection, it is an important tool to drive innovation, and negative perceptions of it can be overcome through education:

> "Of course, developers don't like mandatory connection, but it does drive innovation, it does drive other things, it's not a bad thing, but it's got to be done correctly and there needs to be education and people need to work together in order for it to be successful." (HR/MR/MUD/PM1)

Another indicator of the need for mechanisms to push stakeholders towards DE, is that in regard to energy developers are primarily driven by the building code:

> "… if the code didn't require us to do anything with regards to energy we wouldn't you know that's the brutal honest truth… if the city didn't force us to abide by the new rules, we would just be copy pasting. Really the building code is going to drive building improvements on the energy side from the developer's perspective." (MR/PM1)

Energy Service Agreements

This section will outline what participants would like to see in Energy Service Agreements to improve attractiveness of connecting to a DE system. Energy contracts can also play an important role in mitigating risk to developers, for example the risk of the capital costs of building the DE system being passed down into the operating costs of the building:

> "If I was developing DES it's an easily mitigated risk, it absolutely is a huge risk, but it's usually mitigated through the form of energy contracts with your customers. So, if you have a critical mass of people to sign energy contracts for the next 20 years you know your risk of eating that upfront capital cost goes down because now you can amortize it." (MR/PM1)

Key conditions that stakeholders wanted to see in the energy purchase contracts were:

- Benchmarking of heat prices back to market- Participants wanted some form of guarantee or insurance that heat prices will not rise above a certain level or would be at least tied to the price of the feedstock of the system. Fixed escalation was seen as not favourable to the customer as DE utilities could continue to escalate prices even as the feedstock of the system could be decreasing. Typically, costs cannot be higher than if a conventional system was used. This was important from a developer and property manager perspective:

  > "Whatever I am paying has got to be competitive, that's it. But I wouldn't develop a piece of land and encumber it as a requirement. So if there is a DHC system out

> there, so really that system provider has to go to the developer, not the land developer, the person that's going to do the building, and they have to them with a value proposition that either takes the mechanical costs out of the building, simplifies construction, or gives them a value proposition that they can either pass on to their leases or their homeowners that their competitors don't have." (MUD1)

> "… our costs cannot be higher than what a building would have to do traditionally from a capital cost perspective. So, if they were going to spend a million dollars on mechanical equipment to put it (DE) into a building, alright we can't charge them or we can't recover more than a million dollars' worth of capital from that buildings and at the same time if they put in their own system and they can heat the building for x amount of dollars we can't be charging them more money than what the market generally (bears) so DE on the whole from a business perspective needs to actually come in at equal or less than what a traditional environment allows for." (HR/MR/PM/DEM1)

> "… what are guarantees or what is like the unit rate how is it regulated and what type of stability and guarantees do they offer me on that rate structure." (BO/PM1)

> "I'd like to tie any escalation of the contract to be associated with the feedstock of that district thermal system so if it's largely an electricity-based system like a ground source heat pump system… then my escalation for the contract should be related to the escalation of the cost of hydro." (MUD2)

- Length of contract- A mechanism to revisit heat prices periodically to ensure they are still fair
- Transparency of various elements in the price

Other concerns that arose as items to be addressed in the contract, but not as frequently as the others, were response times to maintenance issues, reliability of service, as well as clarity around who owns, manages and regulates the DE utility, who it is independent from, and the financial stability of the utility.

Role of Government

Participants expressed a need for all levels of government to take more of a leadership role in order to overcome some of the challenges that DE faces:

> "I think that if the government really wants to see progress in this, they're going have to take the lead and they're going have to fund some things." (MR/PM1)

One role applicable to all levels of government that was identified by one participant was for government buildings to look for opportunities to be anchor tenants for DE systems.

One major risk identified on both the municipal and senior levels of government side was the possibility of programs being slashed due to election changes.

> "… the political slash policy risk is actually considered one of the highest risks in the CHP community in Ontario at the moment… you know an election change could completely throw out all of the work that you've done over the last 4-8 years." (MR/PM1)

Municipal Level

Participants saw a need for municipalities to play a more expanded role in the development of DE and saw providing DE as part of the municipalities role in providing infrastructure. In particular, municipalities providing the upfront capital for the DE system was an important factor in deciding to connect.

> "They (should) have a much more aggressive role. They are kind of way to passive." (REIT1)
>
> "I certainly support a municipality being involved in DE in this way it's part of their role in providing infrastructure for the community if you will." (MUD/PM1)
>
> "… they actually provided the capital to build out energy supply for each building and then we entered into a contract to buy the energy from them so for us a big part of it was a way of avoiding having to deploy our own capital to get the job done. So, it wasn't a sort of technical or energy efficiency reason as much of an economic reason." (BO/PM1)
>
> "Not having to deploy capital that was the biggest benefit (of the municipally owned utility) for sure." (MUD/PM1)

Other important areas identified by stakeholders for the municipality to take leadership were:

- using measures to bring costs down and create an environment for DE to be profitable, such as providing upfront capital, designating heat planning areas, aiding in approval and permitting processes, as well as providing access to municipal rights of way.
- Integrating DE with city planning and identifying concise areas for easy implementation

Lastly, one developer/PM put forward that municipalities and DE utilities going into the future may need to redefine what DE means:

> "…the concept of DE needs to change I think DE is not necessarily like the steam system at Creative with fourteen km of pipe underground it's not necessarily UBC, what it is going to be is it's going to be smaller it's going to be with a fewer number of buildings and it will be more of a nodal approach and it will just be part of a solution. So you look at high dense areas well then maybe three buildings are district as opposed to fifteen acres but then maybe it's more of a building solution approach which is still you know it's not district but I get the whole concept of DE for cities because then first of all they have often times have a utility that they can shake a stick at to say you're not meeting requirements and that's changing because they're going to be asking for requirements from you know developers. I think DE is a great tool I don't think it's the be all and end all. It's not going to be like Europe because Europe was generated under a different time and what we call DE in North America will be different and the DE providers need to get that, or they'll be pushed out of the system." (HR/MR/MUD/PM1)

Provincial and Federal Level

Participants saw a need for more funding, support, guidance and leadership from the provincial and federal government to aid in educating municipalities, developers, and consultants, as well as providing the necessary tools and clarity of process to decide whether DE is an appropriate solution in a location. A general lack of funding for non-municipal DE projects was identified as an issue.

> "If they want to see any meaningful progress in this type of technology being implemented more broadly, they're going to have to lead by example. With that said I think there's a tremendous opportunity for me and people like me who have

the understanding of the value that a system like this can create and use it as an entrepreneurial type of vehicle. But we're not going to get the same type of widespread adoption doing one development at a time but compared to a government that starts to make polices or mandate certain things at a provincial if not federal scale… what the government needs to do they need to provide guidance and leadership that's what needed from the government on this topic. They need to lead by example by making their own systems and documenting how they did it, lessons learned how to improve it, and come up with a process that they can offer to municipalities for free and say this how you can do this, this is the process." (MR/PM1)