Planning for District Energy:

Broad recommendations for Ontario Municipalities to help facilitate the development of community based energy solutions.

by

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Author's Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

Abstract

District energy systems are a key component to addressing reductions in green house gases, encouraging compact settlement form and ensuring reliable community energy delivery. System development can also generate local economic benefits like aggregated energy pricing and employment creation. This research focuses on an exploration of Ontario's planning framework with respect to energy generation and thermal energy distribution, providing broad recommendations to municipalities intended to help facilitate the development of district energy systems. In summary, this research was designed to accomplish the following objectives:

1. To craft a set of transferrable recommendations that will help Ontario municipalities facilitate the development of district energy systems where appropriate.
2. To add to the literature available on district energy system development from a municipal planning perspective.
3. To examine the tools available to planning practitioners to help engage communities and municipalities in planning for local energy generation and delivery.

The methodological approach employed for this research is qualitative in nature, relying on an inductive style building from particulars to general themes. The characteristics of a qualitative study are best suited to address the research questions and objectives because community energy planning and land use planning are largely unexplored in conjunction, and this methodology provides a framework to explore where the fields have integrated in practice as well as reveal some of the challenges and potential solutions. Case studies were used to examine the development of two different Ontario district energy systems. Additionally, key informant interviews provide insights from planners, system operators,

customers and industry experts to provide a practice based foundation of information to development transferable recommendations.

The findings suggest that the development of a district energy system is a very complex process, requiring the expertise of many specialists, and the support from local stakeholders. There are planning implications for the implementation of district energy systems, which require forethought at the beginning of the planning process and opportunities to support community based energy solutions through policy. The adoption of a planning regulatory framework will ensure adequate consideration is given to community energy management in conjunction with land use and urban form. Going forward, accounting for the conservation of energy in land use will be imperative for achieving local, regional and provincial goals associated with infrastructure, the environment, and energy resource management.

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Thank you to Rob Thornton and the International District Energy Association for their support of this research. Rob was pivotal in informing my understanding of thermal energy as essential infrastructure in dense, urban environments.

I was able to speak with a number of very knowledgeable district energy experts, system operators, managers, and planning practitioners. Their insights were critical in understanding the challenges and opportunities associated with planning for community based energy solutions. Thank you to all who participated.

Along the way, I accepted a planning position at a leading design consulting firm in Toronto. Landing at DIALOG has been a tremendous opportunity to learn from some of the brightest practitioners in the country. The mentorship provided has been invaluable, and their dedication to thought leadership has allowed me to position this research in the context of the complex urban issues facing our cities.

Most importantly, I would like to thank my friends and family. Their commitment and patience has been unwavering. My mother has shown me the value of perseverance and dedication, and my sister's curiosity has inspired me to search for answers. It is with their support I have been able to complete this research.

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Chapter 1 Introduction

1.1 Research Background

As global demand for fossil fuel resources rises, traditional energy supplies are becoming increasingly scarce (Abramsky, 2010). Research findings from the International Panel on Climate Change (IPCC) suggest with 'virtual certainty' that there will be "warmer and fewer cold days and nights, warmer and more frequent hot days and nights" (2007b, p. 53). The impact of climate change will transform Canada's thermal energy (space heating and cooling) requirements. Furthermore, the severe weather events associated with climate change, often result in disruptions to critical community infrastructure, including energy generation and distribution networks. A quick scan of North American weather events over the past decade illustrates this point quite clearly. The 1998 ice storm that hit eastern Canada; the August 2003 electricity blackout of central Ontario and the northeastern United States; and the 2005 hurricane 'Katrina' which devastated the southeastern United States; all had catastrophic impacts on the distribution of electricity, and thermal energy. Canada is expected to experience escalating fuel costs, as energy security is jeopardized. Additionally, great concern has been voiced by both the public and private sector regarding the reliability of aging municipal infrastructure, greenhouse gas emissions and local energy security (Ontario, 2004 & CCPPP, 2004). These symptoms of a carbon-based energy sector can only be addressed with progressive approaches to the generation and distribution of energy. Anxiety is being coupled with an opportunity for new renewable fuel sources and improved technologies that are revitalizing interest in the potential of district energy systems.

As a result, governments and businesses are giving thoughtful consideration to building design, development and operational requirements in an effort to minimize energy costs and mitigate the environmental impacts associated with energy consumption (Canadian District Energy Association (CDEA), 2008). Municipalities are afforded an opportunity to significantly reduce the impacts of carbon-based energy consumption, but it will require local governments to establish a strong connection between land use, zoning bylaws and the distribution of energy.

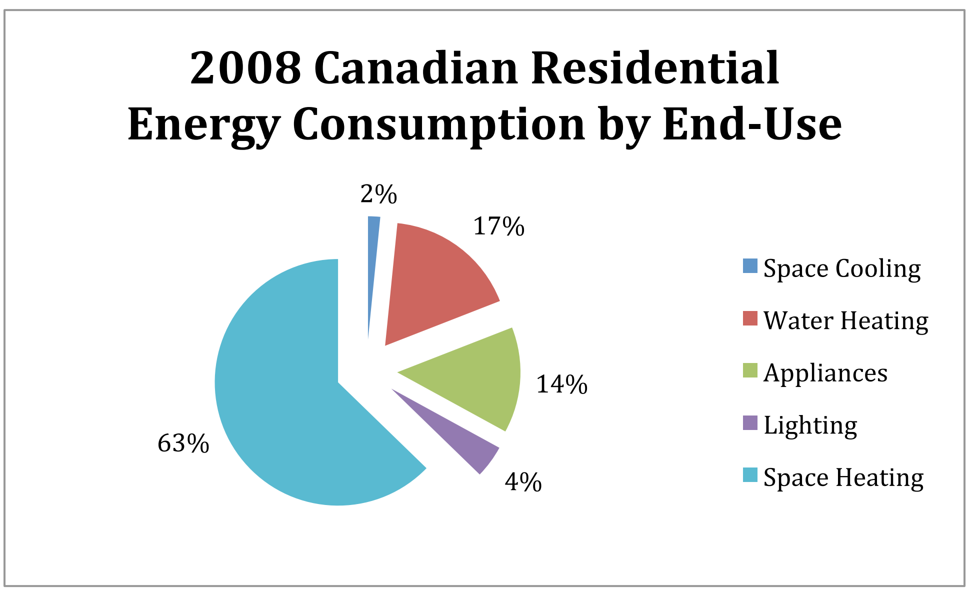
District energy can be described as an energy management system that is implemented and operated at the community level, takes the form of thermal piping (Church, 2007). This infrastructure can utilize several mediums including steam, hot, cold and chilled water, ultimately providing the important local link between energy supplier and consumer (Church, 2007). These thermal energy systems can assist communities in advancing their sustainability agendas while providing a flexible format to shield risk from the unknowns of future energy generation and delivery. Although district energy systems are proven and in place across Canada, challenges exist for the implementation and start up of systems in many Ontario municipalities. Furthermore, as this research will show, land use, urban form, and planning policy has many implications for shaping community energy demand, but the connection between planning and energy is largely lost on the profession.

1.1.1 Urban Energy Consumption

The urban environment presents both challenges and opportunities with respect to energy demand, generation and efficiency. The International Panel on Climate Change (IPCC) estimates that the energy supply sector is the largest producer of anthropogenic greenhouse gas (GHG) emissions globally (2007a). In North America, buildings and urban infrastructure are major contributors to GHG emissions. Research conducted by the Canada Green Building Council concluded that buildings account for 37 percent of Canada's total primary energy consumption and produce roughly 30 percent of the total GHG emissions (2007). Despite improvements in efficiency, Canada's power consumption has risen by nearly 10 percent compared to 1990 levels, and the demand for energy continues to grow (CDEA, 2008). Research suggests that this is due to an increased adoption of electronic equipment for business and residential applications coupled with the growth of energy intensive industries such as the oil and gas and telecommunications sectors (CDEA, 2008). Forecasts for total Canadian electricity demand project an increase to 593 terawatt-hours (TWh) annually by 2020 (NRCan, 2006). Similarly, demands for space heating are estimated to grow by 1 to 2 percent annually over the next twenty years as new residential, commercial and institutional developments are built out in expanding urban centres (CDEA, 2008). Although these trends indicate substantial energy use and increasing demand, the built environment offers the greatest potential of all sectors to reduce global GHG emissions by 2020 (IPCC, 2007a).

Figures 1 and 2 illustrate Canadian end-use energy consumption by sector. Residential energy consumption by end-use shows thermal energy (space heating, space cooling, water heating) accounting for 82 percent of total energy demand. Similarly, commercial and institutional energy consumption by end-use shows thermal energy accounting for 60 percent of total energy consumption. In the residential sector, a higher proportion of hot water heating is the primary reason for a greater share of end-use energy consumption associated with thermal energy demand. In both cases, significant proportions of end-use energy consumption are attributed to thermal energy demand, signaling the opportunity for district energy to surface as a potential solution to improve efficiency and reduce thermal energy requirements.

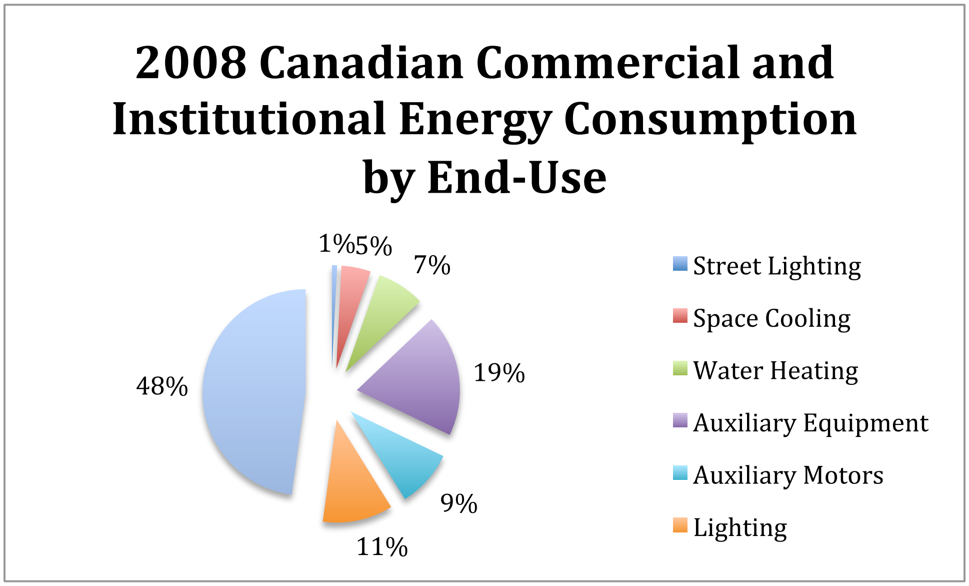
Figure 1: 2008 Canadian Residential Energy Consumption by End-Use



Natural Resources Canada. (2008). Comprehensive Energy Use Database, Residential – Secondary

Energy Use and GHG Emissions by End-Use. Retrieved from http://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/trends_res_ca.cfm. (Accessed March 21, 2011).

Figure 2: 2008 Canadian Commercial and Institutional Energy Consumption by End-Use



Natural Resources Canada. (2008). Comprehensive Energy Use Database, Commercial/Institutional – Secondary Energy Use and GHG Emissions by End-Use. Retrieved from http://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/trends_com_ca.cfm. (Accessed March 21, 2011).

1.1.2 The Shift Towards Local Energy Delivery

Reliability in energy production and delivery is critical for the safe operation of cities, businesses and residences. Pressures on conventional urban energy infrastructure are escalating, requiring municipalities to develop long term plans to address renewal, replacement and the call for additional capacity. Despite the demand for energy increasing, the development and installation of new centralized generation facilities and transmission networks in Canada has slowed (CDEA, 2008). During the early 1980s, advancements in generating and rejected (or waste) heat capture technologies decreased the capital costs of development through the application of smaller-scale plants, especially district energy systems with combined heat and power (CHP) capacity. In addition to being smaller in size and scale compared to conventional power generating stations, these new district-energy systems were located in close proximity to their community of service (CDEA, 2008). In most cases, large-scale power generation plants like the coal-fired systems found in Ontario, achieve low levels of energy efficiency, as much of the heat produced during production is lost to the atmosphere (CDEA, 2008).

1.1.3 Greenhouse Gas Emissions

One of the major problems with carbon-based energy production is the accumulation of greenhouse gases (GHG), which trap heat from the sun within the Earth's atmosphere (Lerch, 2008). The elevated levels of GHGs, principally carbon dioxide, methane and nitrous oxide, are major drivers in accelerated climate change. The Federal government has set a goal of 31 percent reduction in overall GHG emissions relative to 2006 intensity levels by 2020 (Canada, 2007). Achieving this goal will not be easy, requiring a multi-faceted approach to the reduction of overall energy consumption through improvements in energy efficiency in community design and the application, where appropriate, of district energy systems utilizing renewable and alternative fuel sources (CDEA,2008).

Canadian municipalities have a particularly central role in the reduction of GHGs. Municipal governments have direct or indirect jurisdiction over roughly 44 percent of Canada's greenhouse gas emissions (Federation of Canadian Municipalities (FCM), 2009). This represents a huge opportunity for Canadian municipalities to take a leadership role in the effort to mitigate climate change while generating local economic development opportunities and increasing the community's energy security through the application of district energy systems.

1.1.4 Understanding District Energy

District energy systems are a means of distributing thermal energy, that is, energy used for space heating or cooling. A centralized plant generates thermal energy and circulates it through a network of underground pipes in the form of hot water, steam, or chilled water to buildings connected to the system.

In the case of CHP, electricity is produced in addition to the production and distribution of thermal energy (CDEA, 2008). District energy and CHP are able to meet the thermal conditioning requirements of a wide variety of energy consumers with applications in the commercial, industrial, institutional, medical, agricultural, military and residential sectors (CDEA, 2009).

1.1.5 District Energy as a Solution

Given the immense challenges of climate change, fossil fuel dependence, economic insecurity and increasing energy demand, municipalities must explore options to develop local energy infrastructure that is adaptive and resilient. As a method for distributing electricity, heating and cooling energy (thermal), district energy systems have been shown to improve energy efficiency, reduce GHG emissions, accommodate a variety of fuel sources and capitalize on a flexibility of size and scale (CDEA, 2009). Industry, government and academic sources have shown support for district energy systems as a positive way to satisfy the thermal energy and electricity demands of a variety of urban buildings and uses.

The increasing interest in developing district energy stems from the acknowledgement that Canada must look to develop energy systems with flexible fuel sources at a variety of scales. Over the past century, Canadian energy generation has been derived from large centralized production facilities (Reeve, Dewees & Karney, 2010). However, new approaches to energy planning in a post-peak oil economy with an emphasis on low-carbon cities look towards “more decentralized energy production systems, using smaller-scale technologies, where production is more neighbourhood-based and relatively small scale” (Newman, Beatley & Boyer, 2009, p.69). Newman et al. states that “…small-scale energy systems are an essential part of the resilient city of the future” (2009, p.70). The Ontario Ministry of Environment echoes this sentiment stating that the development of local generating capacity will

"…protect people, communities and the economy from the adverse consequences of a system-wide failure" (2009, p.38).

District energy can be classified as a decentralized form of distributed energy production. Although the concept relies on a centralized plant producing and distributing energy to local buildings, it is done at a significantly smaller scale compared to traditional generation and distribution systems. The dominant form of energy distribution systems supply demand at the regional, provincial, national and in some cases, international scale; whereas district energy systems operate on the urban neighbourhood scale. This local distributed generation allows for a precise matching of energy output with specific load demands, which defers or avoids additional investment in central generation and distribution infrastructure (van Sambeek, 2000). Other benefits associated with distributed generation include improved efficiencies in delivery, the potential avoidance of emissions, fuel source flexibility, increased system reliability, reduced vulnerability to external forces and greater embedded resilience to natural and anthropogenic forces (Alderfer, Eldridge & Starrs, 2000; CDEA, 2008; Newman, Beatley, & Boyer, 2009)

1.2 Study Rationale

In addition to the associated benefits briefly outlined above, district energy systems can be leveraged as a key catalyst to accomplishing many core planning principles associated with urban development. Specifically, district energy systems encourage compact settlement form, higher density neighbourhoods and mixed land uses. System implementation can also generate local economic benefits like aggregated energy pricing and employment creation.

Accounting for the conservation of energy in land use is imperative for achieving local, regional and provincial goals associated with infrastructure, the environment, and energy resource management. The development of a district energy system is a very complex process, requiring the expertise of many specialists, and the support from local stakeholders. There are planning implications for the implementation of district energy systems, which require forethought at the beginning of the design and development process. Adopting the broad recommendations provided in this thesis will help to ensure adequate consideration is given to community energy management in conjunction with land use and urban form. In some cases, this process may be a component of a larger Community Energy Plan.

District energy's technical efficiencies are well proven in the academic literature and documented case studies, however more effort is required to facilitate the widespread municipal adoption of district energy systems, where appropriate, through communicating the economic merits and environmental benefits to politicians and community stakeholders (CDEA, 2008 & 2009, IDEA, 2007, Gilmour and McNally, 2010). This research will focus on generating a better understanding of the barriers to district energy development and crafting a set of transferable recommendations for Ontario municipalities hoping to integrate district energy systems into their existing planning process. The recommendations and strategies will consider land-use, urban form, and community energy objectives as well as addressing a greater need for a coordinated approach to energy planning.

Currently, the role of district energy as a tool to accomplish a broad set of municipal objectives is vaguely described in the literature, leaving those interested in system development or connection with little guidance towards implementation strategies. This is particularly evident in the context of the municipal planning process. Through an extensive review of federal, provincial and municipal policy, academic and industry literature identifying the economic and financial constraints and benefits of district energy, case studies of existing systems in Ontario and the carrying out of semi-structured interviews with key informants, this thesis will add to the literature regarding district energy in the municipal planning framework, and on a broader scale, speak to the importance of community energy planning.

1.3 Research Questions and Objectives

This research will explore the potential of district energy systems as a solution to addressing municipal concerns related to urban energy consumption and demand including an expressed interest in reducing GHG emissions, energy security, fuel flexibility, aging infrastructure and efficient delivery. More specifically, case studies will be used to highlight the strengths and benefits of district energy as well as the challenges to successful implementation. The following questions have developed from a review of the relevant literature and will be used to guide the primary research focusing on developing transferrable district energy implementation recommendations for Ontario municipalities:

- What primers prompt the exploration of district energy systems in Ontario municipalities?
- How can district energy systems be leveraged as community assets?
- What challenges prevent wide-scale municipal participation in the development of district energy systems in Ontario's urban environments?
- What transferable lessons can be learned from the Town of Markham and the City of Hamilton to develop and utilize district energy as a means to accomplishing local energy objectives in other Ontario municipalities?
- What is the connection between land use, density, energy demand, and consumption?
    - What is the relationship between district energy development, community energy management and land use planning in the municipality?
- What is the role of the municipal planning department in planning for and facilitating the development of district energy systems?
    - What planning policy tools could be developed to provide a framework for implementing district energy systems?

The specific objectives of this research are:

1. To craft a set of transferrable recommendations that will help Ontario municipalities facilitate the development of district energy systems where appropriate.
2. To add to the literature available on district energy system development from a municipal planning perspective.
3. To examine the tools available to planning practitioners to help engage communities and municipalities in planning for local energy generation and delivery.

1.4 Layout of Thesis

This thesis is structured into six chapters. This introductory chapter (Chapter One) introduces the topic, provides a brief background on some of the key issues, presents an outline of the study rationale and outlines the research questions and objectives. Chapter Two reviews the relevant literature on district energy systems pertinent to this study. Chapter Three explains the study methodology. An overview of the selected case studies is provided in Chapter Four. Chapter Five presents the findings from the interviews with key informants and provides analysis of the empirical data. Additionally, Chapter Five provides broad recommendations for the development of district energy as part of broader based community energy initiatives. Finally, the thesis concludes with a summary of findings, thoughts on significance to the profession, and a discussion of anticipated future research, in Chapter Six.

Chapter 2 Literature Review

2.1 Introduction

North American municipalities are facing numerous challenges related to energy reliability, climate change and economic instability (Gilmour & McNally, 2010). While the federal and provincial governments provide leadership, local levels of government must implement changes to support the need for an increasingly lower carbon lifestyle through the design of community-based energy solutions integrated with land-use planning. As a tool, district energy systems can be leveraged to accomplish municipal objectives related to energy, the environment and the local economy. To capitalize on the advantages associated with district energy systems and overcome implementation barriers, energy planning must become fully integrated into the municipal planning process, giving thorough consideration to future energy demand and delivery, early on in the allocation of land and resources.

The purpose of this literature review is to examine the academic, governmental, and professional reports relevant to district energy in the context of the municipal planning framework, which currently provides little direction with respect to local energy planning. The direction of this literature review will focus on two areas of analysis. Initially, it will provide an examination of the Ontario energy policy context, tracing the development of related legislation and the ramifications for the advancement of renewable energy technologies such as district energy. This will in part, illuminate some of the challenges facing the implementation of district energy in the urban environment. The second part will focus on the implication of land use and urban form on energy, and the need for community energy planning.

2.2 Energy Policy

As Reeve et al., suggests, if the Province of Ontario was not concerned with green house gas (GHG) emissions, pollution, sulphur dioxide, nitrogen oxides and toxic metals, energy policy would be straight forward: burn coal (2010). Currently, coal power is the least expensive energy source and is abundant in Canada and the United States of America (Reeve et al., 2010). However, the pursuit of environmental protection and concerns over human health undermines the continual burning of fossil fuel resources (Makansi, 2007). The province has taken a number of measures to increase the alternative energy component of its portfolio, detailed in the following sub-sections.

2.2.1 Ontario Energy Context and District Energy

Ontario's energy policy developed in part, out of low-cost electricity associated with hydroelectric facilities at Niagara Falls and other major rivers. This attracted energy intensive industry, forming the foundation of the Province's economic development until the late twentieth century (Reeve et al., 2010). Eventually, demand outpaced supply and by the 1960s, Ontario began investing in fossil fuel and nuclear power plants. In the early 1970s, oil prices experienced a sharp increase, drawing the Federal government's attention to the cost of energy (Harris, 2006). The result was the development of demand side management policies. Firstly, the 1973 criterion for energy conservation embedded into the National Building Code followed by the National Home Builders' Association's development of the R2000 building program for new home development in 1981 (Harris, 2006). Additional fuel shortages in the 1980s and early 1990s combined with an increasing international awareness of the linkages between global warming and fossil fuel consumption fostered the 1997 Kyoto Accord, committing participants to GHG reductions (Climate Action Network Canada, 2002).

Today, the economy and population of Ontario continues to grow and electricity demand is being met with the continual development of higher-cost sources (Reeve et al., 2010). As a result, the current scenario dictates a desire for an increase in electricity efficiency and an investment in conservation strategies (Fawkes, 2007).

2.2.2 Policies and Acts

The policies and acts regulating the Ontario energy sector carry a legacy of more than forty years of development. They are the culmination of economic and environmental pressures and are inherently complex in nature. When the *Power Corporation Act* came into effect in 1990, it required Ontario Hydro to provide energy to consumers under a 'power at cost' arrangement (*Power Corporation Act,* 2002). Under this Act, the Province could issue policy directives to Ontario Hydro, guaranteed the corporation's debt and appointed directors (Reeve, et al. 2010). Prior to the introduction of the *Power Corporation Act*, Ontario Hydro had a long-standing relationship with the Province. During the construction of high-voltage lines and nuclear power plants in the greater Toronto area (GTA), residents raised concerns about electric power planning (Ontario Power Authority, 2005). The result was the 1974 Solant Commission Report, which recommended that public consultation should represent a significant portion of the energy planning process (Reeve et al., 2010). This suggests a history of community engagement with respect to energy planning, however the degree and extent to which this is undertaken has not been well documented in the literature.

In 1980, the Porter Commission Report recommended that formal, long-range plans for demand management and capacity expansion should be developed. Ontario Hydro responded in 1989 with a twenty-five year demand-supply plan to address growing future demand (Reeve et al. 2010). However, by 1992 a fall in forecast demand required revisions. The below-forecast demand in combination with the high cost of construction for the Darlington Nuclear Generation Station drove up Ontario's electricity prices by thirty percent in the early 1990s, initiating the Province to freeze prices from 1993 until 2002, forcing Ontario Hydro into a deficit (Reeve et al., 2010). In 1995, the Mike Harris government assembled a committee to develop, study and review competition options within Ontario's electricity system (Reeve et al., 2010). Following the study and review, the Government appointed the Ontario Market Design Committee that developed a set of market rules (Ontario, 1999).

A forthcoming competitive market introduced 1998 legislation to divide Ontario Hydro into three separate companies: Hydro One for transmission, Ontario Power Generation (OPG) for generation and an Independent Market Operator (IMO) (Reeve et al., 2010). The new competitive wholesale and retail markets were opened on May 1, 2002 and were expected to replace the central planning of Ontario's electricity system.

Summer droughts and heat waves in the early 2000s resulted in energy shortages and the development of the Electricity Conservation and Supply Taskforce in 2003 (Reeves et al., 2010). The following year, legislation created the Ontario Power Authority (OPA), mandated to address long-term planning, energy conservation and deficiencies in the competitive markets (Ontario Power Authority, 2005).

Since its creation, the OPA has created the *Integrated Power System Plan* (IPSP) as a twenty-year plan that specifically demarcates Ontario's energy supply mix from conventional sources, demand side management, conservation and renewable resources (Ontario Power Authority, 2011). The plan is currently awaiting approval from the Ontario Energy Board (OEB), the agency that is responsible for ensuring cost effectiveness, economic prudence and regulates the electricity and natural gas sectors in the public's interest. The document suggest a hybrid structure in which a spot market sets a portion of the electricity price, the remainder being regulated by the OEB, the OPG is responsible for most generation, and the OPA manages the bidding process for new types of power supply (Reeves et al., 2010).

Of special interest to this research, the *2009 Green Energy and Green Economy Act* amended the *Electricity Act* allowing municipalities to add up to 10 megawatts (MW) of renewable generation capacity without the need to launch an autonomous operating corporation (Ontario, 2009). These municipal systems are supported by OPA's feed-in tariff (FIT) Program which provides guaranteed rates for renewable generation projects over 10 kilowatts (Ontario Power Authority, 2010). The MicroFIT Program is intended for renewable energy projects rated at less than 10 kilowatts (Ontario Power Authority, 2010).

This legislation allows energy management goals to be defined at the municipal level, prompting municipalities to look at options for local generation and distribution.

After a review of Ontario's energy policy, two predominant trends emerge. Firstly, the market-based nature of the energy sector makes it difficult to produce predictive policies and presents challenges for long-range provincial planning (Fawkes, 2007). In several cases, the Province has had to revisit initial forecasts as demand for supply and infrastructure has either exceeded or did not meet expectations.

Secondly, the research reports that form the foundation of energy policy in Ontario seem to support and encourage a public consultation process in long-range electricity planning (although the effectiveness requires further evaluation and assessment). However, what remains to be formulated into provincial legislation with respect to generation, transmission, pricing and distribution is defined by uncertainty. Although there is clear evidence supporting the Provincial government's desire to reduce the environmental footprint of electricity, the process to accomplish this is surrounded by ambiguity. The role of district energy in achieving these objectives, along with specific approaches to increase end-use electricity efficiency, is currently not well defined by provincial policy.

2.2.3 The Energy Sector and the Relationship with Climate Change Policy

The prevalence of climate change has been cited in the literature for many years and although uncertainties remain as in every area of progressive scientific inquiry, general scientific knowledge has established that significant risks exist. The latest reports from the Intergovernmental Panel on Climate Change (IPCC) suggest that the Earth's climate is warming at an accelerated rate, particularly over the past three decades (2007c). Human based emissions of GHGs, primarily carbon dioxide (CO_2) generated by burning fossil fuels are largely responsible for this perceived warming (Harvey, 2010). As acknowledged by many, the Earth's climate is subject to natural variances and gradual cycles, however, the scientific consensus is that human practices and influence are now the dominant driver behind the changing climate (IPCC, 2007b).

Continual pressures from an increasing global population, energy consumption, transportation and globalization are expected to accelerate climate change over the coming decades (Fawkes, 2007). Global warming is projected to span from 1.1C to 6.4C by the end of the century (IPCC, 2007b). This range represents an increase of roughly double the warming in the twentieth century, and up to ten times greater (IPCC, 2007b). Although the variation in projected range speaks to the uncertainty of the forecasts, the low estimate of doubling would require that emissions growth and climate sensitivity remain at the very bottom range of current projections. The impacts of climate change extend beyond the atmospheric systems that drive the change and range considerably in their influence. Impacts are expected to have adverse effects on ecosystems, hydrology and water resources, food and fiber production, costal systems and arctic regions and human health (Watson, Zinyowera & Moss, 1998).

Recent assessments including the IPCC Reports and U.S. Climate Change Science Program (CCSP) tend to agree that limiting global average warming to 2C by the end of the century will be necessary to avoid the most severe impacts of climate change (Clarke, Edmonds, Jacoby, Pitcher, Reilly, & Richels, 2007). This will require limiting the global atmospheric concentration of GHG emissions to roughly 450 parts per million (ppm) of CO_2 (Clarke et al., 2007). To achieve that limited level of GHG concentration, it is estimated that the world emissions of GHG must be cut by 50 percent to 85 percent of today's levels by mid century (Reeve et al., 2010). It is important to note, particularly in the context of addressing GHG reductions at the city level, that developing countries may delay reducing emissions growth and that developed nations should be prepared to increase their reductions to 80 percent as compensation.

The electricity sector is particularly sensitive to the effects of climate change through shifting demands for space conditioning (residential and commercial space heating and cooling) (Harvey, 2010).

Furthermore, abnormal weather fluctuations such as droughts and heat waves (increased frequency commonly associated with climate change) can effect the transportation of coal (through low water levels) and the availability of nuclear power (lacking emergency water cooling supplies) (Reeve et al., 2010). As a result, power generators should look to diversify their energy portfolios, drawing on a variety of alternative sources to mitigate risks associated with climate change.

There is no doubt that achieving the obligatory reductions in GHG emissions will require a complete transformation to the world's energy system over the next fifty years. The necessary changes will be significant, but the possibility for phased implementation over several decades and the ability to replace old infrastructure with new technologies, lends itself well to the prospect of managing climate change.

2.2.3.1 Crafting Climate Change Policy: Critical Primers for District Energy Systems

Climate change strategies must incorporate measures that provide for adaptation to the impacts associated with climate change. However, when crafting climate change policies directed toward the electricity sector, mitigation strategies, those policies designed to cut emissions and transform the energy system, are of more importance. Edward A. Parson suggests that effective mitigation strategies for the energy sector are comprised of three elements, broadly grouped under policy instruments, sector specific measures and research, development and demonstration projects (2010). Policy instruments can affix pricing to emissions, making it expensive to emit, thus promoting reductions. This can take the form of taxation, tradable emissions permits (commonly referred to as 'cap-and-trade') or a combination of the two. Sector specific measures target high-emitting sectors such as residential and commercial buildings or transportation systems, which may not respond well to broad, market-based policies (Smith, 2010). Municipalities can be the drivers behind these sector specific measures which can include efficiency-based reforms to building codes or reductions in GHG through planning policies, zoning bylaws, permitting and public investment in key infrastructure pieces (Parson, 2010). Finally, measurers are required to promote research, development and demonstration projects for climate change initiatives and technologies. Again, municipalities can take the lead to promote these sort of projects through various planning tools which may include reduced development charges, expedited approvals or waived planning fees for highly energy efficient communities. These municipal planning tools can be leveraged to encourage the development of compact urban settlements with thermal energy requirements supplied by a local district energy system.

2.2.4 Fuel Prices in Ontario

Energy fuel prices, in part, set the agenda to improve energy efficiency through the application of district energy systems in dense urban environments. As fuel prices escalate, customers look towards alternative fuel sources and land use developments that promote higher efficiency. Ontario's fuel prices are in part, market-driven. The natural gas utilities pass the commodity cost of natural gas onto consumers without mark up (Compass Resource Management, 2010). Natural gas prices are released as a 12-month forecast with a quarterly adjustment to rates to reflect the actual costs. The overall rate also includes additional transmission and distribution (T&D) costs which are added to the commodity costs. The T&D costs vary depending on utility provider and are based on cost of service. Commodity prices for fuel are volatile and often cyclical in nature. As many authors suggest, it is probable that the additional costs associated with fuel will continue to increase over time (Ambramsky 2010; Reeve et al., 2010; Gilmour & McNally, 2010; CDEA 2008). When considering major capital infrastructure investments like the development of a district energy system, it is critical to consider fuel costs over a long-term time horizon.

Electricity prices are the sum of commodity costs, T&D costs and additional regulatory fees (Compass Resource Management, 2010). Wholesale electricity costs are determined hourly and established for the province through a market run by Ontario's Independent Electricity System Operator (IESO) (Compass Resource Management, 2010). Output prices for CHP vary depending on the source of electricity generation. As mentioned in the introduction, Ontario's FIT Program offers guaranteed, long-term pricing structures for renewable energy generation rated greater than 10kW (OPA, 2011a). There is also the Micro FIT Program for renewable energy systems rated below 10kW (OPA, 2011a).

Biomass fuels include wood waste, agricultural waste and wood pellets (Compass Resource Management, 2010). Ontario's biomass industry is not fully developed and as a result, no standard price for the commodities exists. The BIOCAP Canada Foundation, with conversions provided by Compass Resource Management in the *OPA District Energy Research Report*, estimates that wood pellets would range in cost from $27 to $32 per MWh, feedstock would range in cost from $14 to $23 MWh and delivered feedstocks would range in cost from $27 to $72 MWh (BIOCAP Canada, 2008). Feedstock is classified as unprocessed biomass with approximate moisture content of 50 percent and a low heat value. Compass Resource Management's research suggests that Ontario's young biomass market could see prices for biomass exceed $25 MWh given OPG's interest in converting several facilities to biomass and increasing demand from the transportation sector (2010). Biomass's flexibility as a combustible fuel material lends itself to a wide-variety of district energy applications in various regions depending on what material is readily available.

Despite being a fossil fuel, the clean burning properties and high levels of efficiency associated with natural gas, makes it a popular choice for use in district energy applications. Natural gas CHP is not eligible under the FIT program's fixed contract pricing. However, the OPA is developing a Clean Energy Standard Offer Program (CESOP) to compensate smaller generators, including natural gas CHP plants, under the assumption that centralized systems offer a host of environmental benefits and provide secure value for ratepayers (OPA, 2011b). The CESOP would top up natural gas GHP projects' variable revenues through the OPA. The payment would be based on the standardized performance of a representative CHP facility determined by the OPA. Although this program has not yet been launched, it is anticipated that contracts will be awarded to facilities with a nameplate capacity of 10 MW or less with a fixed 20-year term (OPA, 2011a).

Similar to biomass, it is difficult to determine a quantifiable commodity price for biogas. The cost of biogas is dependent on a wide range of variables including tipping fees (if derived from municipal solid waste), transportation costs (if derived from anaerobic digestion) and market prices set by a producer if purchased from a private landfill or industrial operation (Compass Resource Management, 2010).

A review of Ontario's fuel prices seems to shed light on two major implications for district energy systems. Firstly, advances in technology, an emphasis on renewable and alternative fuel sources and system flexibility to utilize multiple fuel sources provides municipalities and district energy customers with a hedge against energy sector price volatility. Secondly, the OPA's FIT program provides guaranteed pricing to assist with the transition to renewable technologies. This strengthens the business case for renewable-based CHP in Ontario. In sum, the volatility associated with energy pricing acts as an incentive to support more flexible and economically stable means of thermal energy delivery. The uncertainty surrounding fuel sources and the provincial mandate to shift towards renewable energy technologies may act as a driver for the development of district energy systems.

2.2.5 Greenhouse Gas Emission Factors and Carbon Pricing

Although there has been a great deal of research providing policy direction, Ontario does not currently have a carbon pricing mechanism (NRTEE, 2009). By placing a dollar value on GHG mitigation or emission avoidance, many district energy options become favourable over business-as-usual (BAU) scenarios because of higher equipment efficiency and/or less GHG intensive fuel sources (Compass Resource Management, 2010).

Electricity emission factor will vary depending on the electricity source (Compass Resource Management, 2010). According to Compass Resource Management, natural gas has a GHG intensity of

50kg/GJ of fuel consumed (2010). In 2006, Ontario's average grid emission factor was ~230kg/MWh, reflecting a generating mix of approximately 20 percent coal and 75 percent nuclear and hydro (NRTEE, 2009). When a price is attached to GHG emissions, BAU heating costs increase comparatively to district heating systems; however, the district heating systems have lower net GHG emissions (Compass Resource Management, 2010). Additionally, CHP systems show more sensitivity to GHG pricing, in particular biogas and biomass systems, because of the additional credit received for mitigating GHG emissions from displaced electricity (Compass Resource Management, 2010). Attaching a carbon pricing mechanism to GHG emissions would provide more of a 'true cost accounting' of energy supply. This would increase the financial/economic competitiveness of alternative fuel sources.

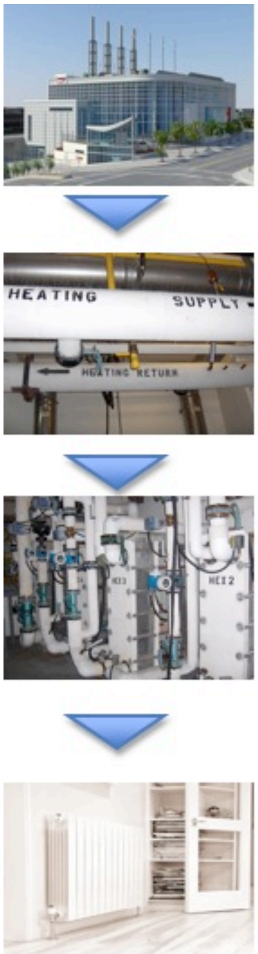
2.3 District Energy Defined

District energy systems connect multiple heating and cooling (thermal) energy users through a network of supply and return pipes from a centralized energy source (IDEA, 2007). The 1992 National Census for District Heating, Cooling and Cogeneration broadly defined district energy as "Any system that provides thermal energy (steam, hot water or chilled water) for space heating, space cooling or process use from a central plant and that distributes the energy to two or more buildings through a network of pipes" (BMS Management Services, 1993 p. 1). The heating component of district energy typically includes domestic hot water (DHW) and the space heating of suites, ventilation air and common areas (Compass Resource Management, 2010). In some cases, electricity is produced and distributed through combined heat and power (CHP) facilities where heat produced is circulated in the district energy system and the electricity output is used on site and or sold back to the local grid (Tridel & Conservation for the Living City, 2006). Depending on the needs of the community, thermal energy production can be derived from one centralized facility or several smaller interconnected plants (MacRae, 1992). District energy systems are inherently flexible, providing the capacity for fuel source adaptation depending on availability, environmental impacts and market pricing (IDHA, 2006).

As a management tool, district energy can help accommodate the energy requirements of different buildings and industries (CDEA, 2008). With efficient design and proper maintenance, district energy systems can reduce GHG emissions, minimize consumer energy costs, and maximize floor space in buildings by centralizing production equipment, capitalizing on economies of scale and optimizing fuel sources (IDEA, 2007). By aggregating the thermal demands of a variety of distinct buildings, district energy systems can utilize industrial grade equipment, capable of utilizing multiple fuels and employing technologies that would not be economically feasible on the individual building scale (Gilmour and McNally, 2010).

There are many different configurations for district energy systems that vary considerably in size and scale (CDEA, 2008). Typically, four main components comprise a district energy system (Depicted in Figure 3).

Figure 3: Typical District Energy System Componentry



Central Energy Centre(s)
(Enmax, 2011)

Distribution System
(Bradford, 2010)

Energy Transfer Stations
(Bradford, 2010)

In-Building Hydronic HVAC System
(Selector, 2011)

The **central energy centre(s)** includes one or multiple plants, which produce the heating and or cooling requirements for customers. The **distribution system** comprises a series of underground pipes, one dedicated for supply and one for return for both heating and cooling, that distribute either steam, hot or cold water to the individual buildings. Each customer has an **energy transfer station** (ETS) located on the premises which meters and controls the thermal energy passed through the district energy system into the building. The final component is the **in-building hydronic HVAC system**, requiring a water-based system to distribute the thermal energy (Compass Resource Management, 2010). The versatility of district energy systems prompts use from a variety of sectors and applications as depicted in Table 1.

Table 1: Applications of District Energy

Sector	Applications
Industrial / Energy / Defense	- Pharmaceuticals and Fine Chemicals - Paper Manufacturing - Brewing and Distilling - Ceramics - Brick and Cement Plants - Food Processing - Mineral Processing - Oil Refineries - Iron and Steel - Timber Processing and Lumber Mills - Ethanol Plants - Utility Companies
Finance / IT	- Telecommunication Facilities - Data Storage Facilities
Commercial / Residential / Transportation	- Sports Complexes - Shopping Centres - Office Buildings - Supermarkets - Convention Centres - Stadiums - Airports - High-Rise Residential - Low-Rise Residential
Medical / Emergency	- Hospitals - Emergency Management Facilities - Law Enforcement - Fire and Hazardous Materials - Laboratories - Nursing Homes - Blood Supply Facilities - Pharmaceutical Stockpiles
Institutional / Government	- Community Centres - University and College Campuses - Schools - Prisons - Exhibitions and Fair Grounds - Museums - Libraries - Military Establishments - Transportation Networks - Water and Waste Water Treatment Facilities
Food and Agriculture	- Horticulture - Manure Processing Facilities - Food Storage and Refrigeration Facilities

(Adapted from CDEA, 2008. Pg 7).

2.3.1 Historical Development of District Energy

The concept of district energy is not a recent revelation, with origins tracing back to Rome where warm water was circulated through open trenches to provide heat for baths and buildings in Pompeii (MacRae, 1992). The fist documented district heating system dates back to the 1300s in Chaudes-Algues Cantal, France, where warm water was distributed to community buildings through primitive wooden pipes (Enwave, 2010). In 1877, Birdsill Holly developed the first commercial district heating system in Lockport, New York (MacRae, 1992). The system generated steam from a boiler and it was circulated through a network of pipes, radiators and condensate return lines. Holly's system originally served fourteen customers, but within three years, it had grown to provide thermal energy for several factories and residential customers connected to a three-mile loop (Enwave, 2010). By the 1880s, American district energy systems had emerged in New York, Boston, Chicago, Detroit and Baltimore (IDHA, 1983). The steam required for the initial development of the electric power industry relied on the enhanced economics associated with centralized district energy systems through waste heat recovery, thermal energy contracts and the sale of electricity (Patterson, 2007)

The first Canadian district energy system was built in 1880, in London, Ontario, servicing the hospital, university and government buildings (Enwave, 2010). In 1911, the University of Toronto installed a campus district energy system followed by Canada's first commercial installation in 1924 in downtown Winnipeg (Enwave, 2010). Older steam-based systems typically use a single supply line for high or low pressure steam, forcing condensate into the local drainage system (CDEA, 2008). Canada's harsh winter climate and abundant low-cost fuel sources have contributed to rank the country as one of the highest international per capita energy consumers amongst developed countries (Enwave, 2010).

As district energy systems emerged in North America, Scandinavian countries were also developing systems (IDHA, 1983). In 1891, the first district heating system was established in Fredericksberg, Denmark, (a suburb of Copenhagen) (MacRae, 1992). Heat was captured from an electrical generating plant and circulated to a local hospital and several government institutions (MacRae, 1992). For the first half of the 20th century, district energy systems primarily prospered in North America, and to a lesser extent, European countries (MacRae, 1992).

After World War II, market pressures in the United States began to push electricity generating facilities outside of urban cores, where land prices were lower (MacRae, 1992). The cost to build dedicated central heating facilities became prohibitively expensive given the abundance of inexpensive oil and natural gas available for electricity production. This caused the decline of district energy development and expansion in North American cities. However, opposite circumstances in Europe gave way to a rapid expansion of cogeneration facilities, particularly in northern climates. Less abundant natural gas and oil resources and increasing electricity and thermal energy demand required the development of district energy systems in Europe to meet the needs of communities.

Today, district energy systems are experiencing renewed interest as an approach to improve energy security and as a vehicle to shift towards alternative energy sources like biomass and waste heat capture. In northern Europe, countries like Denmark, Lithuania, Netherlands, Poland and Finland benefit from 50 percent or more building stock connection to either district heating or CHP systems (IDEA, 2007).

2.4 Benefits of District Energy

District energy provides a wide range of environmental and economic benefits to customers and the community, which are well documented in the literature. In their 2006 publication, the National Advisory Panel on Sustainable Energy Science and Technology stated, "in Canadian communities, the most promising methods of reducing energy use are known, such as district energy and combined heat and power systems" (pg. 70). However, building owners and customers have multiple options for securing their thermal energy supply and district energy systems must be economically competitive with on-site alternatives (IDEA, 2007). The following subsections will provide an overview of the environmental and economic benefits associated with district energy.

2.4.1 Reduction in Green House Gas Emissions and Improved Environmental Performance

The production of energy for space conditioning and electricity demands through the combustion of fossil fuels generates carbon dioxide (CO_2), nitrous oxide (N_2O), sulphur oxide (SO_x), volatile organic compounds (VOC) and particulate matter (PM) (CDEA, 2008). Fossil fuel consumption adds 700 mega tonnes (Mt) of CO_2 to the atmosphere in Canada every year (CDEA, 2008). These emissions have been shown to contribute significantly to climate change and increase smog, air pollution and ground level ozone (CDEA, 2008). Forecast models suggest that if every residential and commercial building in Canada were connected to a high-performance natural gas supplied CHP system, more than 57 million tonnes of CO_2 emissions (9 percent of Canada's total CO_2 emissions) would be eliminated from the atmosphere and almost 897 million gigajoules of energy (11 percent of Canada's total energy consumption) could be saved (CDEA, 2008).

The centralization of equipment associated with district energy systems produces economies of scale which facilitate the use of more efficient technologies or allow for alternative fuel technologies which can be utilized for the same cost or lower than more conventional on-site technologies (Compass Resource Management, 2010). This fuel source flexibility also allows district energy systems to capitalize on waste products such as biomass, industrial waste heat, sewage effluent and in some jurisdictions, garbage, which can be incinerated to produce heat (IDHA, 1983). It is more challenging to switch fuel sources and adopt new technologies when space-conditioning units are located within individual buildings and in-place systems vary considerably in age. District energy systems allow municipalities to address climate change and improve environmental performance through technologies that can easily be integrated with existing heating infrastructure (CDEA, 2008). Utilization of a system can slow increased energy consumption and reduce the harmful GHG emissions associated with growth while minimizing additional environmental impacts from existing building stock (CDEA, 2008). The table below illustrates the versatility in plant type and flexibility in fuel sources for district energy systems.

Table 2: Common Technologies and Fuel Sources for District Energy Systems

Plant Type	Boiler or Generator Technology	Potential Fuel Sources	Output
Heat Only - Hot Water - Steam - Combined Heat & Power (CHP)	Combustion Turbine	Natural Gas, Liquid Fuels	Steam/Electricity 5MW – 25MW
	Reciprocating Turbine	Natural Gas, Diesel, Landfill Gas, Digester Gas, Biogas	Hot Water 500kW – 7MW
	Micro Turbine	Natural Gas, Hydrogen, Propane, Diesel	Hot water 25kW – 500kW
	Fuel Cell - Molten Carbonate - Phosphoric Acid - Proton Membrane Exchange - Solid Oxide	Natural Gas, Hydrogen	Hot Water (Steam for Molten Carbonate and Solid Oxide for Fuel Cells) 1kW – 10MW
	Stirling Engine	Natural Gas, Landfill Gas, Propane	Hot Water 1kW – 25kW
Chilled Water	Lake or Sea Water	Water	Cold Water
	Chillers	Steam, Hot Water, Electricity	Chilled Water
Thermal Storage	Utilizes one or more large storage tanks for hot or cold water		

(Adapted from CDEA, 2008).

2.4.2 Improved Technical Performance

One of the main benefits associated with district energy systems is better technical performance than individual home-based thermal energy systems, in most cases. This is because utility operators will usually undertake regularly scheduled maintenance by trained and qualified operators (IDHA, 2006). The result is less fuel consumed over time and lessened environmental impacts (Compass Resource Management, 2010). Although higher efficiency equipment is available for individual consumer purchase, it comes at a significantly higher price and requires servicing by qualified technicians to maintain performance, which may be avoided due to cost.

2.4.3 Reduced Customer Risk and Increased Flexibility

Residential, commercial and institutional customers want lower energy costs with multiple options for supply, increased reliability to minimize loses during service outages and insulation from fuel price volatility (CDEA, 2008). By removing in-building systems, individual building owners mitigate risks due to malfunction, even if they don't own the actual equipment. Using a utility model, financial and operating risks can be pooled across a larger number of customers. Furthermore, a central utility company will usually employ a higher level of design and operating standards while providing for the ongoing professional management of the system.

Recent increases in commodity fuel costs for oil, coal and natural gas are prompting the exploration of alternative fuel sources for district energy systems (IDEA, 2007). The inherent flexibility of district energy systems' fuel sources allows for the implementation of more efficient and alternative technologies. This flexibility provides shelter to costumers, acting as a hedge against volatile price fluctuations associated with conventional fuels (Compass Resource Management, 2010). Given the significant proportion of end-use energy consumption associated with space conditioning (65 percent residential and 53 percent commercial/institutional), the savings associated with higher-efficiency district energy systems can be significant when compared to conventional heating and cooling technologies (NRCan, 2008).

2.4.4 Impact of Urban Form on Energy Demand

The specific land-use requirements for efficient district energy systems correlate with modern planning principles. Development in Canadian municipalities often produces single detached housing on large tracts of land, located towards the outskirts of towns and cities. This sprawling pattern of growth requires more energy, places stress on the environment, limits alternative modes of transportation, permanently removes productive farmland and strains municipal servicing resources (Owens, 2002).

District energy systems benefit from compact urban form with a variety of permitted uses located within close proximity 0of one an0other (Described in *Table 3: Influence of Land Use Variables on Energy Consumption*). The development of district energy systems can help promote the type of development advocated for by municipal planners by concentrating development through the layout of piped infrastructure while accommodating higher density development (CDEA, 2008). Furthermore, district energy systems match the energy needs of neighboring facilities to minimize energy waste while reducing infrastructure and utility costs (CDEA, 2008).

Table 3: Influence of Land Use Variables on Energy Consumption

Land Use Variables	Factor of Energy Influence	Magnitude of Potential Impact
Collective composition of land use factors (size, shape, interspersion)	Transportation: trip length and frequency	Variation of energy consumption up to 150 percent
Interspersion of activities	Transportation: length	Variation of energy consumption up to 130 percent
Shape of urban area	Transportation	Variation of energy consumption up to 20 percent
Density/clustering of trip ends	Transportation: Fundamental for successful public transportation	Energy savings of up to 20 percent
Density/mixing of land uses and built form	Thermal Energy: Primer for District Energy Systems and or CHP	Energy savings of up to 15 percent. Efficiency of primary energy use improves to 30 percent with district energy systems
Site/layout/landscaping and materials	Microclimate: optimization	Energy savings of 5 percent or more in exposed areas
Layout/orientation/design	Microclimate: passive solar gain	Energy savings of up to 20 percent

(Adapted from Climate Change Action Network Canada, 2002)

http://www.climateactionnetwork.ca/e/publications/index.html

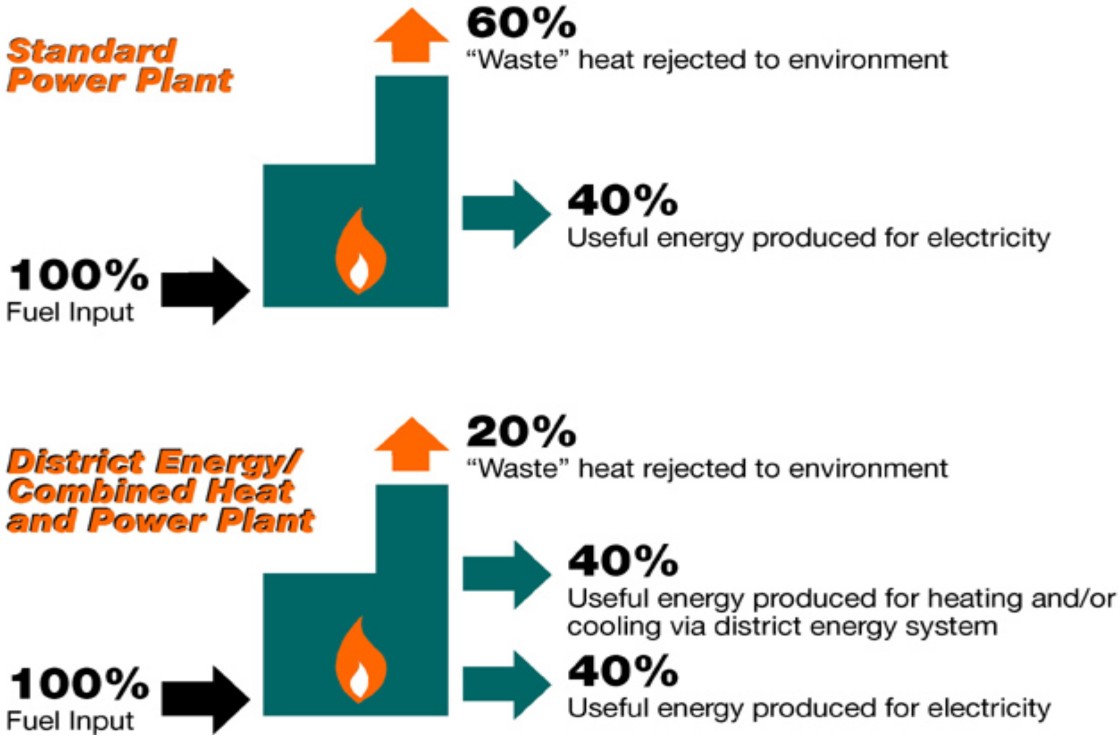
Through the production of thermal energy and electricity, the development of CHP systems can reduce the land required to support distribution infrastructure (Strickland & Nyboer, 2002). A large central generating station requires as much as 493 hectares (1216.86 acres) of dedicated land for operations (CDEA, 2008). The decision to locate district energy systems in dense urban environments can help to conserve open space for recreation and productive agriculture (CDEA, 2008).

In some cases, district energy systems can also act as a catalyst for downtown revitalization and brownfield redevelopment. Private sector investors are often hesitant to invest in derelict properties or former industrial lands. Traditionally, municipalities have used financial incentives to encourage revitalization. However, district energy systems can provide incentives for investors by reducing the amount of capital investment required for on-site space conditioning systems, reducing operating and maintenance costs while generating more saleable/leasable space (CDEA, 2008).

2.4.5 Improved Energy Efficiency

District energy systems with CHP capacity achieve significant efficiencies over traditional fossil fueled power plants. Fossil fuelled power plants discharge roughly two thirds of the energy produced during combustion into the atmosphere, yielding an energy efficiency of only 30 to 45 percent (CDEA, 2008). District energy systems with CHP capacity operate at system efficiencies of 80 percent or higher by producing electrical and thermal energy in the same plant. The improved efficiency translates into a significant reduction in fuel requirements to generate the same amount of energy while minimizing air emissions (IDHA, 1983). Figure 5 provides a comparison of efficiencies for a standard power plant and a district energy CHP facility (IDEA, 2007).

Figure 5: Efficiency Comparison of Standard Power Plant and CHP



International District Energy Association (IDEA). (2007*). District Energy Services Commercial Data Analysis for EIA's National Energy Modeling System – Final Report.* August 2007.

District energy systems also feature the ability to store thermal energy. This allows the system to produce and store thermal energy during off-peak periods and distribute the stored thermal energy during periods of high demand (CDEA, 2008). The result is more consistent utility rates for the customer and lower operating costs for the system.

2.4.6 High System Reliability

Despite improvements in efficiency, energy demand is on the rise. This higher demand increases the probability of electricity grid failure. District energy systems can still provide heat to buildings within their service area during electricity outages and CHP systems can continue to supply electricity to the local grid (Compass Resource Management, 2010).

System reliability, ease of use and convenience are amongst the most citied benefits according to surveys of district energy customers (IDEA, 2007 and CUI, 2010). Operational reliability is one of the hallmarks of the industry, with most district energy systems reporting annual service availability of 99.99 percent (IDEA, 2007). In 1998, a major ice storm hit the Province of Québec and the only utility that reported uninterrupted service was the district steam system in Montréal (IDEA, 2007). Service reliability is particularly crucial for hospitals, campuses, laboratories, computer server housing facilities, military bases and Government operation centres, all of which represent typical subscribers to district energy systems (IDEA, 2007).

2.4.7 Increased Saleable and/or Useable Floor Area

The dense urban environments conducive to district energy typically put a premium value on market saleable space. District energy systems allow for the reclamation of spaces previously dedicated to mechanical equipment, flues and cooling towers by moving thermal conditioning systems to a centralized plant (CDEA, 2008). The reclaimed space can find productive use as common amenity space, rooftop gardens and green roofs, additional saleable floor area or profit centres for third parties (cellular towers, restaurants and leasable footprints) (IDEA, 2007).

2.4.8 Reduced Initial Expenses and Lifecycle Costs

The centralization of equipment may produce cost savings by reducing the equipment requirements through load diversification (peak demand occurring at varying times for different customers), economies of scale in equipment costs and reductions in operating expenses derived from more efficient technologies and optimized operations (Compass Resource Management, 2010). The additional costs often associated with more sustainable technologies can be overcome through the implementation of a utility operating model, waiving the need for consumers to purchase individual equipment upfront. With this operating format, lower financing rates for capital costs and longer amortization periods are available compared to consumer financing. It must be acknowledged that the derived cost savings must be weighed against additional costs of creating a utility, management and administration expenses for the utility. Payback periods on district energy systems range significantly depending on the size, scale and design of the system, fuel type, variety of customers and partnership structure, for financing and continual operation of the system (CDEA, 2008). Typically payback periods range from five to twenty years (CDEA, 2008). Finally, the cost savings associated with centralization are often reinvested into more expensive, but more environmentally responsible forms of generating heat (Compass Resource Management, 2010).

2.4.9 Municipal Revenue Generation and Contribution to Local Economic Development

Mature district energy systems can provide addition revenue to municipalities through full or partial ownership or the taxation of assets. The use of local resources acts as a catalyst for job creation and generates local economic spinoffs (Compass Resource Management, 2010). The district energy sector accounts for approximately 1100 Canadian jobs involved in the operation and maintenance of systems (CDEA, 2009). The CDEA estimated that an average 3.5MW district energy system produces 25 direct and indirect jobs in the engineering, construction and operational sectors (CDEA, 2009).

The development of a district energy system can directly contribute to local economic development through job creation, increased local manufacturing and the creation of education programs (CDEA, 2008). As much as 60 percent of the costs associated with district energy system development can be attributed to labour and nearly half of the equipment required can be sourced and purchased from local suppliers. (Edwards, MacRae & Schorr, 2000). The majority of the capital investment comprised of labour and equipment costs, is distributed locally and retained by the community (CDEA, 2008).

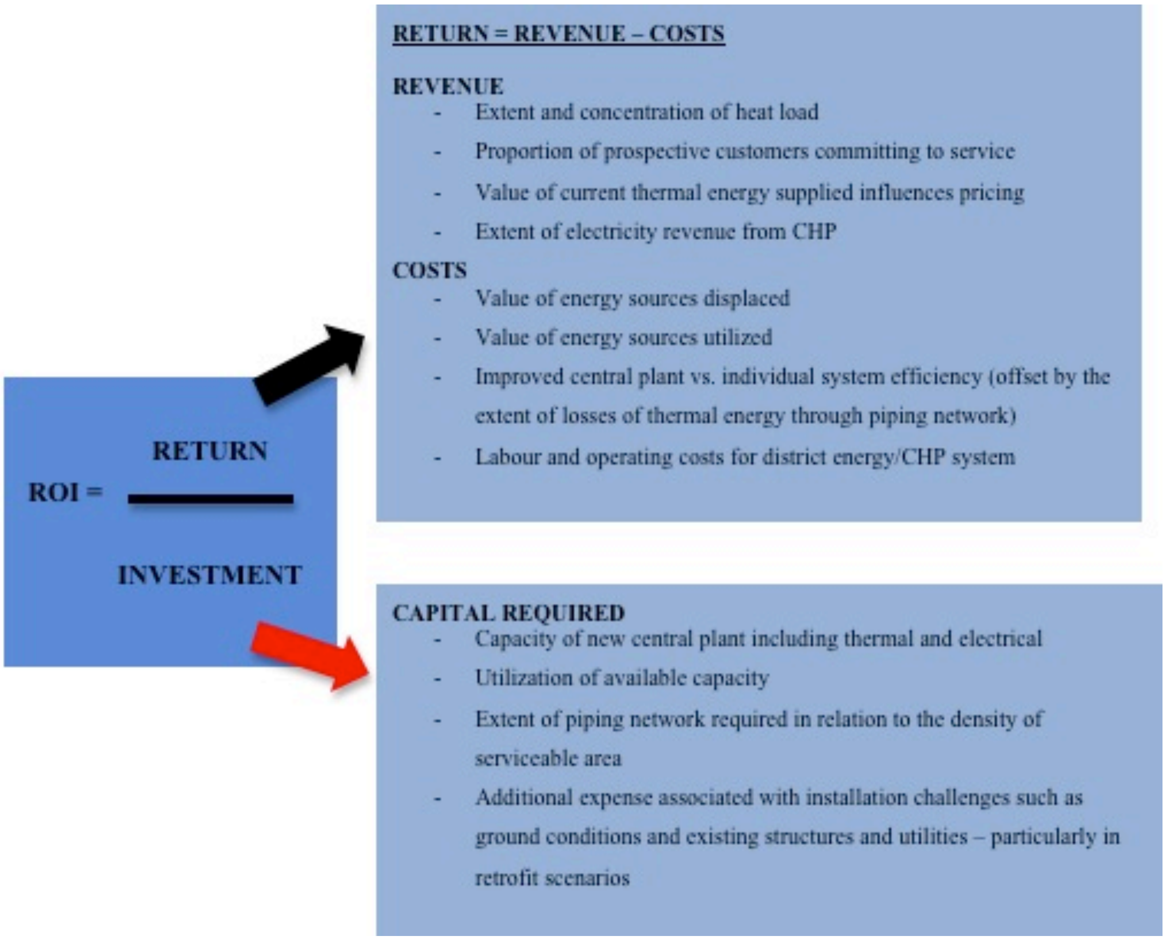
2.4.10 Diversification of Loads

District energy systems centralize the heating and/or cooling source. This allows for a smaller sized central generation facility than the sum of individual building peak loads (Compass Resource Management, 2010). Diversification of load demand reduces capital costs without compromising the ability to meet energy demand.

2.4.11 Competitive Investment Opportunities

Originally, district energy systems were developed to capitalize economic returns by selling off easy-to-access excess thermal energy generated by local industry (CDEA, 2008). The earning potential of a district energy system is defined by the ability to recapture the initial capital investment through fuel cost savings over a long-term period (NRCan, ND). Given that space heating is the most expensive end-use of energy, connecting to a district energy system represents an opportunity to reduce operating expenses for businesses and property owners. The continuing trend of increasing energy prices suggests that district energy systems are well positioned to generate modest returns on investment through the sale of energy, while reducing fuel consumption in comparison to conventional systems (CDEA, 2008). Mature district energy systems in Canada have been shown to consistently achieve returns of 8 to 12 percent on investment (CDEA, 2008). Bond qualifies the primers for creating a positive return on investment (ROI) with district energy systems as shown below in Figure 6 (1993).

Figure 6: Primers for District Energy Positive ROI



Adapted from Bond, G. (1993).

2.4.12 Characteristics of District Energy Systems

In North America, district energy systems are usually located in central business districts of mid to large sized cities where there is dense urban form and a mix of uses (IDEA, 2007). Customer connections to district energy systems range from three or four buildings in the early stages of development to 1,900 or more customer buildings in mature steam systems in the United State cities of New York, Boston, Philadelphia or Indianapolis (IDEA, 2007). Fuel sources vary depending on the cost and availability of resources, but all systems are inherently flexible in their capacity to generate thermal energy (IDHA, 1983). Depending on the size of the system, the capacity of generation equipment and the ownership and operational model, maintenance and operational costs can range considerably.

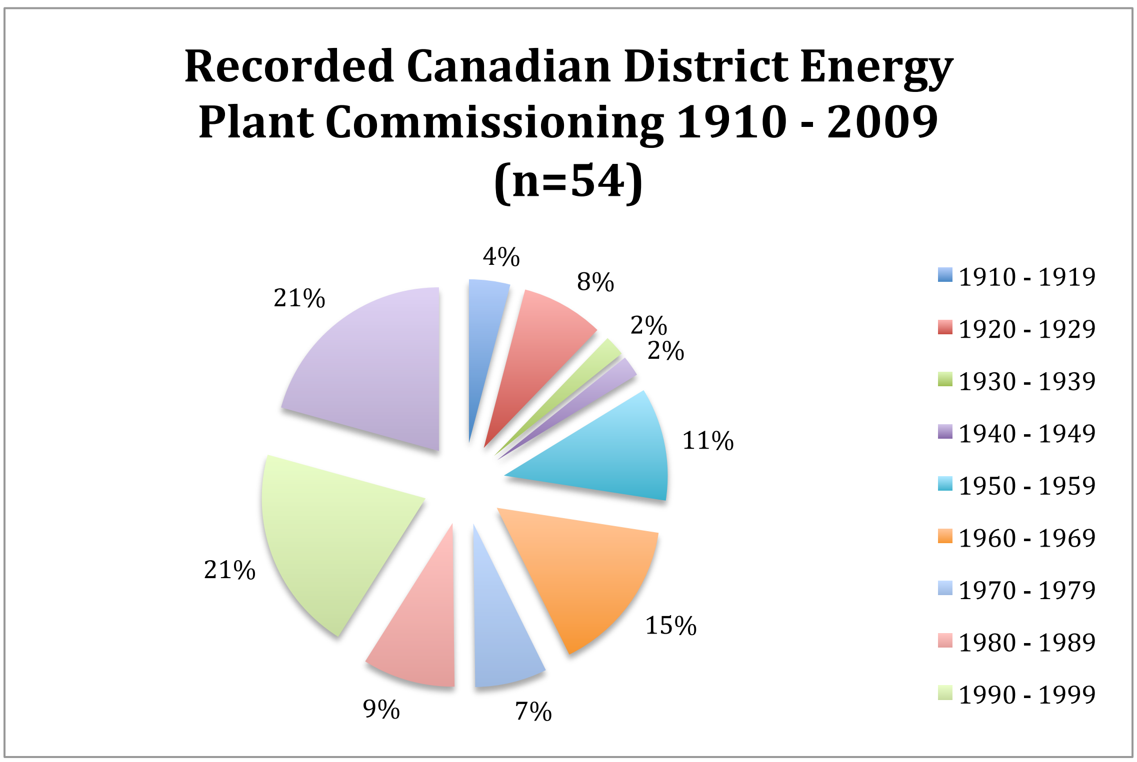
2.4.13 District Energy in Ontario

According to the most recent information available from the 2009 Canadian District Energy Association National Survey Report, there are 118 operational district energy systems in Canada with additional systems in various stages of development (CDEA, 2009). There are 51 operational district energy systems in Ontario, representing approximately 43 percent of all district energy systems in Canada (CDEA, 2009). Ontario's district energy systems service 5,955,298 m^2 of Canada's total approximate 27,000,000 m^2 residential, commercial institutional and industrial floor space connected to district energy systems (CDEA, 2009).

More than two-thirds of all district energy plants in Canada were constructed in the last 40 years (See *Figure 4: Recorded Canadian District Energy Plant Commissioning 1910 – 2009*) (CDEA, 2009). The industry is currently experiencing growth of roughly 1 percent per year. While this growth has been relatively consistent, district energy systems struggle to receive widespread adoption because of expensive capital costs in fiscally constrained municipal environments, and medium to long-term payback periods that don't necessarily appeal to private sector investors. In short, the appropriate financial mechanisms to facilitate development are not always in place.

Two periods of significant growth have occurred in the Canadian district energy market. During the 1970s, dramatic increases in Canadian energy prices motivated investment in district energy systems with CHP, particularly for industrial applications (CDEA, 2009). In the 1990s, the federal government wanted to promote the application of district energy systems as a means to secure more sustainable energy and community planning. Additionally, a heightened awareness of the inefficiencies associated with large-scale power systems prompted by improved generation technology and rejected heat capture led to a reduction in capital costs for small-scale plants (CDEA, 2009). Canadian district energy systems represent more than $12 billion worth of capital investment (CDEA, 2009).

Figure 4: Recorded Canadian District Energy Plant Commissioning 1910 - 2009



(Adapted from CDEA, 2009)

More than 6000 district energy systems exist in North American cities, typically found in historic downtown cores and medical, educational or military campuses (Compass Resource Management, 2010). Since 2000, 11 new district energy systems in Canada have reached operational status (CDEA, 2009). Most of these systems were located in urban environments in Ontario, Alberta and British Columbia, where flexibility in municipal regulation and pressure to restructure the electricity market has spurred development (CDEA, 2009). District energy generation accounts for an estimated 6,050 MW of production capacity, which represents just under 5 percent of Canada's total generation capacity. Ontario has the largest operational capacity with 895 MW servicing primarily commercial, institutional and residential customers (CDEA, 2009). Currently, the median capacity of a Canadian district energy system is 15MW, but this is expected to increase as dense, urban environments develop systems. District energy represents 0.29 percent of total energy sales in Canada, with Ontario's systems accounting for 5,467,790 GJ of energy sold (CDEA, 2009). Despite the small percentage of Canada's total energy sales, district energy systems provide the majority of space conditioning requirements for commercial and institutional buildings in major urban centres.

2.5 The Relationship Between Energy, Land Use Patterns and Urban Form

The relationship between energy demand, supply systems and distribution with the organization of urban form and land use patterns is often discussed but not fully understood (Owens, 1992). The literature generally recognizes a common relationship, acknowledging the characteristics of energy systems will hold influence over the shape and formation of cities, which determines the procurement, distribution, and consumption of energy. Owens characterizes this relationship as unbalanced stating "the energy system may permit or constrain urban change, but it is crudely deterministic to interpret it as a direct casual factor of urban form" (pg. 86, 1992). Therefore, it is understood that energy is one of many socioeconomic factors that shape the form and function of urban environments.

The literature consistently acknowledges that generally the form of North American cities has been influenced by abundant, low cost energy. As Brueckner (2001) and Glaeser (2011) point out, this low cost energy supply has prompted many middle-class North Americans to move away from the urban core, accepting longer commute times in exchange for lower housing prices. This has left a mark on the built form of many communities, developing regions of scattered single-detatched, single use development. Dispersed low-density development makes frequent transit service difficult, further necessitating the use of private automobiles. Newman and Kenworthy explored the impact of spatial dispersion on energy use by comparing American and European Cities (1989). They found that average per capita fuel use in the American cities studied was nearly four times as high when compared to European cities. Newman and Kenworthy suggest that differences in fuel prices, income, and variation and planning policy can be used to explain some of the variation in per capita fuel useage (1989).

Another factor influencing the shape of North American cities has been the prevalence of large-scale centralized energy production. Energy planning in the 20th century has largely been the responsibility of government agencies, particularly at the provincial level. Large-scale generation facilities were viewed favourably under the assumption of achieving economies of scale through centralization and large capital investments (Andrews, 2007). Houghton suggests that the result has been a monopolistic procurement model, where decision making around energy planning has been removed from energy end-users and centralized in the hands of a few large-scale producers (2000). The centralized large-scale energy model has allowed consumers to locate at almost any distance from a generator, with regulation keeping electricity prices low and removing proximity considerations for homeowners and businesses. More recently, fluctuating increases in the price of energy has alerted producers, consumers, and decision-makers to the implications of energy scarcity on meeting local demand (Makansi, 2007).

Jaccard et al. provide a hierarchy to describe the decision-making relationship between land use and energy choices, situating urban land use and infrastructure as the most influential factor, followed by building design, industrial processes and transportation choices as a second tier factors, and energy consuming equipment as a third tier factor (1997). Jaccard et al. place emphasis on land use because density and land use patterns have major implications for energy demand, shaping transportation networks, transmission systems, and opportunities for alternative energy systems such as district energy systems (1997). While building design will determine compatibility with energy using equipment and opportunities for onsite generation, viability of alternative design is usually influenced by land use planning decisions. Decisions related to energy using equipment are influenced by factors higher up in Jaccard's hierarchy. As he points out, the decision to use a bicycle for transportation may be influenced by the availability and extent of a connected bicycle lane network (1997).

Additionally, Jaccard et al. provide a spatial and temporal component to hierarchy of decision-making factors (1997). The scope of decision-making increases spatially moving up through the hierarchy from decisions about individual equipment components to transportation networks, to urban form for the entire city. Similarly, temporal considerations for equipment might have a span of a few years, but the evolution of urban form takes place over generations. Through this framework, Jaccard et al. illustrate the impact of land use decisions on energy decision-making, either supporting or limiting opportunities for building design, transportation, and equipment choices for decades.

It is also important to consider the administrative roles and agencies across the different levels of decision-making within the hierarchy. Typically, government agencies are making decisions about land use, urban form and infrastructure investments while site planning, building design and equipment are more often determined by a developer, builder, or businesses (Jaccard et al., 1997). Knowing how the hierarchy affects decision-making and which agencies are responsible for administrating strategic direction is important for understanding the role of planners in developing local energy solutions.

The fundamental building blocks of cities, urban form, transportation networks, and density among others, all interact to affect energy supply and demand. Owens suggests energy efficiency in the built environment can be achieved in two ways (1992). Firstly, the built environment can be shaped to have inherently low demand through design such as compact form that supports high levels of walkability. Secondly, cities can focus on achieving the maximum output for each unit of primary energy produced through services like public transit and smaller scale power generation (Owens, 1992). That being said, it is important to acknowledge that different energy supply and conservation strategies will have varying levels of success and compatibility dependent on the built environment of a community (Grosso, 1998). Capital intense investments such as district energy systems require substantial serviceable floor area and consistent demand for thermal energy. To justify the financial investment, district energy systems are usually found in dense, urban environments with a variety of uses allowing the central utility plant to operate at maximum efficiency to provide the highest rates of return on the capital investment. Owens makes an important point about planning for energy efficient communities, stating, "it may be necessary to plan new developments from the outset to be structurally compatible with a desired energy supply and conservation strategy" (Owens, 1992, pg. 96).

2.5.1 Density – Compact Urban Form

Jarbardeen describes density as the ratio of people and or dwelling units to land area (2006). Density impacts energy demand for water services, road construction and street lighting. Higher intensity land use allows infrastructure to be shared amongst more users, thus reducing per capita energy consumption associated with construction, maintenance and ongoing operations compared to less dense forms of development (Steemers, 2002; Capello, 1999). Beyond per capita reductions in energy demand, density also influences energy required for space heating and cooling. When a building envelope is smaller relative to the building's volume, it receives less external environmental exposure and generally requires less energy for thermal conditioning (DOE, 2006). This notion is supported by research from Owens who suggests that a single detached household may require as much as three times the energy of intermediate apartments which benefit from the conservation of heat through shared walls (1992).

Furthermore, multi-tenant and mixed use buildings that share components such as exterior walls and roofing may reduce the amount of embodied energy required for the production and transportation of building materials (DOE, 2006).

Planners and design professionals can influence density in a number of ways including: increasing building heights through the up-zoning of land; encouraging building typologies that promote compact urban form (i.e. stacked townhouses, apartments, mid-rise condominiums with mixed use components); permitting higher floor space index (FSI – ratio of building site coverage to total site area); increasing building depth while maintaining smaller frontages; and promoting infill development (Steemers, 2003).

The literature suggests that the demarcation of land uses, mixing of use, and prescribed density are the most significant land use factors affecting energy consumption related to transportation (Kenworthy and Laube, 1999; Owens, 1992; Newman and Kenworthy, 1989; and Rickaby, 1987). Newman's research found that cities in the US with the lowest densities exhibited the highest rates of energy consumption related to transportation in comparison to European cities with higher densities that had lower transportation energy consumption rates (1992). Further, Kenworthy and Laube state "… urban form, and in particular high urban density, is consistently associated with lower levels of car ownership and car use, higher levels of transit use, and lower total costs of operating urban passenger transportation systems" (1999, pg. 719).

District energy systems are typically developed and built at the neighbourhood or community scale. At this level, mixing of uses, density, and building size all interplay to affect and determine the viability of the district energy system (Park and Andrews, 2004). Since district energy systems use a series of underground pipes and wires to deliver thermal energy and electricity to nearby buildings, systems tend to be economically viable where thermal energy loads are consistently high and continuous (Park and Andrews, 2004). Higher density, mixed-use buildings comprising a compact urban form enables district energy plants to run at their highest efficiency. These conditions also support consistent and continuous aggregate loads with higher periods during the evening from residential uses and higher loads during the daytime from commercial demand. Compact urban form provides a higher heat load per metre of distribution piping, amortizing capital installation costs over a larger customer base. All of that being said, an industry report from FVB Energy Inc. points out that density is only one indicator of thermal demand, making it impractical and unrealistic to specify a minimum density to support district energy systems (2007). The same report suggests that building size is a more important determinant of district energy system viability because customer payments must cover the cost of the thermal services delivered and the amortization of connection costs (FVB Energy Inc., 2007). For this reason, the connection cost in a single detached household is much higher than in a multi-tenant buildings, often outweighing the benefit of future savings. However, FVB Energy Inc. indicates that a financial case can be made for connection to higher density typologies such as stacked townhouses where units are metered through a single entity (condominium board).

2.6 Development of Downtown District Energy Systems

2.6.1 1900 – 1960: Downtown District Heating Systems

District energy systems have provided the thermal energy foundation of major North American cities for over a century. In 1906, Thomas Edison constructed his first electricity generating station on Walnut Street in downtown Philadelphia (IDEA, 2007). The initial capital investment was significant and Edison determined that his business would not be profitable solely selling electricity (Patterson, 2007; IDEA, 2007). The generator used to produce electricity also generated steam, so Edison entered into an agreement to sell 'piped in steam' to the nearby Thomas Jefferson University Hospital (IDEA, 2007).

Edison's district heating system acted as a catalyst for the expansion of Philadelphia's downtown steam system.

City centers such as New York, Boston, Philadelphia, Denver, Indianapolis, Cleveland, San Francisco and Baltimore formed the first sector for district energy systems in the United States (IDEA, 2007). These systems, which generally distributed steam for heat, humidification and domestic hot water heating, became widely adopted in the United States with more than 350 commercial district heating systems in operation prior to World War I (IDEA, 2007).

However, the 1960s and 1970s brought advent and expansion of large format nuclear and coal power generation stations to Canada and the United States and as a result, utility companies began to cease electricity production at the smaller scale (IDEA, 2007). Additionally, the combination of city centre emission restrictions and escalating fossil fuel costs saw some local utility companies divest steam-based business assets (MacRae, 1992).

The rising energy costs impacted commercial office design, bringing about tighter building envelopes with sealed windows and minimal air ventilation in an effort to reduce costs. Personal computers and increase employee densities were causing internal office loads to rise, reducing thermal heat energy requirements (IDEA, 2007). This, in conjunction with aging district energy infrastructure in need of repair, caused steam revenues to flatten (IDEA, 2007).

Despite the economic downturn for thermal energy utility companies, some investors saw an opportunity and began to purchase existing systems across North America (Enwave, 2010). New business plans were developed that revisited the fundamental operational considerations of steam plants, investigating cogeneration revenue opportunities and explored the feasibility of district cooling scenarios (NRCan, ND). As a result, confidence was restored to the sector. Changing thermal energy requirements in the food and agriculture, institutional, medical, commercial, finance, telecommunications and military sectors, is renewing market interest in the application of district energy systems as a means to provide secure, reliable thermal energy at economically efficient rates (CDEA, 2008).

2.6.2 1960 Onward: Combined Downtown Heating and Cooling Systems

Many North American district energy systems achieving operational status in the 1960s included provisions for district cooling in conjunction with the district heating infrastructure. Hartford, Connecticut installed the world's first district heating and chilled water district cooling system in 1962 (IDEA, 2007). The system was part of a multi-acre urban renewal project of Constitution Plaza, when renewal development block grants had become common in the 1960s. In many American scenarios, long-standing agreements were made between utility companies and local municipalities that include caveats for street construction permits, traffic interference, rights of way, and limits on commodities to be sold through incumbent pipeline assets. In these scenarios, local governments are usually the benefactors of royalty fees and or payments (IDEA, 2007).

Growth of district cooling continued through the 1980s with utility companies forming non-regulated subsidiaries to construct district cooling systems in addition to the utilities' original thermal heating systems. These subsidiaries capitalized on existing incumbent relationships, transmission infrastructure, existing production facilities and the ability to leverage administrative and management resources for additional district cooling revenue (IDEA, 2007).

In the early 1990s, district cooling experienced growth largely due to the phasing-out off the chlorofluorocarbons (CFCs) commonly used in building chillers (IDEA, 2008). Some building owners subscribed to district energy systems in an attempt to minimize risk associated with replacements and avoid costly conversions (IDEA, 2007). Innovative approaches associated with district cooling allow for operators to capitalize on local natural resources. This is the case in Toronto where Enwave utilizes three high density polyethylene pipes to collect cold water from 83 meters below the surface of Lake Ontario

(Enwave, 2010). The coldness of the water is harnessed through thermal exchangers into the closed loop chilled water supply before being transferred to the City's potable water supply.

2.7 District Energy Market Trends

District energy systems have historically been developed where there is significant vertical floor space density, often lending their application to central business districts and downtown locations (IDEA, 2007). Commercial office space, large hotels, convention centres and sports arenas are market sectors typically served by district energy systems, however an increasingly larger share of condominium developments are connecting to a thermal grid (Tridel & Conservation for the Living City, 2006). However, much of Canadian residential building stock has developed in a low-density sprawling fashion, situating single detached households further away from the city centre (Murphy, 2006)

In 2002, the Climate Action Network Canada reported that the commercial and institutional sectors were running predominantly on natural gas and grid electricity, at 48 percent and 41 percent of their total energy use respectively (pg. 63). However, opportunities for self-generated electricity and district energy systems are materializing. This is largely driven by the need for municipalities and businesses to conserve energy, take a proactive approach to addressing climate change and meet the increasing demand for secure energy (CDEA, 2008).

As advancements develop in renewable energy technologies and the demand for thermal energy continues to rise, some market trends related to district energy emerge. Studies suggest that natural gas will remain the fuel of choice for space conditioning in low GHG emission scenarios for the near future, but the inherent fuel flexibility of district energy systems allows for relatively easy adaptation to renewable fuel sources as they become economically feasible (Climate Action Network Canada, 2002; Reeve et al., 2010; Gilmour & McNally, 2010).

2.8 Challenges to Implementation

Although many examples of successful district energy systems exist across Canada, municipalities and businesses continue to face challenges developing and implementing systems. The private sector and utility companies gravitate towards district energy systems based in established markets with a reliable return on investment (CDEA, 2008). Municipalities are constantly facing pressures to reduce operating costs while attracting additional investment, but must do so on increasingly restricted budgets (CDEA, 2008). The upfront capital costs and lengthy payback period often deters private investment, in many cases leaving the municipality to bear the initial infrastructure expenditure. However, it seems that without a municipal planning framework that accounts for district energy as a consideration for development, opportunities are often missed. The following subsections will address the challenges associated with district energy implementation.

2.8.1 Higher Upfront Capital Costs

As with all major infrastructure investments, district energy systems require significant initial investments to pay for capital construction costs. However, these costs can be managed under a utility ownership model or single institutional owner. This utility model allows for upfront capital costs to be amortized over the long term and recovered through rate payments (Compass Resource Management, 2010). That being said, private investors hesitate to make capital commitments without support from the local municipality. Without a collaborative approach involving the local government, it is difficult to predict where and when new development will occur, despite this information being critical for capacity considerations (CDEA, 2008). Cooperation from the municipality is also required to permit access to public and private rights-of-way and easements for district energy infrastructure installation. The support of the municipality is crucial to alleviating the financial risks associated with district energy development (Owens, 1992). It is also worth noting that although local utilities often have the financial resources to develop district energy systems, they have the tendency to promote their existing services as district energy systems reduce demand and revenue (CDEA, 2008)

2.8.2 Customer Capture and Retention Risk

Securing thermal loads early on in the development phase is critical for viable project economics (Compass Resource Management, 2010). Without mandatory connection provisions, it may be challenging to secure a sufficient customer base for the district energy service which can increase revenue risk to the utility (Compass Resource Management, 2010). Furthermore, if customers disconnect from the district energy service it may result in underutilized equipment capacity. Some municipalities like the City of Vancouver are mitigating these risks by incorporating mandatory district energy connection feasibility studies for all new developments or projects requiring an interim rezoning approval occurring within an area serviced by a district energy system (City of Vancouver, 2010b). District energy is being leveraged as a tool to maximize opportunities for reductions in citywide GHG emissions through innovative planning tools (City of Vancouver, 2010a). However, with mandatory connection comes an obligation to provide some sort of thermal energy price regulation to protect customers.

2.8.3 Retrofitting for District Energy

The majority of district energy projects target new developments. It is easier to design new buildings for interconnection and optimal use of district energy systems rather than providing retrofits for thermal energy connections (Compass Resource Management, 2010). Although it is expensive to retrofit buildings for district energy, it is not impossible. Ontario's buildings are primarily hydronically heated which allows buildings requiring a boiler replacement, to connect to a district energy system if located near a service area. The timing for orchestrating these retrofits is critical. Building owners will not want to replace their boiler systems prior to the end of their serviceable life. That being said, buildings constructed around the same period of time will often require the replacement of boiler units around the same approximate time. Utility companies must focus on targeting aging buildings, likely requiring boiler unit replacements for district energy retrofits. For the small proportion of Ontario's buildings heated by electricity, retrofitting is not an economically feasible option.

2.8.4 Community Engagement

Engaging community members, stakeholders and regulatory bodies early on in the district energy development process is essential to establish support and ensure long-term commitment to the project. Although many community members may be interested in reducing reliance on centralized energy, encouraging alternative renewable electricity generation, improving the economic pricing of their energy and minimizing the environmental impacts associated with energy production, opposition may focus concerns on local emissions, noise and aesthetic issues associated with district energy systems (CDEA, 2008).

Thorsteinsson and Tester (2010) draw interesting comparisons between district heating in the United States, and the systems widely utilized in Iceland (2010). They identify barriers to U.S. market adoption that can be categorized under the sectors of economic, socio-political and technical feasibility. Interestingly, the economic and technical barriers are mitigated with relative ease. It is the socio-political context that presents the biggest challenges for district energy management solutions. Specifically, a lack of public and political education is hampering implementation efforts. This suggests that by adopting a strong municipal planning framework for implementing DE, standardized procedures would be in place to account for the necessary design/feasibility considerations. Although their comparison reflects the U.S. market, their insights and recommendations for a community approach to energy planning may be transferrable in some capacity to the Canadian context. Developers, owners and operators of Canada's most successful systems worked closely with elected officials and municipal staff during the development of the project. This allowed the district energy system to be incorporated as a component of the community's long-term sustainability plans and objectives (CDEA, 2008).

2.9 Institutional Challenges

Ontario's unique institutional environment presents challenges related to policy, ownership structure, the development environment and contract and rates. Complex relationships between Ontario's various energy agencies, ambiguity regarding responsibility, variations in political policies and uncertainty regarding rate programs present risks to district energy development. The following subsection will focus on the institutional challenges associated with district energy implementation.

2.9.1 Ontario Energy Policy

Under the 2009 Green Energy and Green Economy Act, the OPA was charged with the responsibility of procuring alternative energy from a variety of producers (Bill 150, 2009). With respect to district energy systems, alternative energy includes biogas, biomass and biofuel (Compass Resource Management, 2010). BC Hydro Standing Offer program offers fixed price contracts for natural gas CHP achieving an overall efficiency greater than 80 percent, but Ontario does not consider natural gas as green energy (BC Hydro, 2011). Without a standing offer program, natural gas may struggle to compete with conventional fuel sources.

Prior to the OPA's FIT Program, Ontario's Minister of Energy directed the OPA to develop the Clean Energy Standard Offer Program (CESOP) to award 20 year fixed contracts for CHP projects with a nameplate capacity of 10 MW or less (Compass Resource Management, 2010). This program was intended to launch by the end of 2007 but no power contracts have been issued to date, compromising the financial feasibility of new CHP projects.

2.9.2 Ownership Structure

Determining the ownership structure of a district energy system involves establishing the most efficient operating structure and sourcing private equity and access to government grants (CDEA, 2008). Project financing and plant ownership affects cost control and flexibility and the long-term revenue generation. The long payback periods often associated with district energy systems, presents challenges to attract private sector investment (Edwards et al., 2000). As a result, most local district energy systems are championed by the public sector, given municipal government's longer planning horizons, interest in meeting public environmental objectives, access to consistent capital, lowered required rates of return, access to grant funding and in some cases, tax exemptions (CDEA, 2008). Municipal initiation lowers the risk of development and improves the investment attractiveness for private sector companies.

In some Canadian communities, arrangements are made for public-private partnerships (P3) in district energy design, construction, ownership and operation. Public-private partnerships situate the community as a stakeholder, removing risky barriers related to municipal access and commitments, while private-sector equity holders providing access to financing (CDEA, 2008).

2.9.3 Development Risks

Once there is a commitment to develop district energy, several risks to implementation arise. Business cases are sensitive to fluctuations in demand and capital cost assumptions, particularly in the early phases of development (Compass Resource Management, 2010). Thermal demand is a function of the rate of development, the energy performance of buildings, interconnectedness of buildings and building occupancy. Capital cost escalation is a major risk that must be combated with the allowance of adequate contingencies for cost increases (Edwards et al., 2000).

System and building performance as well as fuel prices also pose potential risks for district energy development. Lower than anticipated system or building performance, as sometimes seen with newer technologies, jeopardizes system efficiency (CDEA, 2008). The impact of fuel prices is dependant upon the specific system technologies. For example, an increase in electricity costs may benefit a biomass facility as the competitive benchmark for district energy rates increases but the operating costs for the utility are not impacted (Compass Resource Management, 2010). Conversely, a heat pump district energy system relying on electricity would likely experience an increase in charge out rates and operating costs if electricity prices increased. To minimize the risk associated with fuel prices, long-term contracts should be arranged whenever possible.

2.9.4 Contracts and Rates

Creating a clear understanding of rates for customers is one of the most significant communication challenges facing district energy (Edwards et al., 2000). In most cases the district energy system bills the individual buildings connected to the grid from the energy transfer station located on the premises. The individual building owners are responsible for allocating the charges to the property tenants (Compass Resource Management, 2010). Most systems use the cost of service model or the customer avoided cost model for district energy service billing, with both models hav fixed and variable components.

The cost of service model uses the utility's costs to determine the fixed and variable costs. The fixed cost component is established to recover fixed annual costs and is determined by peak capacity subscriptions or total serviced floor area (Compass Resource Management, 2010). The variable component of this model reflects actual metered energy use and compensates for annual demand variance.

The avoided cost model negotiates fixed and variable rates when customers enter into a contact agreement with the local utility. Fixed costs are determined by the avoided equipment and associated fixed operating and maintenance costs. The variable rate component is based on agreed thermal energy savings by utilizing the higher efficiency centralized district energy system vs. onsite equipment (Compass Resource Management, 2010).

All rate designs have associated benefits and drawbacks, which vary depending on the specific design, local restrictions and owner objectives. The challenge for district energy implementation is developing and communicating a clear understanding of rates between utilities and customers.

2.10 Advancing Energy Planning in Canada

In Canada, energy planning has developed and evolved dramatically over the past forty years (Gilmour & McNally, 2010). Energy planning was originally done by supply agencies with the main consideration being supply (Reeve et al., 2010). The energy crisis of the 1970s brought about a more holistic approach where planners began to examine energy systems, comprising of natural resources and technologies for space conditioning and the distribution network required for service. Energy utilities began to consider both the supply and demand side management, weighing the cost of incremental supply projects against the benefits of customer-side demand reductions (Gilmour & McNally, 2010). Planning for energy still remained largely focused on equipment efficiencies and improvements to the building envelope, failing to consider urban form and the social drivers of energy use. This lack of consideration for urban form increases the risk of developing energy-intensive land use patterns by default (Owens, 1992).

A study conducted by Jaccard, Failing and Berry was one of the first to identify the significant impact of urban form on all aspects of energy use (1997). More specifically, their findings indicated that density and land-use patters determine the size and type of dwelling as well as commuting distances, transportation modes and energy supply systems which all dramatically impact energy service requirements. Despite the influence of land-use patterns on community energy profiles and supply cost to consumers, energy use is often overlooked when considering the location of a new home, the operation of commercial services, options for transit and the layout of road networks (Gilmour & McNally, 2010). Additional support for integrating energy planning into the land use planning process recognizes that physical structures are largely permanent while the future of energy is highly uncertain (Owens, 1992). Therefore, it makes sense to consider the volatility of energy to ensure long-term flexibility in the context of urban development. Many community planners are not giving enough consideration to the energy impacts of high-rise versus low-rise developments, density versus sprawl and mixed use versus monotype zoning. Table 4 illustrates the correlation between land use and energy related decisions from Jaccard's et. al, (1997).

Table 4: Impacts of Energy-Related Land-Use Decisions

Energy-Related Decisions	**Dimensions**		
	Timeframe for Implementation	Space Requirements	Jurisdiction
Land-Use and Infrastructure	Years to Decades	Neighborhood Scale to Community-Wide	Public
Building and Site Design	One to Three Years	Site Lot/Parcel	Public/Private
Energy Consuming Equipment and Technology	Less Than One Year	Dedicated Utility Space in Buildings and or Structures	Private

(Adapted from Jaccard, Failing, & Berry, 1997).

It is important to minimize the investment risk for the start up and continual operation of a district energy system. Many authors have indicated that urban planning, zoning conducive to a mixing of uses and compact urban form all play a considerable role in the mitigation of district energy system investment risk (Gilmour & McNally, 2010; Gilmour, 2009; CDEA, 2008; IDEA, 2007; Edwards et al., 2000). This connection has also been echoed through industry surveys with the report summation stating "It can be difficult to predict when and where new development might occur; however, this information is required to help determine the size of a plant, the cost of a system and the potential return on investment. Newer systems being constructed today are generally well placed to benefit from immediate access to concentrated heat loads, such as communities with mixed-use compact urban design. This can also be attributed to a renewed focus on communities planning for and incorporating different types of built for that supports district energy." (CDEA, 2009 p.9). The local land use planning process is "a critical mechanism for implementing climate change adaption at the municipal level" (Ontario Ministry of Environment, 2009 p.61) Although the connection between land use, patterns of development and energy demand has been made in academic and industry literature, relatively little work has been done in few jurisdictions translating this information into applicable planning policies.

2.10.1 Energy Planning at the Municipal Level

Energy planning at the municipal level calls for municipalities to abandon business as usual practices in exchange for a new level of planning capacity. New techniques may encourage municipalities to identify energy opportunities and vulnerabilities through a more holistic approach to planning processes such as integrated land use, infrastructure, sustainability and climate change planning. Energy planning benefits from the quantification of the municipality's corporate and community energy use as a means to identify areas of improvement, set numeric targets and evaluate changes. Tracking energy use at the municipal level allows for the pursuit of precise energy-related targets and produces energy plans that reflect the specific energy profiles of the community (FCM, 2009).

Local governments hold jurisdictional influence over their local energy sector by either regulating energy generation and use through policy and programs or by participating directly in the generation of local supply (CDEA, 2008). Both spheres of influence require the municipality to consider energy in the municipal decision-making and planning process. Municipalities giving the most thorough consideration to energy planning will often do this through integrated community energy management strategies, energy mapping, community energy plans and local energy management programs (Gilmour, 2009).

Planning for energy contributes to reducing energy costs and lessening environmental impacts (CDEA, 2008). Energy use in communities is a product of independent component system design and their collective functions when working collectively to respond to individual demand (NAPSEST, 2006). Until recently, Canadian municipal governments have not played an active role in the energy sector, with energy consumption being regarded as a by-product of consumption patterns for residents and businesses (Gilmour & McNally, 2010). However, some Canadian municipalities are now taking a leadership role providing energy management in two ways. Firstly, and the primary subject of this thesis, is through the direct provision of energy services by establishing district energy systems or exerting influence over local distribution companies (Gilmour & McNally, 2010). With the Province of Ontario's introduction of the Green Energy Act, 2009, some municipalities are providing direction to their electric local distribution company (LDC) to ensure new powers regarding conservation and renewable generation are capitalized on (*Bill 150, Green Energy and Green Economy Act*, 2009; Gilmour & McNally, 2010).

Incorporating district energy into the municipal planning process through bylaws can stimulate interest in system development and ensure that no opportunities are overlooked (Vancouver, 2010a). Municipalities can generate conditions conducive to district energy development by encouraging high-density, mixed-use urban form. When commercial and residential lands are located in close proximity, they generate significantly more demand for thermal conditioning (CDEA, 2008). Higher thermal demand across a variety of building types translates into lower energy infrastructure costs amortized over more customers. Municipalities that incorporate district energy in their planning documents and approval processes, demonstrate commitment to resilient growth, economic development and long-term energy security.

Municipalities have also become a driving force in the development of energy policies and plans forming the foundation of community energy plans (CEP) (Gilmour & McNally, 2010). The CEP focuses on engaging local community members like utilities, the LDC, energy consumers and industry in developing a vision for energy reduction extending 25 to 100 years. St. Denis and Parker have also noted the emerging trend of CEPs, where a desire to reduce GHG and drive for energy autonomy is resulting in accountable energy action at the municipal level (2009). They stress the benefits of local management because CEPs tend to accomplish these goals through improvements to energy efficiency, energy conservation and converting to renewable resources. District energy has a role to play in achieving all of these community objectives. Identifying demand side management (DSM) practices and the integration of renewable resources as sources for local energy generation and engaging the community to develop and manage its energy delivery is central to the success of CEPs (Gilmour & McNally, 2010). Ramachandra describes a similar concept, but expands it to encompass the region (regional integrated energy plan), where a regional planning exercise identifies the optimal combination of available resources and energy demand to maximize overall system efficiency (2009).

The British Columbia Energy Council (BCEC), established in 1992, was central to mandating the planning and policy development for energy in the Province (Gilmour & McNally, 2010). In 1994, the BCEC released *Planning Today for Tomorrow's Energy*, which laid out a strategy to establish and implement energy planning in British Columbia (BCEB, 1994). This watershed document created awareness that municipal planning could not be siloed from energy planning, rather, the two must be considered cohesively in conjunction with one another. Since the early 1990s, CEPs have become more formalized with support from Federal government agencies like Natural Resources Canada (NRCan) (Gilmour & McNally, 2010).

However, despite increasing recognition as an approach for addressing municipal energy issues, CEPs in Canada still face many challenges. Considerable time and resources are directed towards DSM reduction strategies but collective approaches to reducing consumption remain fragmented (Gilmour & McNally, 2010). The fact remains that little communication occurs between gas and electricity DSM planning, or between land use, energy, water, transportation and waste planning at the municipal level.

Land-use planning directs community development, including places to live and work, specifies the location of roads, sewers and other essential services and dictates areas for future growth. The public participatory process associated with land-use planning allows citizens and businesses to develop a community vision and goals for addressing social, economic and environmental challenges. One new approach to increasing the cognitive linkages between land use and urban form with an understanding of energy consumption, demand and supply is undertaking a community energy mapping exercise. Energy mapping studies provide municipalities and utilities with a visual means to evaluate existing energy consumption and help plan to improve energy efficiencies through land use planning, enhanced building standards and alternative energy supplies (City of Calgary, 2008).

Despite the considerable influence over future energy consumption and feasible energy efficiencies, most communities in Ontario fail to integrate energy considerations into the regulatory requirements for land-use planning (Gilmour & McNally, 2010). Although over thirty CEPs have been established in Canada, they have focused on energy reduction strategies advanced through municipal corporate actors rather than broadly engaging the community across a variety of sectors (Gilmour and McNally, 2010). Straight line projections for future growth of population and employment as well as building types are acceptable for short to medium term planning horizons (ten to fifteen years) however, longer term projections must be flexible to account for changes in land use patterns over time. Population, employment, density and building types have immediate and profound impacts on the base-line energy level of a community (Gilmour & McNally, 2010).

2.11 Research Questions

This literature review has highlighted the need for new approaches to address increasing energy consumption and demand within the province of Ontario. The materials covered revealed a general consensus that current format for energy generation and distribution lacks flexibility, contributes to environmental degradation (particularly in relation to GHG emissions and climate change), exposes customers to the volatility associated with the non-renewable energy market and compromises the resiliency of Ontario communities. The resulting impacts are anticipated to be significant. There is no doubt that municipalities will play a central role in the advancement of new energy generation and distribution solutions to address the aforementioned challenges.

However, it seems as though Ontario municipalities lack supportive frameworks to accomplish objectives related to improving energy efficiency and reducing reliance on conventional fuel sources. As energy supply and demand is a product of land use, this is intrinsically linked to the way communities are planned and zoned for uses and densities. Given this context, it is of interest to consider the challenges facing district energy implementation at the municipal level. The following research questions have evolved from a review of relevant literature:

- What primers prompt the exploration of district energy systems in Ontario municipalities?
- How can district energy systems be leveraged as community assets?
- What challenges inhibit wide-scale municipal participation in the development of district energy systems in Ontario's urban environments?
- What transferable lessons can be learned from the Town of Markham and the City of Hamilton in other Ontario municipalities to utilize district energy as a means to accomplishing local energy objectives?
- What is the connection between land use, density, energy demand, and consumption?
    - What is the relationship between district energy development, community energy management and land use planning in the municipality?

- What is the role of the municipal planning department in planning for and facilitating the development of district energy systems?
  - What planning policy tools could be developed to provide a framework for implementing district energy systems?

Chapter 3 Methods

3.1 Methods

The methodological approach employed for this research is qualitative in nature, relying on an inductive style building from particulars to general themes. Creswell defines qualitative research as "a means for exploring and understanding the meaning individuals or groups ascribe to a social or human problem" (2009, p.4). Qualitative research uses an interpretive and exploratory approach, allowing for more research flexibility compared to quantitative methods (Dezin & Lincoln, 1994). Similarly, Palys describes qualitative methodology as "research methods characterized by an inductive perspective, a belief that theory should be grounded in the day-to-day realities of the people being studied, and a preference for applying phenomenology to the attempt to understand the many 'truths of reality'" (1997, p. 423). This permits and promotes the development of new ideas and theories (Merriam, 1988). The characteristics of a qualitative study are best suited to address the outlined research questions and objectives because community energy planning and land use planning are largely unexplored in conjunction, and this methodology provides a framework to explore where the fields have integrated in practice as well as reveal some of the challenges and potential solutions.

In order to determine the challenges and key primers for district energy implementation and the role of municipal planners in developing energy efficient communities, a qualitative approach is suited to reviewing the relevant literature and industry documents, and to analyze the key informant interview data. Some quantitative data associated with the two case studies described below, will be used to supplement perspectives about the perceived benefits and challenges associated with district energy systems.

3.1.1 Triangulation

A mixed methods approach is used to obtain data relevant to the implementation of district energy systems in Ontario municipalities and this is referred to as triangulation. Hoggart, Lees & Davies state that “triangulation involves employing complementary methods or data sources to circumvent the potential inadequacies of single data sources” (2002, p.312). Triangulation allows the researcher to collect different types of information. In some cases, the information may overlap, compliment or contrast, providing a more holistic understanding of the data (Creswell, 2009). This study will use triangulation as data is obtained from a review of literature, documents and interviews.

3.2 Research Framework

This research utilizes a case study framework. Creswell explains case studies as

… a strategy of inquiry in which the researcher explores in depth a program, event, activity, process or one or more individuals. Cases are bounded by time and activity, and researchers collect detailed information using a variety of data collection procedures over a sustained period of time (2009, p.13).

District energy systems in Markham and Hamilton were selected as case studies to explore the role of municipal planning in system implementation. The rationale for case study selection is discussed in the following subsection.

3.2.1 Case Study

This research utilizes a case study approach to investigate contemporary phenomena in two different district energy system scenarios. Case studies can be utilized for empirical inquiries that explore contemporary phenomena in relation to their real-world context where multiple sources of evidence are used (Yin, 1994). The case study approach allows the study to emerge as exploratory, descriptive and or explanatory (Yin, 1989). Additionally, case studies permit the investigation to capture the dynamic details of real-life events, such as the managerial and organizational processes particularly relevant to this research (Yin, 1994). Merriam describes qualitative case studies as having four common characteristics: 1. case studies are particularistic meaning they examine a particular phenomenon or situation within a bounded unit of analysis; 2. case studies are descriptive, providing rich accounts of the phenomenon under analysis; 3. case studies are heuristic, furthering the reader’s understanding of the phenomenon under analysis; and 4. case studies are inductive, relying on inductive reasoning (1988). Merriam provides an accurate description of the case study research methodology utilized in this study:

"…generalizations, concepts or hypotheses emerge from an examination of data – Occasionally one may have tentative working hypotheses at the outset of a case study, but these expectations are subject to reformulation as the study proceeds. Discovery of new relationships, concepts and understanding, rather than verification or predetermined hypotheses, characterizes qualitative case studies" (1988, p. 13).

Existing theories and research may provide an initial foundation for research, it is important to test these theories and remain open to new emergent themes, theories and ideas that may be revealed through case study analysis.

3.2.2 Case Study Selection Rationale

Two case studies, Markham and Hamilton, were selected from the Ontario context to determine the role of municipal planning departments in community energy planning, and exploring the challenges and opportunities of developing and district energy systems. Multiple case studies were selected to allow for similar and contrasting results (Yin, 1994). Both Markham and Hamilton have been referenced in the relevant industry literature for their innovative planning and implementation processes. Additional investigation proved that Markham and Hamilton offer distinctive but balanced perspectives on the development of municipal plans and programs that facilitate or hinder district energy system development.

District energy systems in Markham and Hamilton were selected for several reasons:

1. *Development Context* – Markham Centre was largely a greenfield when the idea of developing a district energy plant was initially tabled. This provides an opportunity to explore municipal efforts to integrate energy and land use planning at the beginning of the development process. Conversely, Hamilton's district energy system was developed within the existing downtown core of the city. The literature suggests that developing district energy within the existing built

environment may become more common in the future as cities look to intensify, and presents a unique set of challenges worth exploring.

2. *Local Policy Initiatives* – Both Markham and Hamilton have policy initiatives supporting the development of more sustainable communities, supported by a variety of stakeholders across a number of municipal jurisdictions, including planning. Case studies of Markham and Hamilton will provide the opportunity to explore the connection between the integration of land use and energy planning and the interface with broader policy initiatives.

3. *Ownership Model* – The literature suggests that the model of district energy system ownership can influence a number of key factors related to system development and implementation. It may also influence or determine the role of municipal planners in the community energy planning process. Markham and Hamilton utilize different ownership models which have proven to be effective for the initial development of district energy systems, and provide learning opportunities yielding recommendations for other municipalities.

3.3 Research Methods

Several research methods are employed in this study including a literature review pertinent to the topic, review of relevant municipal planning documents and key informant interviews. This section will detail the approach taken for each of the research methods utilized.

3.3.1 Review of Literature

A comprehensive literature review of academic, governmental and industry sources has provided the researcher with the necessary background knowledge to complete this study on municipal planning considerations for district energy systems. Additionally, the literature review helped craft the questions comprising the interview guide which examined the themes identified in the review with key informants.

The literature review also played a role in determining which research methods would best address the research questions.

The literature reviewed was classified under the following categories: energy policy, district energy defined, benefits of district energy, development of downtown district energy systems, district energy market trends, challenges to implementation, institutional challenges and advancing energy planning in Canada. Each category was broken down further into specific subsections to explore the topic at greater detail. Peer-reviewed journals and other scholarly articles primarily addressed the broad relationship between urban form and community energy demand as well as the development and progression on energy planning in the municipal context. Industry papers, reports and surveys provided a thorough understanding of district energy systems, the associated benefits and implementation challenges.

3.3.2 Review of Relevant Municipal Planning Documents

Planning documents prepared by the Town of Markham and the City of Hamilton were reviewed to identify and document considerations for energy planning in conjunction with land use planning. Document review can be a useful research method despite the potential for bias, providing supplemental information to corroborate other sources (Yin, 1989, Merriam, 1988). The process of document analysis allows the researcher to determine the specific language and words used by the various municipalities, while highlighting municipal planning considerations to address local energy demand (Creswell, 2009). Specifically, the document review focused on identifying the themes and practices related to the integration of energy and land use within relevant municipal documents, and explored the key agencies and approval processes related to the development of community energy systems. The documents reviewed outline the land use planning policies related to their respective municipality and in some cases, express considerations for energy demand management. The information reviewed provided context for the key informant interview data and supplemented the content of the selected case studies.

3.4 Data Collection

The data collection process for the key informant interviews is explained in the following subsections.

3.4.1 Key Informant Interviews

Key informant interviews were conducted in May and June of 2011. All of the interviews took place in the work environment of the individual interviewee. The participants have been placed into categories defined by relationship to their corresponding district energy system as shown in Table 5 This categorization aggregates respondent's results for data analysis, highlighting the broad trends while providing anonymity amongst individual participants.

Table 5: Interviewee Classification by Sector

Category of Participants	Number of Participants
Municipal Sustainability/Planning Staff (MS)	5
District Energy System Management (SM)	3
District Energy System Customer (CU)	1
District Energy Industry Expert (IE)	2

The interviews utilized a semi-structured format with open-ended questions. The questions provided were developed as a catalyst to corroborate and expand upon the findings from the literature review and case study examinations. This promoted more in-depth interviews than a structured format would permit. The semi-structured format also allowed for participants to develop ideas that were not apparent in the materials reviewed in preparation for the interviews, while minimizing the researcher's influence over responses (Patton, 1980). As a result, some questions prompted strict information and others provided opportunity to share opinions. In some cases, the questions focused on a particular direction because of emphasis and relevancy. Citation levels are uneven because some interviewees had little information to offer. This speaks to the lack of knowledge around the subject area, particularly in the field of planning. The questions developed for the interviews can be found in the Appendix.

Upon consent of the interviewee, an audio recorder was used to tape the interviews. This allowed the researcher to focus on active listening throughout the interview. Each interview lasted approximately one hour, at the conclusion of which, the interviewees were permitted to ask their own questions related to the research. In total 11 interviews were conducted.

3.4.1.1 Rationale for Interview Selection

Key informant interviews were conducted to gain insights from municipal planners (MP), industry representatives (IR), system managers (SM) and customers (CU) from each case study system with respect to the relationship between land use planning and community energy demand management, and the challenges facing district energy system implementation. Interview candidates were identified and selected based on their employment in relation to the selected case studies and expertise in either land use planning, district energy and or community energy demand management. The objective was to interview at least one participant from each category per case study selection. Some of the interviews led to snowball sampling in which those originally selected to participate in the study, recommended other informants who could contribute to the research (Hay, 2005).

3.5 Research Methods Analysis

Through analysis of the data collected, conclusions have been drawn to address the initial research questions of this study.

3.5.1 Case Study Analysis

The general analytic strategy for case study analysis was the development of a case description where the case study framework uses a description of general characteristics to address the phenomenon in question (Yin, 1994). Case study analysis was characterized by a step-by-step process, which Daniel (2007) describes as requiring the researcher to define the study questions, clarify objectives, perform data collection through qualitative methods and utilize a qualitative lens for data analysis. Logic is used to draw linkages from the data results to the research questions and study objectives. Conclusions and discussions situated the findings in the specific context related to each case study while situating the results in the larger context of literature related to the topic.

3.5.2 Semi-Structured Interview Technique

This research utilized McCracken's long interview approach for semi-structured interviews. This approach was selected for the following five reasons:

1. It allows for the analysis of multiple complex issues, and their interrelated connections;
2. It provides a clear set of 'steps of inquiry' (described below);
3. It relies on literature review to build on existing theories while continuing to explore new emergent themes and ideas;
4. It prompts thorough investigative efforts with fewer interviewees rather than exhaustive superficial interviews with many participants. Given the limited expertise related to the integration of energy considerations within land use planning, it provided the opportunity for in-depth discussions with a limited number of professionals with extensive knowledge related to study; and
5. It encourages intensive research rather than extensive research. McCracken suggests that the intensive nature of the research provides "an opportunity to glimpse the complicated character, organization and logic of culture" (1988, p. 17).

McCracken specifies a four step method of qualitative inquiry for the long interview approach, described in greater detail below (1988, p.30):

1. Literature review;
2. Preparation of the investigator as an instrument of inquiry;
3. Questionnaire construction and interview procedure; and
4. Discovery of analytic categories and write-up.

Literature review

In order to familiarize the researcher with related existing scholarship, identify existing gaps in the literature, and formulate research questions, McCracken suggests a comprehensive literature review as the initial step in the long interview approach (1988). The review provides a benchmark of expectations with which to compare interview findings where divergence may mark new themes, theories or understanding for the field of study. Additionally, the literature review is critical for the formulation of interview questions (McCracken, 1988).

Preparation of the investigator as an instrument of inquiry

McCracken's approach to long interviews requires the preparation of the investigator as an instrument of inquiry, given the strong reliance on the individual investigator to understand and respond to emergent data throughout the research process (1988). The researcher must reflect on their own experiences with the study issue to identify themes, categories or other issues not identified in the literature review process, with the intention of formulating questions to further probe the issues. It provides the opportunity to identify, understand and minimize any individual biases that may appear in the interview procedure through neutral prompts and open-ended questions. This stage also allows the researcher ensure that the interview process will minimize reactive bias. Palys defines reactive bias as unintentional cues given off by the researcher that may influence the nature of the interviewee's responses

(1997). Palys recommends incorporating neutral prompters in the interview questionnaire is one strategy to minimize response bias.

My previous internship experience at the Canadian Urban Institute provided an initial foundation of knowledge to draw upon. While this learned understanding of planning and community energy initiatives served as a catalyst for this research, it also exposed the study to potential bias in my analysis. As Palys suggests, I mitigated potential bias by testing my questionnaire with planning colleagues to screen for leading questions (1997). The open-ended question structured allowed for the discovery of emergent issues.

Questionnaire construction and interview procedure

The interview questionnaire should commence with biographical questions, transitioning to open-ended questions that concentrate on the issue of study (McCracken, 1988). The biographical information collected provides the researcher with a consistent compilation of data across all participants, which can be useful during analysis. This information may also provide telling insights into the interviewee's approach to the issue or worldview (McCracken, 1988). Additionally, biographical questions may serve to develop a rapport with the interviewee before proceeding to more challenging questions. As the interview transitions to more open-ended questions, respondents should be encouraged to share their insights without over specifying the substance or perspective of the research (McCracken, 1988). The open-ended nature of questions allows for neutral prompts and opportunities for the interviewee to elaborate on answers.

The interview questionnaire prepared for this study provided a structure for the interview (found in the Appendix). Given the range of professional experience and familiarity with the topic of study, some of the questions were not applicable to all interviewees, and some of the interview questionnaires required tailoring to ensure relevancy. As I became more familiar with the subject, some of the questions evolved allowing deeper exploration of emergent themes and phenomenon.

Discovery of analytic categories and write-up

The interview questionnaire was developed and structured to reveal emergent themes and issues, and to allow for the analytic categorization of interviewees responses. The following section provides more discussion on the key informant interview analysis process, and details the analytic categories that materialized through data analysis.

3.5.3 Key Informant Interview Analysis

Interview data was qualitatively evaluated through a thematic analysis. Huberman & Miles (2002) describe the process of thematic analysis as involving familiarization, identification of a thematic framework, indexing and charting, and interpretation.

Prior to interview data analysis, the researcher must become familiar with the broader scope of the data, noting the variety and depth of interview content (Huberman & Miles, 2002). The researcher conducted all of the interviews first-hand which translated into greater familiarity with the content of each interview. Additionally, as each interview was recorded, the researcher was able to re-listen to the discussions and form initial impressions about the emergent themes of each interview.

The familiarization process allowed the researcher to take notes on the emergent themes discussed in the interviews. Further review of these notes prompted the researcher to identify a thematic framework for evaluation through the detection of key themes, concepts and issues (Huberman & Miles, 2002). Table 6 provides a summary of the analytic categories contained within the thematic framework for interview data analysis.

Table 6: Analytic Thematic Framework – Themes and Concepts

Benefits of district energy	Challenges to district energy system development
Energy autonomy and system resilience	Municipal planning policy and regulations
Flexibility and the role of alternative fuels and technologies	Provincial policy and regulations
Urban growth centres and land use planning	Local economic development
System efficiency	Business cases and economic feasibility
Financing and ownership models	Future growth and trends in the energy sector
Customer attraction	Primers for district energy development
Community energy plans	Community consultation and education

The themes and concepts that emerged from the interview data analysis were indexed in accordance with the interviewee's initial categorization listed in Table 6. The researcher utilized the process of charting where data was taken from the original interview context and rearranged according to the appropriate thematic reference (Huberman & Miles, 2002). The process of charting helped to create a broader picture of the data in its entirety by capturing the range of responses under each theme or concept.

Finally, after indexing and charting all of the data in accordance with the thematic index, the data was interpreted as a whole to highlight similarities and differences in personal experiences. Chapters 5 and 6 provide discussion and conclusions on the results of the data analysis.

3.6 Ethics Approval

This study received clearance from the University of Waterloo's Office of Research Ethics on May 25, 2011. All of the study participants were provided with a package that contained an information letter and consent form. A copy of the ethics approval, information letter and consent form can be found in the Appendix.

Chapter 4 Case Study Overview

4.1 Markham District Energy Incorporated, Markham, Ontario

The Town of Markham is a suburban community located north of Toronto in York Region, and is one of Canada's fastest growing municipalities. As of 2009, Markham had a population of 303,000 with forecasts projecting growth to 386,000 residents by 2021, and increasing to 421,600 by 2031 (Town of Markham, 2011). Population projections are in keeping with the growth schedule presented in the 2006 Growth Plan for the Greater Golden Horseshoe which stipulates that the urban growth centres of Markham Centre and Langstaff are to achieve a combined 200 residents and jobs per hectare (Ontario, 2006). Currently Markham Centre is achieving an approximate density of 230 residents and jobs per hectare (MS 2, 2011). This calculation includes valley lands where development is prohibited. Proposed development in the Langstaff growth centre will see densities approaching an astonishing 800 persons and jobs per hectare if the market can support it (MS 2, 2011).

Table 7: Markham Projected Residents, Jobs and Housing Mix, 2031

	2009	2031
Residents	303,000	421,600
Dwelling Units	88,000	153,000
Housing Mix	100%	100%
Singles	55%	39%
Semis/Townhouses	32%	29%
Condominiums/Apartments	13%	32%
Jobs	160,000	240,400

(Town of Markham, 2011)

Markham has experienced rapid post-war growth attributed in part to access to relatively inexpensive greenfields conducive to development and access to inexpensive fuel (MS 2, 2011). This has attracted new residential, commercial and industrial developments to the Town. As a result, Markham's residential and employment lands have sprawled outwards. Continual development pressures, rising energy costs and community concern over air quality are all jeopardizing the Town's ability to facilitate continual growth while supporting the long-term sustainability objectives of the community. Fortunately, Markham has taken some pro-active steps to focus intensification and improve environmental performance including the development of municipally owned district energy system.

4.1.1 Municipal Planning

4.1.2 2005 Official Plan

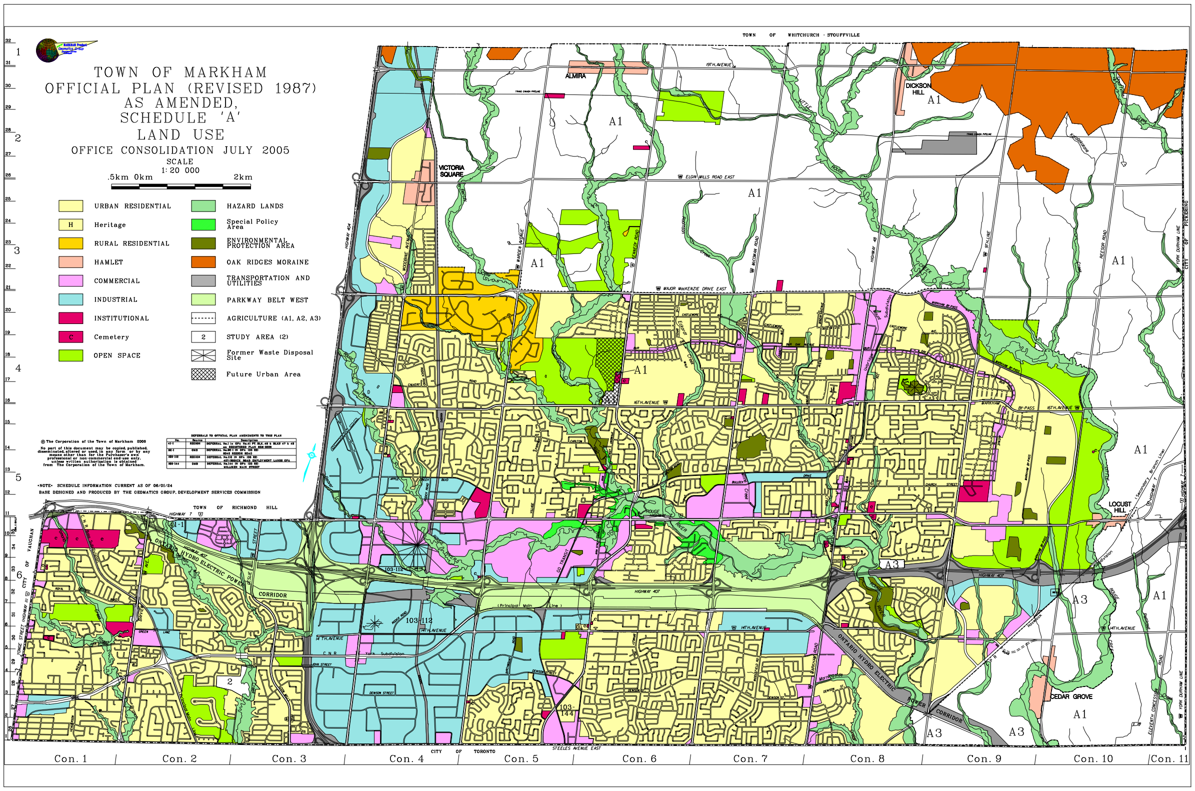
Predominantly suburban communities like Markham face different challenges than older urban centres. While many larger cities already contain the density, variety of uses and compact urban form conducive to district energy, typical suburban developments are restricted by monotype zoning, sprawling form and hampered by much lower densities. Therefore, the task of communities like the Town of Markham isn't to capitalize on existing development, but rather, to plan places with new potential.

The Town's current Official Plan (OP) was adopted in 2005 and serves as a statutory document to specify land uses, guide future development and direct growth. The (OP) includes forty-six Secondary Plans providing more specific land use polices for various neighbourhoods and districts in Markham as shown in Schedule B Figure 7. In its current form, Markham's OP gives some consideration to energy efficient land use patterns with prescriptions for compact urban form, but stops short of referencing the Town's district energy system. Section 3.14.2, identifies *Goals and Objectives* related to identifying the lands shown on Schedule 'A' – 'LAND USE as future urban area. Specifically, the *Official Plan* calls to:

d) Maximize the efficiency of the development and delivery of urban infrastructure and other services by promoting a more compact urban form which also increases the viability of public transit and ***is more energy efficient*** *(emphasis added).*

Outside of this specific sub-section, no additional reference is given to 'energy' in the OP

Figure 6: Schedule A Town of Markham Land Use



Source: *(Town of Markham Official Plan, 2011).*

As mandated by the Planning Act, an OP must be reviewed every five years to reflect current development patterns, projected growth trends and other municipal initiatives (Ontario, 2011). As of spring 2011, Markham municipal staff are developing a new OP, with the intention of releasing a draft by the end of the year (MS 2, 2011). The new OP is required to conform with Provincial policies, the York Regional Official Plan and contain a land use manifestation of the principles outlined in the newly adopted GreenPrint Plan. Intensification will be encouraged along transit corridors and in the urban growth centres specified by the Province. Additionally, the new OP will be crafted to reflect and emphasize the priorities of local council.

As part of the OP review process, Markham has outlined strategic objectives to guide the development of the new OP (Town of Markham, Markham's New Official Plan Towards a Sustainable Community, 2011). The strategic objectives inadvertently speak to planning principles conducive to district energy systems and call for efficient, green infrastructure. Specifically, the new OP intends to

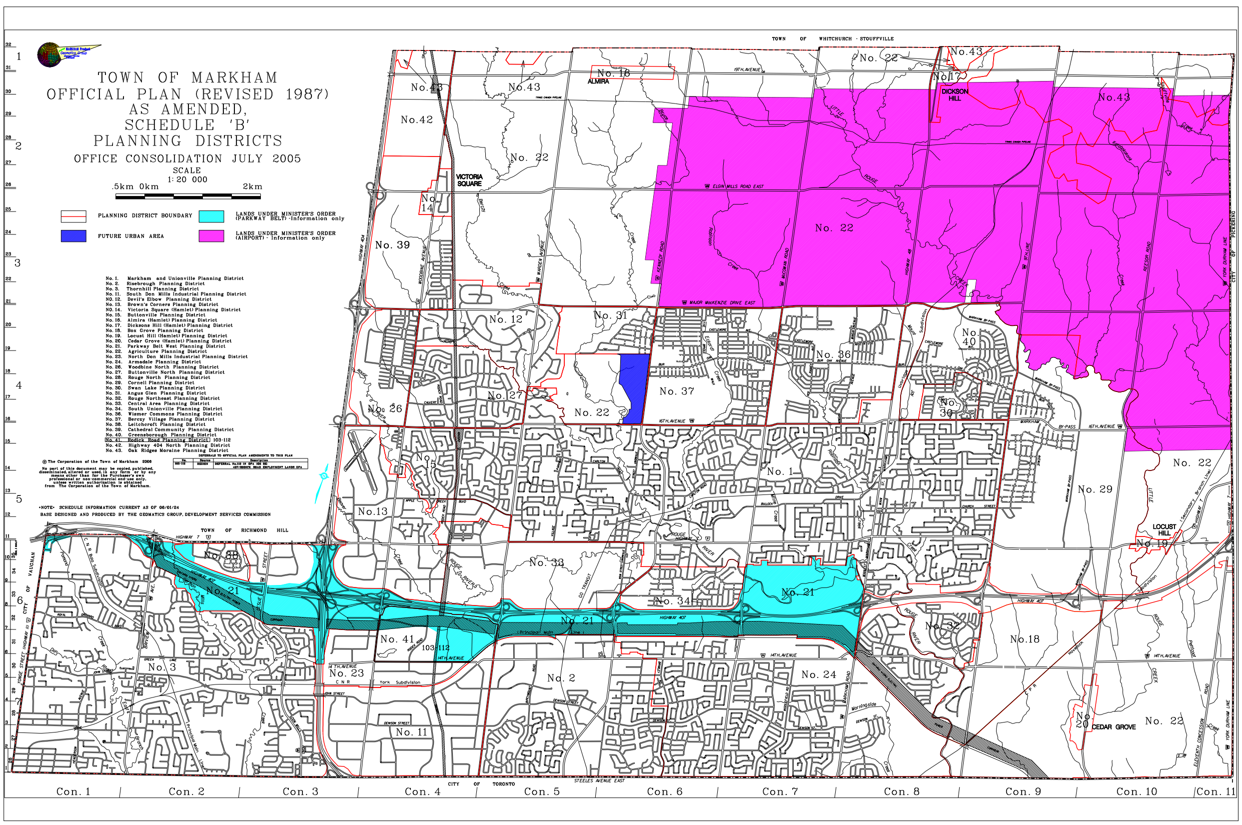
"Develop sustainable, compact and complete communities incorporating healthy active living, excellence in community design, efficient infrastructure…." and "increase adaptability in the community through green infrastructure (water, waste, energy), innovative technology, resource conservation and other sustainable practices to address long term climate change impacts" (Town of Markham, Markham's New Official Plan Towards a Sustainable Community, 2011 pg. 5).

Additionally, Markham's OP review process emphasizes the importance of building sustainable communities. In doing so, planning will support district energy development by "intensifying and improving the mix of new development and directing it to designated centres and corridors" and "ensuring that communities provide for complete community design… energy conservation and renewable technologies…" (Town of Markham, Markham's New Official Plan Towards a Sustainable Community, 2011 pg. 12, 13).

Markham is directing the anticipated residential and employment growth towards higher density urban centres: Markham Centre and Langstaff growth centres as indicated in the Growth Plan and Cornell Centre (Markham East) which planning staff refer to as a *Key Development Area* (MS 2, 2011). The Key Development Areas are targeted for intensification and generally have a land use relationship with Yonge Street, the Highway 7 Corridor or significant transit opportunities like GO Transit or planned higher order transit along Steeles Avenue (MS 2, 2011). Cornell's secondary plan was updated and adopted three years ago and planning staff are now completing a precinct plan for Cornell Centre to identify priorities and objectives on a block-by-block basis. All three of these Key Development Areas will offer a mixing of land uses, higher density and compact urban form with thermal energy requirements serviced by Markham District Energy (MDE) (SM 1, 2011).

Markham Centre was the Town’s first higher density urban centre to receive district energy. The plans call for sustainable, transit-supportive and attractive developments to accommodate approximately 25,000 residents and provide for 17,000 jobs (Town of Markham, N.D.). Community energy was considered very early on in the planning process, nearly a decade prior to the district energy system achieving operational status. However, interviews revealed that this initiative came from outside of the planning department.

Figure: 7 Schedule B Town of Markham Planning Districts



Source: *(Town of Markham Official Plan, 2011).*

4.1.3 Markham Centre Performance Measures Checklist

The primarily greenfield development of Markham Centre presented a unique opportunity for the municipality to create an intensified downtown. In May of 2002, the Markham Centre Advisory set out to develop and draft a Performance Measures document with the intention of guiding and monitoring new development in Markham Centre, and ensuring new projects meet the broader community's goals and expectations for sustainable development (Town of Markham, Performance Measures Doc, 01/02/2011) . The resulting *Performance Measures Checklist* is in accordance with Markham Centre's 11 guiding principles and categorizes evaluative metrics into five groups: Greenlands, Transportation, Built Form, Green Infrastructure and Public Spaces.

In March 2003, Council adopted Official Plan Amendment 101 to formally incorporate the 11 Guiding Development Principles that articulate the Town's goals and objectives for the development of Markham Centre, into the Markham Centre Secondary Plan, through Official Plan Amendment 21 (OPA 21) (Town of Markham, Performance Measures Doc, 01/02/2011). Additionally, the Performance Measures Checklists was adopted as an appendix to OPA 21 to provide direction to stakeholders interested in the development of Markham Centre, serving as a consistent and transparent assessment tool for proposal evaluations.

All developments in the Markham Centre are required to complete and submit a Performance Measures Checklist as part of the development application process. The checklist is comprised of 60 performance metrics designed to assess the inherent sustainability of each development and challenge stakeholders to provide better community solutions. Within the checklist, *Built Form Item #11* inquires "Does the building design support the Town of Markham Energy Strategy?" (pg.2). By posing this question, the developer is obligated to consider the district energy system available in Markham Centre as a tool to accomplish performance measure objectives. Applicants will enter into discussions regarding thermal energy service with MDE where a competitive offer is negotiated (SM 1, 2011). Once all parties agree on a tentative service arrangement, a memorandum of understanding (MOU) is drafted in which the necessary infrastructure is required for building permit approval (SM 1, 2011). "When (the developer) returns to the City and declares they are doing district energy, it becomes part of their development conditions for approval just like permitted height, bike rack requirements, park space or anything else; it becomes hard-wired" (SM 1, 2011)

The Markham Centre Development Checklist connects planning decision making with the broader vision for Markham Centre, and focuses on key criteria to promote best practice solutions. By explicitly requiring developers to consider the Town of Markham's Energy Strategy, the municipality encourages higher environmental and efficiency performance. Connection to MDE provides applicants with a means to accomplish these objectives.

4.1.4 Energy Planning Initiatives in the Town of Markham

The Town of Markham has a number of programs and initiatives that support the improved performance of energy efficiency and reduction of GHGs in corporate operations and across the community.

4.1.5 Markham Energy Conservation Office

In 2005, the Markham Energy Conservation Office was established through the Markham Sustainability Office, and is charged with the task of creating and facilitating programs to improve the energy performance of the municipality while encouraging energy conservation amongst community members and local business. The Markham Sustainability Office is housed in the Chief Administrative Officer's (CAO) office, championing sustainability initiatives throughout the municipality and the community. By conducting operations out of the CAO's office, the Markham Sustainability Office benefits from perspectives needed to align efforts with the strategic goals of the municipality and the flexibility to equally disseminate information amongst all departments. With that being said, the ultimate goal is to dissolve the Sustainability Office once its guiding principles have been disseminated and peculated throughout all aspects of the municipality and ingrained into daily-decision making.

4.1.6 Greenprint Sustainability Plan

Over the past two years, input from residents, community groups and local businesses have assisted municipal staff in developing Markham's Greenprint Sustainability Plan, which was formerly adopted by council in June 2011. The document embodies the Town's vision and priorities for a sustainable future and will satisfy the funding agreement for the Federal Gas Tax fund, between the Federal government and municipalities, requiring the development of an Integrated Community Sustainability Plan (ICSP) (Town of Markham, 2011). The data collection process commenced in 2008, followed by the outlining of goals, targets and strategies, consolidated into a draft plan released publically for review and comment in June 2010. Drafting of the document came from a large commission including Markham's CAO, the municipal senior management team and city staff (MS 1, 2011). Significant public consultation was conducted with community members and local businesses as well as 'in-reach' with every municipal department's director and managerial staff.

One of the key strategies within the Greenprint is to achieve net-zero energy, water, waste and emissions by 2050. District energy plays an important role in achieving net-zero energy because it is represents a localized solution for thermal energy production and power generation in the case of MDE's CHP plant (MS 1, 2011). A transition towards renewable fuel sources like biomass and biogas will be required, but district energy provides a flexible platform to make this transition.

Another important action item embedded in the Greenprint is a call for the development of an Energy Descent Action Plan (EDAP) to reduce GHG emissions from buildings, transportation, waste and agriculture. The EDAP would take a robust look at energy supply and provide descent analysis for creative adaptations in the realms of the economy, health and education sectors (Town of Markham, 2010). Currently, Markham spends almost $6.5 million on energy (district energy, natural gas, electricity and fuel) annually, a significant portion of the $100 million operations budget (MS 1, 2011). As the municipality strives to position itself to develop and implement an EDAP, a better understanding of energy consumption is required in order to capitalize on opportunities for conservation and reduction. One of the next steps will be to develop a baseline of energy consumption for the corporate operations and broader community through metering and monitoring (MS 1, 2011).

The Greenprint establishes a number of evaluative metrics to determine environmental performance baselines and provide evolving evaluation. The report acknowledges that "communities have significant control over local land use, transportation patterns, building energy use and solid waste disposal, which are all significant contributors to greehouse gas emissions" (Greentprint, 114). The municipality recognizes that a reduction in GHGs and air pollutants will come from the widespread adoption of renewable energy sources. Adding a localized component to energy production will increase the community's resilience by providing a flexible platform to adapt to unknown futures.

4.1.6.1 Emissions by Sector

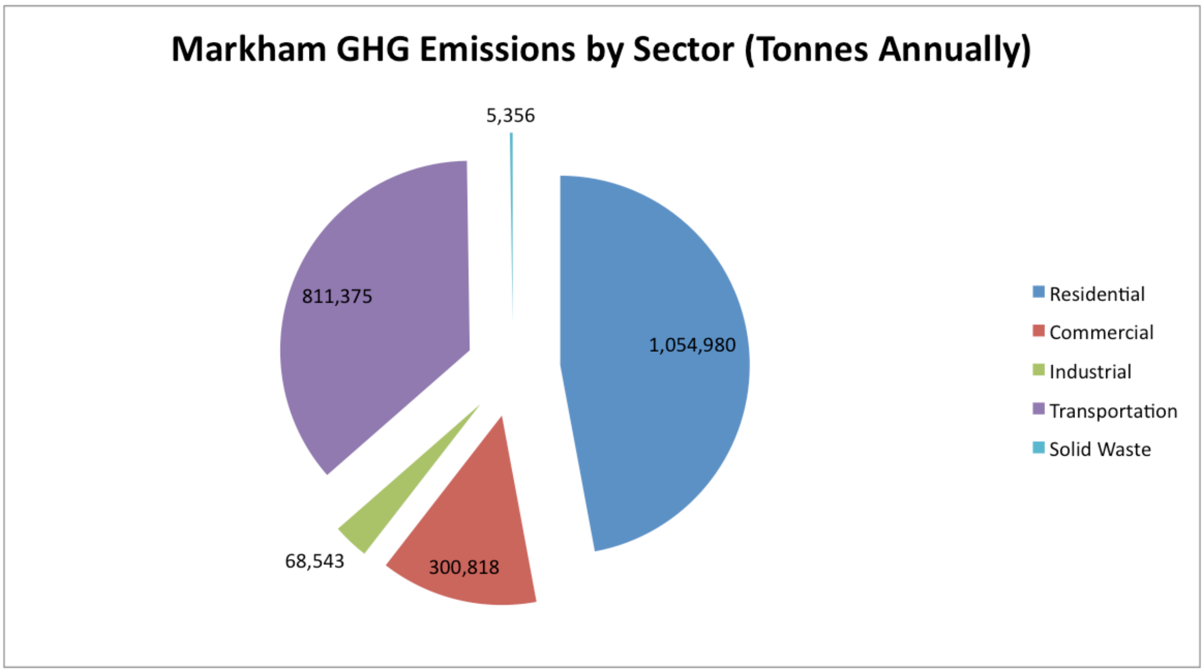
A comprehensive understanding of emissions produced by each sector will prompt the development of directed mitigation and reduction strategies. As shown in Figure 8, residential and commercial sectors account for 61 percent of sectoral GHG emissions, highlighting the significant opportunity for reduction, potentially in part through renewable district energy development (*Town of Markham Greenhouse Gas Emissions Inventory and Local Action Plan for Emission Reductions, Final Report Oct. 6, 2008, ICLEI Canada, 17).*

Table 8: Markham Greenhouse Gas Emission by Sector

Sector	GHGs Emissions (tonnes)	GHGs (%)
Residential	1,054,980	48%
Commercial	300,818	13%
Industrial	68,543	3%
Transportation	811,375	36%
Solid Waste	5,356	0%
Total	2,241,070	100%

Source: (*Town of Markham Greenhouse Gas Emissions Inventory and Local Action Plan for Emission Reductions, Final Report Oct. 6, 2008, ICLEI Canada, 17).*

Figure 8: Markham GHG Emissions by Sector (Tonnes Annually)



(*Town of Markham Greenhouse Gas Emissions Inventory and Local Action Plan for Emission Reductions, Final Report Oct. 6, 2008, ICLEI Canada, 17).*

4.1.6.2 Energy Consumption by Fuel Source

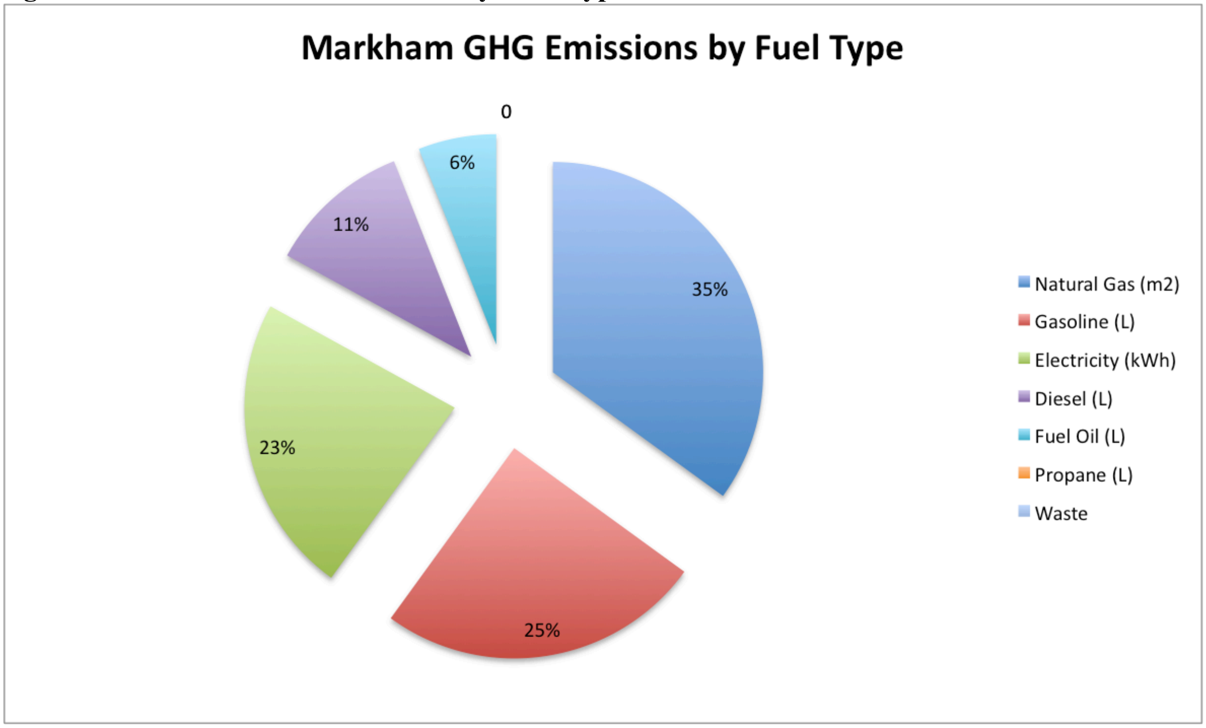
Energy fuel source determines the amount of GHG emissions produced. Monitoring and evaluating the GHG emissions of each fuel source will direct mitigation measures. The *Town of Markham Greenhouse Gas Emissions Inventory and Local Action Plan* for Emission Reductions indicates that gasoline for transportation uses in conjunction with natural gas for thermal conditioning and industrial processes accounts for nearly 70% of local emissions. The Greenprint anticipates that gasoline consumption will decrease as private vehicle use declines with community improvements to transportation options. Additionally, "natural gas consumption will decline as buildings become more efficient, are connected to Markham District Energy and as renewable heat sources are developed" (Greenprint, 2011 pg. 117). In order to accomplish the Greenprint's objective of netzero energy, the Town's district energy system will require alternative fuel sources to natural gas (MS 1, 2011). Table 9 depicts the Town's energy use by fuel type. Figure 9 depicts the Town's GHG emissions by fuel type.

Table 9: Markham Energy Type and Use

Energy Type and Unit	Annual Use	GHGs (tonnes)	GHGs (%)
Natural Gas (m^2)	413,643,910	777,680	35%
Gasoline (L)	234,251,200	553,280	25%
Electricity (kWh)	1,965,962,00	519,010	23%
Diesel (L)	92,287,120	252,000	11%
Fuel Oil (L)	45,104,870	127,650	6%
Propane (L)	3,986,880	6,100	<1%
Waste	n/a	5,360	<1%
Total	-	2,241,070	100%

Source: (*Town of Markham Greenhouse Gas Emissions Inventory and Local Action Plan for Emission Reductions, Final Report Oct. 6, 2008, ICLEICanada, 17*

Figure 9: Markham GHG Emissions by Fuel Type



Source: (*Town of Markham Greenhouse Gas Emissions Inventory and Local Action Plan for Emission Reductions, Final Report Oct. 6, 2008, ICLEI Canada, 17).*

4.1.6.3 Dollars Spent on Energy Expenditures and Potential Revenue

Increased consumption of traditional non-renewable fuel sources is expected to drive the price of fuel upwards. In the case of Markham, dollars spent on energy could rise to $330 billion annually, based on 150,000 households with a $2,400 annual energy expenditure (Greenprint, 2011). The Greenprint states "understanding total energy costs facilitates the development of business cases need for developing localized energy production" (pg. 118). Additionally, metrics must be developed to quantify the potential revenue generated through localized energy production. Maximizing this potential is critical to making the business case for local energy infrastructure investment.

4.1.7 Integrated Sustainability Plans as a Municipal Requirement

The Greenprint Plan serves as an over-arching document to integrate Markham municipal planning and decision making with the community vision for sustainability over the next 50 to 100 years. It aligns objectives of the Official Plan, the Diversity Action Plan, the Growth Management Strategy, the Integrated Leisure Master Plan, the Transportation Master Plan and the Vision 2020 Economic Development Strategy with Markham's sustainability agenda. This integration breaks down silos that often exist between various municipal departments and unifies sustainability objectives.

In the 2005 budget, the federal Government of Canada created the New Deal for Cities and Communities to provide dedicated funding to municipalities for green infrastructure projects. The New Deal distributes revenue generated from the Gas Tax Fund for sustainable asset investment. As a condition of funding, municipalities must create an Integrated Community Sustainability Plan (ICSP) to direct and prioritize a green vision as specified in Schedule G of the Gas Tax funding agreement.

4.2 District Energy Systems in Markham

Markham District Energy (MDE) was created in 1999 and achieved operational status December 1, 2000 at 3:00pm. The company was developed to build a thermal energy grid to serve the emerging planned community of Markham Centre, approximately 1000 acres bordered by Warden Avenue, Kennedy Road, Highway 7 and Highway 407 (SM 1, 2011). Initially, three buildings provided an anchor customer based of 90,000m^2 floor area connected to the first system plant with 3 MW of CHP electricity capacity. Today, three plants in Markham Centre provide heating and cooling thermal energy to thirty different commercial, institutional, residential and public buildings complemented by 8.5 MW of CHP electricity capacity. An additional 2.5MW will be added to the system shortly, bringing the total CHP electricity capacity to 11MW. At full build out, the Markham Centre district energy system will supply thermal energy to 150 buildings with a CHP electricity capacity of 30MW connected to the grid.

4.2.1 The Birth of District Energy in Markham

The development and implementation of district energy in the Town of Markham was the product of three catalyst events during the late 1990's and characterized by three different storylines. First, the ice storm in 1998 that left many municipalities in Ontario and Québec without power illustrated how vulnerable communities can be to the effects of storms and blackouts through their dependence on centralized power grids. At the time, Mayor Don Cousens wanted to ensure Markham had a resilient energy system for the community's thermal and electrical requirements in case of a catastrophic event (SM 1, 2011). Council began to investigate European models of district heating supplemented by CHP capacity as a way of delivering life-supporting heat and power in the face of crisis. Subsequent studies suggested that the district energy model would be viable in Markham Centre. The outcome of an inquiry into energy security and reliability has been Markham's added capacity to initiate emergency procedures through MDE. The emergency procedures effectively dedicate 8.5 MW of supply power to the Civic Centre, YMCA, and two schools, providing power and thermal conditioning to millions of square feet for shelter and critical services.

The second key storyline pivotal to the development of district energy in Markham emphasizes thermal energy systems as catalysts for economic development. IBM, manufacturer of computer hardware and software, had established itself as Markham's largest employer when the company began to investigate opportunities for the development of a new 24 hour-a-day software laboratory to house an additional 3,000 employees (SM 1, 2011). Competition to land the new IBM facility spanned the globe with strong bids from many locations in North America, Ireland and countries of the former Soviet Union (CU 1, 2011). Once again, Mayor Don Cousens took a leadership role to position the Town of Markham as a leader in attracting technology businesses by exploring ways to secure a competitive advantage.

Technology businesses have key requirements related to thermal energy reliability, redundancy and system scalability. Mayor Cousens recognized this and approached IBM with the idea of developing a district energy system to address these specific requirements. IBM undertook a business case analysis to determine if outsourcing their thermal requirements to MDE was financially prudent. The key benefits that emerged were the secure source of thermal conditioning required for continuous high-tech operations, the flexibility in infrastructure associated with increased electrical demand and the avoided expenses of constructing an on-site utility plant (CU 1, 2011). Ultimately, IBM decided to build the new software laboratory and take advantage of Markham's district energy offering.

Many considerations were taken into account when siting the new location for IBM's software laboratory including talent attraction (over half of the employees at the Markham facility have PhDs), taxation advantages and research and development opportunities. District energy was not the definitive factor that placed the new facility in Markham, but IBM did see it as a benefit and provided Markham with a distinguishing competitive advantage.

After installation and in more than ten years since the district energy system came online, IBM has found that the adoption of district energy was a very good decision for their development. At the time of construction, power demands for a data centre or software laboratory were approximately 15 or 20 watts per square foot (CU 1, 2011). Today, the same facility demands up to 200 watts per square foot. If IBM had constructed its own utility plant, it would have been very difficult and expensive to accommodate this power demand increase. As a result, the scalability to the power demand curve was revealed to be a more substantial benefit than originally identified in IBM's business case assessment.

Another benefit that was noted included the ability to focus management resources on designated tasks affiliated with leadership positions. If IBM had pursued and developed their own utilities plant, it would have required human resources to maintain, budget for and manage the facility. This would come at enormous financial costs and contribute to a loss in productivity for IBM's senior management team (CU 1, 2011). By offloading this responsibility to MDE, departmental management did not require report writing and the preparation of presentations to secure funding for utilities management from the operations budget, allowing the financial resources to be spent elsewhere. As one interviewee described

"Overtime, as it developed and installed, the real benefits of DE became much more evident, and it turned out to be a more positive and bigger thing for IBM than the original business case suggested" (CU 1, 2011).

The final contributing factor to the development of MDE was a shift in provincial and municipal policy related to planning density and electricity procurement. Smart growth principles, which advocate for denser, compact urban form, were taking hold in Markham and provided the initial foundation for the planned development of Markham Centre. By concentrating densities and mixing permitted uses, the plans for urban form took a shape conducive to the successful development of district energy. At the provincial level, an amendment to the Ontario *Electricity Act* in 1999 allowed municipalities to make investments in energy-related businesses energy. This legislative change prompted the Town of Markham to create Markham District Energy through its holding company, Markham Enterprise Corporation.

4.2.2 Ownership Model

Markham District Energy (MDE) is a wholly-owned subsidiary of Markham Enterprise Corporation, with sole shareholder interest held by the Town of Markham (Figure 10). The MDE Board of Directors comprises of the Mayor, Town Councilors, and local business leaders. Dedicated corporate and plant management staff guide MDE operations independently from municipal staff, however a coordinated approach to district energy utility operations is required between MDE and the Town. Currently, MDE employees 13 full-time staff members, with 5 employees working in the main office and 8 system operators (SM 1, 2011)

Figure 10: MDE Ownership Structure

4.2.3 System Development

After securing the first anchor customer in 2000, MDE developed and constructed the first of four planned plants in Markham Center. The MDE system utilizes natural gas fired cogeneration plants to provide heating, cooling and electricity services to customers connected to the local grid. Additional customer base and increasing load demand in Markham Centre required the construction of a second plant facility in 2007. The third plant in Markham East (Cornell Centre) is currently under construction, expecting to achieve operational status in 2012. The proposed fourth plant system has been designed to grow with the community, bringing on new production facilities as required by increased thermal energy demand in the urban centres.

Markham Centre is currently under construction and is approximately one-quarter developed to full build-out, with anticipated completion in 20-30 years. All of the buildings constructed in Markham Centre thus far, have connected to the district energy system with long-term service contracts. In total, approximately 500,000 m2 of customer floor area will be serviced by the district energy plants, including two school and community buildings, six commercial buildings, fourteen residential high-rise buildings and 175 town-houses (Compass Resource Management, 2010). At present, the system is serving roughly 70, 000m^2 of residential and 120,000m^2 of commercial floor area. After full build out, the district energy system in Markham Centre will provide a CO2 reduction of 99,236 tonnes annually. This represents a fifty percent reduction over business-as-usual CO2 emissions and a 198 tonnes or seventy-eight percent reduction of NOx emssions (NRCan, 2009a). In the future, additional reductions in emissions associated with the district energy system may be realized with the adoption of alternative fuel sources and or improvements to efficiency through the development of additional CHP and thermal storage. The continual development of MDE is strongly linked to the Town's vision for a sustainable Markham Centre community as indicated in the Greenplan.

4.2.4 Technical Overview

The MDE system is comprised of heating, cooling and power generation equipment. Thermal energy is distributed through a 20km distribution-piping network. Heating and cooling requires two sets of underground pipe for supply and return. The heating equipment consists of three natural gas fired boilers with a total production capacity of 12MWt. The cogeneration equipment consists of 8.3MW of reciprocating natural gas-fired engine capacity. The exhaust and jacket heat expelled from the electrical generation equipment is captured and fed into the district energy grid, providing an additional 8MWt of thermal production. Four centrifugal chillers and one absorption chiller provides cooling capabilities, with a total combined production capacity of 4,600 tonnes. The absorption chiller utilizes waste heat from the combined heat and power (CHP) units during the summer and shoulder season electricity generation to provide cooling for local customers.

When thermal energy arrives at individual customer's buildings via the distribution piping system (primary side) it must pass through an energy transfer station (ETS) to the in-building distribution system (secondary side). The ETS allows customers to avoid capital costs associated with on-site hot water boilers or chillers because all of the baseload and peak equipment in centrally located in the MDE facility.

MDE recently installed a large thermal energy storage (TES) tank to avoid unnecessary natural gas consumption for heating equipment, further reducing GHG emissions. The CHP engines fire during the day to insure peak pricing for electricity output. Waste heat from the CHP equipment is captured and stored during the day in the TES tank for use in the evening when heating demand increases (Compass Resource Management, 2010).

4.2.5 Financial Overview

The total initial capital cost of the MDE plant was $16 million in 2000. Early growth saw a higher than anticipated increase in demand prompting rapid expansion. Municipalities have a number of financing tools available to transform their communities through capital infrastructure investment. MDE has received two rounds of funding from the Federation of Canadian Municipalities (FCM) Green Fund for capital expenditures. The first round of FCM funding came in 2004, directing $5 million towards MDE capital projects. Of the initial $5 million in funding, $1.5 million was a grant and the balance was received as a long term, low interest loan (SM 1, 2011). In 2008, MDE successfully applied for a second round of FCM funding to help finance a $15 million capital program system expansion, for which MDE received another $3.5 million long term, low-interest loan. In 2007, MDE and the OPA entered into a 20-year power purchasing agreement for a 5MWe CHP plant that provides 5MWt to the district energy system. Additionally, the Provincial government has supplied low interest capital loans through the infrastructure Ontario loan program (SM 1, 2011).

The 2005 New Deal for Cities and Communities distributes the federal gas tax revenue to help support eligible environmentally sustainable infrastructure investments in Canadian municipalities. Under the program, community energy systems like MDE are eligible for project funding. As a result, the Town of Markham allocates half of the gas tax grant funding towards district energy infrastructure.

4.2.6 Rate Structures

From the customer's perspective, MDE supplies heating and cooling to their buildings. If they had opted not to subscribe to MDE services, their buildings would have probably required natural gas fired boilers and a chiller plant powered by electricity. Customers are secured through negotiated contracts with rate structures that are split into the two or three components described below:

1. Variable Energy Charges (VEC) calculate the average cost of heating energy required by each customer in a business-as-usual, in-building heating system. The calculation is based on each customer's monthly metered consumption of thermal energy and converted to notional gas and electricity input volumes based on contractually agreed BAU efficiencies through current gas and electricity utility rate schedules. Each independent building has a unique energy demand profile and as a result, energy rates vary on a case-by-case basis. Typically, MDE contracts are signed on a virtual efficiency between 68 – 74 percent efficiency, had the building operated its own thermal energy system (MS 1, 2011).

2. The Fixed Capacity Charge (FCC) represents the customer's avoided operation and maintenance cost plus annualized capital. This includes the costs associated with a business-as-usual thermal energy approach such as equipment, engineering consulting fees for servicing and structural

supports, stacks, electrical and natural gas servicing, going on maintenance contracts, risks of ownership and replacement reserves.

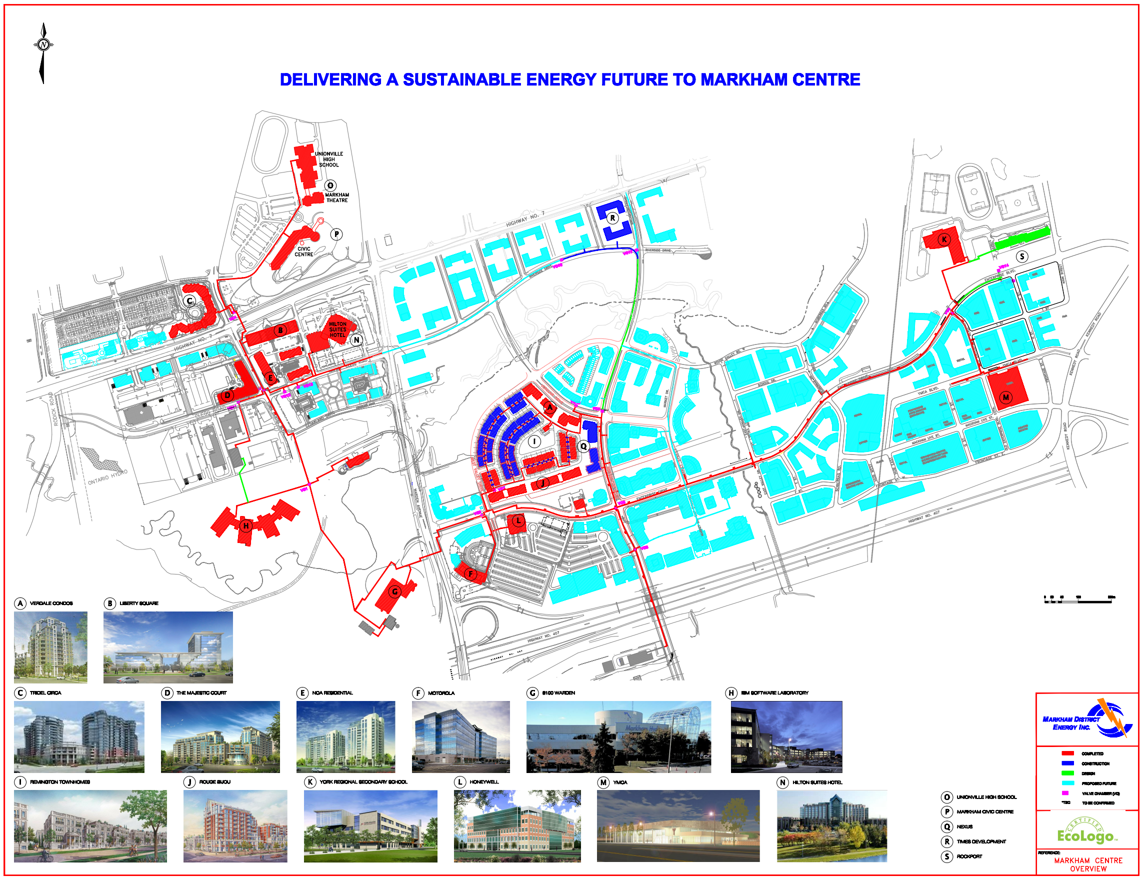
3. In some cases, a separate connection charge is levied for institutions that do not place value on the avoided capital costs of connection. This connection charge manifests itself as a separate fee rather than being embedded within the FCC.

Rates vary building to building due to different demand profiles, requirement of capacity and estimated equipment efficiencies.

4.2.7 Institutional Overview

MDE operates as a for-profit corporation whose sole shareholder is the municipality of the Town of Markham. As a municipal subsidiary, the corporation can take advantage of loans and grants only available to municipalities. Additionally, MDE benefits from municipal interest in expedited development approval processes, rights of way and building scale connection. Site plan and building approvals are still required, but MDE has located plants on municipally owned lands, avoiding amendments to the official plan and zoning bylaw.

Figure 11: MDE Future Expansion



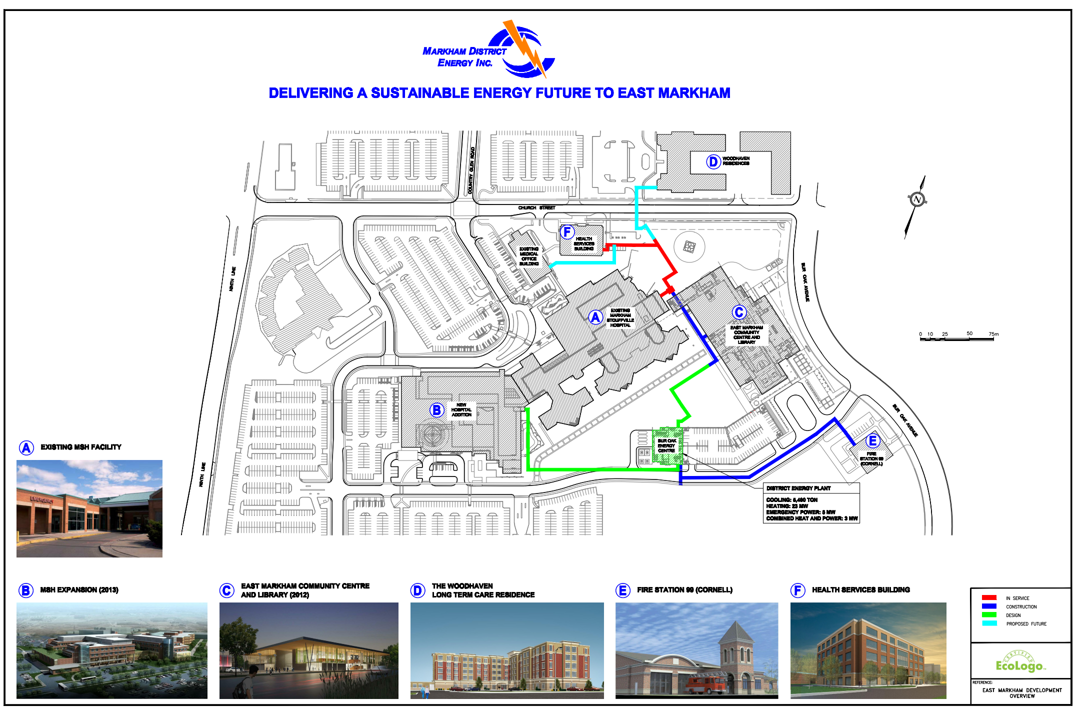
Source: *(Town of Markham Official Plan, 2011).*

4.2.8 Future Expansion

MDE's growth has outpaced initial projections with three of four planned plants having already been constructed in Markham Centre. In 2010, MDE's third plant, the Birchmount Energy Centre was commissioned. Later that year, MDE broke ground on its fourth energy plant, the Bur Oak Enery Centre, the first for the East Markham system. The Bur Oak Energy Centre will provide service to new development on 250 acres of land in the East Markham (Cornell) key development area. The new plant will be initially anchored by the Stouffville Hospital, a firehall, library and community centre, retirement home and heath services building, totaling approximately 1 million square feet of serviced floor area (Figure 11). At build-out, the Bur Oak Energy Centre is projected to service 4 million square feet of floor area (SM 1, 2011).

Two other areas have been sited for MDE development in the future. Markham's Langstaff growth centre located at Highway 7 and Yonge St is expected to be an appropriate location for the third MDE system based on projected densities (Figure 12). This location is scheduled to receive Toronto Transit Commission (TTC) service in approximately 10 years which will act as a catalyst for development (SM 1, 2011). The fourth MDE system may be located in the key development area at the Highway 404 and Buttonville Airport. Given the strong support of MDE from the Town of Markham, it is unlikely that any development application for these areas will be approved without first consulting with MDE about connection (SM 1, 2011).

Figure 12: MDE East Markham Expansion



Source: *(Town of Markham Official Plan, 2011).*

4.3 Hamilton Community Energy, Hamilton, Ontario

The City of Hamilton is located on the eastern shores of Lake Ontario with a population of approximately 540,000 residents. Hamilton's economy is undergoing a transformation from heavy industry dominated by steel manufacturing, to emerging medical, technological and educational sectors. As the economic base reinvents itself, the urban fabric is transforming, increasing Hamilton's regional connectedness. Hamilton's location in the Greater Golden Horseshoe (GGH) situates the City as a major node in the Niagara-Toronto corridor (Florida, 2008).

As a city anticipating growth to 660,000 residents and 300,000 jobs by 2031, Hamilton has a genuine opportunity to ensure long-term energy security for the community through the planning process (Ontario, 2006).

Table 10: Hamilton Projected Residents, Jobs and Housing Mix, 2031

	2011	2031
Residents	540,000	660,000
Dwelling Units	210,000	270,000
Housing Mix	100%	100%
Singles	60%	54%
Semis/Townhouses	12%	17%
Condominiums/Apartments	28%	29%
Jobs	230,000	300,000

(Adapted from Places to Grow 2006 and Hemson Consulting, 2005 – The Growth Outlook for the GGH, 2005)

The industrial smoke stacks that line the City's harbor still garner images of a environmentally tainted past, but Hamilton has taken major steps to improve air quality over the past ten years (Clean Air Hamilton, 2009). The *Clean Air Hamilton* initiative is a group of concerned stakeholders that have emerged to help improve local air quality. Their work has influenced municipal staff and council to pursue the development of thermal distribution systems and local energy generation.

4.3.1 Planning and Policy Context

4.3.1.1 2009 Urban Official Plan

The City of Hamilton is comprised of many communities with a diverse geography and unique history. Hamilton's Official Plan (OP) provides strategic direction for community management, land use policies and physical development for the next thirty years. The policies contained within the document are meant to enable change and provide implementation to the principles expressed in the *Vision 2020* document and strategies outlined in the *GRIDS* document described in following subsections. The 2009 Urban Official Plan is the first adopted OP after the provincially mandated community amalgamation of Ancaster, Dundas, Flamborough, Glanbrook, Hamilton and Stoney Creek in 2001 (Canadian Urban Institute, 2009).

The OP is a single-tier plan that acts as a hybrid between broader regional objectives and specific local implementation policies. As a result, the OP is structured into three distinct volumes to be interpreted as a whole. Volume 1 provides plan context, community vision, city-wide designations and policies. Volume 2 contains neighbourhood level Secondary Plans with community specific guidance for growth. Volume 3 is comprised of Special Policy Areas (SPA) not contained in Secondary Plans and require more specific policies to provide development direction.

Hamilton's OP gives reference and broad consideration to *energy* in the following sections:

Chapter B – Communities

Section B – Communities, contains policies that direct the physical shape of the built, natural, social and cultural environments of the City. Within Section B, subsection B.3.0 *Quality of Life and Complete Communities* directs attention to a number of factors including specific policies directing urban design for the public and private realms.

Section 3.3 Urban Design Policies

The urban design policies intend to “create compact and interconnected, pedestrian-oriented, and transit-supportive communities…” (OP, B.3 pg. 11). This focus on compact, interconnected community development is conducive to the development of district energy systems. The Plan acknowledges that “the design and placement of buildings, infrastructure…and community amenities, as well as how these features are connected and work together” is imperative for a city that is “…successful socially, economically and environmentally” (OP, B.3 pg. 11)

Section 3.3.1 outlines the Urban Design Goals. Subsection 3.3.1.6 states:
“Create places that are adaptable and flexible to accommodate future demographic and environmental changes” (OP, B.3 pg. 11).

Although not explicitly mentioned, the literature review has revealed a general consensus about district energy as a flexible solution for changes in fuel sources and thermal energy requirements. This type of policy is supportive of district energy development.
Subsection 3.3.2 outlines general policies and principles to accomplish the urban design goals articulated in Subsection 3.3.1. Subsection 3.3.2.8 states that urban design should promote environmental sustainability by:
“f) Encouraging energy efficiency in neighbourhood design and development as set out in Section B.3.7.1” (OP, B.3 pg. 15)

This policy connects land use with energy consumption, expressing a requirement for energy efficiency in neighbourhood design and development. This can be accomplished effectively by satisfying thermal energy requirements through a local district energy system.

Section 3.6 Health and Public Safety Policies

Within Section 3.6 Health and Public Safety Policies, the City of Hamilton OP address Air Quality and Climate Change in subsection 3.6.2.

"Air quality and climate change have significant direct and indirect impacts on the community health, the environment, and the economy of Hamilton. Local sources of air pollutants contaminating clean air include personal and commercial vehicles, industry, and energy sources used for heating and cooling." (OP, S.B3, pg. 43).

This specific reference to 'local air pollutants' from energy sources used for 'heating and cooling' qualifies thermal energy as source of emissions requiring attention in an effort to mitigate and adapt to climate change. Mitigation measures involve actions to reduce GHG emissions and adaptation strategies involve plans to reduce a city's vulnerability to climate change impacts. Hamilton's policy of promoting compact, mixed use communities is a mitigation measure intended to improve air quality and reduce GHG. Subsection 3.6.2. concludes with several adaptation strategies:

"Prohibiting new development on hazard lands, and incorporating urban design features that reduce climate impacts on public works and urban infrastructure - roads and associated infrastructure, bridges, water and waste waters systems, and energy distribution, are climate change adaptation strategies" (B3 pg. 45 of 54).

The OP recognizes that energy distribution infrastructure will play a role in adapting to climate change impacts. District energy systems' efficiency and fuel source flexibility provides a level of resiliency, assisting the City of Hamilton in accomplishing goals related to air quality and climate change.

Section 3.7 Energy and Environmental Design

The City understands that energy efficiency, environmental design and increasing the renewable source portfolio of energy production benefits human health, reduces strain on the environment, and decreases the demand for energy resources and the associated regional distribution infrastructure. As referenced in Subsection 3.3.2 on urban design policies, Section 3.7.1 calls for energy efficient land patterns. Specifically, support for energy efficient land use will be obtained through:

a) a compact urban form with a nodes and corridors urban structure;
b) development of mixed use urban environments that support public transit and active transportation;
c) employment opportunities in proximity to housing thereby reducing commuting distances and traffic congestion; and,
d) designs that facilitate the establishment or expansion of public transit in the

future. (B3 pg. 53)

The City's development measures highlighted in bold and outlined in Subsection 3.7.2 promote the consideration of district energy systems throughout the planning process. Subsection 3.7.2 outlines the City's measures for supporting energy efficient and environmental designed development:

a) approval of planning applications, including applications for zoning by-law amendments, site plan approval, and plans of subdivision or condominium, as appropriate;
b) the use of environmental building rating systems such as certification under the Leadership in Energy and Environmental Design (LEED) program or an equivalent rating system for upgrading/retrofitting of existing development and new development;
c) designs which use renewable energy systems or alternative energy systems;
d) designs which use cogeneration energy systems;
e) designs which minimize building heat loss and capture or retain solar heat energy in winter, and minimize solar heat penetration in summer. Consideration shall be given to such measures as green roofs or reflective roofs, discouraging excessive surface parking, allowing direct access to sunlight, and effective landscaping;
f) building or structure orientations that maximize solar or wind energy;
g) designs that encourage sustainable forms of transportation, including active transportation, transit, and energy conserving vehicles;
h) designs that facilitate cooperation/joint energy efficiency between developments to optimize the efficient use of resources;
i) energy conservation initiatives, including energy demand management;
j) water and storm water conservation/management practices such as green roofs, water recycling systems, urban storm water swales, etc.;
k) encouraging the use of reclaimed building materials as appropriate;
l) pilot projects and community energy plans as appropriate; and,
m) other environmental development standards that encourage energy efficiency and environmental design as contained in the City's approved engineering policies and standards and master planning studies, and are supported by the City's financial incentive programs. (Section B3, pg. 54)

Planning tools such as applications for zoning by-law amendments, site plan approval, and plans of subdivision or condominium could be leveraged to stipulate the deliberation of alternative energy sources, district energy, or cogeneration (CHP). Pilot projects and community energy plans are encouraged when appropriate, and can be useful in facilitating long community energy objectives.

In subsection 3.7.4 the City outlines its intentions to promote increasing the supply of energy, specifically sustainable forms of energy by:

a) permitting energy generation facilities to meet existing and planned needs, including renewable energy systems and alternative energy systems, both as principal and accessory uses. These facilities shall be permitted in all land use designations subject to the other relevant policies of this Plan, Policy B.3.7.3, compatibility with the surrounding land uses, and in accordance with the provisions of the Zoning By-law; and,
b) protecting existing and future utility corridors. (B3, pg. 54)

Additionally, Subsection 3.7.5 states that all renewable and alternative energy systems will be permitted in accordance with all federal and provincial policy and requirements. By permitting energy generation facilities as principal and accessory uses in all land use designations, subject to other relevant policies, district energy facilities can be developed where density levels support a minimum base load.

Chapter E – Urban Systems and Designations

The City of Hamilton is an amalgamated product of six local municipalities and one regional municipality. The former municipalities are characterized by compact cores forming the urban foundation for their local communities. Hamilton's OP commits to managing urban growth in a way that balances the economy, the community's social needs and the environment.

Section *E 3.0 Neighbourhoods Designation* speaks to the diversity and unique character of Hamilton's neighbourhoods. This designation recognizes that neighbourhoods are comprised of more than just residential houses, and include a variety of land uses. This designation is intended to indentify the relationships between land uses, appropriate scales of development and design requirements for various land uses as neighbourhoods organically evolve. The promotion of compact, mixed use neighbourhoods is reiterated as a policy goal within the section. Additionally, Subsection 3.2.12 states:

Innovative neighbourhood designs incorporating energy and environmental design standards and the conservation of natural resources shall be promoted in accordance with Section B.3.3 – Urban Design Policies and Section B.3.7 – Energy and Environmental Design Policies.

This policy could be interpreted as energy and environmental design standards to improve energy efficiency and conservation of natural resources within Hamilton's neighbourhoods. District energy systems can improve energy efficiency, and utilize cleaner burning fuels like natural gas (compared to coal) or renewable fuel sources.

Chapter F – Implementation

The objectives, goals and policy directives stated in the OP are tied to implementation strategies detailed in Chapter F - Implementation for delivery. The Planning Act provides mechanisms through application requirements to ensure that developments are in conformity with the provincial and municipal legislation. Subsection 1.19.5 states the requirements of all Planning Act applications:

1.19.5 *A Planning Act application(s) shall be deemed complete provided that:*
a) it satisfies all applicable provincial requirements;
b) it satisfies all requirements set out in this Plan; and,
c) it shall be accompanied by all the other information and materials listed in
Table 1.19.1 as determined by the procedures of Policy F.1.19.1 or F.1.19.3. (Chapter 5 pg 10)

Table 1.19.1 identifies additional information and materials required by the City of Hamilton for approval of Planning Act applications, OP amendments, Zoning By-Law amendments, draft plan of subdivisions and site plan approval. The objective of the additional required materials is to ensure proposed developments are in accordance with Provincial and Municipal policies and Council's guidelines. Of particular interest, the table indicates the requirement of an *Energy and Environmental Assessment Report*. Subsection 3.2.9.1 Energy and Environmental Assessment Report states:

Proponents of development applications may be required to prepare an Energy and Environmental Assessment Report to indicate how the proposal incorporates environmental and sustainable design features and practices, such as active transportation, energy efficiency through building and site design, and water conservation and is consistent with the principles and policies identified in Section B.3.7 – Energy and Environmental Design and other applicable policies in Chapter E – Urban Systems and Designations.
3.2.9.2 The need and scope for the preparation of an Assessment Report shall be

determined by the City at the formal consultation stage of the development review process and submitted as part of the associated application. The specific requirements of the Assessment Report shall be reflective of individual applications and determined on a case by case basis. (Chapter F pg. 10)

This provision allows City staff to require thoughtful consideration of energy efficiency through building and site design early on in the development application process. The City determines the Terms of Reference for the preparation of the *Energy and Environmental Assessment Report*. For the purposes of district energy development in areas with existing or planned thermal energy services, the policy could be strengthened by requiring project proponents to specifically address district energy connection within the body of the report.

Chapter G – Glossary

The City of Hamilton OP contains an extensive glossary of planning related definitions in Chapter G – Glossary. The following two definitions are included with respect to district energy and community energy planning:

Cogeneration Energy Systems: *means systems in which thermal energy (heat) and electrical energy are produced at the same time using the same process* (Glossary, Section G 3 pg. 22).

Community Energy Plan: *means a City-wide plan that addresses energy security concerns and which may also address climate change, and may include the objectives of reducing energy consumption, developing renewable energy or alternative energy supplies, ensuring reliable conventional energy supplies, or of reducing greenhouse gas emissions* (Glossary, Section G 3 pg. 22).

Despite defining Community Energy Plan, the City of Hamilton does not currently have one. To a certain extent, other documents such as *Vision 2020* and the *Corporate Energy Plan* contain similar objectives, but opportunities for energy efficiencies and opportunities for conservation through land use planning and built form networks are not discussed.

Overall, Hamilton's OP expresses interest in the conservation of energy and improved efficiencies in use and delivery. Many of the favourable conditions for district energy system development are expressed such as compact urban form, higher density neighbourhoods and mixed-use development. Mechanisms are provided through the Planning Act to require additional materials for development approval. The City has included the provision to potentially require an *Energy and Environmental Assessment Report* to provide planning staff with details on opportunities for improved energy performance within proposed developments.

However, opportunities exist for more explicit direction. It would be worthwhile to give specific reference to the HCE system within the OP to generate awareness amongst community members, staff and potential development proponents of this downtown infrastructure asset. Additionally, requirements for the completion of a connection feasibility study for developable lands within district energy service areas as part of the *Energy and Environmental Assessment Report*, would ensure that economically viable opportunities were not missed.

4.3.1.2 Growth Related Integrated Development Strategy

The Growth Related Integrated Development Strategy (GRIDS) is an integrated infrastructure master plan, intended to guide growth related development in the City of Hamilton over the next thirty years. Using employment, household and population forecasts, the GRIDS strategy determines the best locations for nodes and corridors, targets for density, intensification, employment, and land use and transportation patterns. This planning process tool integrates land use, transportation, water, wastewater and storm water planning into a single holistic project to support a preferred model of growth. Sustainability is the uniting thread, which considers the role of infrastructure in accomplishing social, environmental and economic objectives. The GRIDS integrated approach promotes a coordinated time and cost effective system to guide investment in the public and private sectors. The City of Hamilton council motioned to adopt the GRIDS on February 12, 2003.

The GRIDS process has developed a municipal corporate culture that encourages staff and politicians to considered the long-term implications of their decision-making. Research findings from several other studies including the *Background Study on Hamilton's Vulnerability to Climate Change* support the strategic directions outlined in GRIDS. The background study on climate change links the impact of planning and infrastructure decisions on localized GHG emissions (City of Hamilton, 2004). Given their objectives related to infrastructure planning and decreased localized GHG emissions, these documents would benefit from further discussion on of the impacts of land use planning on community energy demand.

4.3.2 Energy Planning Initiatives in the City of Hamilton

4.3.2.1 Vision 2020

In recognition of increasing threats to air quality and environmental degradation, the City of Hamilton developed the *Vision 2020* document in 1992 to provide direction and guidance in moving towards a more sustainable city. The visions of council, staff, local businesses and citizens provide the fundamental foundations for the document, and every five years since its inception, the stakeholders collectively gather to revisit the document and ensure it is still relevant in a highly transformative world.

After revisiting the *Vision 2020* document in 2003, it was integrated with the *Growth Related Integrated Development Strategy (GRIDS)* and the *Official Plan* under the *Building a Strong Foundation (BSF)* initiative, tasked to implement the *Vision 2020* plan. New master plans for transportation, water and wastewater, and social development are currently being drafted and will complement the BSF initiative.

The BSF initiative speaks to many issues related to growth planning and city sustainability including thematic discussions related to energy and climate change. *Vision 2020* identifies the theme of "Consuming Less Energy" where it articulates Hamilton as

"an energy aware community that works with utilities and private energy companies to promote and finance energy-efficient investments. Homeowners, businesses and developers all have access to

information to take advantage of long-term cost savings from energy investments. Local energy resources are used to build a strong local economy" (City of Hamilton, n.d. '14 Theme Areas of Vision 2020').

Several of the other themes in the document address concerns associated with climate change and highlight local generation and infrastructure systems as critical mitigation and adaptation tools. Specifically, the goals identified are as follows:

- Have effective plans that identify, reduce and manage risks
- Reduce GHG emissions by twenty percent from 1990 levels
- Encourage development which makes efficient and economical use of infrastructure and services
- Ensure the City has the best air quality of any major urban centre in Ontario

4.3.2.2 City of Hamilton Corporate Energy Initiatives

In May of 2006, the City of Hamilton established the Office of Energy Initiatives (OEI) to provide municipal oversight of energy management and concentrate jurisdictional responsibility (SM, 2011). The OEI is mandated with the management of procured energy resources and tasked with improving energy efficiency and reducing energy consumption through infrastructure, waste water, rate optimization and commodity purchasing. The OEI operates within the Public Works Energy Fleet Services and Traffic Division and oversees discussions related to district energy operations.

In November of 2007, city council adopted the *Corporate Energy Policy* to facilitate the reduction of municipal energy demand, provide for ongoing energy monitoring, targeting of utility usage, and provide direction to the development of capital energy investment policies. This document specifies a twenty percent reduction in energy use from 2005 levels in municipally owned facilities and operations by 2020 which translates into a reduction of approximately 1.5 percent annually (City of Hamilton, 2007).

The *Corporate Energy Policy* out of the OEI supports the City of Hamilton's commitment to the FCM's *Partners for Climate Protection* (PCP) program. Under this program, the City pledges to curb corporate emissions by ten percent of 2005 GHG levels by 2012, and a subsequent reduction of twenty percent of 2005 GHG emission levels by 2020. The FCM targets have acted as a foundation to direct the City's initiatives for improved energy and environmental performance. The following table provides an account of the City of Hamilton's initiatives related to energy and the environment:

Table 11: City of Hamilton Energy and Environment Initiatives

Year	City of Hamilton Energy and Environmental Initiative
1992	*Vision 2020* document developed.
1995	City of Hamilton joins the FCM's 20% club (now know as the Partners for Climate Change). Council commits to reducing corporate and community-wide emissions by twenty percent of 1990 levels.
1999	Municipal corporate analysis of GHG emissions is completed.
2002	City Council adopts the FCM's resolution encouraging the Federal government to ratify the Kyoto Accord.
2003	City Council renews the *Vision 2020* document in conjunction with the *Growth Related Integrated Development Strategy* to provide a comprehensive approach to addressing anticipated growth and infrastructure requirements.
2004	The City completes the *Climate Change Vulnerability Background Study* to support the GRIDS growth strategy.
2006	The Office of Energy Initiatives (OEI) is established and the first phase of the *Corporate Air Quality and Climate Change Action Plan* is adopted.
2008	Phase II of the *Corporate Air Quality and Climate Change Action Plan* is adopted.
2009	The City completes its *Greenhouse Gas Inventory* and forms a Community Energy Collaborative to explore the implications of peak oil scenarios.
2011	Hamilton's Energy Mapping Exercise is completed in conjunction with the Canadian Urban Institute. **Phase 2** of the Community Air Quality and Climate Change Action Plan is under development.

4.3.2.3 Climate Change Vulnerability Background Study

The 2004 *Climate Change Vulnerability Background Study* was completed in conjunction with the GRIDS growth strategy to identify Hamilton's vulnerability to climate change issues and generate solutions to mitigate local impacts (City of Hamilton, 2004). The study provides several general recommendations but appropriate responses have not been thoroughly developed in detail. The City acknowledges that development growth patterns and aging infrastructure play a role in characterizing Hamilton's vulnerability to climate change and in part, define mitigation strategies. In an effort to instill local resiliency to the adverse effects of climate change, the study recommends that land use patterns should be designated to facilitate decentralized energy supplies through community energy and the incorporation of renewable resources (City of Hamilton, 2004).

In August 2006, the City commenced phase I of the *Corporate Air Quality and Climate Change Action Plan*. This initiative intended to develop a strategy framework to achieve a ten percent reduction in municipal GHG emission by 2012 and a further reduction of twenty percent by 2020 (City of Hamilton, 2008a). City Council approved phase II of the *Corporate Air Quality and Climate Change Strategic Plan* in 2008 emphasizing partnerships with external stakeholders to reduce local GHG emissions. The Plan contains the following action items related to infrastructure, air quality and community energy management (City of Hamilton, 2008a):

1. Give consideration to the energy usage and associated air and GHG emissions related to municipal operations, equipment and purchasing.
2. Research and investigate the potential use of renewable technologies in securing and supplying energy to existing and new municipal facilities.
3. Examine and incorporate climate change and air quality policies into the City of Hamilton's Official Plan.
4. Retrofits to Hamilton City Hall should include improvements to energy efficiency, waste management, water efficiency, and a reduction in GHG and air emissions.

4.3.2.4 Greenhouse Gas Emissions Inventory Program

The City of Hamilton recognizes the importance of monitoring and evaluating local emissions as a metric for measuring broader goals related to energy and the environment. The City conducted its first GHG emissions inventory in 1999. However, due to municipal reorganization through amalgamation and the lack of a fully formulated methodological approach for calculations, the 1999 results were deemed unacceptable.

During 2009, the City of Hamilton conducted a *Greenhouse Gas Inventory* of its operations and broader community in accordance with the FCM's requirements for the Partners for Climate Protection Program. The study found that Hamilton's municipal operations were responsible for 135,058 tonnes of CO2 equivalent in 2005 and had increased by 3.2 percent in 2007 (City of Hamilton, 2009a). The broader community emitted 12,758,652 tonnes of CO2 equivalent in 2006 with an increase of 2.9 percent by 2008.

The trend of increasing emissions brought forward by the *Greenhouse Gas Inventory* suggest that under a business-as-usual scenario without the development of any additional mitigation programming, the City's emissions are forecasted to rise to 17,349,621 tonnes of CO2 by 2020. This represents a 36 percent increase above the 2006 emissions levels and a 56 percent increase above the targeted 20 percent reduction of 2006 levels by 2020 (City of Hamilton, 2009a).

4.3.2.5 Hamilton: The Electric City – Report

In 2003, Hamilton began a 30-year development strategy to situate the City as a transportation and business hub. Central to the strategy, was the creation of an 'aerotropolis' airport-centric economic development model where expanded air transport infrastructure would increase passenger and freight flights (Lerch, 2008). In 2005, some councilors and community members voiced opposition to the aerotropolis plan, citing concerns related to peak oil and future energy constraints. This prompted the City to commission a Richard Gilbert report on the impacts of future energy constraints and Hamilton's long-term planning strategies.

Gilbert's report entitled *Hamilton: The Electric City*, was released April 2006, and assessed how the City should address future energy constraints through its role as a public service provider and energy user (Lerch, 2008). The report calls for the City to give more consideration to energy issues through its strategic planning documents and suggests that energy be defined as a guiding principle when directing new growth.

The report emerged from the efforts of local citizens and personal interest of elected officials regarding concerns related to energy, peak oil and the 'aerotropolis' economic development model (Lerch, 2008). As a result of Gilbert's report, the City has commissioned an external report to assess the potential impacts of future energy constraints on long-range planning and development. However, it seems that progress has stalled on developing and producing the second report.

4.3.2.6 Strategic Planning for Energy Constraints

By incorporating energy considerations into the planning process, municipalities can establish quantitative targets and metrics to evaluate progress towards desired outcomes. The City and municipal framework acts as an enabler, creating the right conditions to reduce energy consumption, rather than prescribing technologies or solutions. This is similar to land use planning, where the City facilitates development rather than actually building the urban environment.

Gilbert calls for a two-thirds reduction in per-capita energy use for transport, residential, commercial and institutional buildings (pg. 21). The future of Ontario's energy mix is ambiguous with nuclear generation presenting many risks, commitments to stop coal-fired generation and the increasing cost of natural gas (Gilbert, 2006). Greater reliance on electricity produced in central Ontario could jeopardize Hamilton's ability to reduce energy consumption. Alternatively, Hamilton could direct efforts to producing local energy through renewables sources complemented by CHP production. Accordingly, Gilbert recommends to generate the total amount of Hamilton's electricity consumption within the City, while continuing to trade with the Provincial grid (23). Hamilton Community Energy (HCE) is noted for its role in local energy production, distributing hot and cool water for thermal energy requirements and the generation of electricity from natural gas. It is recognized as a vehicle to increase efficiency, minimize transmission losses, and reduce vulnerability to large-scale system failure.

The report provides seven principles for land-use planning with energy constraints, outlined below:

1. *Make energy use and production the principal determinant of land-use decisions.*

   Gilbert suggests that this fundamental principle will define a culture of community, influencing appropriate infrastructure investment and decisions.

2. *Give 'greenfield' development low priority.*

   All new development, whenever possible, should be occur within the existing urban boundary. This encourages density and the compact urban form that is inherently more energy efficient. In addition to acknowledging the benefits of reduced requirements for transportation energy, Gilbert expands to say "intensive development also makes district energy systems more feasible, and reduces the energy cost of infrastructure generally" (pg. 37).

3. *No abandonment of existing low-density areas.*

   In a severely constrained energy scenario, temptations to abandon low density areas may exist because of high dependency on automobiles. It is recommended that selective intensification and judicious use of transport systems, as he describes personal rapid transport, could maintain viability.

4. *Plan for mixing of uses.*

To reap the benefits of intensification, employment, residential and retail must be collocated to reduce automotive dependency and decrease transportation related energy consumption.

5. *Aggressively pursue 'brownfield' development.*

   Development on previously used land that has undergone remediation will support intensification. Hamilton's abundance of brownfield sites provides many opportunities for new mixed-use development.

6. *Foster vibrant centres.*

   Hamilton's downtown has taken steps to improve vibrancy, but still requires effort to emerge as the true centre of economic and social activity. The municipality has several other smaller centres that if strengthened, could reinforce the social and economic benefits of intensification in an energy constrained future.

7. *Arrange that development supports low-energy transport*

   Transport's key role in reducing energy use underlines the connection between land-use planning and energy consumption. Gilbert suggests that in an energy constrained future, it may be necessary to lay the foundation for transportation planning first, and plan land uses around transportation networks.

4.3.3 Energy Production Opportunities

Considerable thought has been given to local energy production through Hamilton Community Energy's combined heat and power operation. Additional opportunities for solar, wind, deep lake water cooling, hydro-electric, biogas, energy from waste and district energy have been outlined by Gilbert.

Hamilton Community Energy operates a district energy facility servicing several buildings in the west of downtown. Circulating hot water conditioned through a natural-gas fired cogeneration plant provides thermal heating and produces approximately 0.1 petajoule of electricity annually (pg. 43).

4.3.4 Hamilton Community Energy Collaborative

The City of Hamilton acknowledges the likelihood of an increasingly carbon constrained future and as a result, developed the Hamilton Community Energy Collaborative (HCEC) to address community vulnerabilities associated with peak oil and provide recommended responses (City of Hamilton, 2008c).

4.3.4.1 Energy Mapping Exercise

In 2010, Hamilton completed an energy mapping exercise to better understand the connections between urban form, land use, transportation, alternative energy sources and demand-side management strategies. The project entitled *Integrated Energy Mapping for Ontario Communities* was led by the Canadian Urban Institute and aimed to provide cost-effective long-range strategies for investment in critical energy infrastructure. (CUI, 2010). Hamilton is leveraging the findings of this project to complement the forthcoming *Community Air Quality and Climate Change Action Plan* (CAQCCAP). The City's CAQCCAP in conjunction with McMaster University, Environment Hamilton, Green Venture and the Conservation Authority will eventually prescribe reduction targets for community emissions, although council has not prescribed any at this time.

4.3.5 District Energy Solutions in Hamilton

4.3.5.1 Primers, Drivers and Forces of Change

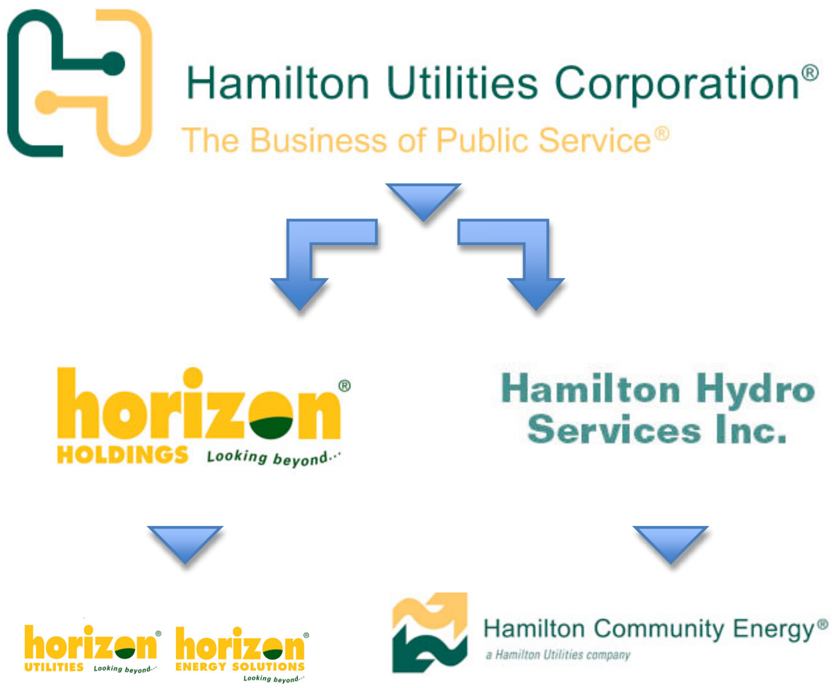
The City of Hamilton commenced its initial investigation into district energy in the early 1990s as a solution to supply heating to downtown residents and businesses by utilizing waste heat from existing industrial plants. However, the proposal failed to gain momentum after initial feasibility studies cited initial capital costs as prohibitive because long distances of underground piping were required to connect the waterfront waste heat sources and loads to be supplied with district heat.

The district energy concept was revisited in the late 1990s through visioning exercising conducted for the City's *Vision 2020* strategy. Several local councilors had visited Scandinavian countries and were interested in exploring opportunities to replicate their success with district heating. The deregulation of Ontario's energy markets in the late 1990s provided the basis for the development of the Hamilton Energy Centre. Feasibility studies revealed that Hamilton's downtown core contained densities to support a district energy system. Hamilton's district energy system was initially implemented in part as a catalyst for business in the downtown core, but increasingly earns merit for its ability to decrease emissions and improve air quality (NRCan, 2009b).

4.3.5.2 Ownership Structure

The district energy systems in Hamilton provide heating and cooling capacity and supply electrical power. The Hamilton Utilities Corporation (HUC) is a multi-utility company owned by the City of Hamilton and operates components of the district energy system directly or through subsidiaries. Horizon Holdings Inc. is one of two business subsidiaries owned by HUC, in which they maintain an approximately seventy-nine percent share. Hamilton Hydro Services Inc. (HHSI) is wholly owned by HUC (HUC n.d., About Hamilton Utilities Corporation). Horizon Utilities is the regulated local energy distribution company (LDC) and Horizon Energy Services provides non-regulated energy services. Both companies are subsidiaries of Horizon Holdings Inc. Hamilton Hydro Services Inc. is responsible for operating the non-regulated companies of the HUC in which Hamilton Community Energy (HCE) provides district energy services. Specifically, HCE is the developer and operator of Hamilton's district heating loop and cogeneration plant supplying electrical power to the grid. District cooling services in downtown Hamilton are provided through HHSI but are delivered through Hamilton's Central Utility Plant under the operation of staff at the Office of Energy Initiatives. The ownership structure is depicted below in Figure 13.

Figure 13: Hamilton Community Energy Ownership Structure



(Adapted from Hamilton Utilities Corporation, N.D.)

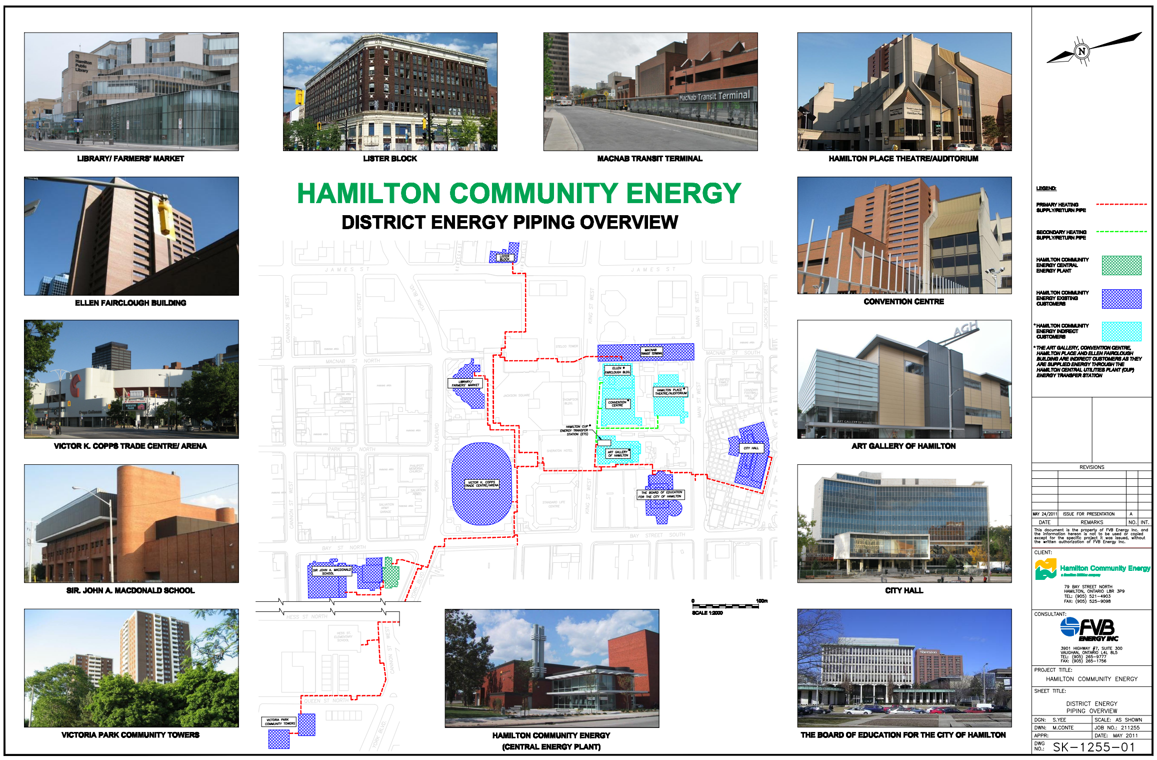
http://www.hamiltonucorp.com/single_pages/about.shtml

4.3.6 Hamilton Community Energy

The Hamilton Community Energy (HCE) Centre has been providing distributed heat and electricity from a combined heat and power (CHP) to an initial cluster of 10 large buildings on the west side of downtown Hamilton, since it came into service in 2003 (HUC, n.d., current projects). Located on the grounds of Sir John A. MacDonald Secondary School, HCE has introduced public educational opportunities for secondary school and college students. Table 12 provides a development timeline of HCE. Currently, HCE is undergoing incremental expansion as permitted by new business development and financial feasibility.

The system produces 3.5 MW of electricity through a high-efficiency, natural gas fired engine. Exhaust heat from the engine is captured in the form of hot water and is distributed via an underground piping network to service the heating requirements of 12 buildings including Copps Coliseum, the Central Library and Farmer's Market, City Hall and 540 apartment units (SM 3, 2011).

Figure 14: Hamilton Community Energy Service Map



Source: (Hamilton Community Energy, 2011).

HCE is committed to expanding their district energy services into new areas and exploring opportunities to service additional existing building stock through retrofits as the serviceable life of conventional in-building thermal equipment expires. It is acknowledged that this will be achieved through sound, financial sustainability, the development of relationships and partnerships within the community, the provision of highly efficient and reliable system performance and the continual exploration of new thermal energy opportunities.

Table 12: Hamilton Community Energy Timeline

1999	Pre-feasibility study is commissioned and conducted to assess the economic potential of a downtown district energy system
2000	Hamilton Community Energy is registered as a for-profit commercial entity
2001	System planning and approval process is undertaken
2002	Tendering process concludes and plant construction commenced
2003	Customer connections were completed and the Energy Centre officially opened
2004	Hamilton Community Energy expanded the system to Victoria Park Community Homes (VCHP), two municipally owned, non-profit high-rise residential apartment buildings. This marked the first Canadian connection of a high-rise, multi-unit residential dwelling, to a district energy system.
2009 - present	In 2009, Hamilton Community Energy expanded services to Hamilton City Hall as part of a major energy retrofit project.

Adapted from Natural Resources Canada, 2009b

Hamilton's district energy system supports the City's *Vision 2020* initiative for more sustainable growth and development. The cogeneration component supplies electrical power to the grid or leveraged to back up critical municipal buildings in the event of a utility power grid failure. Since commencing operating in 2003, HCE has replaced 28 in-building, low-efficiency natural gas fired boilers, and led to the reduction of over 4,000 tonnes of annual GHG emissions in comparison the BAU operating scenarios (Natural Resources Canada, 2009b). Emission reductions are primarily achieved through the cogeneration capacity which produces an overall energy efficiency rate of approximately 80 percent, compared to the range of 40 to 60 percent typically achieved with individual conventional instillations. Natural Resources Canada estimates the system payback period to be between 15 and 20 years with a variable return rate based on capped electricity prices (2009b).

4.3.6.1 District Cooling Loop

Hamilton's district cooling loop is operated out of the Central Utility Plant and managed by the OEI. The district cooling loop rounds out the complete district energy portfolio by providing cooling capacity to the system's municipal buildings. System build out was completed in early 2011 at a cost of $10 million, providing a total of 4000 tonnes of cooling capacity (MS 4, 2011)

The decision to develop a district cooling system came about as 13 chillers at the Central Utilities Plant reached their serviceable life expectancy (MS 4, 2011). Additionally, new legislation coming into effect in 2011 would restrict the use of CFC refrigerant employed in older chiller units (Lupton, 2008). After conducting a life cycle cost (LCC) analysis on combining and connecting the serviced buildings to a district cooling loop, the City decided to replace the aging chillers with high efficiency units on a district system. The LCC analysis revealed that a district cooling loop was the best life cycle option, building a case around cost savings, efficiency gains, and environmental benefits achieved in relation to the Corporate Energy Policy and Vision 2020 document. As a result of the efficiencies gained through the district layout, only 9 variable frequency chillers were required to service the cooling load. This has translated into a 41 percent reduction (556 tonnes) in annual GHG emissions (Lopez-Pacheaco, 2009). Energy cost savings total $181,000 from the $445,000 annual utility costs, and a life cycle cost benefit of approximately $2.5 million over the 30-year operational expectancy of the chiller equipment (Lupton, 2008).

Hamilton's district cooling system is designed in a way to accommodate future expansion in the downtown as demand permits. The City plans to connect all of the municipal buildings in the downtown to one of two chiller plants servicing the district (City of Hamilton, n.d., "Welcome"). All of the current connections service municipally owned buildings but private building owners will have the opportunity to connect as the system continues to build out. Currently, Hamilton's district cooling system has an additional 800 – 1000 tonnes of cooling capacity or approximately 600,000 square feet available for expansion without requiring additional chillers (MS 4, 2011).

4.3.7 Planning, Developing and Retrofitting for District Energy

Several recent projects in Hamilton have incorporated the provision of infrastructure for district energy to service their heating and cooling requirements. Hamilton Community Energy and OEI benefit through cooperative servicing, installing piping for heating and cooling at the same time, providing a reduction in capital costs.

Renovations to Hamilton City Hall are intended to improve the energy performance of the building. The City decided to incorporate district heating and cooling on-site. Although the existing chillers at City Hall had not yet reached the end of their productive service life, the municipality made the decision to convert to district heating and cooling services due to proximity to the existing loops. “A big part of the equation was timing. Timing was good for the municipal cooling project. A lot of the equipment needed to be replaced and we had the looming coolant issue, so the timing was absolutely critical for the retrofit” (MS 4, 2011, 26:30) The cooling equipment previously serving City Hall was put back into service at other municipal buildings.

The Lister Block redevelopment project exemplifies the thoughtful exploration of district energy feasibility when reinventing a site. Originally constructed as commercial and retail space in 1886, the building was subsequently rebuilt in the Renaissance style after a fire in 1923. A commercial exodus of Hamilton’s downtown left the Lister Block building into a state of ill repair and operations formerly closed in 1995. The City of Hamilton purchased the site and embarked on a redevelopment project to revitalize the Lister Block, ultimately containing 32,000 square feet of retail/office use over six stories (Manson, n.d.).

The City hired a consultant to explore the options to meet the thermal conditioning requirements of the Lister Block redevelopment. In a 2009 report to Council, the consultants determined that given the site's proximity to the existing thermal grid, the calculation of the lowest total lifecycle costs, lowest energy consumption and fewest GHG emissions, connecting to district energy was the preferred option over in-building boiler units and chillers (City of Hamilton, 2009c). Additionally, it was also recognized that connection to the downtown district energy systems provided built in redundancies beyond what was possible with stand alone in-building equipment. The staff report referenced policies that support this project and the implementation of district energy servicing including the *Corporate Energy Policy, the Corporate Strategic Plan* and *Vision 2020* all of which call for improvements in energy and environmental performance. Finally, the Lister Block redevelopment was an opportunity to showcase civic leadership on a number of fronts including improvements to energy performance and efficiencies, and that the City's adoption and participation may act as a catalyst for future expansion of the system to additional private clients.

Photo: Paul Dolanjski, n.d. "Corner View of Lester Block" retrieved electronically from http://historicalhamilton.com/beasley/lister-block/p-1244-corner-view-of-lister-block.html July 23, 2011.

The Lister Block connection to district energy is expected to provide substantial savings over the life expectancy of the equipment. The district energy system connection is estimated to require a total capital cost of $1,160,000 for initial development. However, the consultants calculated that after discounting the purchase price of stand alone in-building equipment that would have been required without district energy servicing and removing the capital costs paid by HCE, the net capital cost to the City of Hamilton was projected to range from $60,000 - $160,000. It was recommended that the remaining capital cost borne to the City should be funded through the Federal Gas Tax Reserve for infrastructure projects (City of Hamilton, 2009c). In comparison to conventional in-building heating and cooling equipment, the district energy system is estimated to provide a total life cycle cost savings of $212,000 - $532,000 over a twenty year period.

Woodward Avenue Cogeneration Facility

Woodward Avenue's Wastewater Treatment Plant houses a distributed cogeneration facility powered by renewable methane gas. Similar in concept to many district energy systems, the Woodward Avenue 1.6 MW cogeneration facility captures waste energy from out other outputs and leverages them as inputs to improve overall efficiency. In this case, the methane gas produced by the wastewater treatment process on site is captured and used to produce 13.6 million kWh of electricity, or enough to supply the electrical demand of approximately 1,600 households. The waste heat from the cogeneration engine is collected to provide heat for the wastewater treatment facility, translating into an annual fuel savings of $500,000 (City of Hamilton, 2008b).

The Woodward Avenue cogeneration facility provides several economic and environmental benefits to the City of Hamilton. It is anticipated that the sale of energy to the provincial grid will provide the City with a net benefit of up to $1,000,000 (City of Hamilton, n.d. "Together"). The facility will provide a reduction of approximately 6,500 tonnes of GHG emissions annually and a reduction of roughly 130,000 tonnes of GHG emissions over the 20 year contract of the project (City of Hamilton, 2008b). The plant came online in September 2006, and plans are currently being developed to increase the generation capacity of the facility (SM 3, 2011).

4.3.8 Future Expansion

Both Hamilton Community Energy and Hamilton's district cooling operations have existing capacity for immediate expansion, but the development of new facility operations will require further planning.

The district cooling operations are looking for a footprint to install a new facility for expansion into a different part of the downtown core (MS 4, 2011). Staff members within the Office of Energy Initiatives have identified several potential sites, but no formal development planning has taken place.

The other option would be to extend the existing loop depending on the cost. However, “You need to have multiple buildings in order to expand if you’re going beyond City buildings. You need to have more buy-in, so timing is very important” (MS 4, 2011, 31:56). It was noted that Hamilton lacks policy to encourage private sector consideration of district energy connection. “We are a municipality, so we don’t have a sales force, we are not really building it (district energy) like a private sector business where they would have a marketing department” (MS 4, 2011, 34:16). Municipally driven initiatives often require both ‘carrot and stick’ incentives to prompt interest from outside stakeholders (SM 3, 2011).

Hamilton Community Energy represents a mature system, with only roughly 500,000 – 600,000 square feet of serviceable capacity remaining. “These facilities, they lend themselves well to a node style development, you can do it the other way (by extending the existing loop), but you’re talking about a lot of pipe. It makes more sense to start another node, and then when you reach maturity there, you can interconnect with the existing system, providing redundancy and synergetic operations at the junction” (SM 3, 2011, 34:16).

The City of Hamilton has given considerable consideration to energy across a range of policy documents and reports. In particular, *Hamilton: the Electric City* report is quite comprehensive, underlining the connection between land use development patterns, urban form and energy efficiency. The creation of the Office of Energy Initiatives, the Corporate Energy Policy and the advent of evaluative metrics for greenhouse gases support advancements in energy efficiency. However, a framework for development of district energy systems, where appropriate, is lacking. Without guidelines, it will be difficult to expand Hamilton’s district energy system.

Chapter 5 Empirical Data Analysis, Findings and Recommendations

After an extensive review of relevant literature, case study analysis, and interviews with municipal staff and district energy experts, this section seeks to provide analysis of the primary and secondary research, and extract key findings to serve the research objectives of this thesis.

An honest acknowledgment of research limitations is required prior to data analysis. Inevitably, some bias may be reflected in the interview questions as they were developed after the literature review process. The questions were designed and structured to uncover the challenges exposed in the literature review and initial case study analysis, and reveal potential solutions. During the interview process, additional questions and directions for individual interviews could be subject to bias from the discussions in preceding interviews. These potential biases must be accounted for throughout the data analysis and presentation of results.

Additionally, time and resource constraints limited capacity to interview a representative sample of planners and industry experts. Interviewees were solicited based on their affiliation with the selected case study projects, and additional interview contacts were made through snowball effect throughout the research segment.

With potential bias identified, the analysis of interview data and case study findings can be presented in an appropriate context. The Analysis and Findings section of the thesis will be sub-sectioned appropriately to further categorize the discussion. In some cases, findings have prompted recommendations for Ontario's municipalities, which have been incorporated into this section. Other findings are more observational in nature, and do not directly translate into explicit recommendations.

5.1 Connecting District Energy Systems to Municipal Objectives

In Ontario, and more broadly speaking in the Canadian context, most district systems are developed by municipalities (IE 1, 2011). Research participants suggested that the municipality's ability to tie district energy systems to the delivery of other municipal objectives was a key driver in their support of community energy projects (IE 1, 2011). Municipalities are able to pull all of the various stakeholders and different departments together, developing a coordinated approach to system development. This typically comes from a group of strong political motivators and champions because the reality of district energy development is that a private entity is unlikely to see a substantial return on investment for several years with additional risk associated with ambiguity around densities and access to connections (IE 1, 2011).

"Where the municipality has a key role, is recognizing that they actually influence the entire energy process, and that they can build a very viable system, and they can ensure cost effectiveness; but they may not want to be the long-term operator of the system, or they may want to sell the asset. Its interesting, because there are always people willing to buy the asset, but people aren't as willing to take the risk and the associated higher cost of the development, because there is a premium on financing for higher risk projects" (IE 1, 2011 19:40).

The guaranteed land-tax income generated by municipalities allows most to benefit from a AAA credit rating. The combination of access to lower-interest rates for financing, availability of equity, and control local policy and regulation reduces the risk of district energy system development. Coordinating the purchase of equipment, installing infrastructure, and establishing service contracts still presents upstart challenges requiring a great deal of expertise. As a result, many systems develop incrementally, expanding as demand permits. Ultimately, some municipal systems operated at arm's length through a wholly owned subsidiary, are sold off to private entities once they are established, matured, and the financial risk has been reduced (IE 1, 2011). "You have pension funds that often buy assets, but they are buying stable long term assets; but they will pay a premium for them. So you have the municipality that will take the risk early on and sell the asset later on" (IE 1, 2011).

Both Markham and Hamilton took pro-active roles in developing district energy, setting up arm's-length entities responsible for the procurement and delivery of thermal energy. In both cases, energy efficient municipal operations were attached to broader municipal objectives related to sustainability. Markham's use of a sustainability checklist required for site plan approval prompts foresight on the part of the developer, requiring consideration for a number of 'green initiatives', including those related to thermal energy. It does stop short of requiring connection to the system in areas serviced by Markham District Energy's thermal grid.

5.2 Vulnerability of Existing Energy Infrastructure

All energy infrastructure, whether urban, rural or conventional in nature, is vulnerable to varying degrees of failure. With electricity passing through lines, it takes as little as a tree collapsing to shut down a highly integrated system. Similar chain reactions can be seen with natural gas energy, where a line blockage has major implications for the rest of the network. How redundancy is incorporated into the energy network is critical to reducing vulnerability (IE 1, 2011). It has now become regulated within municipalities to provide back up power for some services like hospitals, effectively transforming these key institutions into islands unto themselves. Beyond that, factors buildings, state and condition of infrastructure, and regional demand on energy resources.

Although district energy systems provide an additional layer of redundancy, water supplies through a piping network are only effective when pumps are circulating water. Back up power supplies may provide security for a few days, but if a system is experiencing more significant complications lasting a week or more, basic human needs for thermal conditioning could be jeopardized. This was illustrated in 1998 ice storm that ravaged Quebec, leaving many communities cutoff and isolated, without power for up to three weeks (SM 1, 2011). With centralized power, energy travels further, increasing likelihood of interruption over a greater distance. The high visibility of energy volatility in the late 1990s and early 2000s acted as a primer to explore the feasibility of district energy in Markham.

What all of this underlines is that cities are highly dependent on a very integrated network of utilities, and if systems fail, for whatever reason, communities become exposed. Questions of energy vulnerability are questions of trade-off; how likely is the risk of service interruption relative to the investment a city could make to provide an additional layer of redundancy, and is the risk high enough to justify the additional investment?

Although Ontario is largely dependent on the grid, most cities are relatively robust in their shelter from energy interruptions. Over the past decade, the Province has made gains in diversifying its energy portfolio, moving away from sole reliance on a combination of coal and nuclear sources, to incorporate smaller-scale sustainable sources into the supply network. This is one of the most effective means of reducing vulnerability in the electricity network (IE 1, 2011).

Recommendation: Municipalities should consider the development of district energy systems as a means to increase local energy redundancy and reduce dependency on centralized energy.

5.3 Impact of District Energy on the Existing Grid

The localized nature of district energy systems has broader effects for the existing energy grid. Current transmission delivery through wire has a finite amount of capacity before the wire will melt or malfunction. The implications for Ontario's existing grid are substantial. "We have areas where the infrastructure limits how much more power can go through the wires. In what is classified as 'red areas', we can't push any more power through the wires. Keep in mind this is over long distances – but when you produce a 100 units (of energy) in Ajax, it ends up in Toronto at 35 or 40 units, but in terms of the notion of the ability to send power out – the longer the distance, physics equals resistance, resistance means loss. The longer you go, the greater the loss, meaning there is less power at the end of the line to meet that demand" (IE 1, 2011).

This consideration has significant ramifications for land use planning. A lack of secure power supply, or the inability to satisfy certain demand profiles, limits the ultimate land use on a site. A location beyond a certain distance from power generation may not be able to support a variety of industries because transmission efficiencies are lower.

The same can be said for residential uses. Adding additional residential units to an area may not increase energy demand beyond capacity, but it may exceed requirements for *useable energy*, that is, energy that can be delivered to service the demand (IE 1, 2011). If demand exceeds draw, communities will suffer from brownouts. The result is a need for more localized power solutions, such as the ones offered through district energy and CHP. To capitalize on the benefits of localized energy distribution, CHP is most effective if the district energy system is built with its own, separate power grid.

Recommendation: As part of a comprehensive community energy planning exercise, district energy systems should be explored in areas where new development may jeopardize the capacity of existing infrastructure to deliver energy. This would require coordination with Ontario Hydro and other agencies responsible for the delivery of energy to determine the amount of anticipated energy demand in the future.

5.4 Understanding District Energy

As was expected, industry experts, plant operators, and informed customers were all able to clearly articulate numerous benefits associated with the development and operation of community-based district energy systems. The planning staff interviewed had varying degrees of knowledge related to district energy, but in general knew less than the aforementioned participants.

While many of the benefits mentioned by the interviewees have been captured in the existing literature, several responses framed the advantages in a more localized context. As demonstrated in the Markham case study, district energy can play a significant role in meeting specific commercial requirements, attracting businesses to a location to meet a broad spectrum of energy demands (CU 1, 2011). In some cases, district energy has the ability to lower the operational costs for commercial, industrial and residential uses by removing the valuable space requirements for heating and cooling equipment (MS 1). District energy, when coupled with CHP, provides some capacity to address urban resiliency issues by supporting full service requirements for thermal conditioning and power demand (IE 1, 2011). The robustness of district energy is especially apparent when systems can respond to the energy market with thermal (tank) storage, allowing the production of energy at off peak hours. The utility can effectively respond to the demand of the local community, and offer a response to reduce GHGs and in some cases, reduce energy requirements.

As one interviewee put it, “DE is the movement of energy to different buildings to meet their various demands, so in that simple sense, DE is all kinds of energy whether its through natural gas and the burning of it to produce thermal energy, to the capture of solar energy to produce hot water and using that to heat things, to using biofuels – it helps to actually capture all of these alternative and in some cases renewable energy sources to meet our heating, cooling and power requirements of the built environment” (IE 1, 2011, 4:25).

The fuel flexibility of district energy systems may see a system fueled by non-renewable or conventional fossil fuel sources. Although this compromises sustainability, a district energy system fueled by fossil fuels still presents benefits when compared to larger-scale, conventional systems. Conventional power systems maximize generation to service high levels of demand. In the process, extensive distribution networks experience significant electricity losses the further transmission lines extend from the generation system. District energy, because of its localized scale, does not experience the same extent of efficiency losses in electrical transmission. The major benefit is using the electricity for thermal energy, as it represents a high quality use. However, district energy competes with natural gas as a very viable source of thermal conditioning, which benefits from a strong business as usual environment, built around structured supply and demand. As a result, new construction typically defaults to natural gas for thermal conditioning (IE 1, 2011).

Moving outwards from the plant itself, greater efficiency can be achieved at the individual building scale. Having a team of full-time expert operators at the DE plants ensures that boilers are operating at maximum efficiency 365 days a year (IE 2, 2011). It was noted that smaller scale boilers operate much like a furnace and require little maintenance beyond annual servicing, but larger systems, such as those found in a hospital or large library, require full-time maintenance (SM 2, 2011). “Facilities management these days is becoming more of an ‘academic exercise’ with more of a focus on office space planning than maintenance planning, so this is a service we can provide for people that don’t want to hire additional staff with specialized training” (SM 2, 2011, 6:06)

5.5 Primers and Drivers for District Energy

Primers and drivers for district energy systems are very localized and interviewees noted that they could vary by community. “Just like any service provider, the development of district energy is a response to a need” (IE 1, 13:20, 2011). The Town of Markham’s Mayor had visited several Scandinavian cities after the Québec ice storm in 2008, searching out solutions to address a number of cascading issues related to energy security. What he found was that district energy provided the energy security to ensure the continual operation of vital city services, but also offered a response to climate change, economic development opportunities, improvements in energy efficiency and delivery, and a framework for long term sustainability planning (IE 1, 2011).

“The driver for these (district energy systems) are generally the same things. They (municipalities) want to be seen as a leader, they want to bring in new businesses; but there is something that is driving the overall requirement for the system other than just generating power or thermal energy, because it (thermal energy) is done by different things. Now, when the argument is a part of a solution to climate change adaptation, the requirement for local resilience, not worrying about the failure of the larger grid which could greatly compromise a community’s ability to carry on with their operations – these all are very good arguments, it is just a very costly investment” (IE 1, 2011, 23:42).

These responses suggest that district energy systems gain traction when numerous synergestic benefits are coupled together to provide a comprehensive solution to a number of municipal challenges.

New regulations and the cost of energy have also been cited as a primer for the exploration or development of district energy systems. During the 1990s, regulations that required the phasing out of chlorofluorocarbons (CFCs) brought about great uncertainty regarding chiller units and technology. Currently, new mercury and air toxics (MATs) standards are in development. In both cases, the uncertainty around proposed regulations prompts developers, building owners, and municipalities to take a look at alternatives for thermal regulation (IE 2, 2011).

5.6 Streamlining Planning for District Energy Development

Understanding the connection between land use, proximity, and energy consumption is critical to developing a framework in which district energy systems are viable options. Interviewees had a range of familiarity with the sort of qualifiers that might be useful screening tools to make an early assessment of site potential for district energy.

Amongst district energy experts, it was suggested that 5000 m^2 of gross floor area or 2 acres would be an appropriate threshold to require that a development proposal include a district energy feasibility study as part of the site plan approval process (IE 1, 2011). At this size, development could potentially provide enough serviceable floor area to anchor a district energy system. Since all developments require provisions for servicing, development applications require a response from utility companies when site plan applications are submitted. A similar process could be arranged for areas serviced by district energy systems.

However, it was noted that “the whole point in planning is not to be selective of the technology, which is always the dilemma for the municipality but to encourage the exploration of different types of alternative energy options. Rather than stipulating connect to electricity, or connect to natural gas, development proponents should explore if there are other ways to meet energy demand locally, through the local energy sources vs. connecting to the grid sustained supply" (IE 1, 2011, 1:10). Any time there is a new planning precinct, or new downtown development it is a great opportunity to explore district energy as a solution for addressing thermal energy requirements.

Although the implications for a developer are largely related to provisions in building design, district energy prompts a much broader discussion around energy demand. In a sense, the current business model is at odds against the development of district energy systems, because new development connects to existing service providers as a default. Systems providing thermal energy through natural gas or electricity are well established and have already been built out, facilitating a straightforward connection that has become routine. If district energy infrastructure is not in place, it requires a greater degree of up-front evaluation.

Within a 100-year time horizon, the risk structure for municipalities may look very different with increased vulnerability across the energy and resource sectors. The location of key pieces of infrastructure, and every land use decision influences the energy demand, requiring a long-term perspective to community energy planning.

Planners influence the location, form, density, and uses of future development, and should take a proactive position in the early identification of nodes of activity supportive of district energy. Clear criteria metrics should be established to trigger pre-feasibility studies. As a starting point, 1 – 5 million square feet of floor space could potentially support a district energy system financially, and is a good approximate estimate to warrant further feasibility investigation (SM 1, 2011). This size parameter often precludes most residential developments as initial anchor tenants. As demonstrated in Markham's Langstaff system, hospitals can provide enough floor space to serve as anchor tenants.

Planners can give consideration early on in the site plan approval process or subdivision agreements to require additional studies related to district energy system connection or development, when appropriate (MS 2, 2011). The limitation of this would be that a developer may have the tendency to respond that the procurement of district energy is beyond their mandate and the responsibility of a utility (MS 3, 2011). This is a challenge that extends beyond the scope of municipal planning exercises.

5.7 Considering Energy in Planning Documents

Energy is not often considered in planning documents because it is not seen as an immediate issue in planning, however in some communities, it is emerging as part of a broader municipal discourse around sustainability and resilience. “You are starting to see language around energy efficiency in land use and transportation networks and we should take actions to reduce energy consumption through the orientation of buildings, through the transportation network, so people are realizing that there are notions and activities that reduce the consumption of energy by the way you do land use” (IE 1, 2011, 38:44). Markham and Hamilton touch on the subject of energy efficiency and reductions in GHGs in some of their policy documents, but explicit direction for community based energy solutions is not provided. Going forward, municipalities may come to realize they have more a of a role to play with respect to energy, and that there are proactive opportunities for community energy solutions that can be explored for their residents and businesses.

5.8 Community Energy Plans (CEP)

The strength of a plan can be gauged on its effectiveness at communicating ideas, intentions, and significance. Master planning initiatives often provide strategies to coordinate various initiatives. Like environmental planning, energy planning touches everything. However, Community Energy Plans are ineffective if the people charged with implementing them don’t understand their significance (MS 1, 2011).

It is hard for municipalities to provide direction to build district energy systems in capital restrictive environments. In order to better position district energy as a key piece of infrastructure, it must be considered as part of the community development from the onset, clearly articulated in the secondary or precinct planning for a designated area (MS 2, 2011). The redevelopment of Regent Park in Toronto situated a district energy plant in the basement of one of the new condominiums, servicing all new development within the community. As a result, the system has been integrated into a 25-year financing plan for the community. This upfront consideration better positioned district energy as a viable option for the community (IE 1, 2011).

CEPs help municipalities identify goals related to energy planning, what opportunities might exist, what the role of the local utility might be, and how to coordinate with various agencies in order to implement the plan (MS 1, 2011). While Hamilton and Markham are without CEPs, they have been able to successfully move forward on the development of district energy systems. “CEPs will not solve all your problems overnight. It is really an awareness building exercise that allows for informed development of what is viable in your community, and can lead to making strategic decisions about the longer-term opportunities” (IE 1, 1:16, 2011).

According to industry experts involved in the development of several CEPs, the plans shouldn’t be technical documents (IE 1, 2, 2011). Rather, analysis of community opportunities should be identified prior to developing a CEP to determine what options are economically feasible so that viable solutions are brought forward for the purposes of outlining what works best in the context of the existing and future planned community, and investigating potential partnerships for development.

Once a CEP is established, it is relatively straight-forward to coordinate a CEP with other planning documents such as zoning bylaws, official plans, secondary plans, and precinct plans. The CEP firmly establishes the consideration of energy as it relates to land use, prompting adequate consideration early on in the land use planning process and highlighting opportunities for community energy based solutions.

5.9 Leveraging Planning Tools to Create Conditions for District Energy Opportunities

Municipalities have a number of tools and resources available at their disposal to strategically encourage the development of district energy systems. Zoning bylaws capture potential land uses within a municipality. Planners can zone for, dedicate and or assemble lands for district energy facilities. Community improvement plans, zoning activities, and powers of subdivision offer the opportunity to negotiate the review of district energy. As demonstrated in Markham, a sustainability checklist allows for an upfront review of development assumptions, and provides the opportunity to require further alignment with municipal objectives, or at least further discussion. Community Improvement Plans can be leveraged to collect monies or levies through a tax increment grant or a tax increment financing district to assist with the financing of district energy systems (MS 2, 2011).

Incentives such as the provisions allowed under a Section 37 agreement, could allow municipalities to negotiate provisions for district energy (MS 3, 2011). However, this must be acknowledged upfront in the municipality's zoning or official plan. The permissions must be in place and vetted through a public process for acceptance, otherwise it could create an unfair development advantage (MS 2, 2011).

Engaging stakeholders early on in the development process about the opportunity for a district energy system is critical. In order to capitalize on potential opportunities for connection, timing must be considered with respect to the development of the district energy system, age of existing equipment, and connections to new services (IE 2, 2011). Municipalities may require additional development studies to examine the feasibility of district energy connection for proposed developments, but it is the opinion of the author that ultimately an economically viable business case must be in place, prompting the connection (MS 2, 2011).

Planning must make sure the conversation takes place well in advance of development. This is planning's main role, and one of the most challenging aspects of developing district energy, because many planners don't have a thorough understanding of what is involved or required to develop and plan for community based energy systems.

5.10 Expanding District Energy in Size and Scale

District energy providers must carefully create the conditions for expansion. Additional boilers or turbines can be added with relative ease. The challenge is to synchronize timing with new development or retrofitting opportunities to capitalize on expanding the customer base. Depending on the operating mandate of the district energy system shareholders, this may or may not be a priority.

Recommendation: Where district energy expansion opportunities exist, an inventory of existing boilers and chillers should be developed to clarify equipment lifecycles and equipment replacement as part of efforts to bring new customers online.

5.11 District Energy in Existing Built Environments

Developing district energy in an existing built environment is inherently more complex than in greenfield developments. It is challenging to develop a system initially because investment returns may be poor without a secured load of customers. Hamilton's system capitalized on existing supply systems that were approaching the end of their productive lifecycle, and forward thinking allowed for the provision of anchor tenants. District energy development within an existing built environment requires a thorough understanding of how many customers are required to make the system economically viable at launch, carrying the cost of capital financing, and how long a payback period is anticipated on initial capital costs (IE, 2011).

When a new system is built in a city, the customer base often consists of approximately 50% new construction and 50% existing building conversions, with customers committed under long-term contracts (IE 2, 2011). In an effort to attract customers that still have viable chillers, some district energy utilities have entered into an interruptible arrangement. This contract stipulates that the district energy utility will supply the existing building with chilled water for a certain percentage of time (for example 70%). As the district energy utility reaches its peak supply, they have the opportunity to curtail service and allow the existing building to switch to their own chillers, offering a rate differential in return. This method has merit when the district energy system is in a mature market with fairly new building stock. When looking at an overview of a community's thermal map, the question is not only how old is the building stock, but equally important to determine the age of the HVAC equipment. If the boilers or chillers have been replaced in the past 10 years, they probably have another 10 – 15 years of service life, and it is unlikely that a property owner will be replacing them prematurely (IE 2, 2011).

Each building will have different energy demand profiles influencing the cost of services. For example, if a potential customer has 100,000 ft^2 serviceable space and is located one block from the central plant, the capital costs of connection may be nominal and worth being absorbed by the district energy company in exchange for a guaranteed investment return over the life of the contract. However, on a smaller building situated further away requiring additional pipe, the smaller revenue profile may require that the customer contribute to the capital cost of connection to make the hurdle rate (IE 2, 2011). Hurdle rate analysis allows a business to target a rate of return on investment in plant and pipe to determine the viability of the capital outlay (IE 2, 2011).

This type of analysis allows the district energy provider to assume risks in the establishment of the system, but ensures that existing customers don't fund new expansion. Having a transparent hurdle rate allows the district energy company to provide a fair assessment of new customers cost of expansion. "When the system has matured and you have 50 buildings online, if they don't meet the hurdle rate, you are allocating plant and pipe to connect them, that will put upward pressure on your rates. You want to be able to say to your customers that you treat them all the same, communicating the hurdle rate and ensuring they all meet it" (IE 2, 2011).

Recommendation: As demonstrated in the Hamilton case study, it is important to catalogue the age of building stock and corresponding HVAC equipment in order to capitalize on opportunities for connection to existing building stock. Interruptible arrangements should be explored as a means to secure new customers in established markets with newer building stock, or HVAC equipment with remaining serviceable life. Additionally, developing and communicating a transparent hurdle rate for return on investment in necessary to evaluate the viability of system expansion.

5.12 Servicing the Condominium Market

With all of the benefits associated with district energy, it came as a surprise to see little penetration into the condominium market. Interviewees agreed that in most cases, previously constructed residential condominiums were designed around in-house boiler systems. It is very difficult to take boilers out of basements and chillers off of roofs. The best approach is to initiate conversation very early on in the approval process, to ensure proper coordination with the developer and the district energy supplier.

When a condominium is constructed, the builder provides connections for services under a short-term contract. Condominium corporations are not legally allowed to enter into long-term contracts with any thermal service provider, to ensure the corporation can renegotiate terms on a regular basis (SM 1, 2011). However, with electricity and natural gas, only one provider typically exists, so negotiation is minimal. This represents another challenge for district energy providers, which typically look to secure long-term contracts. The solution, as demonstrated in Markham, is to sign a shorter-term contract that can be renegotiated and signed on to a longer-term basis once the condominium board is in a controlling position. As Ontario's housing market transitions to higher density development typologies including mixed-use buildings and condominiums, district energy systems can be incorporated into greenfield, brownfield, and greyfield sites.

Recommendation: Municipalities should flag areas planned for higher density and mixed use development as sites with district energy potential as part of the planning process. Pre-feasibility studies should be conducted to explore opportunities for a district energy system, or connection to existing infrastructure. If a district energy system is in place, or to be commissioned, then new development within the serviceable area should be required to explore the feasibility of connection, and submit a study with recommendations as part of the site planning approval process.

5.13 Fuel Flexibility, If You Plan for It

Fuel flexibility is often cited as a benefit associated with district energy systems (CDEA, 2008, IDEA, 2007, IDHA, 1983, Compass Resource Management, 2010), with opportunities for economic multipliers when utilizing a local fuel source. "If biomass can be a viable source of local fuel, the plant is not running on Kentucky coal, or Abu Dhabi oil. Communities want to have a thermal network. An aggregated thermal network allows low-carbon options to emerge" (IE 2, 2011). However, in order to capitalize on local fuel sources, ample consideration during the initial system design phase is required to ensure the system can support alternative fuel sources in the future. For example, biomass has a different combustion and burning temperature than natural gas. As a result, boilers installed must be able to support a variety of temperatures resulting from use of different fuel if fuel source flexibility is desired.

In some European countries, it is common practice to fuel district energy plants with municipal waste. In these instances, municipalities can benefit from a local fuel source and address the need to dispose of garbage. Waste to-energy requires incineration to release energy from fuel. Waste contains valuable feedstock energy embedded through production, signaling the importance of reusing existing energy. However, even if the fuel is more sustainable, such as biomass, burning produces CO_2 emissions (IE 2, 2011).

Although energy from waste presents many exciting opportunities as a potential fuel source, it is met with considerable anxiety related to emissions, including mercury, other metals and particulates. This largely stems from failed and mismanaged attempts from decades past. “When you visit a well-managed and designed facility in Europe, it is difficult to detect its presence. European facilities have a refined appreciation for flow control, or the sorting and separation of fuel source” (IE 2, 2011, 1:07:29). In the United States, many incinerators were developed for the sake of burning trash instead of diverting waste from landfills. Instead of utilizing the heat produced, it was dissipated into the atmosphere. Municipal waste wasn’t thought of as an energy source.

The main challenge with incineration is that Ontario municipalities have not sorted their waste stream system for a waste-to-energy model to make socioeconomic sense (IE 1, 2011). For example, plastics contain an enormous amount of feedstock energy, permitting a very high burn temperature, but that doesn’t necessarily mean they are the best source of fuel to burn. Public perception of incineration as a ‘dirty’ form of energy plays a major role in inhibiting the development of these energy systems. To improve this, waste collection services must do a better job at sorting and separating waste to secure desirable fuels such as wood waste from industrial manufacturing.

Most of the waste derived from private Industrial/Commercial and Industrial uses ends up in public landfills. There is an opportunity to capture this high-quality feedstock energy for reuse as fuel, but it will require a comprehensive approach to waste management that provides a higher level of refinement for sorting (IE 1, 2011). Considerable potential exists in this field requiring further exploration.

Recommendation: As part of the Community Energy Planning process, an initial assessment should be conducted to identify local and/or indigenous fuel sources. This may include biomass or biogas products, or it may include a portion of fuels sourced from local waste. Boilers should be selected to ensure compatibility with a variety of energy sources, with particular consideration for fuel sources that are locally available.

5.14 Breaking Down Silos: Engaging Planners and Energy Professionals

After discussions with industry experts, planning and municipal staff, and district energy system operators, it became clear that conversations related to the set-up, structuring, and development of district energy opportunities do not typically occur between energy departments and/or local distribution companies and municipal land use planning staff. As one interviewee noted “Planning is primarily responsible for permission-based activities, essentially the regulation of land use and its efficient development relative to the growth and public interest needs of the community” (IE 1, 2011, 1:07: 14). In contrast to the policy regulation of planning, electricity or thermal energy infrastructure standards are often the responsibility of other departments, which don’t necessarily interact.

Increasing cross-department communication is a difficult task because priorities are often siloed within individual departments as direction is provided through municipal council and upper management. The planners interviewed in Hamilton and Markham had only peripheral knowledge of the district energy systems operating in their respective downtown cores, and were largely unaware of plans for future expansion. Unless direction is provided to clearly outline community objectives as they relate to cross-department coordination, this challenge will persist.

Beyond internal communication challenges within municipal departments, the successful development of district energy systems must address coordination amongst local energy utilities in an effort to evaluate the supply of energy to the community. “Since electricity and natural gas are competing services, all a developer does is come in and contract to Enbridge or Union Gas or the LDC and say, I need to ensure you supply energy to this building” (SM 1, 2011, 56:01). It is important to foster a collaborative approach involving the local government and the development proponent to identify the direction and location of new development and growth. Additionally, communication with municipal agencies allows for an efficient approval process. With the support of the municipality, district energy development proponents can alleviate some of the financial risks associated with the development. Cooperation from the municipality is also required to permit access to public and private rights-of-way and easements for district energy infrastructure installation.

5.15 Challenges Impeding District Energy Development

Challenges associated with developing district energy systems are often complex and interrelated, where one problem plays into, or contributes to the next. Based on the responses from those interviewed, challenges can generally by classified into three broad categories: 1) *Leadership; 2) Expertise, Capital and Coordination,* and *3) Legislative.* The following subsections will examine each category.

5.15.1 Leadership

Within the municipality, a champion showing vision and leadership is required to advance any large-scale initiative. This holds true for district energy where initiation is complicated by a large, up-front capital outlay, financing, resources, and developing base-load demand, among other challenges. Leadership does not necessarily have to come from city staff or a politician. It could be the local utility that expresses interest in the concept of district energy, or a business calling for greater energy resilience because of the potential impacts for its business model. Leadership can theoretically come from anyone, but if we don't have regulation for thermal energy, it won't be encouraged. As it stands, LDCs are primarily concerned with the distribution of electricity; natural gas companies consider thermal energy, but only in the capacity of transporting it through piping in the form of fuel. Without a champion, the benefits associated with district energy and is prepared to pursue development in their community, district energy systems will not be built, because there are other ways of satisfying thermal demand with more electricity or adding more gas. "A champion has identified something, a real issue for a community, that can't be met with those types of services, and that's where district energy comes into play" (DE 1, 2011, 33:10). Without a district energy champion, complacency and the path of least resistance will continue to persist.

One of the interviewees underscored the importance of a developer mindset as a key characteristic for a district energy system champion. The individual requires a longer view of the investment over time. A successful system must grow fairly quickly because once extensive capital outlays have been made revenue must be generated to carry the costs. One of the challenges with establishing a new system is that it requires a team of people who understand their prospective roles under the steady management direction of a leader with experience in managing a permitting cycle, financial processes, and a thorough understanding of the technical issues. "When you are looking at building a plant, 80% of the lifecycle costs are in operating the plant, with 20% accounted for capital construction. Too often decisions are made on the first 20% being capital costs at the expense of the potential value of the asset over time" (DE 2, 2011).

This set of talents doesn't always exist within a municipal government context, but sometimes can thrive within a utility or subsidiary of utility. In the United States, most new systems have been launched by subsidiaries of utilities, with motivated individuals committed to the success of the system and rewarded accordingly.

5.15.2 Expertise, Capital, and Coordination

Expertise, capital, and coordination present numerous challenges to the development of district energy systems. Without an integrated approach, the project will receive additional exposure to risk. The enormous infrastructure requirements require access to equity. The LDC probably does not have access to the capital required to underwrite the initial development costs. Natural gas companies, because of their broader jurisdiction and access to additional revenue, probably could supply sufficient capital. However, even in satisfying upfront capital expenditures, outside investors or agencies may be hesitant to proceed with the development of a district energy system without the municipality underwriting the risk for the load (DE 1, 2011). This is where coordination becomes a challenge. Outside investors are looking to minimize risk by ensuring a sufficient base load is present when the system becomes operational. Municipalities exert substantial control over this through land use, zoning bylaws, development process, site plan applications, building permits and other requirements for development.

Additionally, coordination with respect to other municipal capital undertakings can be a challenge. Ideally, servicing of district energy infrastructure, or the instillation of new infrastructure would be coordinated with other capital projects. However, political cycles and budgets make this difficult to do (SM 2, 2011). Connection costs can be substantial. Boring into buildings and removing old boilers must be accounted for, with the customer bearing the cost of connection (SM 2, 2011)

There are a number of fatal mistakes that can be made including: overstating the thermal load, a lack of understanding around capital costs and financing, failing to understand the construction timeline and permit cycles, and a lack of accounting for underground interferences (DE 2, 2011). Buildings don’t start fully occupied, typically receiving service from district energy providers months in advance of occupancy, which may be phased. This must be modeled into the hurdle rate analysis. For example, if a building is going to come online for service at a certain date, revenue must be feathered in towards full occupancy which may be several months later as service load demand increases.

Having an understanding of all the economic drivers, with an expertise tailored towards district energy system development, is critical to achieving financial viability. “When you have a residential load, an event load here, a hospital load, and three office buildings connected to a system, and you were to combine all of their peak demands, they might have a 20,000 tonnes of cooling requirement. However, (a district energy expert would recognize) that you could probably serve this with 12,000 tonnes of cooling because they all peak at different times” (DE 2, 2011, 21:10). This diversity and understanding of energy demand profiles is a fundamental advantage of DE, particularly when you incorporate thermal storage, it becomes an economic driver. This allows the plant to operate at a higher efficiency with a higher load factor all the time.

One of the problems with air conditioners and boilers is that they operate at part load 90% of the time. For maximum efficiency, they would operate around 80% of maximum capacity all of the tume. When a plant is equipped with thermal storage, as is the case with Markham's system, the plant can operate at its highest point of efficiency all the time, bringing operating costs down. The result is a more competitive thermal offering, or it can be accounted for in LCC analysis (DE 2, 2011 21:10).

It is not easy to determine the life cycle cost of district energy systems, and district energy utilities can set themselves up for failure when poor analysis forms the foundation of such studies. It is difficult to compare the stand-alone building costs (which would typically occur in a business case analysis to evaluate new boiler and chiller equipment) against the equipment required for a district energy connection, since a district energy system is servicing multiple buildings. However, determining an accurate account of capital and operations costs is critical for both financing and setting customer pricing structures.

DE providers typically charge for both a capacity and consumption. The capacity charge represents the customer's thermal requirement of the plant's total thermal allocation, their peak demand, and what they are going to need on a peak day. This is built into their contract. Then based on their tenant mix and square footage, the district energy provider estimates what their load profile will be and how much they will need on a metered basis.

When considering whether or not to connect a building to a district energy system, mechanical engineers under contract to architect, may only look at capital costs and consumption costs in a crude analysis considering fuel and or the equipment efficiency rating. One of the interviewees compared the analysis to that of a business mile for company travel: "When you drive a business mile, and it is recorded on mileage, you can deduct $0.52 a mile. If you have a car that gets 20 miles to the gallon at $2.00, $0.20

cents accounts for the gasoline and $0.32 cents is depreciation, insurance, wear and tear – the same analysis, the owning costs must be factored – in the case of individual building equipment for thermal conditioning, they are often understated and undervalued" (DE 2, 2011). Additionally, it was noted that engineers collect a higher fee when they design a mechanical room for an individual building, encouraging a standard default to this format for thermal conditioning.

5.15.2.1 Capital Outlay, Financing and Subsidies

Major infrastructure investments require a large outlay of upfront capital. This involves varying degrees of risk to investors, particularly investors from private entities.

One of the interview respondents noted that Hamilton Community Energy experienced financial difficulties earlier on in their operations, requiring the temporary shut down of their CHP component (DE 1, 2011). Hamilton's slow growth in the downtown area limited the ability to bring on new customers. With district energy, "your currency is building space. If you overbuild your system in anticipation that more building space will come online, and you don't get that (additional building space), then you loose; but if you build your system small, and you get the demand, but then you may not be in a position to expand" (DE 1, 2011, 23:10). For this reason, municipalities are in a strengthened position to spearhead the development of district energy systems because they are acutely aware of future planned development in size, scale, and use.

Risk can be mitigated through the proper evaluation of the net present value (NPV) as a cost measure of investment performance. Investors may look at a typical investment horizon of 7 – 10 years and compare capital invested in a bond or a district energy system. While the bond may produce a 6 percent return, when accounting for capital costs, operating costs, and fuel source prices, a district energy system would have a lower return over the same period. Initial capital costs may take 15 – 20 years to pay off, yielding an annual rate of return of roughly 4 percent for most systems (DE 1, 2011). Although district energy systems make money, this underlines the fact that most private investors would look for a higher rate of return on investment with a shorter payback period and lower risk, even with a confirmed base load (DE 1, 2011).

Recommendation: Municipalities are often ideal candidates for district energy system development because of their influence over future planned development, and their ability to tolerate a lower rate of return on capital infrastructure investment, over a longer period of time.

Several financing models have been utilized to provide the necessary capital for district energy development, providing a favorable interest arrangement. Within federal and state governments, law stipulates the specific parameters of revolving funds. When established for the purpose of infrastructure development, revolving funds institute a basis under which financing for the cost of goods or services furnished to or by a government agency originate. The revolving fund is replenished through charges made for goods or services, in this case, the provision of thermal energy (IE 2, 2011). In the US, the revolving fund allows the developer to avoid payments on borrowed capital and interest during the initial 24-36 month period. This defers the amortization period to align with the plant commissioning and initiation of billable operations.

As was the case with the Markham district energy plant, a special purpose entity is often beneficial when initiating a district energy start up. Some investors or potential customers might be wary of getting involved with an entirely municipally run organization, and prefer to see something operated at arm's length from the municipality. "If there is a board, its composition should contain members and users to create an environment where the participants are trying to do something collectively that they couldn't do individually. When they have this asset (DE system), they are thinking about it in a way that is constructive and worthy of continual investment. You want the thought leaders of the community to continue to nurture the asset as something that is seen as valued to the community – this is often the approach in Scandinavian countries" (IE 2, 2011, 1:11:03).

5.15.2.2 Burying Pipe

Controversy may arise in determining who buries the pipe when expanding or developing district energy systems. As one respondent expressed "pipe is money" and accounts for a major portion of upfront capital expenditures (IE 2, 2011). Determining who puts the pipe in the ground, where it is placed, how far in advance, and under what circumstances are all questions that must be addressed.

A plant can be built in a linear sequence, with a parcel owner expressing interest in development, obtaining the necessary permits, securing the appropriate financing, undertaking the associated engineering, purchasing the equipment, and constructing the plant. This results in a tangible, visible asset. However, when you put pipe in the ground, you are making an investment that is amorphous, with indirect beneficiaries and the inability to reclaim that investment. Good industry practice suggests securing an anchor customer that accounts for 20%-30% of the plant's initial capacity. This is often a local government entity or subsidiary, known as a 'safe entity'.

In Canada and the United States, the district energy plant and piping infrastructure (provider) are owned by the same entity. District energy systems in Denmark often see the municipality as the owner of the piping infrastructure, while a separate entity is responsible for the plant. In some North American cities, there was the notion that municipalities could charge for right-of-ways and soil displacement as new sources of revenue. Most of the time a franchise agreement is reached, with a fixed amount paid to the municipality, sometimes it is paid in cash, but in other instances, donations are made in the form of community amenities or benefits For example, the district energy system in Cleveland, Ohio provides an annual donation of $25,000 - $50,000 to a tree fund (IE 2, 2011).

One of the challenges is to coordinate with the planning department for compatible zoning and site permissions to locate a concentration of load as close as possible to the plant to minimize infrastructure costs (SM 2, 2011).

Recommendation: Municipal planners should have regard for future community energy demand, and provide a corresponding planning framework that enables the concentration of a variety of uses and building typologies.

Additionally, municipalities should develop land use regulations and policies that support energy efficient community design and support district energy systems.

Determining appropriate city-wide zoning for district energy plants is a challenge that exists in many Ontario municipalities, requiring a solid definition of 'district energy plant' with the specificity to ensure the plant is consistent with the vision for the community, but also broad enough to be applicable in a variety of contexts. Interviewees indicated that regulation and consistency through the development process is critical to the advancement of district energy systems. Ontario municipalities interested in developing community-based energy solutions such as district energy should review their zoning bylaws to identify barriers that might negatively impact the feasibility of a district energy system, and update regulations to encourage the development of desirable urban form.

5.15.3 Legislative

5.15.3.1 Provincial Regulation

British Columbia offers guaranteed rates for natural gas that achieves 80 percent efficiency, however, Ontario's FIT program doesn't currently provide incentives for natural gas. The Ontario Power Authority (OPA) is responsible for flowing money, and only with respect to electricity, not natural gas. The Ontario Electricity Board (OEB) regulates energy providers in Ontario, specifically the Local Distribution Companies (LDC) for electricity and natural gas. The OPA provides a planned framework for the distribution of power, which in some cases, relate to natural gas or the pumping of water (IE 1, 2011).

As it stands, natural gas is available across Canada with one or two providers per province. When they expand their infrastructure, it is written off across their entire network and the cost is carried by all of the customers. Their business model doesn't ask the individual community to bear the cost of expansion. Instead, a small fraction of the cost is absorbed by every customer. If natural gas companies were legislated permission to provide thermal energy, adopting this model would be beneficial to the development of district energy systems, aggregating expensive infrastructure costs, achieving purchasing efficiencies, and reducing risk (IE 1, 2011)

The OPA does not need to provide an incentive for natural gas. Rather, regulations should evolve to allow natural gas providers to become more than transporters of energy, providing a full range of energy services. This would require the Ministry responsible for the energy portfolio to provide direction and legislation to accommodate an enhanced mandate for natural gas companies, and the OEB to provide regulation specifying who provides what service and at what cost (IE 1, 2011).

"Most policy drivers in the US and Canada are electricity related: renewable portfolio standards, production tax credits, wind and solar renewable credits…its all about electricity. People follow the money, and as a result, we haven't seen comparable investment in district energy systems" (IE 2, 2011, 28:22). Some energy operators argue that subsidies are not a good thing because they create an artificial demand when it may never have been appropriate or required. In some cases, subsidies may produce a market that has changed with an entirely different demand.

"Ontario doesn't need to have incentives - if we took off all of the electricity and said 'replace with whatever makes the most economic sense, and by the way it needs to be clean burning and set some targets' – everyone would be building something towards that, whether they needed the incentive is a good question. It would be better if we said 'we're going to take the perverse incentives that are already underwriting the costs of fossil fuels out', then we would have a competitive market. Instead we are

adding incentives to cover off other incentives that have been built in to make systems viable" (IE 1, 2011, 39:10).

Recommendation: The Provincial Government should consider legislating permission to natural gas providers to develop and operate district energy systems. Their inherent experience with constructing and delivering sophisticated piping infrastructure as well as their unique financing model for capital investments makes them ideal candidates to champion the penetration of district energy systems into new markets.

5.15.3.2 Electricity and Natural Gas Rates

As market comparables, electricity and natural gas rates exert considerable influence over the financial viability of a district energy facility. For example, district cooling has had success in cities where there is a very high electricity demand charge or a peak hour charge, set by the local utility (as published rates). It is not as easy to understand local rates on the heating side where district energy systems are generally competing with natural gas fueled systems against conventional natural gas furnaces or boilers. This makes it more difficult to obtain an economic advantage.

In some cases, advantages can be secured when a district energy company purchases a higher volume of natural gas and the plant secures a direct pipeline to the plant. That being said, a district energy plant primarily fired by natural gas gains its main advantage by utilizing a standby fuel such as oil or propane, providing fuel flexibility in times of volatile energy pricing (SM 1, 2011). With a commercial office building, the footprint may not exist for sufficient floor space to accommodate a standby fuel, meaning the building is a firm customer contracted for 100% natural gas, potentially subjecting the customer to higher fuel rates compared to a customer contracted with interruptible service.

For district energy providers, the fuel switch is made on a price signal, stipulated in corporate policy, where when the price of natural gas reaches a certain point, the system switches to an alternative standby fuel (SM 3, 2011). Typically, district energy providers purchase 80% of their annual natural gas in advance because they have a good understanding of their load requirements for the year. The remaining 20% is hedged to capitalize on fluctuating market prices. It is critical to understand how to manage risk, volatility, and supply as it relates to market pricing and the system's client base and their service requirements. Prices for customers are articulated in rate block pricing, much like commercial rates, known as an escalator. "In 2001, there was a real run up in the price of natural gas… a lot of commercial property owners got spanked, and they didn't have the cost recovery mechanisms (for fuel) in their leases to recovery the cost from their tenants, so they took a big (financial) hit. A lot of them came back to their DE company or went to their neighbour and said 'how was the steam?' ' Steam was pretty good, because when the price of gas went to $11, the district energy system switched to another fuel'" (IE 2, 2011, 37:00).

Although contracts between district energy service providers and customers are largely fixed, some risk of exposure to market fluctuations exists as most contracts include stipulations allowing district energy providers to pass along price fluctuations to the customer. Service is guaranteed in terms of quality, pressure, and 24/7 service.

In the near future, North American systems will shift to utilize more local fuel sources (biomass, biofuel, industrial heat waste) representing an indigenous supply. Ideally, this would comprise 80% of the fuel source with natural gas shifting to the 20% of standby fuel. This is in part what makes DE so compelling and a key piece of the sustainability argument, providing the opportunity to reduce the carbon footprint of thermal energy delivery (IE 2, 2011).

As the amount of renewables continues to rise, there may be balancing problems with uncontrollable variable solar and wind supply. For example, wind power must be backed up with a non-intermitted turbine. Co-generation district energy could provide a stable base load, enhancing opportunities to contract with variable renewables.

5.15.3.3 Municipal Bureaucracy

Municipalities might become more attractive sites for DE development if they simplified the development process and waived some of the fees associated with obtaining Right-of-Way (ROW) permits, soil displacement, and other discretionary expenses. In some cases, interviewees felt that DE was at an unfair disadvantage compared to other service providers. For example, cable television providers may use a Ditch Witch to remove a narrow width of road infrastructure from the centre of the right–of-way, and are only expected to patch what was removed. The result is a new piece of infrastructure transposed over top of existing critical infrastructure (SM 2, 2011). When a DE provider attempts to lay twin 30 inch pipes, they are required to find an appropriate ROW minimizing infrastructure overlay, or relocate existing services, and complete major infrastructure repairs as part of the process. In some cases, this may require curb-to-curb maintenance and resurfacing, even if the section removed was only several feet wide (IE 2, 2011).

Recommendation: Consideration the lessening of permit fees and the reasonable and consistent treatment of infrastructure improvements should be part of a municipal offering to attract district energy development.

5.16 Implications for the Planning Profession

The implications of land use planning on the energy demand profile of a community have been documented in the literature. Additionally, a broader role in the area of sustainability initiatives exists within the relationship of land use, energy efficiency, and opportunities to reduce energy consumption through land use and transportation infrastructure.

One of the respondents described this linkage: “The benefits of DE beyond its robustness and resiliency is in the sense of meeting energy issues. It forces people to think about the continuum of energy decision making, but also the way people think about the decision making process about how you plan for infrastructure." (IE 1, 2011, 5:20) The key message is that district energy can contribute to the thinking and shaping of the physical land use in a sense that where your buildings might be located, and the mix of those buildings, and the density of those buildings, might be not only more financially viable, but also making the thermal demand of those buildings reasonable. Instead of having more energy demand going forward, it can encourage a more energy efficient built form and at the same time, be a supplier to meet the energy demands of those buildings using a very energy efficient format for system delivery, but also being able to use a variety of clean fuel sources. (IE 1, 2011, 5:20). Implications span the entire supply chain from the format of energy, fuel source, distribution, and end use, district energy can provide value to communities across the delivery of services at every stage and in doing so, has a mutually reinforcing role with many widely accepted urban planning principles.

"DE has created that much broader discussion is that, every decision we make influences that energy demand, and we are finding out that the risk structure 100 years from now is going to be more vulnerable, but our roads and people will be here so what should we be building now to make ourselves more resilient? And planners included, the systems set up are fighting against what we would like to see because we have a business model that says, connect to power, connect to water, connect to thermal – those systems have been built out already, so the infrastructure is in play versus DE, if it's not there, it's wait a minute, lets evaluate and see if we can connect. So the important part for planner is related to future development. Where will you direct development, what will be the density, and what will the built form look like? Will it support a DE system?" (IE 1, 2011, 45:22).

Chapter 6 Conclusions

As revealed in the case studies and findings section, land use planning can play a considerable role in supporting the realization of more sustainable community based energy solutions. This chapter will briefly summarize the recommendations for municipalities and planners interested in advancing the development of district energy systems, outline several shortcomings of the study, and provide a general discussion of the role of urban planners and the planning framework in delivering more energy efficient communities.

6.1.1 Summary of Recommendations

1. Recommendation: Municipalities should consider the development of district energy systems as a means to increase local energy redundancy and reduce dependency on centralized energy.

2. Recommendation: As part of a comprehensive community energy planning exercise, district energy systems should be explored in areas where new development may jeopardize the capacity of existing infrastructure to deliver energy. This would require coordination with Ontario Hydro and other agencies responsible for the delivery of energy to determine the amount of anticipated energy demand in the future.

3. Recommendation: It is important to catalogue the age of building stock and corresponding HVAC equipment in order to capitalize on opportunities for connection to existing building stock. Interruptible arrangements should be explored as a means to secure new customers in established markets with newer building stock, or HVAC equipment with remaining serviceable life.

Additionally, developing and communicating a transparent hurdle rate for return on investment in necessary to evaluate the viability of system expansion.

4. Recommendation: Municipalities should flag areas planned for higher density and mixed-use development as sites with district energy potential as part of the planning process. Pre-feasibility studies should be conducted to explore opportunities for a district energy system, or connection to existing infrastructure. If a district energy system is in place, or to be commissioned, then new development within the serviceable area should be required to explore the feasibility of connection, and submit a study with recommendations as part of the site planning approval process.

5.Recommendation: As part of the Community Energy Planning process, an initial assessment should be conducted to identify local and/or indigenous fuel sources. This may include biomass or biogas products, or it may include a portion of fuels sourced from local waste. Boilers should be selected to ensure compatibility with a variety of energy sources, with particular consideration for fuel sources that are locally available.

6. Recommendation: Municipalities are often ideal candidates for district energy system development because of their influence over future planned development, and their ability to tolerate a lower rate of return on capital infrastructure investment, over a longer period of time.

7. Recommendation: Municipal planners should have regard for future community energy demand, and provide a corresponding planning framework that enables the concentration of a variety of uses and building typologies.

8. Recommendation: The Provincial Government should consider legislating permission to natural gas providers to develop and operate district energy systems. Their inherent experience with constructing and delivering sophisticated piping infrastructure as well as their unique financing model for capital investments makes them ideal candidates to champion the penetration of district energy systems into new markets.

9. Recommendation: Consideration for the lessening of permit fees and the reasonable and consistent treatment of infrastructure improvements should be part of a municipal offering to attract district energy development.

6.1.2 Integrate Community Energy Objectives into the Land Use Planning Process at the Onset

In both Markham and Hamilton, interviews revealed that there was a strong municipal desire to pursue the development of a district energy system. However, district energy systems developed despite each municipality lacking a planning framework that gave thorough consideration to the implications of the land use framework on community energy objectives.

The development of energy mapping, community energy plans (potentially as part of broader Integrated Community Sustainability Plans), and/or integrated energy concepts that outline potential energy supply and conservation strategies for various planning districts were identified by planning professionals, industry experts as key strategies for advancing community based energy solutions. Adopting and integrating an energy concept with performance based measurements for community energy consumption and conservation as part of local land use policy would help to ensure desirable development outcomes in keeping with municipal objectives for energy conservation and reduction in GHGs.

Conversations with planning staff and industry experts in Markham and Hamilton suggested that energy planning initiatives should be developed and in place prior to any precinct plans or in conjunction with larger secondary plans. In practice, this would be similar to the process in which municipalities develop transportation master plans. Community energy planning must be undertaken with input from the local distribution companies who possess data related to distribution networks, energy management capacity and projected demand. By developing community energy plans, and integrating considerations for community energy at the start of the planning process, opportunities for sustainable energy outcomes are more likely to be supported by land use planning decisions.

6.1.3 Develop land use regulations and policies that support energy efficient community design and support district energy systems.

Determining appropriate city-wide zoning for district energy plants is a challenge that exists in many Ontario municipalities, requiring a solid definition of 'district energy plant' with the specificity to ensure the plant is consistent with the vision for the community, but also broad enough to be applicable in a variety of contexts. Interviewees indicated that regulation and consistency through the development process is critical to the advancement of district energy systems. Ontario municipalities interested in developing community-based energy solutions such as district energy, should review their zoning bylaws to identify barriers that might negatively impact the feasibility of a district energy system, and update regulations to encourage the development of desirable urban form.

6.1.4 Role of the Municipality

As discussed throughout this thesis, Ontario municipalities are prime candidates to spearhead the development of district energy systems. Involvement may take a variety of forms including the commissioning of an arm's length private corporation like Markham District Energy or participation as a subsidiary through the local energy distribution company as is the case with Hamilton Community Energy.

6.1.4.1 Planner and Strategist

The municipality has an integral role in planning and strategizing for the provision of community based energy solutions. The municipality controls the policy and planning framework to either encourage the development of district energy through mixed-use zoning, compact urban form, community energy plans, and checks and balances incorporated into the approval processes, or inhibit development through a rubber stamping approach to monoculture, sprawling growth and a weak policy framework that only gives consideration to thermal energy delivery as an after thought. This realization thrusts the municipality to the forefront of planning for community based energy solutions, and municipalities must take a pro-active role in strategizing and giving careful consideration to the multitude of factors that will impact the feasibility of developing district energy.

6.1.4.2 Leader and Innovator

The municipality must have a desire to abandon business as usual practices and genuinely want to do something different. Connecting individual buildings to natural gas is easy, convenient, and relatively affordable. There must be a driving desire to implement and realize environmental objectives, increase resiliency, and ensure the community has a multitude of energy source and supply options. This requires the municipality to exhibit leadership when making difficult decisions, choosing to undertake complex energy planning that requires a tremendous amount of coordination, and a marked decision to innovate, finding new solutions to challenges traditionally addressed through other means.

6.1.4.3 Provider and Deliverer

Whether directly or indirectly, the municipality may play a role in the procurement and delivery of thermal energy. Like any business, district energy systems must exceed customer's expectations and provide exceptional customer service and reliability as part of making a compelling case against competing energy providers (natural gas, electricity, etc.).

6.1.4.4 Advocate and Lobbyist

Developing a district energy system requires a strong champion or series of advocates committed to coordinating agencies and processes, developing a customer base, securing permits, approvals, and regulatory requirements, and driving the overall process forward. Dedicated municipal staff and members of council should work together with a coordinated approach to developing community based energy systems and provide consistent advocacy through their involvement in other initiatives as a means of disseminating this vision to a wider audience.

6.1.4.5 Facilitator and Connector

Tying planning and strategy, leadership and innovation, procurement and delivery, and advocacy and lobbying together requires a strong commitment to the roll of facilitator and connector. Developing district energy systems becomes possible when a group of dedicated individuals can connect all of the various interests and agencies to move a project forward. This may start with the municipality undertaking a Community Energy Plan to clearly identify opportunities for community based energy solutions. Like Hamilton, it may involve taking stock of existing HVAC equipment to determine the life expectancy and align replacement timing. Like Markham, it may involve actively seeking out potential customers as part of a robust economic development strategy. Having dedicated, knowledgeable staff on hand is essential to making these connections and facilitating the development of a community asset.

6.1.5 Disseminate energy planning principles into the planning professional practice and post-secondary curriculum

The planning professionals interviewed were not very familiar with the concept of district energy outside of knowing that their respective communities contained a system. The one exception this was one individual who was a full Member of the Canadian Institute of Planners (MCIP), but whose employment was classified under district energy industry expert. As a result planning staff were not actively collaborating with the local district energy utilities in a way that would see land use decisions providing consideration for community energy opportunities.

This was echoed by staff from the district energy utilities who expressed a disconnect in communication between the planning department and the district energy utility, often primarily coordinating with the Sustainability Office (in Markham) or Energy Initiatives Office (in Hamilton). A lack of knowledge about district energy or broader interest in energy issues from municipal staff may decrease district energy feasibility as a consequence of land use decisions.

By including the consideration of local energy issues as part of a post-secondary planning curriculum, future land use decisions may incorporate many of the design principles outlined in the existing literature that promote energy efficient communities. Additionally, disseminating this information through professional associations, such as the Canadian Institute of Planners and the Provincial affiliates, practicing planners may come to learn of the opportunities associated with district energy, and move forward with advancing community energy systems.

6.2 Questions and Considerations for Future Research

Planning is a vibrant profession, with academics and practitioners constantly curating new areas of research. Due to resource constraints and scope parameters, this research has been limited in a number of areas. However, review of literature, case study analysis, and key informant interviews have prompted several additional questions and considerations for future research:

- What is the role of the municipal planner in coordinating connections with new development situated in areas serviced by district energy?
- How will legislative requirements for district energy feasibility studies, or in some cases, requirements for connection impact property values?
- Explore how community energy plans have been tied to the land use planning framework.
- What legislative requirements and/or amendments are necessary to allow natural gas providers to enter the market as district energy utilities?
- Identify specific opportunities to educate future and practicing planners on community energy issues and the relationship to density, land use, and urban form.

6.3 Final Thoughts

The research conducted in this thesis has demonstrated that there is a need for a more coordinated approach between traditional land use planning and community energy planning. Energy planning often occurs in silos, but the multidisciplinary nature of the associated challenges requires agencies to work together to develop strategies and solutions for local energy demands.

Building off of the work of others related to energy efficiency and land use, and highlighting district energy as a potential solution to realizing municipal objectives related to energy performance, this research has attempted to provide broad recommendations to help overcome some of the obstacles identified in the literature, case study analysis, and key informant interviews when developing district energy systems, particularly in the municipal context.

Community Energy Plans seem to be one of the most promising strategies for drawing a strong link between community energy considerations and planning policy, particularly when having regard for one another. One of the biggest challenges is educating and increasing awareness amongst the planning profession about the ramifications of land use decisions for community energy demand.

Appendix A

ETHICS APPROVAL FORM

INTERVIEW REQUEST FORM

INTERVIEW QUESTIONS

Planning for District Energy Systems: A Case Study Examination of Selected Systems and Recommendations for Ontario's Municipalities

Research Conducted by Brad Bradford

<u>Interview Questions</u>

District Energy Development and Implementation

1. Please describe your position and role within ______ and responsibilities within the organization.
2. Please describe the benefits in your perspective, associated with your community's district energy system.
3. What primers brought about the decision to develop a district energy system?
4. Is the development, operation and planned expansion of the district energy system tied to any municipal objectives? If yes, please elaborate.
5. What challenges or obstacles inhibited the development and implementation of the district energy system in your community? How did your organization overcome them?

Energy Infrastructure, Distribution and Adaptability

I would like to ask you a few questions related to energy distribution in the Province of Ontario and its relation to fuel sources, economic uncertainty and emission related challenges

6. Do you think the current energy infrastructure servicing _______ is vulnerable to the volatility associated with the energy sector (pricing, outages, climate change challenges)? What is your perspective on the situation in most Ontario communities?
7. What are the lifecycle costs (LCC), energy use and GHG emissions with the district energy system? Could you provide some comparison to a business-as-usual (BAU) stand-alone building heating and cooling system?
8. What are the effects of district energy system on the electricity distribution system (scale, where is the electricity coming from), customer and developer risks/benefits and local air pollution (is this only determined by fuel)?
9. Would you characterize district energy systems as adaptable? Why or why not?
10. What capacity exists for the system to expand in size and scale? What would be required to initiate such a process?

11. What fuels can your system accommodate and what are the restrictions on fuel sources
12. Has the district energy system considered using any other fuel sources than the ones currently employed today? If so, what has been considered and under what conditions would these alternative technologies be deployed?

Perceived Community Benefits

I am interested in learning about the perceived benefits by the municipality, customers, businesses and the general public associated with district energy. Comparisons to BAU scenarios or the situation in your community prior to the development of a district energy system, would be helpful.

13. Could you comment on the experience of district energy for end users and the municipality? Is it better with district energy in comparison to BAU scenarios?
14. Has district energy been a source of attraction for new development in your community?
15. Do customers care about energy autonomy/resilience? What is your organization's perspective?
16. What has been the general public's response to the development of a district energy system? Has public engagement been a deliberate part of the process?

Energy Planning

For the final section of this interview, I would like to ask you a few questions about the relationship between planning for district energy and community energy management and overall land use planning in the municipality.

17. What additional departments within the municipality and or other organizations are involved with the district energy system and in what capacity?
18. What interaction does the planning department have with the electricity management department?
19. What is the common discourse related to community energy management? How does your organization engage with citizens and stakeholders?
20. How is energy efficiency, consumption and distribution consider in planning documents? What are your thoughts on Community Energy Plans (CEPs)?
21. What policies, bylaws, planning tools or incentives are used, if any, to encourage the development, implementation, operation and future expansion of district energy systems in your community?
22. How could the development of district energy systems be incorporated and integrated into the planning process? How could the process be streamlined for development?

That completes my interview questions. Do you have any other thoughts or ideas you would like to share with me at this time? Do you have any questions to ask of me?

Is there anyone else who has been involved in the development of district energy and energy *planning in ____________, or even elsewhere in the province, who you would suggest I speak to regarding this issue?*

Thank you for your time and participation.

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