Advancing District Energy in Ontario's Urban Municipalities:

Lessons Learned from Planning for the Expansion of the Keele Campus District Energy Network

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Report of a Major Project submitted to the Faculty of Environmental Studies in partial fulfillment of the requirements for the degree of Master in Environmental Studies

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II. Abstract

As municipalities in southern Ontario seek out ways in which to accommodate urban growth, energy is an ever-increasing concern given its connection to land use, urban form and infrastructure. Many local governments are considering district energy systems as a solution, but their application depends on close integration with community planning and land development, which is an underexplored interface. The purpose of this project is to understand and demonstrate some of the high-level aspects of planning for district energy as a means to facilitate implementation, primarily for planners and other municipal staff interested in district energy.

Given the interdisciplinary nature of planning for district energy, a mixed-methods approach was followed, in which methods of both social sciences and engineering were employed. A literature review and interviews with land developers, municipal staff, district energy experts and university personnel provided the basis for conceptual discussion. In addition, a case study of the opportunity to expand York University's Keele Campus district energy network, which employed several quantitative methods, yielded important practical lessons regarding planning for district energy.

The predominant challenge for district energy is its organizational complexity as this introduces uncertainty, which translates to risk. However, findings suggest that integration of system design and operation with community planning and land development can reduce this complexity by aligning the priorities of building developers and district energy developers. Also, it is clear that municipalities must lead this process and that integration with strategic priorities can further improve prospects for implementation. Planning for district energy can build the commitment and leadership that is necessary to move towards implementation in the absence of provincial policy and regulatory support.

There is also a substantial opportunity to expand the Keele Campus district energy network to potential new development in the near future. Upon full build out of the campus, conservative estimates indicate an annual carbon dioxide emission reduction between 8,000-10,000 tonnes. Also, there is the potential to add 15-25 megawatts of combined heat and power, which would further reduce emissions. Such an initiative can act as a platform to build interdisciplinary curricula and drive student enrollment. At the very least, the findings suggest that more detailed studies of these opportunities are warranted.

III. Foreword

I began the Master of Environmental Studies program with a vague notion that sustainable energy and urban planning somehow intersected to the extent that I could fashion a project on the subject. Yet it took a full year and the completion of an internship abroad to identify district energy as the subject matter that would elevate my interest to actual research. My Area of Concentration, “Sustainable Energy Planning and Policy in Ontario”, is embodied by this project, though not in the manner that I had envisioned at the start of the program.

Initially, I intended to focus on renewable energy and although the distinction between renewable and sustainable is marginal, it has significant implications in this project. Notwithstanding its name, district energy represents a commitment to infrastructure, not fuel. While I would prefer that all district energy systems utilize renewable fuels, it is not realistic, at least not yet. However, once the infrastructure is in place, a district energy system offers choices not available for individual buildings.

While I had intended to engage with formal policymaking as it applies to district energy, it is also to me clear that municipalities cannot rely on the possibility of future provincial legislative or regulatory support. As such, though this report does address provincial policy and regulation, recommendations are oriented towards municipal policymaking that can facilitate district energy irrespective of provincial action.

Perhaps the most important lesson learned during this project and during my time in the MES program, is that not only is there a role for municipalities in energy planning, but that municipalities must plan for energy if we, as a society, are to make any progress addressing climate change. Given this emerging realization, my intent is that by exploring the opportunity to expand the Keele Campus district energy network, this project can demonstrate some of the approaches to energy planning.

Finally, on a personal note, I wish to emphasize the benefits of supplementing coursework with praxis, especially in emerging fields such as energy planning. York University is a tremendous institution at which to engage in experiential education and I hope that future MES students continue to see the value in this approach to learning.

IV. Contents

V. Acronyms

BAU	Business-as-usual
CAD	Computer-aided Design
CDM	Conservation and Demand Management
CEP	Community Energy Planning
CEI	Community Energy Initiative
CEM	Community Energy Management
CHP	Combined Heat and Power
CO_2	Carbon Dioxide
CSBO	Campus Services and Business Operations
CUB	Central Utilities Building
DE	District Energy
DG	Distributed Generation
DHW	Domestic Hot Water
ECO	Environmental Commissioner of Ontario
ekWh	Equivalent Kilowatt Hour
ESA	Energy Service Agreement
FSI	Floor Space Index
GFA	Gross Floor Area
GHG	Greenhouse Gas
GIS	Geographic Information System
HVAC	Heating, Ventilation and Air Conditioning
IESO	Independent Electricity System Operator
kW	Kilowatt
kWh	Kilowatt Hour
kV	Kilovolt
LCA	Life Cycle Analysis
LDC	Local Distribution Company
MEP	Municipal Energy Plan
MNECB	Model National Energy Code for Buildings
MURB	Multi-unit Residential Building
MUSH	Municipal, University, School, Health Care
MW	Megawatt
MWh	Megawatt Hour
OEB	Ontario Energy Board
OP	Official Plan
OPA	Ontario Power Authority
PDM	Property Data Map
TCHC	Toronto Community Housing Corporation
TGS	Toronto Green Standard
TS	Transformer Station
UGC	Urban Growth Centre
YUDC	York University Development Corporation

VI. Figures, Tables and Maps

Part I: Advancing District Energy Concepts

1. Introduction

Efficient, reliable and sustainable energy systems have become a land use planning problem for urban municipalities in Canada. In southern Ontario, municipalities are considering establishing district energy (DE) systems and combined heat and power (CHP) plants as a means to meet increasing energy demands in a manner that is compatible with growth. Although the technology was first commercialized more than a century ago and several municipalities have previous experience with DE, concerns regarding the provision of energy infrastructure, the reliability of the electricity system and reducing greenhouse gas (GHG) emissions are driving a renewed focus towards energy solutions that are efficient, resilient and local.

However, municipalities have been absent from the energy planning process for decades in Ontario, which is unremarkable considering that the system has functioned well under provincial control for the most part. However, recent occurrences indicate that the centralized approach to energy planning is ill-equipped to adapt to the pace at which change is occurring: intensified urban growth raises doubts about the adequacy of energy infrastructure; extreme weather events and political interference bring to light the vulnerability of the electricity system; and uncertainty regarding future GHG emissions invites criticism of energy policy. Yet in every challenge there exists an opportunity and in some cases, a synergistic solution can meet multiple challenges. The purpose of this report is to discuss and demonstrate how municipalities can engage with energy planning by drawing on literature, interviews and a case study of the opportunity to expand the Keele Campus district energy network.

DE may very well be the only energy solution that is compatible with urban growth, resilient and energy efficient, and it is the infrastructure that enables this. A district energy (DE) system (Figure 1) is a thermal grid, comprised of a network of pipes that distributes thermal energy between the point of supply (where fuel is used to generate the energy) and the points of demand – i.e. multiple buildings whose inhabitants require energy services (Gilmour & Warren, 2008). The network can distribute steam or hot water and/or cold/chilled water. In some cases, electricity can also be generated at the point of supply and then distributed. When the excess heat from the electricity generation process is captured and distributed through the thermal grid, this application is referred to as CHP and DE-CHP schemes are more energy efficient than typical power plants (Gilmour & Warren, 2008). Compared to electricity generation with modern combined-cycle gas turbines, which are 50-60% efficient at best, DE-CHP, by capturing and using waste heat, can be 85-90% efficient. Figure 2 compares the efficiency of the business-as-usual approach (grid electricity and standalone boilers) to CHP.

Beyond energy efficiency, DE systems, through the sharing of infrastructure, bring numerous benefits to the buildings they connect and to the communities in which they are located. First and foremost, DE networks are a platform through which renewable fuels and new technologies can achieve significant penetration into urban areas. The economies of scale offered by a DE system allow for fuel switching that would otherwise be cost-prohibitive for individual buildings with standalone heating and cooling systems (Compass Resource Management, 2010). Second, DE systems are resilient: the distribution infrastructure is less vulnerable to extreme weather events; depending on the system configuration, central plants can often operate in the event of disruptions to the electricity or gas grids; and when they include CHP, the additional embedded generation can reduce stress on the electricity grid during periods of peak demand and

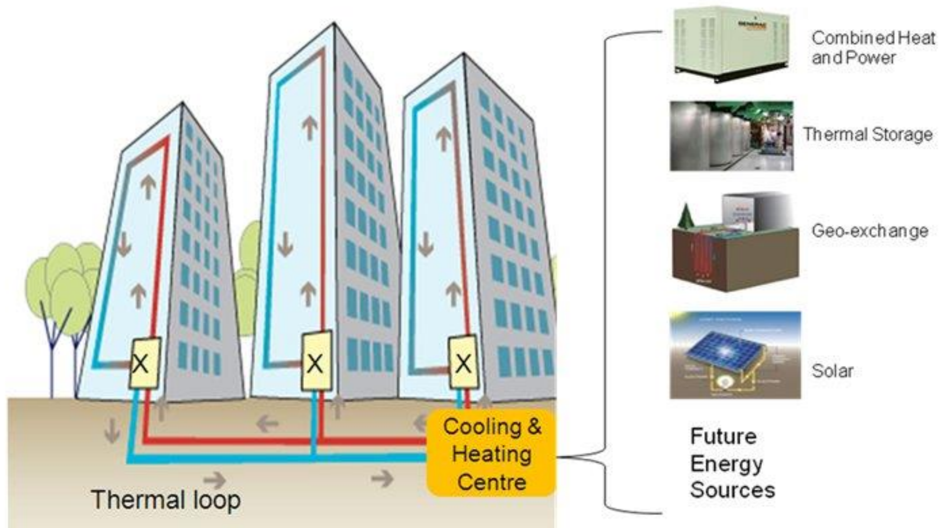


Figure 1. Simplified illustration of a DE system (City of Toronto Energy Efficiency Office, n.d.).

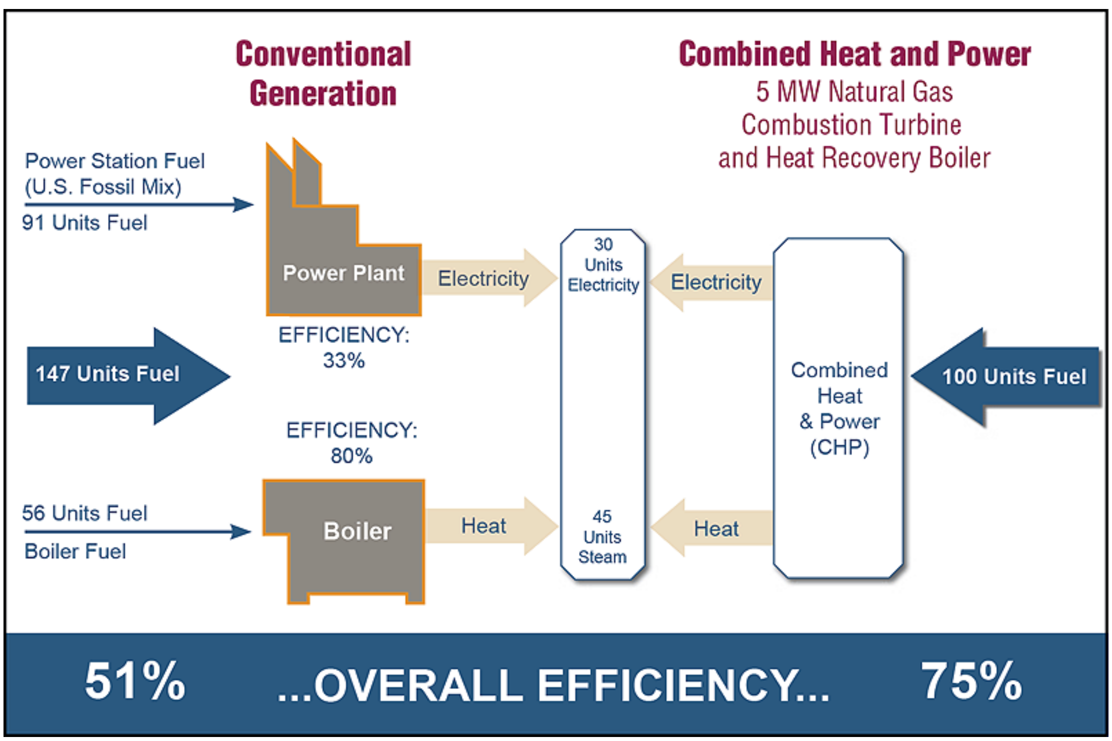


Figure 2. Energy efficiency of CHP compared to conventional electricity generation (Environmental Protection Agency, n.d.)

prevent grid failure (Beck et al., 2012). Finally, DE systems are conducive to local economic development. A greater proportion of expenditures on energy services are retained within the municipality that is served by the system and in addition, they can incent development by attracting developers and businesses with explicit concerns regarding reliability of energy supply (Gilmour & Warren, 2008).

Despite these benefits, implementation of DE systems is challenged by the organizational complexity inherent to a major infrastructure undertaking, but for which there is no specific policy direction or regulation at the provincial level. In addition, as energy planning has not been a traditional municipal responsibility, the perception of DE utilities as unproven and the lack of internal expertise can further complicate opportunities for DE. Yet recent examples of the implementation of DE systems in Ontario suggest that not only can municipalities develop DE systems, but that success indeed depends on municipal leadership.

Despite the fact that over 50% of end-use energy is thermal (NRCan, 2011), there is no provincial policy direction regarding thermal energy and DE utilities are not regulated by the province. As a result, DE utilities are subject to uncertainty among local governments, building developers and citizens because electricity and gas utilities have benefitted from decades of a centralized energy planning regime and technological path dependence.

Although municipalities are beginning to have more substantive input in energy planning, plans for DE will depend on the extent to which municipalities understand their role as active producers and consumers of energy rather than just passive centers of demand. This shift in thought is not trivial; it positions energy infrastructure, including DE networks, as a fundamental component of city building. In this way, DE can be understood as more than just an energy solution. Instead of reduced emissions, cost savings and improved efficiency, DE in the context of city building can represent better air quality, a stronger local economy and improved emergency response. However, with often no formal process or policy for DE, building and maintaining a commitment to DE is essential. Municipalities have extensive experience with the planning of networked infrastructure such as sewer and water, but the organization complexity of DE requires a more deliberate level of integration with community planning and land development.

Planning for DE must take into account the various technical and financial parameters of a particular application in order to determine feasibility and community planners can add substantial value to this process. With respect to the built form and typology of a particular area, DE requires a certain density to be economical and operation benefits from a mixture of building uses. Identifying growth areas or locations where redevelopment is planned offers an opportunity to consider local energy supply and distribution, including DE.

At a more detailed level, plans for servicing must take into account numerous utilities, and when identified early in the land development process, DE is just another utility that building developers must accommodate. Furthermore, DE requires building mechanical rooms to be designed with specific technical features in order to be connected. As such, communication of intentions to pursue DE can facilitate implementation by aligning responsibilities among parties involved in development.

Finally, and most important, given the uncertainty and risk associated with land development, flexibility in plans for DE is essential to adjust to changes, especially phasing. The most evident risk for DE is build out and so a slower rate or lesser scale can expose DE system operators to reduced revenues and building developers and residents to increased costs. As such, planners and real estate experts can reduce risk by providing input regarding changes to plans or external factors such as the market value of land. However, as many of the aforementioned factors are beyond the control of a municipality or the influence of planning staff, DE benefits from more concrete alignment with broader municipal goals.

DE, on its own, is not expected to drive particular goals for community development and so it benefits from connection to the core strategic priorities of a municipality. For example, emergency preparedness or economic development may be strategic priorities and for the reasons outlined previously, DE is a viable way to meet these goals. Connection to strategic priorities elevates DE beyond the status of an energy solution and allows for consideration of how the infrastructure furthers city building.

Community energy planning (CEP), which is the high level analysis of the opportunity to integrate energy planning with land use and infrastructure planning, has emerged as a useful means to connect DE to municipal objectives (Jaccard et al., 1997). Owing to its infrastructure, a DE system can be a central component of a community energy plan. Though the approach itself is not new and many municipalities in Ontario have created community energy plans, implementation is challenged by a lack of enabling legislation and difficulties in coordinating actions among the various actors involved (Tozer, 2012).

Although there is a strong rationale and opportunity for municipalities to advance DE, they may not have the internal expertise necessary and so there is also need for new approaches to planning for DE. The nodal approach to DE, which begins with a few buildings and grows in increments, is a flexible strategy that can reduce risk for building and DE developers. Campuses, can serve as key locations to initiate nodes given consolidated land ownership. Using planning policy to require DE studies and DE-ready buildings as part of planning applications can facilitate future connections.

In addition, energy mapping has become a useful method to understand the spatial aspects of CEP and DE. A Geographic Information System (GIS), by combining quantitative and qualitative data, can be utilized to identify locations where DE systems might be feasible and if data on individual buildings is available, can be used to begin preliminary system design by identifying plausible locations for infrastructure.

1.1. Research purpose

With respect to engineering and financing of DE systems, the number of operational systems – over 100 in Canada – suggests that DE is viable given the right circumstances. Furthermore, the majority of the infrastructure is buried and modern central plants can be well integrated with their surroundings to avoid locational conflict. All of this to say that the predominant challenges are not technical, nor economic nor political; rather, the challenges are organizational because DE is a complex undertaking owing to the level of coordination required amongst various parties and the required integration with community planning and land development.

The purpose of this research project is to reduce this complexity by exploring conceptual and practical approaches to planning for DE and this will be done by answering several questions. First, what is the context for DE at the municipal level and what are the opportunities and challenges it faces? Second, where and how does DE integrate with community planning and land development and what are the potential synergies and conflicts therein? Third, why is DE a component of city building and what is the importance of municipal leadership in that process? Fourth, given the need for expertise at the municipal level, what are some of the emerging approaches to planning for DE? Drawing upon scholarly literature, interviews and a case study of the opportunity to expand the Keele Campus district energy network, this research project concludes that planning for DE, by providing the information necessary for commitment from decision makers and by reducing the uncertainty among parties involved, facilitates implementation.

The research was also motivated by a practical need to identify, understand and communicate opportunities for DE in Toronto. In 2010, a *Node Scan* of Toronto identified 27 locations (Figure 3) where DE was considered feasible based on certain criteria (Genivar Consultants, 2010). One of the nodes identified was York University's Keele Campus, though its ranking was poor relative to the other opportunities across the city. However, at the time that study was done it did not consider potential new development in and around the Keele Campus for both academic and broader community uses. As more information regarding development scenarios at the Keele Campus has become available and given the scale anticipated by the York University Master Plan (Figure 4), which is approximately 1.4 million square metres of new gross floor area, it seems prudent to revisit the opportunity. Though DE on university campuses is a straightforward operational decision, new development surrounding the Keele Campus may be executed through lease agreements with third parties; in other words, the buildings will not be owned and operated by the university. As such, this research project took advantage of this timely opportunity to evaluate a possible expansion of the Keele Campus DE network and demonstrates the potential to advance municipal DE development in Ontario.

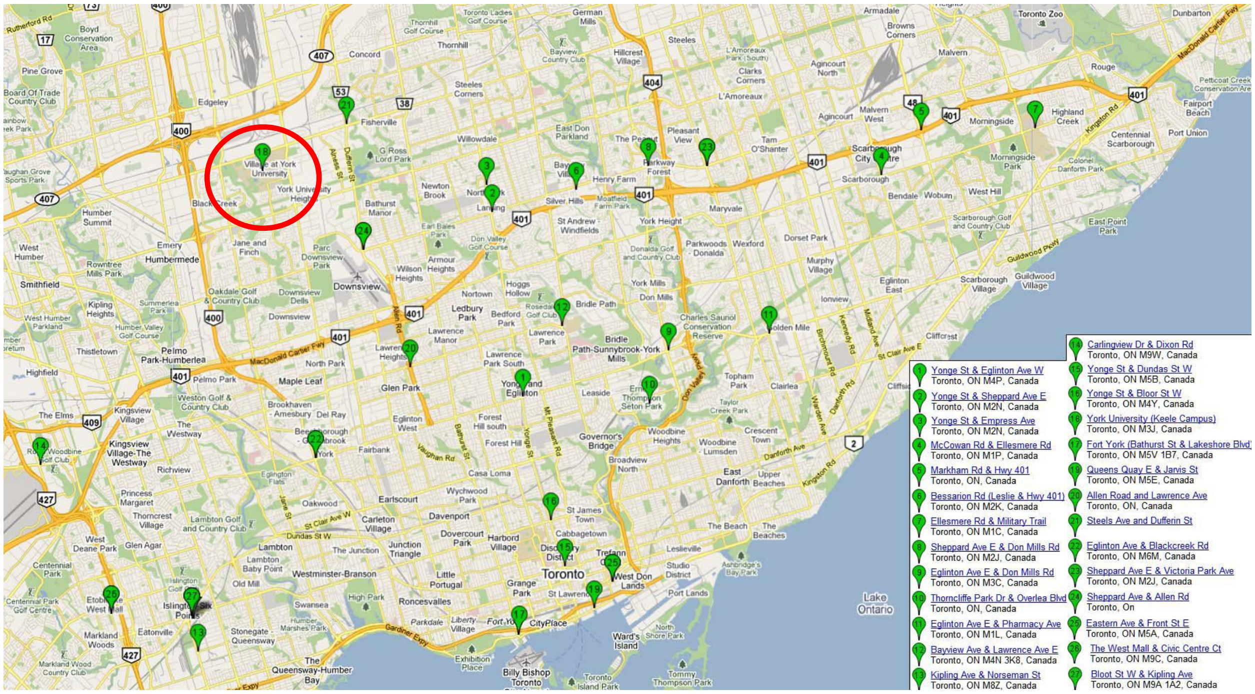


Figure 3. Locations of potential DE nodes in Toronto – Keele Campus circled. (Genivar Consultants, 2010).

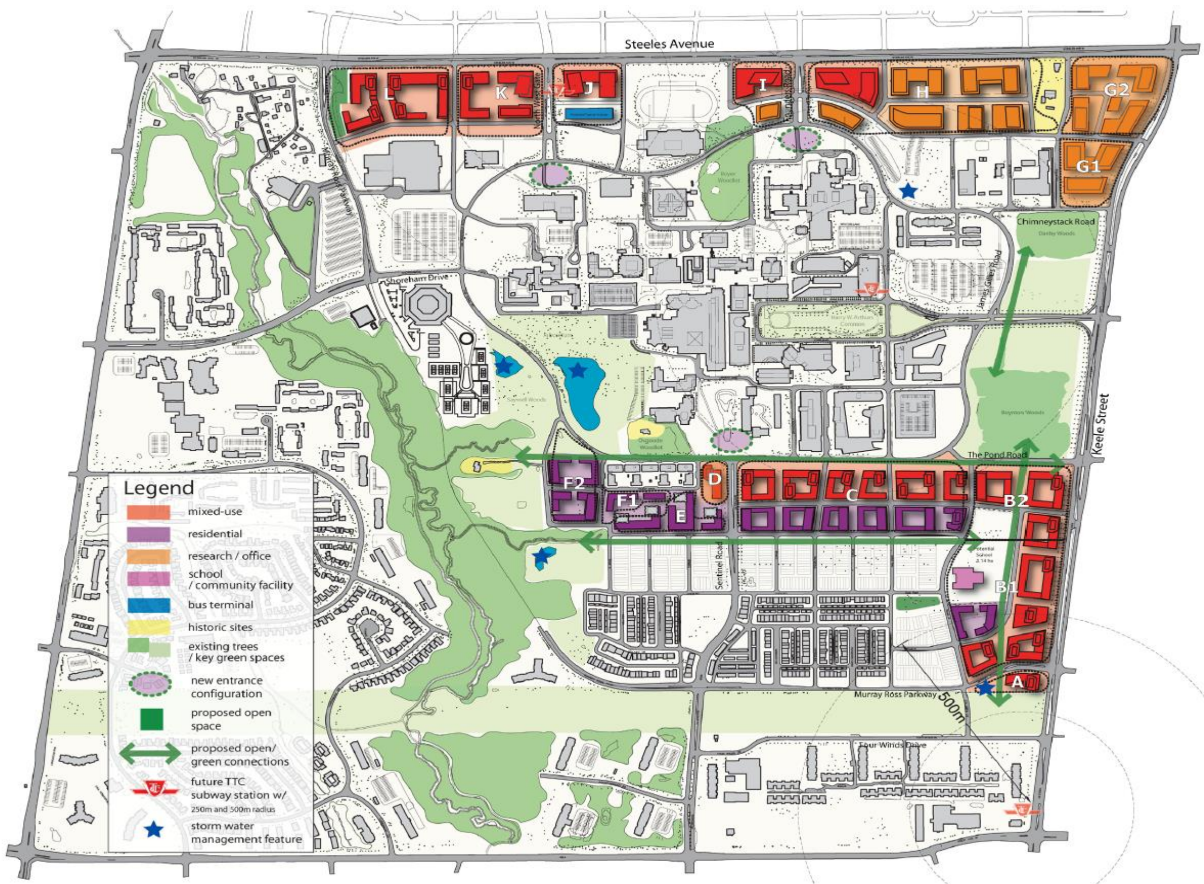


Figure 4. Concept Plan for the Keele Campus (Brook McIlroy Inc., 2009)

1.2. A note on scope

The Master of Environmental Studies Program at York University encourages interdisciplinary approaches to research and practice, but also emphasizes the importance of breadth and depth in academic work. Community energy planning (CEP), which connects energy use with land use and infrastructure, encompasses many different energy concepts and DE is only one such example. A project such as this is broad in that it does acknowledge the diversity of technology, actors, policies and plans that connect with DE. However, an in depth understanding of any one of several particular aspects of DE requires parameters. First, the focus here is planning for DE and though implementation flows from this, this project draws a line here – detailed discussion of financing, ownership and operation is best left to future work. Second, this project concentrates on the demand side (buildings) and the distribution network, though there will be some consideration of plant location and CHP. Readers may notice use of the terms 'DE system' and 'DE network' throughout the report. For clarity, system refers to the distribution network and the central plant, while network refers only to the distribution infrastructure. Finally, the conceptual and practical context for this project is the province of Ontario and growing urban municipalities such as the City of Toronto, but it is hoped that lessons from this work will be useful for community energy planners in other jurisdictions.

1.3. Report organization

This report is divided into two parts: Part I, Advancing District Energy Concepts, which is a written synthesis of findings from the literature and interviews; and Part II, District Energy Planning in Practice, a project report on the findings from the case study of the Keele Campus District Energy Network. Though separate, the report is designed so that the sections are mutually reinforcing. Interviews and literature inform recommendations flowing from the project report and the analysis enriches the findings of the synthesis. Having said that, the separation is deliberate; Part I is oriented towards readers who may have a curiosity about the broader, conceptual aspects of planning for DE, while Part II is a more detailed investigation of the merit of specific practical approaches to planning for DE.

Part I: Advancing District Energy Concepts

The purpose of Part I is to discuss the conceptual aspects of planning for DE. Section 1 presents background information, identifies the purpose and provides the research scope. Section 2 outlines the research methods utilized, though the methods used in the project report will be discusses in greater detail in Part II. Section 3, divided into six chapters, discusses findings from the literature review and interviews. Chapter 1 examines the context for energy planning and DE in Ontario, with the focus on how external drivers have altered the geography of supply, demand and the governance of the relationships therein. Concomitant with this are the effects on energy infrastructure and the spatial aspects of urban energy use. Chapter 2 is devoted to understanding the aspects of DE that set it apart from other competing technologies, in particular economies of scale, resilience and contributions to local economic development. Chapter 3 then delves into the most salient challenges to DE – misconceptions, the need for expertise and the lack of provincial support – as the reasons why DE must be led by municipalities. Chapter 4 outlines the rationale for integrating DE with community planning and land development. Chapter 5 discusses the importance of integrating DE with strategic municipal priorities. Chapter 6 then briefly goes through some of the approaches that municipalities can take advantage of to facilitate DE, in particular CEP and energy mapping. Section 4 concludes with lessons learned and recommendations and Section 5 discusses areas for future work.

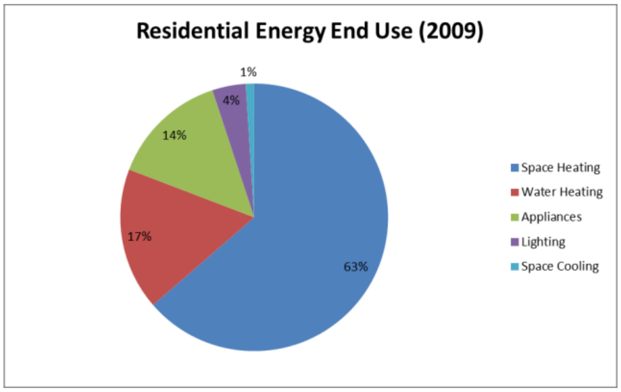
Part II: District Energy Planning in Practice

The purpose of Part II is to demonstrate some of the practical approaches to planning for DE. Section 1 presents the rationale for considering developing/expanding DE at the Keele Campus. Section 2 discusses the historical development of buildings and DE infrastructure. Section 3 details the methods used to undertake the analysis. Section 4 discusses the findings from the analysis and makes some preliminary conclusions.

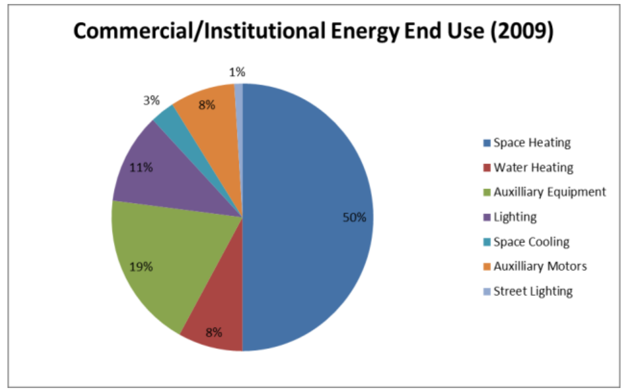
1.4. Context

Cities represent the largest demand for primary energy – the majority of which is provided through the combustion of fossil fuels – and it is estimated that they account for 71% of global energy-related greenhouse gas (GHG) emissions (IEA, 2008). Given that cities are the drivers of the global economy, which is powered by fossil fuels, the majority of global GHG emissions are attributable to the production and consumption activities of cities (Hoornweg et al., 2011). Actionable strategies to reduce GHG emissions, however, require more specific targets.

Canadian municipalities are estimated to have direct control and indirect influence over approximately 45% of national GHG emissions (FCM, 2009). While transportation, buildings and industry represent the most energy and emission-intensive sectors in Canada, at the municipal level, sector-specific intensities will vary based on local and regional factors. In Toronto, for example, the combustion of natural gas to meet the thermal requirements of buildings is estimated to account for more than 50% of GHG emissions (Toronto Atmospheric Fund, 2012). Figures 5a and 5b indicate that space and domestic hot water (DHW) heating account for approximately 80% and 58% of energy end uses in residential and commercial/institutional buildings, respectively (NRCan, 2011).



a) Residential Energy End Use in Canada, 2009.



b) Commercial/Institutional Energy End Use in Canada, 2009.

Figure 5. Canadian energy use and emissions by sector, 2009 (Adapted from NRCan, 2011).

In Ontario, the current business-as-usual approach to energy provision is represented by standalone equipment in individual buildings (natural gas-fired furnaces or boilers for space and DHW heating; electric chillers for space cooling) supplied by large, central facilities (i.e. power plants) through regional natural gas and electricity grids. However, DE systems are smaller, local networks that produce and distribute thermal energy to multiple buildings, which would obviate the need for standalone equipment in individual buildings and reduce reliance on regional grids. While not discussed within the scope of this report, the desire for a more sustainable future, of which energy is one component, underscores the goals of this research project.

2. Research Methods

The choice of methodology in this report, which incorporates aspects of social science as well as engineering, reflects the novelty and complexity of planning for DE. Method and methodology, though similar, have very different definitions. A research method describes an approach to an identified problem; it has a specific design and incorporates particular techniques.

On the other hand, a methodology is akin to an epistemology, a way of thinking about how to do research at a more philosophical level. As background to this project, consideration was given to literature debating the merits of both qualitative and quantitative methodologies, though they are often employed separately. Some researchers have questioned whether complex planning problems can be addressed through a single method in isolation and suggest that not doing so could be detrimental to the planning process (Gaber & Gaber, 1997). Triangulation or a mixed-methods approach, though susceptible to the risks and biases associated with any methodology, is best-suited to understanding the interdisciplinary nature of planning for DE and is the approach adopted here.

2.1. Triangulation

Energy planning, in particular planning for DE, is instructive as a subject area in need of a mixed-methods approach: there are technical challenges involving system design; the location, density and use of buildings affect operations; project financing, ownership and consumer rates must be delineated to manage risk; and actors, institutions and government policy affects all of the above. Overall, research on DE presents an organizational challenge and while it requires collaboration in practice, the single planning researcher must choose a methodology that often incorporates several of these various aspects in order to deliver a robust analysis. The process of triangulation – analysis utilizing multiple points of view (i.e. methods) – is well suited to DE planning given the prevalent organizational challenges. As described by Neuman (2011), the triangulation method employed in this research combines qualitative and quantitative methods. Alternatively referred to as mixed-methods research, the triangulation method enriches the analysis because the weaknesses of a single method are complemented by the added strengths of another (Neuman, 2011). Indeed, interviews and other personal communication undertaken in relation to the case study of the Keele Campus supports Neuman's arguments – once interviewees and other individuals were satisfied with the conceptual merit of expanding the DE network, they often wanted to know how it would actually work in practice.

Figure 6 depicts a simplified version of the methodological approach employed in this project, though its structure does not reflect the order in which tasks were carried out. The actual process was much less linear: the literature review and data collection were initiated first and they occurred simultaneously, but results of the case study then necessitated further exploration of the literature later on; though the literature review and case study results informed the interview questions, findings from the interviews required revisiting both the literature and the case study for further analysis. As such, the intent of this figure is to highlight where qualitative and quantitative methods were used in keeping with the mixed-methods approach and how the research was organized.

2.2. Research methods used in Part I

The first section is a synthesis of some of conceptual approaches to planning for DE in urban municipalities in southern Ontario. It relied on qualitative methods, specifically literature review and interviews.

2.2.1. Literature review

A literature review is a thorough account of the secondary literature that is relevant to the research problem and it is used to synthesize the salient debates and identify where gaps exist. Literature reviews contribute to the researchers knowledge and offers space in which the

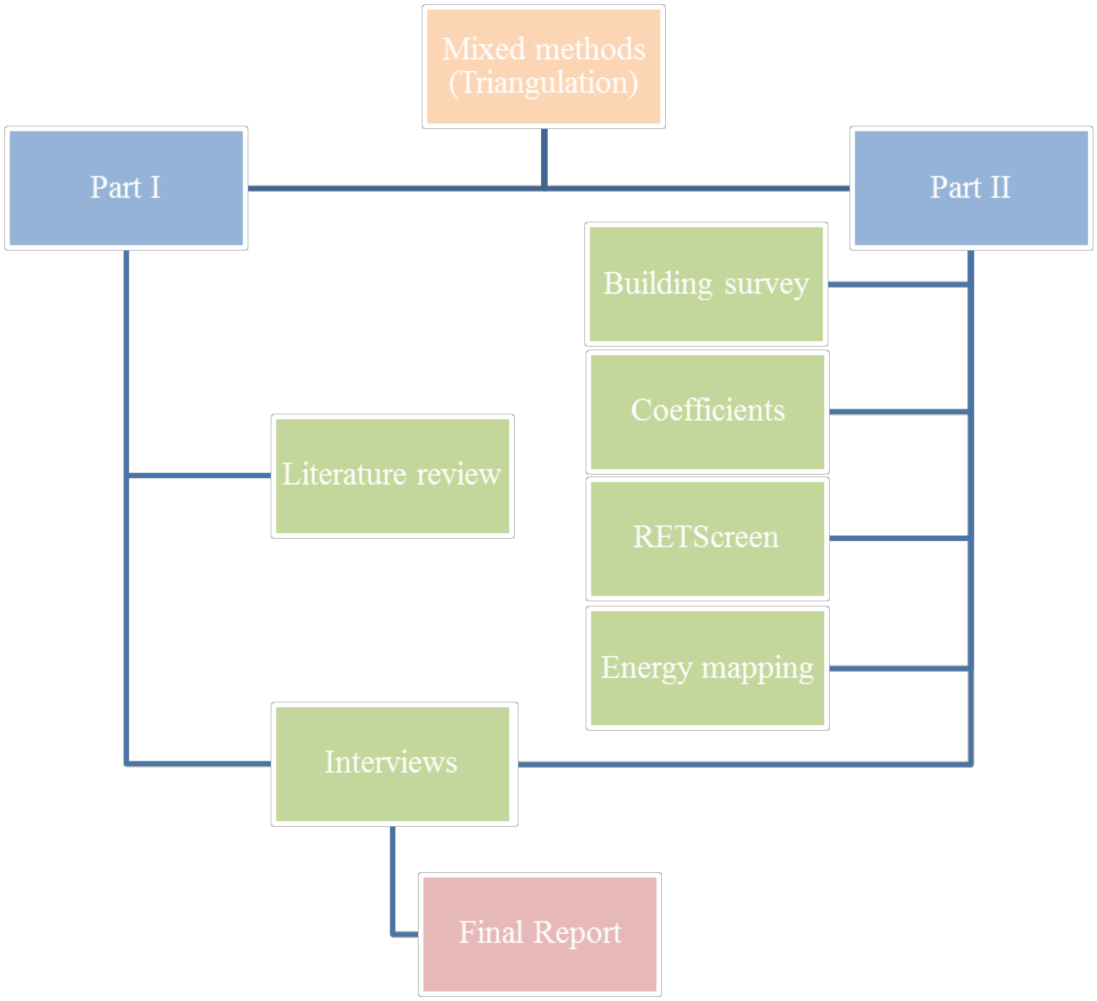


Figure 6. Organization of the research

researcher can advance knowledge. Neuman (2011, p. 125) categorizes literature reviews using various typologies, the choice of which depends on general considerations (e.g. project timeline and scope) as well as project-specific considerations (e.g. research goals and intended outcomes). The literature review employed here is a *Context Review*. Given that the project case study is embedded within a broader context – one that the case study intends to inform – the literature review is designed to situate the case study within this context so that lessons learned from the case study can further already accumulated knowledge.

2.2.2. Interviews

Interviews ask particular questions of targeted individuals in order to gather answers not provided in the secondary literature. Sometimes referred to as key-informant interviews, interviewees are solicited based on the assumption that they can provide information not otherwise available to the researcher. Neuman (2011) explains that as our understanding of social realities has evolved, interviews have become more conversational (p. 341), designed in a more nuanced approach than surveys or questionnaires. To help frame the approach to interviews, Silverman (2006) challenges researchers to ask three questions, the answers to which will determine the analytical treatment: "What status do you attach to your data? Is your analytic position appropriate to your practical concerns? Do interview data really help in addressing your research topic?" (p. 146).

The status of interview data (i.e. responses) depends on the researchers' perspective. If responses are understood to be facts about social reality, this is in keeping with the positivist paradigm, which tends to employ structured interviews to collect data. On the other hand, if the responses are understood to be a mutual construction of social reality, this represents the constructionist paradigm, which relies more on casual conversation. In between is the emotionalist paradigm, where data provides an "authentic insight into people's experiences" (p. 118) and unstructured or open-ended interviews are typically utilized.

The practical concerns of this project – understanding how planning can facilitate the implementation of DE and the opportunity to expand the Keele Campus DE network – require factual responses (e.g. answers to technical questions) as well as reflections on how the interviewees, as practitioners, are dealing with these issues *in situ*. The interviews in this project fall somewhere between the positivist and emotionalist paradigms, hence the application of the semi-structured interview technique.

Contrasted with structured interviews, semi-structured interviews do not attempt to elicit responses that reinforce the researchers' assumptions; rather, open-ended guiding questions are supplemented with probes to allow for the interview to proceed as a conversation, evolving as both the researcher and the interviewer respond to each other (Rapley, 2001). The advantage of this approach is that it allows for serendipitous findings while mitigating some of the bias associated with a predetermined structure. However, given the flexibility inherent to a semi-structured interview, understanding the particular context has greater bearing on the analysis (Rapley, 2001).

Neuman (2011) warns that the conversational approach to interviewing is criticized for being informal and vulnerable to the introduction of bias from misinterpreted questions. However, the organizational complexity and context specific nature of DE requires a flexible structure to understand how the various aspects and practitioners interrelate and was a successful approach to gathering information.

Selection rationale for interviewees

Drawing on the literature review and field experience in community energy planning , the initial grouping of categories was designed to provide a cross-section of the various sectors that operate at the urban development-district energy interface and it includes land development, municipalities, university operations and technical expertise (Table 1). Within the Land Developer category are master developers and building developers. Master developers, with

Category	Role in DE/Planning	Organization
Land Developer	Master Developer	York University Development Corporation
		Toronto Community Housing Corporation
	Building Developer	The Daniels Group
Municipal Staff	Community Planner	City of Toronto
	Community Energy Manger	City of Guelph
	Community Planner	
Technical Expert	Energy Developer/System Operator	Markham District Energy Inc.
	System Designer	FVB Energy Inc.
University Operator	Campus Networks	U of T Facilities/Operations
		York University Campus Services and Business Operations – Energy Management

Table 1. Research interviewees

control over the land to be developed, would be part of the DE planning process from the outset. Locating infrastructure and outlining building specifications – which are essential in DE planning – would be considered at the master development stage. In some cases, this would be the time to specify conditions as part of the land transaction process, such as having DE-ready buildings or even compelling connection to an existing network.

Building developers, whether leading a project or subject to a master development agreement, are responsible for designing, constructing and transferring ownership of the buildings. In the case where there is no master development agreement, the opportunity for DE must be communicated directly to the building developer, who may or may not have interest. For example, buildings must have hydronic HVAC systems, at-grade connection points and if the development is multi-phase, ideally have a single mechanical room. Furthermore, building density, use(s) and design characteristics also have a bearing on the opportunity for DE as they all impact the load profile of the building.

In the Municipal Staff category are community planners and community energy managers from the cities of Toronto and Guelph, both in southern Ontario. The rationale for this category is that both municipalities are involved in CEP, including DE. Given that DE has been framed here as an important component of a community energy plan, representatives from the municipal category were chosen to highlight this relationship and how, if at all, CEP contributes to DE. This includes community planners working in areas where a community energy plan and/or DE study have taken place and community energy managers operating within the municipality.

Technical Experts include system developers/operators and designers. This group provides the expertise necessary to discuss the technical challenges that planning must address in order to facilitate DE system development or network expansion, including the required building design, minimum densities, network efficiencies and ideal infrastructure locations. These interviewees in particular inform the case study by confirming the validity of the inputs and calculations that are used as well as the accuracy of the outputs.

University Operators represent the individuals who deal with the day-to-day responsibilities of operating a university campus DE system. Given that the Keele Campus is the case study, a representative from the Energy Management department of York University Campus Services and Business Operations (CSBO) was interviewed. In addition, as the context for the Keele Campus is unique, a representative from the the University of Toronto was also interviewed in order to understand if the history and expected future development of the campus with regards to DE and CHP can provide insight into the opportunity at the Keele Campus.

Approval to conduct interviews was granted by The Faculty of Environmental Studies' Human Participants Research Committee on September 24th, 2013. Ten individuals were interviewed on nine separate occasions (one interview involved two participants) between

September 25th and October 22nd, 2013. Eight of the interviews were conducted in person and one over the phone.

Interview Analysis

Interviews were analyzed using an approach described by Seidman (2006), which he refers to as “Making and Analyzing Thematic Connections” (p. 125). It is a straightforward, almost intuitive approach to interview analysis and it is useful in this project given that the interview data is being treated as factual, lived experiences. The first step in the analysis is to assign a particular identifying code to each of the interviewees based on their categorization in the Selection Rationale: Land Developer (LD); Municipal Staff (MS); Technical Expert (TE); and University Operator (UO). Next, the transcribed interviews are reread and responses that reflect an important finding from the literature are marked for further investigation. Once this is done for all transcripts, the marked responses are classified thematically so that for a particular theme, multiple responses from various interviewees may be compared. Table 2 depicts the classification. These themes form the basis for the discussion and allow for connection with literature and in this particular project, the case study as well.

2.3. Research methods used in Part II

Neuman (2011) defines case study research as examining multiple features of a limited number of cases or even a single case and though research is often qualitative with this approach, it can include quantitative methods. For Johansson (2003), the object of the case study is the case, which he suggests must be: “a complex functioning unit; investigated in its natural context with a multitude of methods; and contemporary” (p. 2). Given that specific methods are used to understand a particular case, a case study might be better understood as a “meta-method” (p. 4).

Broad Categorization	Specific Theme
Challenges to planning for DE	1) Perception and communication 2) Institutionalization, expertise, leadership 3) Provincial policy challenges/Regulation
Rationale	4) Resilience 5) Reducing GHG emissions (only way for buildings)
Alignment with community planning	6) Community planning and infrastructure 7) Growth planning and DE alignment
Importance of integration	8) Development phasing and flexible plans 9) Competitiveness and construction challenges
Planning approaches/tools	10) Community Energy Planning/Energy mapping

Table 2. Thematic classification of interviewee responses

The preeminent challenge for any researcher employing a case study is to what extent the results are generalizable to other cases given that a particular case is representative of a specific place and time frame (Johansson, 2003). The literature review and interviews confirm that DE is context specific and as such, the recommendations espoused in this report are framed so as to be applicable to any large institution (e.g. a municipality or university) considering DE. Following is a brief introduction to the methods used; a more thorough account is included in Part II.

2.3.1. Existing building survey

In the CEP process and planning in general, the first step is often a thorough account of the existing conditions in focus area. In this case, the existing conditions refer to the existing buildings within the catchment area (the area that is serviceable by the existing DE network) that are not currently connected to the network. A Building Survey (Appendix A) adapted from the Building Survey Information form prepared by the Energy Efficiency Office (City of Toronto) was used to identify and assess opportunities for connection of existing buildings on campus. By collecting information on energy consumption, mechanical equipment and ownership, preliminary conclusions were drawn as to whether a particular building or group of buildings on campus are amenable to connection.

2.3.2. Potential new development

The next step is to estimate what the energy consumption, energy demand and GHG emissions of new buildings would be in the future and there are two crucial sets of inputs necessary to calculate these metrics: 1) assumptions about the planned development and proposed buildings' physical properties, specifically use and gross floor area (GFA); and 2) energy intensities (a particular energy value normalized to a unit floor area) for the various building uses, which are referred to as coefficients (Appendix C) in this project (please refer to Section 3.2.2. for a detailed explanation of the coefficients). By selecting the coefficient that is specific to the building use and then multiplying it by the gross floor area, energy consumption, energy demand and GHG emissions for a particular building on an annual basis were estimated.

2.3.3. RETScreen analysis

Once these baseline energy metrics are established, the next step is to quantify the change in the baseline (business-as-usual) as different measures are implemented. RETScreen Clean Energy Project Analysis Software (RETScreen 4) is a suite of tools developed by Natural Resources Canada to calculate these changes based on selected user inputs. Though RETScreen can be used to undertake detailed feasibility analyses of various projects, the intent here was to use it as a calculation tool to estimate the reduction in carbon dioxide emissions and the potential capacity for CHP when business-as-usual is compared to DE. There are numerous software applications that can do such analyses, but RETScreen is user-friendly, visually instructive and inputs can be revised so as to create different scenarios with ease. RETScreen was made available for this research through the Faculty of Environmental Studies' Sustainable Energy Initiative (SEI).

2.3.4. Energy mapping using a GIS

Finally, given that both CEP and DE have a significant spatial component, the consumption data for existing buildings and the estimated energy performance of potential new development were then mapped using a Geographic Information System (GIS) in order to visualize quantitative data. For this project, ArcMap 10.1 was used, though there are many open source applications available as well. A GIS is a decision-assisting tool that can help a user analyze a spatial problem in multiple ways and so it might also be considered a meta-method. However, in this project it was employed as more of a visual tool, where gathered data was displayed on a map for informational purposes. For example, rather than using the GIS to measure the precise length of a pipe run between two buildings, it was used to identify development parcels and buildings suitable for future retrofits and to locate new thermal plants.

3. Discussion and Findings

Chapter 1 – The Context for DE in Ontario

There is an implicit assumption in much of the literature regarding DE that, as a well-established technology, it should be a straightforward concept to buy in to and so discussion tends to focus on issues that pertain to implementation. Much less has been written about the changing spatial and socio-political context for DE resulting from new patterns of urban growth and the movement towards local energy planning. Experience with recent energy policies in Ontario has shown that failure to appreciate local context can lead to unintended and counterproductive outcomes despite the best intentions. This chapter will outline the context for

DE in Ontario with respect to how external drivers are creating local conflicts and the resulting movement towards local energy planning.

3.1. An energy system in transition

The first commercial DE systems developed in the late 19th century took advantage of the concentration of buildings in urban centres and were often anchored by the substantial steam requirements of industry (Gochenour, 2001). With fuel difficult to transport, it became profitable to distribute steam from a single source to multiple buildings. However, as urban centres expanded and long-distance electricity transmission became feasible, economies of scale favoured centralized generation and large utilities rose to prominence in North America by offering inexpensive electricity (Rutter & Kierstead, 2012). Centralized electricity production became more efficient over time and DE systems transitioned back to heating only systems, which led to a decline in fuel efficiency and economic productivity.

With electricity now used for lighting purposes, gas utilities concentrated on heating and again, economies of scale favoured the large gas providers. In addition, the DE systems that continued to employ cogeneration could no longer compete on price with the centralized electricity generators and the cost of thermal energy rose as a result. Customers left the DE provider, revenues declined and systems shutdown (Gochenour, 2001). Furthermore, the loose regulation of DE utilities at that time meant that building developers were free to install standalone heating systems, which was the popular choice given the availability of inexpensive fuel oil and later, natural gas. The shared infrastructure that defines DE systems was obviated by the improving technology of standalone heating and cooling equipment and costs were justified by the economies of scale offered by large commodity distribution grids.

This approach is described by Lovins (1977) as the "hard energy path", typified by large power plants that are centrally planned. In his critique of American energy policy, he offers the alternative of "soft energy paths", which he describes as "flexible, resilient, sustainable and benign" (p.38). Soft energy paths: utilize renewable fuel sources; are spatially distributed; are conceptually accessible to end-users; are appropriately scaled and located; and match end-uses to energy quality. Most important, these two paths are not differentiated based on levels of energy consumption; rather, it is the difference in "technical and sociopolitical structure" that makes the soft energy path novel in its approach (p. 38).

This centralized approach to energy provision has defined energy planning in Ontario for decades. There are indications that this model is ill-suited to address contemporary challenges for urban municipalities and as a result, a transition towards local energy planning is increasingly being discussed. Rutter & Kierstead (2012) argue that energy transitions are the result of several factors: an increase in the energy intensity of fuel (e.g. switching from coal to natural gas) and the resultant increase in per capita consumption; more complex infrastructure and organizational frameworks (e.g. local supply chains to national grids); policy interventions to incent innovation when the existing system was perceived as problematic; and broad changes in society and technology such as the effect of rail transport on urban expansion (Rutter & Kierstead, 2012). However, given the constraints of resource availability, infrastructure requirements and climate change, the authors suggest that the next energy transition may be a reversion towards local energy planning:

> "On the one hand, the increased use of nuclear power and large-scale renewable energy would fit well with the existing system of centralised supply…leaving cities in their current roles as largely passive centres of demand. On the other hand…smart grid technologies and combined heat and power must be embedded

directly within the urban fabric, suggesting a return to the late 19th century model of ‘‘local’’ utilities” (p. 79).

The belief that a transition is underway underpins this research project. Anecdotal evidence would support the notion that Ontario’s energy system in a transitory period and as such, there are evident conflicts with respect to energy planning. On the one hand, decisions over the last decade seem to reinforce the path of centralized planning. The Portland’s Energy Centre, a 550 MW gas power plant in Toronto, was constructed as a result of Ministerial directive despite concerted local opposition. Also, consider the *Green Energy and Green Economy Act, 2009*, designed to direct investment to the renewable electricity market in order to reduce GHG emissions and re-establish Ontario’s declining manufacturing sector. Its passage amended the *Planning Act, 1990* to remove municipal authority in siting decisions in an effort to streamline the approvals process and this change has incited a bitter conflict between the provincial government and the residents of rural municipalities where wind farms are being planned (Manning & Vince, 2010). One final example is the cancellation of the gas plants in Mississauga and Oakville. Although planned by the Ontario Power Authority (OPA), it was the provincial government that cancelled them in order to maintain a political foothold in those jurisdictions. Winfield (2013) argues that questionable decision making with respect to the siting of the plants is not to blame; rather, it is the increasing role of politics in energy planning.

On the other hand, however, recent provincial decisions also suggest that the commitment to centralized planning may be somewhat fungible. During the summer of 2013, the OPA and the Independent Electricity System Operator (IESO) engaged municipalities in consultations regarding regional electricity planning and in particular, the siting of large infrastructure. Furthermore, the Ministry of Energy also announced a revolving fund available for small and medium sized municipalities to use to develop Municipal Energy Plans (MEP). Finally, and perhaps most intriguing, was the decision not to pursue the construction of new nuclear facilities in light of cost uncertainties and falling electricity demand across the province. Such decisions imply a growing opportunity for substantive municipal participation in energy planning.

However, the extent of devolution of authority in energy planning to municipalities will depend on whether municipalities remain passive consumers or take a leadership role in deciding their energy future. Devine-Wright (2007) argues that the social and psychological aspects of the soft energy path must be understood if it is to be considered a sustainable energy system. The centralized approach to energy planning has treated citizens as passive, uneducated and uninterested, so responsibility for energy planning is best left to technical experts that seek to further this hegemony (Devine-Wright, 2007). However, though renewable, distributed energy planning with local involvement is seen as the antithesis to the central approach, there is an implicit assumption that the process will be accepted. Devine-Wright & Wiersma (2009) question this assumption by contesting the meaning of local and its ambiguity with respect to scale, developer trust and community ownership. The benefits of renewables and decentralization notwithstanding, how this approach to energy planning is reflected in the construction of spaces will be crucial to its success (Devine-Wright & Wiersma, 2009).

3.2. The spatiality of urban energy systems

In addition to this transition in energy planning are changes to the spatial component of energy demand that are accompanying new urban growth patterns in southern Ontario. Intensification within built up areas, driven in part by the Growth Plan for the Greater Golden Horseshoe, 2006, is concentrating energy demand to areas known as Urban Growth Centres

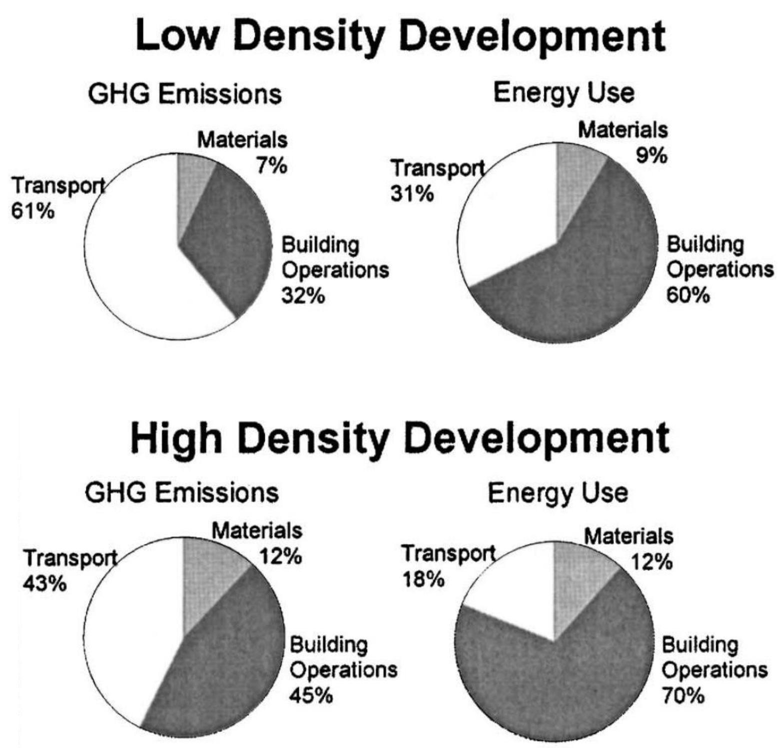
(UGCs). Given the connection between built form and energy use, in particular the inverse relationship between density and energy consumption, this concentration enhances prospects for DE because high density development spreads fixed costs over more end users. The cities of Markham and Guelph have linked plans for DE growth to strategies for meeting the population and employment targets set by the Growth Plan. This connection between land use and DE provides an opportunity for planners to get involved with DE planning at a detailed level.

Andrews (2008) argues that a “new spatial structure of energy systems” (p.231) is emerging. Whereas siting centralized generation facilities was the predominant concern among energy planners in past decades, the focus is shifting to planning for distributed generation, taking into account how land-use decisions and urban form drive energy demand (Andrews, 2008). A major driver has been the Growth Plan and its enabling legislation, the *Places to Grow Act, 2005*. It is a regional growth management strategy designed to direct population growth and employment to urban areas by requiring municipalities to amend Official Plans to be in accordance with the mandated targets. Much of the language in the Growth Plan is drawn from the Smart Growth movement; in fact, it emerged when the then new Liberal government shuttered the Conservative-led Ontario Smart Growth Panel in 2003(Filion, 2007).

One of the elements of any Smart Growth strategy is recognition of the relationship between land use, urban form and energy, and by extension, GHG emissions. In urban areas, buildings and transportation uses account for the majority of local emissions, but the degree to which they contribute is influenced by development pattern (Steemers, 2003). For example, Kenworthy & Newman (1990) found that the major reason for greater gasoline consumption in North American cities relative to other cities was the distance travelled, which is a direct result of urban density. Norman et al. (2006) conclude that the low-density residential development typical of suburban areas is 2-2.5 times more energy and emissions intensive compared to the higher density, multi-unit residential development of urban centres on a per capita basis. While in low density developments, transportation accounts for the bulk of GHG emissions and building operations for the bulk of energy use (Figure 7a), in high density developments, building operations account for the majority of both GHG emissions and energy use (Figure 7b). This is explained by the fact that in higher density scenarios (holding area constant), transportation is reduced and building operations are intensified relative to lower density scenarios.

While increased density translates to reduced energy consumption for applications such as lighting and space conditioning (Anderson et al, 1996) there is an optimum building density at which the gains due to concentrated thermal load are partially offset by reduced passive solar gain and the need for improved ventilation (Steemers, 2003). Furthermore, higher density development has the added benefit of reducing the costs of infrastructure through economies of scale – buildings are located closer together and also because the fixed costs are distributed amongst more users (Rickwood, 2008).

The above is particularly relevant to the Greater Toronto Area (GTA) and the eventual formulation of the Growth Plan. When the IBI Group (1990) conducted a study that assessed the effects of various urban form scenarios on energy and emissions related to transport use in the GTA, results suggested that central (urban intensification around the core) and nodal (dispersed intensification) development patterns were more efficient than spread (expansion of suburban areas). This study was an important aspect of the Central Zone Panel, which proceeded to



a) Relative contributions of material production, building operations, and transportation to annual greenhouse gas emissions and energy use for low density development (Norman et al., 2006).

b) Relative contributions of material production, building operations, and transportation to annual greenhouse gas emissions and energy use for high density development (Norman et al., 2006).

Figure 7. Relative energy use and GHG emissions in high and low-density developments

identify the nodes that would later become the Urban Growth Centres (UGCs) in the Growth Plan (Filion, 2007). It is these UGCs (Figure 8) where development and energy demand has tended to concentrate.

Scarborough Centre, Downtown Guelph and Markham Centre are three distinct locations spread across southern Ontario and each is at a different stage of maturity with respect to DE: a study has been completed for Scarborough Centre; Downtown Guelph is at the initial stages of developing a node; and Markham Centre has had an operational system for approximately 15 years. Yet they share a common characteristic: all three are designated UGCs and significant development is being planned for. DE is a growth-oriented industry and as municipalities update Official Plans to reflect provincial targets, DE is benefitting from integration with growth

Figure 8. Urban Growth Centres identified in the Growth Plan for the Greater Golden Horseshoe, 2006 (Ministry of Infrastructure, 2013).

planning policies (MS 3, 2013). In Markham, Official Plan policies identify DE as part of the planning framework for the growth centres (TE 2, 2013). As Cornell Centre – identified in the York Region Official Plan as a growth centre – started developing, Markham District Energy began development of its second node. In Guelph, the long-term goal is to meet 50% of the cities projected thermal demand with DE by 2041, which is the extended range that municipalities must plan to manage growth until (MS 2, 2013).

The Growth Plan, by limiting urban expansion, is also aligning the broader goals of community planning with DE (MS 2, 2013). Density is a crucial determinant of the economic feasibility of a DE system, so often system developers will look for a certain GFA, a cluster of buildings, the number of units or number of people in a given land area (LD 3, 2013). The suggestion here is not that facilitating district energy requires the prescription of minimum densities; density is partly a function of land economics and does not, on its own, equate to 'good' planning. Rather, community planners, by recognizing a certain density as an opportunity to implement DE, can plan for it at the outset. One interviewee, reflecting on the integration of energy with community planning, suggested that "…as a planner you can get nitty-gritty into the type and scale and anticipated timing of growth projections in an aligned way; get to understand …all the nuances about mixed uses and expectations of planning aligning with infrastructure – water, wastewater, electrical (MS 3, 2013). Knowing where the growth is anticipated to occur and the possible densities only answers the most basic questions with respect to planning for DE, but community planners have the ability to add value by providing context and detail that complements the technical parameters influencing DE development.

3.3. Infrastructure concerns

Any development proposal may raise concerns regarding the provision of infrastructure, but in some already built-up areas, the density and scale will be a significant servicing challenge. In Toronto's designated UGCs, for example, it is expected that a density of 400 jobs and people per hectare will be achieved by 2031 (Ministry of Infrastructure, 2013). City Planning data collected between 2007-2011 shows that over 62,000 residential units were constructed, 78% of which are condominium apartments. As of 2012, the 1,871 proposals in the development review process include 151,900 residential units and over 4 million square metres of non-residential floor space (City of Toronto, 2012). The Official Plan indicates that this development will be accommodated through intensification within 25% of the total City lands (City of Toronto, 2012). This equates to substantial intensification within already built up areas, which will place greater burdens on the existing infrastructure servicing these areas.

Though the Growth Plan includes policies and programs for the necessary infrastructure to support this development, there is no mention of electricity infrastructure. This task will be left to the Local Distribution Companies (LDCs) as per provincial regulation. However, the pace, intensity, typology and pattern of the development is creating a challenge for managing electricity distribution and past underinvestment in infrastructure raises questions about the vulnerability of the electricity system. In Toronto, for example: 1) With little physical space available for local generation and new transmission lines taking years to plan and construct, Toronto's electricity supply is essentially fixed; 2) With most development occurring in already electricity-constrained areas (the Centres and Downtown), demand must be managed to ensure reliability; and 3) With the primary type of development being multi-unit residential buildings (MURBs) and traditional heavy industrial uses decreasing in these areas, the issue becomes one of managing peak electricity demand for domestic use as buildings of the same type tend to have similar load profiles (Beck et al., 2012).

Recent consultations by the OPA and IESO indicate that municipal leaders are concerned about the vulnerability of electricity infrastructure and the lack of integration of electricity plans with growth planning and land use planning in light of recent siting conflicts (OPA & IESO, 2013). This vulnerability was exposed by the July 8th storm that flooded the Manby Transformer Station in Toronto and disrupted power supply to 300,000 people (Mills, 2013) Low probability, high impact events and the growing tension between municipalities and the province over infrastructure siting invites consideration of more resilient approaches to energy planning, which is part of the motivation for this research project.

Chapter 2 – The Value of District Energy

The core values of DE – resilience, fuel switching capability and contributions to local economic development – set it apart from competing energy solutions. Other technologies can provide these benefits to a certain extent, but it is only though the sharing of infrastructure that they can be delivered at the same time. Such a conversation can quickly engage with technical and financial comparisons, but the intent here is to discuss the broader rationale in planning for DE.

3.4. Resilience

The previous chapter identified the vulnerability of electricity infrastructure as a major municipal concern given the pace of growth and development. The antithesis to vulnerability is resilience and there is a growing body of literature dedicated to understanding the relationships between resilience and sustainable development, climate change and energy issues. Walker et al. (2004) describe resilience as "the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks" (p. 2). Much like the concept of sustainable development, resilience is contested and often co-opted to suit particular points of view (Walker et al., 2004). To distinguish it from ecological systems, the authors add a human dimension to resilience through social-ecological systems. In addition to resilience, these systems are defined by adaptability (the extent to which actors in a system can alter its resilience) and transformability (establishing a new system when external forces render it defunct). In this research project, energy resilience encompasses two aspects of DE: the ability of a DE system to continue providing thermal energy in the event of a local electricity or gas supply disruption; and the local approach to planning for DE systems as an alternative to the vulnerable centralized energy planning.

The resilience of an energy system can be defined by many parameters: degree of penetration of renewable energy technologies; ability of infrastructure to operate under stress; freedom from political manipulation; extent to which there is community involvement in the process; and others (O'Brien & Hope, 2010). Based on the above and taking into account the effects of weather events, infrastructure siting and political interference, there is an evident lack of resilience in the business-as-usual approach to energy planning in Ontario – large, inflexible infrastructure, high costs, and top-down, undemocratic decision making.

Although DE faces competition from other technologies with respect to efficiency and cost, consideration of resilience favours DE. One could argue that there are other scenarios whereby buildings could be cost-effectively heated and cooled with little to no associated GHG emissions. Using an electric heat pump, powered by a hypothetical emissions-free grid, is an efficient way to meet the thermal requirements of buildings, though costs can be significant given the use of electricity (Compass Resource Management, 2010). However, should there be a grid-failure and loss of electricity distribution, these buildings will be without heating and cooling. This point was summed up best by one of the university personnel when discussing the idea of importing less expensive electricity from Quebec, where the grid is predominantly supplied by hydroelectric generating facilities:

> "If you need reliable power, cheap and reliable is not the same thing. Yes, there is a lot of cost pressure and a lot of criticism around things in the electricity sector – that's a key problem…ultimately the focus needs to be, if carbon is the critical thing then look at carbon – don't get hung up on electricity. Let it optimize locally and you can't do that from Pickering to downtown Toronto and that's what makes

> district energy – it allows you to jump across the different utilities that you don't otherwise get the opportunity to do" (UO 2, 2013).

Although imported power from Quebec would, theoretically, be less expensive and less emission-intensive than the current supply in Ontario, the infrastructure would be vulnerable to extreme weather events and reinforce the centralized planning paradigm, furthering the lack of municipal and individual decision making with respect to energy planning. In essence, energy efficient and emission-free are not proxies for resilience.

Notwithstanding the environmental and economic benefits, the main driver for DE is emergency preparedness (TE 1, 2013). The 1998 ice storm that decimated regions in Eastern Ontario spurred DE development in Markham and stories of universities "keeping the lights on" during Hurricane Sandy have reinforced this notion of resilience (TE 1, 2013). The July 8th rain storm that flooded the Manby Transformer Station (TS), disrupting electrical distribution to a large area of Toronto, was an obvious example that electricity infrastructure is vulnerable. The buried distribution network of a DE system is physically more resilient to such low probability, high impact events. Furthermore, owing to the smaller scale of DE plants, a large network can have several, each of which can provide some energy services in the event that one is compromised (TE 2, 2013).

DE-CHP systems are crucial to planning for resilience because the embedded generation of CHP helps alleviate strain on the electricity grid and minimizes the risk of failure during times of peak demand. Should grid failure still occur, embedded generation can assist the local utility in powering essential services such as hospital functions, much in the same way that universities would use emergency power for critical laboratory functions (UO 2, 2013). At the Keele Campus, the opportunity to add embedded generation might prove to be an attractive prospect, both for the university and Toronto Hydro. Of the two transformer stations that feed the campus, Bathurst and Finch, the Bathurst TS may be constrained (UO 2, 2013). Without data from Toronto Hydro on the connected load, it is difficult to estimate the degree to which it is constrained, but the potential addition of 1.4 million square metres of new GFA at the Keele Campus, combined with additional development surrounding the campus, could be problematic for Toronto Hydro. Furthermore, additional embedded generation at the campus means that in the event of grid failure, critical functions for York and non-York buildings could be preserved.

The above highlights the more concrete, infrastructure aspects of resilience with respect to DE, but the approach to planning for it must also be resilient. Would DE still be considered resilient if it was planned for in the same manner as electricity and gas grids are, with very little public input or ownership? It is generally held that the average citizen is naïve with respect to the provision of energy, whether electrical or thermal. The assumption, reiterated by several of the interviewees, is that most people would not care what the particular technology is so long as they have heat and light and other energy services (TE 1, LD 3, 2013). Does this embody the concept of resilience as outlined previously? Notwithstanding that the energy system is rather esoteric to most, it does not follow that this obviates DE utilities from engaging the public. In fact, it could be argued that by inviting public participation in decision making, the planning process for DE would be better-served. During consultations regarding the redevelopment of Regent Park, DE was presented as an option to the residents and when compared against business-as-usual, it was something people accepted and even desired (LD 3, 2013). Of course, there were obvious questions about DE, but the potential for avoided conflict upon implementation far outweighs a more rigorous consultation process at the outset.

3.5. Fuel switching capability

Cogeneration and district heating networks have been referred to as "transitional energy technologies" (p. 46) – applications that will use fossil fuels efficiently for a short period of time until renewable fuels can be incorporated en masse (Lovins, 1977). Once the distribution infrastructure is in place, central plants can be modified to accept future fuel sources without affecting the energy service. Though the current fuel of choice in Ontario is natural gas, DE systems can take advantage of numerous energy sources and technologies: waste heat from industry, "free" cooling sources such as low temperature water from aquifers, lakes and oceans; geothermal and solar thermal heat; biomass fuels; and more (Gilmour & Warren, 2008).

A research report prepared by Compass Resource Management and FVB Energy (2010) indicates that the choice of fuel depends on a number of factors, including cost, availability, carbon pricing schemes, emission reduction targets and others. Depending on the context, there are other technologies that compete with DE (e.g. heat pumps in jurisdictions with electricity grids that use emission free sources) and natural gas-fired CHP is not automatically the most economical or environmental option. Nevertheless, the authors find that

> "Getting the infrastructure installed as part of an economically viable district system in the early years is important. Through load growth, lower unit costs of alternative energy technology over time and potentially higher business-as-usual (BAU) costs, alternative technologies may become more viable" (p. vii).

With respect to CEP and aspirations towards implementing renewable energy technologies, DE is a crucial platform that provides future choices.

For most urban municipalities, transportation and buildings are the two sectors where the most significant GHG emissions reductions are achievable (Steemers, 2003). Urban design has a significant influence in both sectors, but the predominant challenge for buildings is the low rate of turnover of the existing stock. The business-as-usual approach to thermal services – standalone boilers and chillers – locks a building in to a future that makes conversion more difficult. Efficiency is only one measure of building performance and standalone equipment, notwithstanding that it may be energy efficient, ensures a path dependent future for that building; in other words, fuel and technology choices are essentially fixed for the lifetime of that equipment. When looking at the broader community, even the most energy efficient building is still an energy silo if it is not sharing thermal energy (TE 2, 2013). In the long-term, it will be virtually impossible to switch from fossil fuels to renewables on a large scale without a thermal grid. When discussing the City of Guelph's GHG reduction targets, one interviewee concluded "we know we will not get there unless we have district energy systems. Our current infrastructure just does not allow for driving GHG reductions down to such levels…It's really the fuel choices that district energy brings that allows us to drive low carbon solutions" (MS 2, 2013). The issue here is one of cost, not technology. There are numerous ways to incorporate renewable fuels into the thermal systems of individual buildings, but costs will be prohibitive for many building owners. The economies of scale offered by DE systems reduce the fixed costs of fuel switching by spreading them over a much larger base.

For an organization that owns or manages a portfolio of buildings, the trade-off is straightforward: invest the capital now to reap operational savings in the future (LD 3, 2013). When the price of natural gas spikes or a carbon pricing scheme emerges, would you rather replace 40 boilers in 40 buildings, or five boilers in one building? The example seems crude, but it is not without merit. Universities realized this early on and were able to transition from coal, to fuel oil, to natural gas with relative ease. Without the economies of scale afforded by DE infrastructure, this would have been challenging to accomplish without substantial investment (TE 2, 2013). The same will hold true for the transition from fossil fuels to renewables; whether biomass, geothermal or solar thermal, the fuel choice is irrelevant to the infrastructure – it distributes thermal energy, not fuel.

The question is how far is the particular organization willing to look? The example at the Keele Campus is poignant in this context. Previous lease agreements for non-York buildings range from 49 to 99 years and assuming that new development will also be executed through lease agreements, York could begin taking control of these buildings in 50 years. Notwithstanding that the lease could be renewed, there is the potential that the university might be exposing itself to the risk of high cost utilities and/or hefty carbon prices in the future. A retrofitted connection is possible, but at a much higher cost. The argument of long-term risk mitigation is more applicable to large, public institutions, but no less important to a commercial property owner or condominium board. Office buildings and condominiums built today might reasonably be expected to stand more than 50 years, so it would be prudent to take into account the potential for DE to reward future operational savings irrespective of fuel or carbon prices.

3.6. Local economic development

DE systems can also stimulate investment in areas where they are located. In Markham, DE has been positioned as a key contributor to economic development, particularly through the attraction of businesses. Though any local energy technology will have some economic multiplier effect (e.g. job creation, local expenditures, etc.), DE has proven to be attractive to businesses that are especially concerned with security of its energy supply. Bradford (2012) found that the City of Markham was able to attract IBM to locate its new data centre in Markham

Centre by offering the provision of reliable thermal services. Though DE was not the deciding factor for IBM, the company found that the security, flexibility and avoided costs provided a competitive business advantage relative to other locations (Bradford, 2012).

The City of Guelph is also utilizing DE as a platform to incent economic development at its Hanlon Creek Business Park, a 675 acre site that is expected to accommodate 10,000 new jobs by 2031 as per its commitments to Growth Plan employment targets (Envida Community Energy, 2013). Businesses considering locating here will be given the option of connecting to the DE network and several organizations have already expressed an interest in the competitive advantage of outsourced thermal energy services (MS 2, 2013).

There is also some recent empirical evidence that local energy solutions contribute to economic development. Premised on the notion that electrical capacity could be a limiting factor on development in Toronto, Beck et al. (2012) used growth projections, electricity demand intensities and various data sets (construction, employment, wages, expenditures, development charges and taxation) to estimate the economic and fiscal benefits of adding 1 MW of electrical capacity to the central Toronto grid. They found that this scenario allows for $131 million and 745 jobs in new construction; 568 residents who spend $21 million within the city; 295 new jobs; $2.7 million in development charges; and $1 million in property taxes. The authors do not specify how the 1 MW is added, noting that CHP, conservation and demand management (CDM), other distributed generation (DG) resources or some combination of the above, could be applied. Though conservation is typically the most cost effective approach to energy efficiency, it will be impossible to offset the added demand of new development in Toronto through conservation alone. CHP, especially when utilized as the prime mover in a DE system, is a very efficient complement to conservation. In dense, urban municipalities with limited available land, DE is perhaps one of the few major infrastructure projects that can be implemented (Walker, 2008).

Chapter 3 – Challenges to Planning for DE

When discussing DE, the secondary literature is often skewed towards the challenges or barriers that pertain to implementation – zoning, rights of way, financing, operation, etc. However, these are the challenges that the DE proponent would want to have because they imply that the commitment is there. One interviewee summarized his experience with DE at the municipal level as “trying to build the bridges before you cross them” (MS 2, 2013). Crossing the bridge represents the crucial commitment and planning, through identification and communication of the opportunity, can help build it. The interviewees identified several key challenges to planning for DE, some of which are entrenched, and most evident is a lack of understanding about what it really is.

3.7. Misconceptions and communication difficulties

The majority of the interviewees suggested or implied that DE is not well-understood, though reasoning differed based on their positions. Among the more technically inclined, it was clear that the dominant rhetoric in Ontario is electricity-oriented, despite thermal energy accounting for more than 50% of end uses in buildings (NRCan, 2011). DE is not distributed energy, the latter describing power generation technologies that are dispersed throughout the electricity grid. Whereas the electricity grid utilizes wires to distribute electricity and the natural gas grid uses pipes to distribute natural gas, a DE system utilizes pipes to distribute thermal energy and is, by definition, a thermal grid. The distribution infrastructure is technology agnostic – whatever is used to generate the thermal energy is irrelevant except for the fact that some thermal grids distribute steam, others hot water and others chilled water or some combination of the above.

Part of the difficulty in building understanding is that in Ontario there are so few DE utilities and at municipalities, even fewer dedicated staff. It was suggested that there is perhaps a generational gap, where education and training must catch up to the advancing practice of modern DE (TE 2, 2013). The corollary to this is that the industry is also small in Canada, smaller so in Ontario. Granted, there is a number of consulting engineering firms that specialize in DE, but for a municipality, the commitment to DE implies deliverables well beyond technical and economic feasibility (MS 2, 2013). As one interviewee stated "I would hate to have to manage a company that was going to come in and do consulting work or analytical work to support the whole menu of things that we've got to develop here – from policy, planning, awareness, community support, all the way down to business economics" (MS 2, 2013). This point was reinforced by another interviewee, who suggested that DE is not so much a project as it is a decision, one that has long term and ongoing implications (TE 2, 2013). For a municipality, DE is as much about city building as it is about energy distribution, but recognizing this requires a fundamental reorientation of the perception of energy planning. Rather than being the passive centre of demand associated with the centralized planning paradigm, DE obligates the municipality to consider its role in production, distribution and consumption.

As an organizational challenge, DE requires constant communication amongst involved parties (MS 2, 2013). However, as an infrastructure investment that is, in essence, invisible, municipal staff expressed difficulties with respect to incorporating policies/requirements into community plans and communication materials. Community planners indicated that DE-specific planning policy could be seen as aggressive and liable to challenge at the Ontario Municipal Board (MS 1; MS 3, 2013). Furthermore, whereas certain sustainable energy technologies are more visible, DE is challenged by its invisibility to the public. While community engagement is essential to moving forward with the nodal approach to DE, success will partly depend on precedent examples that the public can engage with (MS 1, 2013).

The perception among some interviewees is that DE is still an emerging energy solution and it must be proven against the electricity and gas utilities. Whereas the process for connecting to electricity and natural gas is established and understood by planners and developers, DE utilities are perceived as an unproven competitor (LD 1, 2013). This is not to say that a developer would be hesitant to connect; rather, that in addition to plant siting and route layouts, a developer would want to know who owns and/or operates the system and then, the contingencies in the event of a service disruption (LD 1, 2013).

This is no small task given the entrenchment, or path dependence of these incumbent utilities. Simmie (2012) describes path dependence as the idea that various historical factors lock-in a particular technology or approach and institutional arrangements reinforce it regardless of merit. Though the technology is well-established, the nodal approach to DE is emerging as a new path when compared to electricity and gas utilities and its diffusion will depend on the extent to which it can occur alongside the current energy planning paradigm. Simmie (2012) also emphasizes the importance of public support in moving a technology from a niche to mainstream commercialization given that emerging technologies may be more expensive than path dependent technologies at initial stages. While success stories in Markham, Guelph and Regent Park indicate that DE is no longer in a niche, the lack of public support – which includes citizens and government – is a limiting factor in its diffusion. This is not to say that it is being suppressed, but rather that it occupies a policy and regulatory void with respect to both community planning and energy planning. Perhaps the passage of time and more successful implementation will improve acceptance, but for municipalities concerned with climate change and resilience, a concerted effort must be put towards communicating DE as a viable energy solution.

3.8. Institutionalizing DE: Building expertise and leadership

For public institutions, whether a local government or university, one of the fundamental issues that must be addressed is developing the internal expertise to manage DE. In fact, Hammer (2009) argues that "capacity" is the "critical determinant" (p. 1) for action on local climate change and energy planning. When the City of Guelph sought to advance thermal energy, it moved the unregulated arm of Guelph Hydro, Envida Community Energy Incorporated, into a municipal holding company so that the local government would have input into how Guelph Hydro is supporting the Community Energy Initiative (CEI). With respect to local utilities, one interviewee remarked that "They're not in the business to advance the long-term infrastructure – the City is" (MS 2, 2013). City building is the responsibility of the municipality, and though there is a business to DE, it is part of city building.

The lack of institutionalization means that consideration of DE or CEP is project specific and it will depend on those involved with planning the project (MS 1, 2013). One interviewee referenced the Toronto Green Standard (TGS) as an example of institutionalizing energy considerations in planning applications (MS 1, 2013) – developers are required to meet Tier 1 of the TGS and are offered an incentive to meet the optional Tier 2 standard. Though DE is suggested as a way to meet performance targets specified in the TGS, there is no formal requirement in the document. Whereas the TGS is building-specific, DE requires a significant infrastructure investment and the coordination of multiple building developments (MS 1, 2013).

This challenge is particularly salient at academic institutions such as York University, where DE is an operational decision that supports academic functions and does not drive any broader planning goals. The consensus from university personnel was that in order for the DE network to be expanded to new development, there would have to be a willing third party to own and/or operate the system (LD 2, UO 2). “Essentially the university isn’t in the business of generating, distributing and selling energy to third parties” (LD 2, 2013). The university does indeed provide a few non-York buildings with energy services, but these buildings were constructed in close proximity to the existing distribution network. The scale of the potential new development and the significant investment to expand the network may create the perception that the university is moving into business development.

To a certain extent, the university addressed this issue when the administration created the York University Development Corporation (YUDC) amidst questions regarding the legality of a public institution selling land that was endowed to it. The purpose of land sales, and leases for that matter, are to generate revenue that is used to further the academic mission of the university. When the campus was created, this function was also not envisioned; it developed as a response to economic challenges. With respect to expanding the DE network, there is an opportunity to generate revenue that can be used to maintain the existing asset, which is essential to current academic operations. Furthermore, such an undertaking could provide a valuable practical component to new curricula in engineering, planning, business and law faculties.

It is almost certain that a third party entity will be involved because the university does not have the internal human resources to manage DE in this new direction. Once external customers are involved, DE expansion cannot be managed internally as an additional activity because the scale of such an initiative requires staffing and resources (UO 2, 2013). Granted, YUDC would be involved by specifying DE requirements to potential developers, and Energy Management would be responsible for ensuring that expansion does not disrupt existing operations. However, a third party would provide the necessary personnel and it may be more effective for York to engage with that process rather than attempt to build it in to internal operations. Yet expertise and human resources are not the only determinants; success also depends on leadership.

It is evident that in municipalities where CEP and/or DE have been institutionalized, leadership has been critical to success and is some cases, implementation of DE systems has proceeded where no specific planning policy exists. When examining situations where implementation has been successful, the literature often cites the presence of a champion, someone driving the process given the lack of formal policy requirements (Gilmour & Warren, 2008). In this context, the Markham example is illustrative. When IBM was searching for a location for a data centre in the late 1990s, Mayor Don Cousens presented to the company and within one year, Markham District Energy was operational (TE 2, 2013). There was little formal planning and no community energy plan, but the council recognized the opportunity and communicated their commitment to this large anchor customer, initiating a DE node. Henceforth, DE has become institutionalized and the distribution infrastructure is part of the urban fabric (TE 2, 2013).

3.9. The provincial role?

Unlike gas and electricity utilities, DE utilities are not regulated by the Ontario Energy Board (OEB), confirmed by a 2009 decision against Enbridge Gas (EB-2009-0172). This does not mean that an existing gas or electricity utility could not develop a DE system; rather, they cannot recover investments through the rate base as they do for electricity and gas distribution. Regulation of DE is a contentious issue and there are advantages and disadvantages to this approach. The intuitive advantage is that regulation provides a sense of certainty, both to building developers/owners and system operators, which mitigates risk to a certain extent. In theory this would reduce the costs of energy services because the operator would have monopoly rights to a distribution area. The initial stages of DE network development are the riskiest as there are few customers covering the fixed capital costs. The ultimate risk is that the anticipated build out will not materialize, leaving the customers and operator vulnerable to cost pressures.

Perhaps the challenge is best summed up by the perspective of one land developer that was interviewed. “I know what Toronto Hydro is and I know what Enbridge Gas is so I know generally what those costs are. With the district energy model, we don’t have a lot of experience yet, but I don’t think there’s that consistency because each model is a little bit different – heating sources, financial model, etcetera” (LD 1, 2013). As an unregulated utility, DE does not have a standard template for connection of a building; each connection is negotiated through an Energy Service Agreement (the contract that specifies the rates for the services the DE utility provides to the building owner), which introduce some uncertainty in the process. Therefore, the response from this interviewee suggests that while developers may consider DE, connection requires a more rigorous vetting process.

Regulation also establishes a requirement that as the monopoly service provider, the utility is responsible for dealing with potential service disruptions. Again, this would be negotiated in the ESA, but the perception is that the DE utility must prove itself against these pre-established models. Although regulation may indeed accelerate the implementation of DE, is this the model that should be pursued? If one of the major utilities in Toronto was afforded monopoly rights to distribute thermal energy in the city, could it not perhaps be vulnerable to the same pitfalls associated with the incumbent utility model – concentration of political power, a lack of public participation, diseconomies of scale – notwithstanding that it might be energy efficient?

Another disadvantage of regulation is that it can act as an encumbrance to implementation, which is evident with electricity distribution in Ontario (MS 2, 2013). In the City of Guelph, developing a DE node at the Hanlon Creek Business Park, a greenfield site, has proven to be challenging. In order to scale the network to the desired size, it was determined that CHP units would be the prime movers and waste heat would be distributed to buildings. Regulation specifies that the local utility has exclusive rights to distribute electricity across property lines, which means that the electricity generated from CHP units must be used in within one property or exported to the grid. However, the OPA rules for exporting power from CHP are such that thermal contracts from customers must already be established and although the City has shown its commitment to DE and there are already businesses interested in thermal services, the

Hanlon Creek node has not progressed as the City anticipated (MS 2, 2013).

This story illustrates a major challenge to planning for DE in Ontario, which is the lack of any thermal energy policy at the provincial level. Though interviewees' opinions were more nuanced with respect to regulation, they were unequivocal as to the importance of a provincial framework for thermal energy and it begins by recognizing that 50% of end-use energy is thermal (TE 1, 2013). However, when the province discusses energy, such as in the Long Term Energy Plan or the Green Energy Act, energy is a proxy for electricity (TE 1, 2013) and the policies and programs that follow from these documents are skewed towards the electricity sector.

Perhaps the issue is that the province is prioritizing the solution when it should be prioritizing the problem. For example, the *Green Energy Act* prioritizes renewable electricity generation as a means to reduce emissions, but if reducing emissions was the priority, it does not follow that solar and wind farms would be the priority projects. Though it is important that renewables are developed, the significant emissions reductions in Ontario over the last 10 years are the result of the closure of the coal plants and the increasing reliance on nuclear power plants (TE 1, 2013). In other words, the low hanging fruit for emissions reductions are not in the electricity sector despite what the rhetoric indicates. In fact, emissions from utility electricity generation are projected to increase as reliance on natural gas power plants increases in the medium term during the nuclear refurbishments (ECO, 2013b).

As stated by the Environmental Commissioner of Ontario (ECO), the connection between energy and climate policy is not well established at the provincial level (ECO, 2013a). Though the province is on track to meet its 2014 GHG reduction target, projections based on current policies and programs indicate that it will only achieve a 9% reduction below 1990 levels by 2020, well below the 15% target of 150 mega tonnes (ECO, 2013b). In order to meet future targets, the province must acknowledge the importance of thermal energy in buildings given the extent to which fossil fuels are used for space and water heating.

Chapter 4 – Integrating DE into planning and land development

The development of a DE system is context-dependent and given the importance of context to community planning and land development, integrating DE with these processes should facilitate implementation. Some of the factors that determine the applicability of a DE system include: building density and mix of uses; market demand for land, development timing and anticipated build out; and the efforts made to communicate DE to developers early in the development process. The point here is not to suggest that DE should be what dictates community planning or land development as each of these processes involves some balance between public policy choices and market demand. Instead, the aim of this section is to understand why planning for DE must be integrated and to identify where in the processes such opportunities occur. The interviewees agreed that planning is important for DE, though opinions differed as to the specific role(s) that it plays. Perhaps most important, indications are that community planning is taking steps to be more proactive with respect to energy issues, whether reducing emissions or consumption, or facilitating the implementation of renewable energy technologies (MS 3, 2013).

3.10. The importance of density

Areas with higher density buildings will have a larger energy density (demand per unit area) owing to a larger population, which means that the costs of the network are distributed across more users and buildings, and the marginal costs of expansion are reduced. The customer rate for energy services from a DE utility is typically divided into fixed (cost of connection) and variable (cost of fuel, maintenance, etc.) costs. While fuel costs are determined by external markets, the infrastructure (pipe) costs are a function of the built form, particularly the density of the area served by the network. For a typical DE project, pipe costs can range from 50-75% of the total costs so the ideal system would serve a large number of users per linear unit of pipe, such as urban centres, building clusters and industrial parks (Dincer & Zamfrescu, 2011). The situation is not unique to DE infrastructure; it applies to sewer and water pipes just the same.

Though a DE project may be pursued for other reasons, there is a minimum energy density needed in order to be cost effective and it depends on numerous exogenous and endogenous factors (Dincer & Zamfrescu, 2011). Dalla Rosa et al. (2012) examined the feasibility of a district heating (DH) network for various neighbourhood archetypes in Ottawa, Ontario. They found that in order for the customer rates of a DH network to be competitive with the current costs for natural gas heating, a minimum linear heat density (density per length of pipe) of 1.5 MWh/metre/year was necessary (Figure 9). However, the authors also acknowledge that various design parameters could be altered to improve economic feasibility in lower density areas and suggest that as a rule of thumb, dense urban areas should be the immediate focus (Dalla Rosa et al, 2012).

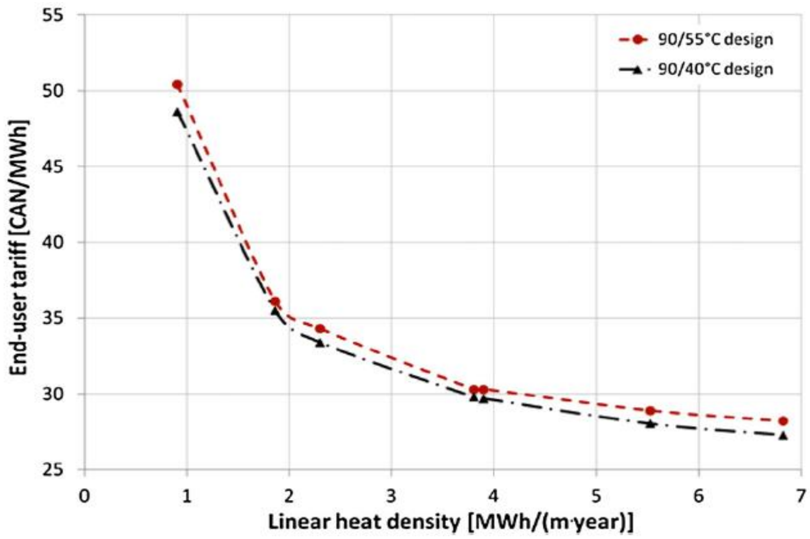


Figure 9. End-user DE rates as a function of the linear heat density (Dalla Rosa et al., 2012)

3.11. The advantage of mixed uses

DE systems not only benefit from large users with high demand, but also from groups of users who have different demands at different times, such as mixed-use areas (Steemers, 2003). By linking together multiple, diverse buildings, DE networks facilitate demand management because the rate and duration of energy consumption varies from building to building as a function of the principal use (Church, 2007). As an example, consider the situation of an area with only multi-unit residential buildings. Though the density may be large enough such that a DE system could be implemented in a cost-effective manner, the pattern of energy use (the load profile) will be similar – peak demands will tend to occur simultaneously and the plant output will fluctuate with this profile. However, if another use, such as a cluster of office buildings, was located close to the residential development, the aggregated load profile of the two uses would be less peaky and the central plant could operate more efficiently (Church, 2007). Figure 10 depicts how DE flattens the aggregated load profile of multiple buildings. Though thermal storage can

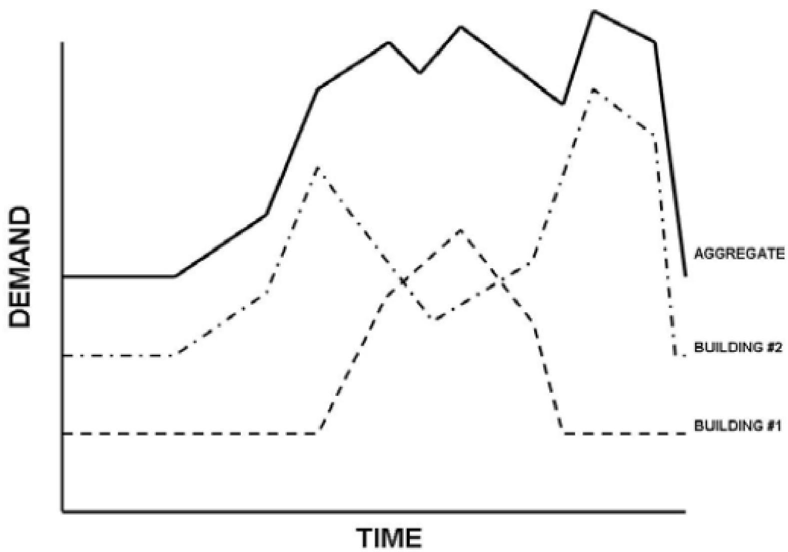


Figure 10.Aggregated demand-use profile of multiple buildings (Church, 2007).

also be employed to smooth load profiles, the ideal scenario for a DE utility is to serve an area with a mix of uses.

3.12. Integrating the infrastructure

During the interviews, the notion of DE as "standard infrastructure" emerged numerous times. From a building development perspective, establishing DE as part of the development plan from the outset implies that it is an additional utility that the building must be designed for (LD 1, 2013). Once the decision is made, a developer would need to know where the infrastructure is to be located so as to avoid conflicts with other utilities – the rest is engineering (LD 1, 2013). At Regent Park, DE was included in the subdivision process along with requirements for water, storm and sanitary services. For the inclusion to be seamless, however, early communication is essential and in the past, DE engineers did not engage with community planners (TE 1, 2013). This implies that planners and DE engineers may have had different objectives in mind for the same building developer, which would complicate the process.

TCHCs efforts to identify and communicate the opportunity for DE in the early stages of the redevelopment process contributed to the successful launch of the system. The organization first hired consultants to conduct a detailed Lifecycle Cost Analysis (LCA), which helped to attract a willing investor, Corix Utilities (LD 3, 2013). Developer concerns were assuaged by the upfront knowledge of costs and the presence of a dedicated operator (LD 1, 2013). However, it would be difficult to apply the Regent Park model to most situations as there is not always a master developer (TCHC) and there may be more than one building developer involved – in other words, more decision makers whose priorities may not always align with respect to infrastructure.

This is the situation facing most municipalities and so the integration of energy and planning policy becomes difficult as the framework for inclusion of DE infrastructure is not formalized. Monstadt (2007) argues that as energy planning transitions away from the traditional model of public ownership and government regulation, urban governance of energy, including infrastructure, is limited by challenges to municipal coordination. Though his arguments are drawn from a case study of Berlin, many of the external drivers that have reshaped Berlin's governance of energy – waning confidence in public monopolies, climate change policies and technological innovation – are already evident in Ontario. Municipalities do indeed have extensive experience with the planning of networked infrastructure in the form of sewers and roads. Yet, for DE to be understood as standard infrastructure municipalities must first commit to the notion that DE is part of city building.

The preceding indicates that perhaps a more nuanced understanding of planning and DE is required. Instead of trying to understand how one might plan for DE, it might be more accurate to ask, how does one plan for DE-facilitative development? Reframing the notion of DE planning in this way invites discussion of how building development, driven in large part by land economics, influences DE. Furthermore, notwithstanding that a committed developer might perceive DE as standard infrastructure, the notion that the bottom-line is their only concern requires unpacking.

3.13. The need for flexibility

As DE is driven by growth, ultimate build out – especially if less or slower than expected – represents the most pervasive risk. For a potential system operator, this means fewer customers, which exposes the operator to the risk of stranding assets and incurring losses (LD 3, 2013). Furthermore, existing customers are exposed to the risk of greater fixed costs. This is, in part, similar to the one of the reasons behind pre-selling condominiums – buyers expect condo fees to be reasonable so developers must delay construction until a certain amount of units are purchased. To mitigate risk in the Regent Park DE system development, expansion has been phased with development: distribution infrastructure is deployed as buildings are developed and capacity is added in increments at the central plant (LD 3, 2013). This is not the only approach, but it offers the most flexibility, something that the interviews all agreed was essential for success. In fact, it was suggested that, depending on the context, phasing could be more important than density as the timing of development indicates how long one can delay capital expenditures while still earning revenue (TE 1, UO 2 2013).

This realization has ramifications for the potential expansion of the Keele Campus DE network and the analysis undertaken in this project. Though the subway is likely to drive development (MS 1; LD 2, 2013), there is much less certainty as to where development will initiate because land economics is the driver in phasing (LD 2, 2013). It would be intuitive to assume that land adjacent to the subway stations would be the most desirable to developers as the Secondary Plan allows for the most density at these sites. However, YUDC has the opportunity to extract more revenue from these sites if adjacent parcels are developed first (LD 2, 2013). Furthermore, with phasing to take place over the course of at least three decades, it is impossible to predict how external events could alter the rate and scale of build out. Regent Park was re-phased partway through development in response to new opportunities and without the clarity and flexibility offered by the framework in place for DE, it may have been challenging to respond (LD 1, 2013).

As an example, based on the estimates of how building uses might be distributed, the case study indicates that the north end of the Keele Campus could accommodate 250, 000 square metres of office space, which one interviewee equated with having First Canadian Place (the tallest building in Toronto) at York University (LD 2, 2013). The context for development is very different than that of Downtown Toronto and ultimate amount of office space could be much less than anticipated. Considering that the energy projections are based on the floor area and use of a particular building, changes to the building would change the projections. At the scale of over 1.4 million square metres, such changes suggest that further analyses should utilize scenarios that take into account real estate parameters such as market demand for certain uses.

As another example, land values have a significant influence on siting of the central plant. Though distribution infrastructure typically represents the greatest costs, the central plant could be large, which would add substantial costs if land is at a premium. This was the main reason behind the decision to locate the central plant within what would have been the lowest levels of parking underneath the first TCHC building at Regent Park (LD 3, 2013). While the intuitive approach to plant siting is to locate nearest the largest thermal demand, phasing could change that decision. At the Keele Campus, the existing plant would be the default approach (TE 1, 2013). However, if development initiates at the opposite end of the campus, this would require a substantial capital expenditure with little revenue generation – i.e. a long pipe run with few customers. When considering the potential of a smaller plant located in close proximity to the first new building, land value becomes a consideration. The buildings adjacent to the Pioneer Village subway station will have the highest thermal demand, but also the highest land value. Plant location will be a trade-off between the linear heat density necessary to justify the capital outlays and the value of land (TE 1, 2013).

Taken together, this suggests that while using a Concept Plan as an analytical basis may have merit, any strategies for DE must be flexible in order to respond to changes in demand for land. Concept Plans and Master Plans provide an idea of the major components, but the built form will differ (MS 1, 2013). Nevertheless, these plans are meant to be include some measure of flexibility and risk allocation, so for the purposes of planning for DE, they do provide a reasonable basis for which to make projections (LD 2, 2013). Overall, there is a clear need for close integration between planning and land development in order to facilitate DE.

3.14. Developer perspectives

Literature suggests that the "principle-agent problem" – where the benefits of some investment by the developer accrue to the ultimate building owner – is a challenge for DE (Wilson et al., 2006). In other words, why would a developer be willing to pay for the infrastructure when the lower operating costs will benefit the building owner and future residents? This narrative coincides with many of the interviewees' opinions of developers, that they are focused on the bottom line. To a certain extent, this is accurate, but the perspective of one developer indicates that reality is more nuanced. Granted, the primary concern for developers is that the commitment to DE does not compromise their competitiveness with other developers (LD 1, 2013). However, following this priority is a responsibility to the ultimate purchasers (e.g. a condominium board) of the building in the sense that the decision to connect to DE does not increase the fees that are passed on to residents (LD 1, 2013).

The topic of developer perspectives is contentious and the sample size of the interviewees in this project cannot be used to assume that all developers would respond in this manner. However, it does reinforce the necessity of a tight linkage between community planning and DE planning because the developer requires upfront information on the required design of the mechanical room, estimates of the capital costs to install the infrastructure, the long-term operating costs and the entity or entities that will own and/or operate the DE system, in order to decide on whether to develop the land (LD 1, 2013). It becomes a conversation of risk allocation and the more certainty that the parties can provide, the less risk is allocated. When a master developer requires building developers to connect to a system, a potential operator is more likely to invest knowing that they will have customers, which then allows the operator to provide the necessary information to the developers so they can decide whether or not to develop. In the absence of any positive covenants, such as in Markham and Guelph, municipal commitment and leadership is even more important as developers and system operators are exposed to more risk.

Dense, mixed use locations enhance the prospects for implementation of DE systems, but once the right urban form is identified, building and DE system developers still require lead time and flexibility above all else. Lead time allows for the necessary studies to be completed and any uncertainties to be addressed. This in turn reduces risk, which should appease any apprehensions on the part of developers, system owners and even future residents. Flexibility is the key, however, because plans, land values and phasing, which have a significant effect on DE economics, are liable to change. It was intriguing to discover that perhaps some developers do consider the long-term operating costs of a building when making decisions about short-term capital expenditures, though this finding is likely not applicable to all developers. Though findings support the notion that integrating DE with planning and land development facilitates implementation, in situations with limited lead time and greater uncertainty, DE is benefitted by connection to strategic municipal priorities.

Chapter 5 – Connecting DE to strategic municipal priorities and the role of CEP

Despite the strong rationale for DE in urban municipalities, evident challenges and organizational complexity necessitate connection with the broader strategic priorities of a municipality in order to reframe DE as more than just an energy solution. The following section will discuss the cities of Markham and Guelph as examples of where this connection facilitated the implementation of DE systems and how this might be applicable to York University. Findings suggest that this connection is established at the highest level of a municipality, be it political or bureaucratic, and direction is disseminated down to staff responsible for planning and implementation. The findings also indicate that such a connection, though difficult to instantiate, can bridge siloes within the municipality and thereby coordinate efforts towards a common goal. However, this chapter will first introduce community energy planning (CEP) and the role it can play in formalizing such connections, notwithstanding that community energy plans do not have enabling legislation in Ontario. A DE system is only one application amongst the numerous that a community energy plan often includes, but based on how it is planned for and it operates, it can be a central component.

3.15. Community energy planning

The formal conception of CEP is credited to Jaccard et al. (1997), where the authors outline the idea of community energy management (CEM), also referred to as community energy planning. They define CEM as…"a planning and management process that focuses on energy strategies that can be implemented at the neighbourhood, municipal or regional level" (p. 1066), which expands the traditional focus on individual buildings and energy using equipment therein to the broader relationship between energy, land-use and infrastructure (Jaccard et al., 1997). Furthermore, CEM emphasizes the community perspective – while utilities, developers and provincial governments would have key roles, CEM is designed to be a bottom-up approach to energy planning. Table 3 depicts some of the strategies encompassed by CEM. Notably, district energy is included as a strategy in both the land use planning and energy supply categories.

Yet despite the fact that 232 municipalities in Canada had some version of a community energy plan as of 2012, plans have proven to be difficult to implement in practice (Rizi, 2012). St. Denis & Parker (2009) analyze the community energy plans (some of which are broader climate and/or sustainability plans that include energy) of 10 Canadian municipalities and they find that the motives, planning process, actors involved, level of community participation and the choice of intended outcomes varied significantly. Tozer (2012) analyzes the implementation

Sector	Goal	Sample Strategies
Land Use Planning	• Access-by-proximity • Support waste heat utilization	• Target strategic locations for high density, mixed use, transit oriented development • Offer financial incentives to developers for preferred densities, mixes and amenities • Increase proportion of multi-family housing • Establish a strict urban boundary • Locate heat sources near heat sinks • Establish district heating zones with special standards for density, diversity, growth, etc.
Transportation Management	• Shift the mode of travel • Shift to alternative fuels	• Improved transit, high-occupancy vehicle, pedestrian and cycling facilities and services • Parking pricing strategies • Employer trip reduction programs • Fleet fuel switching
Site Design	• Increase efficiency • Increase use of microclimate	• Reduced lot size and setbacks from street • Use of vegetation for shading or window-shielding • Building standards/performance certification • Financing and technical assistance for efficiency improvements
Energy Supply	• Exploit local resources • Increase use of clean resources	• Distributed generation • District heating and cooling • Heat pumps, solar technologies • Recovery of waste heat • Financing and technical assistance for homeowners, businesses and developers to invest in alternative technologies

Table 3. Strategies for community energy management (Adapted from Jaccard et al., 1997)

challenges faced by five Canadian municipalities and finds that jurisdiction, perceived costs and expertise were some of the most salient challenges.

Among communities that have, or are pursuing an energy plan, emissions reductions are often cited as the main driver (Rizi, 2012). Jaccard, Failing & Berry (1997) applied CEM scenarios to four communities in British Columbia and models indicated that GHG emissions could be reduced by 30-45%. Depending on the jurisdiction, however, municipalities have few avenues through which to drive sustained reductions. Tozer (2012) suggests that the difficulty lies in establishing a commitment to long-term change outside of municipal operations. Yet the author also found that “Combined heat and power and district energy was an important element of the generation portfolio of CEP implementation." (p. 11) and credits this to the notion that as a significant infrastructure undertaking, DE affirms the municipality's long-term dedication to reduce fuel consumption and emissions.

3.16. Connecting DE to strategic municipal priorities

The Canadian District Energy Association (2011) found that the most significant barriers to DE development occur at the community and project levels and they included a lack of understanding of the role of DE in the community energy plan. The prevailing challenge is that, as unofficial documents, community energy plans have no legislative backing through which to enforce policies and are sometimes relegated to checklists that do not lead to projects (TE 1, 2013). Even in larger municipalities like the City of Toronto, Secondary Plan policies that are the result of a community energy plan can only go so far as to require potential developers to conduct a study as part of a complete application. Yet this is still important because it initiates the conversation that can perhaps lead to concrete projects.

In order to elevate the community energy plan to more than a checklist, it requires connection with strategic priorities that go beyond energy. Tozer (2012) found that "when the goals of the [community energy plan] are broadly integrated into decision-making and municipal expenditures instead of being considered additive, CEP implementation is more comprehensively successful, particularly in the establishment of a base for long-term transformative action" (p. 13). At the City of Guelph, Community Energy was originally grouped with broader environmental initiatives. However, the municipality realized that Community Energy had the potential to play a central role in municipal development and it became a direct function under Finance and Enterprise Services along with Downtown Renewal and Economic Development

(MS 2, 2013). Given the challenges posed by policy siloes at the municipal level, this type of realignment can be a significant undertaking, but as Hammer (2009) notes, "policy interconnections of this type generally hold value because they force stakeholders to look past their normal, policy remit (p. 5).

In addition to this administrative restructuring, Guelph's Community Energy Initiative (CEI) was also framed as an economic development tool (MS 2, 2013). It is likely no coincidence that Guelph is the only municipality in Ontario where a DE system has emerged as a direct result of a community energy plan (TE 1, 2013). By connecting the CEI to economic development, a goal such as leveraging city assets to support the CEI can equate to initiating a DE node, which was the reasoning behind thermally connecting two City-owned buildings and forming the Downtown node (MS 2, 2013). Furthermore, energy security become more than just the notion of keeping the lights on; it now means that business with critical functions can be attracted to employment lands with DE systems, such as Guelph's Hanlon Creek Business Park node. As mentioned earlier, reducing GHG emissions and transitioning to renewable fuels are also important considerations, but meeting a target is different than meeting a goal. Economic development speaks to the core of municipal government functions and as such, the connection to CEP can accelerate implementation of specific projects. Had Community Energy remained separate from Economic Development and Downtown Renewal, it stands to reason that perhaps a Downtown DE node would not have been initiated because DE would still be considered a technology option rather than key infrastructure.

The core functions of York University, like most universities, are teaching and research. Generating revenue, whether through land leases or selling energy services, is more of target that feeds back in to the goal of advancing teaching and research (LD 2, 2013). Although DE has been framed as an operational consideration for most universities, there is an opportunity for substantial academic value to be gained. Public universities in Ontario are facing tremendous fiscal pressure as a result of reduced provincial funding. As such, they are being encouraged to differentiate with respect to course and program offerings so that limited provincial funds can be allocated as effectively as possible (Bradshaw, 2013). Though it is too early to predict how this conflict will play out, it would seem prudent to consider ways in which to drive enrollment and expand curricular offerings into new and innovative fields that combine theory and practice in pedagogical approaches.

DE can act as a platform for students, faculty and staff from various disciplines to collaborate on projects amongst each other and with external parties such as building developers and DE operators. Environmental studies, engineering, business and law are only some of the relevant faculties that would be involved in such an undertaking. This multidisciplinary, experiential approach to education is being tested at other Canadian universities. The University of British Columbia is partway through replacing its district steam network with a hot water network and exploring the incorporation of alternative fuels. It has developed a biomass research facility where students from engineering and forestry collaborate on new fuel sources that could be used in the DE system and it has been branded the “Living Laboratory” (UBC, n.d.). Linking energy planning with strategic priorities can help facilitate the implementation of specific applications, including DE.

Chapter 6 – Emerging approaches to planning for DE

The convergence of municipal interest in DE and provincial support for municipal energy plans might suggest a shortfall in expertise in the near future as many municipalities have little experience with energy planning. Furthermore, given the context dependent nature of DE systems, locational attributes of a particular project cannot be transposed to other municipalities to assist with implementing DE systems. The question for planners is, in the absence of the above circumstances, how can planning approaches facilitate implementation or at least, identify and communicate the opportunity in the hopes of securing a commitment to DE? The following section is meant to discuss some of the emerging conceptual and practical approaches towards local energy planning with a particular focus on DE.

3.17. Develop nodes

That fact that DE is well-positioned to address many of the challenges that face urban municipalities does not mitigate the risks associated with implementation. To reduce risk, the current conceptual approach to planning for DE focuses on developing smaller, distributed nodes. The nodal approach connects small clusters of buildings during initial development and then later, connects separate nodes to grow the DE network in an almost organic manner (MCW Consultants, 2010). As a strategy, its flexibility helps mitigate the risks associated with build out and it reduces initial capital outlays. A node can be initiated by utilizing an existing energy plant and connecting it to a second building or by connecting multiple buildings to a new energy plant.

Genivar Consultants (2010) completed a *Node Scan* of locations where a DE system would be feasible in the City of Toronto. Using a set of criteria of what constituted a preferred node (e.g. high density development, electricity-constrained, proximity to existing DE network), the authors then select a particular prime mover (engine) and they calculate the minimum size of the node (square metres of floor space) necessary to balance supply and demand. For the case of a DE-CHP scheme without central cooling, the node size was determined to be approximately 1,035,000 square metres. At this size, they identified 27 locations in Toronto where DE is feasible and as expected, most are Downtown and within the Centres. Based on the engine chosen, each node would embed 4.4 MW of electrical capacity into the distribution grid. However, this size of node would be rather large for many municipalities outside of Toronto and so the criteria, engine choice and operating parameters would change. The authors acknowledge that more detailed analysis is necessary to determine feasibility as this level cannot examine the very particular context inherent to each node (Genivar Consultants, 2010). Nevertheless, the nodal approach is useful for identifying opportunities for DE and providing a high level prefeasibility analysis.

3.18. Start with campuses

Buildings in the MUSH (municipal, university, school and health care) sector are recognized as the important hubs for the implementation of DE systems and CHP (CDEA, 2011). There are several reasons for this, most notably because they: are generally large institutions with long life spans; consume substantial amounts of energy; and in the cases of universities and hospitals, often include missions critical operations (e.g. laboratories and life support systems) that cannot fail. However, what makes them most attractive for DE is there are often multiple buildings on a single parcel of land and real estate decisions are made by a single entity. As such campuses, which are essentially any multi-building development on a single parcel of land, are, well-suited to the nodal approach to DE.

3.19. Use planning policy

Regent Park benefitted from the presence of an existing district steam system and in Markham Centre, the fortuitous arrival of a major tenant presented an opportunity to initiate a node (TE 2, 2013). However, notwithstanding that a municipality may be growing and increasing in density and notwithstanding that it may have a commitment to DE, it remains a challenge to implement DE-specific planning policies, especially those with positive requirements. The lack of thermal energy policy at the provincial level means that a municipality has a limited ability to require compliance with DE policies outside of its own property (MS 2, 2013). Although the City of Guelph's Official Plan has policies that identify opportunities to require connection to a DE network, the lack of enabling legislation leaves them vulnerable to appeal (MS 3, 2013). Contrasted with British Columbia, where DE is regulated by the BC Utilities Commission, the City of Vancouver has implemented bylaws in specific locations that require connection to a DE network if the size of the development meets a certain threshold (City of Vancouver, 2011). In Ontario, the Town of East Gwillimbury has emulated this model, though the OP policies are under appeal at the Ontario Municipal Board (ECO, 2013a).

With no enabling legislation or regulation, the approach in municipalities such as Guelph is value driven: "We look at it as how do we plan a city that actually will enable this business?... we have a plan so how can we encourage the marketplace, advocate for it, use these softer words and surround it with process and urging in many ways? (MS 2, 2013). At a high level, the city has identified DE zones and is moving towards having developers conduct a DE study and design the building to be DE-ready as part of a complete application (MS 3, 2013). This approach has the advantage of providing for future connections in an area where a DE system is being planned for, but is not yet operational. While this may ease developer apprehensions, it would do little to attract a system operator given the lack of an anchor customer. Recognizing this, the City of Guelph initiated the Downtown node by connecting two City-owned buildings and negotiations are currently underway to secure its first external customer, a condominium (MS 2, 2013). Leveraging city-owned assets and the strategic use of planning policy can initiate a DE node in the absence of any compliance tools.

The situation at the Keele Campus combines elements of Regent Park and Guelph, so there is an opportunity to learn from each. As the master developer, York University (through YUDC) has the ability to include positive covenants in lease agreements that require building developers to connect to the existing DE network. However, there are concerns that mandatory connections could be hindrance to attracting development partners (LD 2, 2013). Unfortunately, without any sense of guaranteed customers, the university would be challenged to attract a third party operator notwithstanding a commitment to the idea of expanding the system. Furthermore, without a comprehensive DE framework established up front, implementation would be challenged by the likelihood that there will be multiple development partners on campus. Though the existing asset eliminates much of the upfront capital and risk associated with a greenfield system, there is no guarantee that the first customer could be connected.

3.20. Create energy maps

Given the level of integration between land use and infrastructure in local energy planning, one of the implications therein is that the spatial dimension of energy is a key aspect of decision making. First of all, energy solutions are influenced by urban form and second, as the infrastructure becomes embedded in municipalities, the potential for conflict increases.

Energy mapping has evolved in conjunction with CEP as a tool to characterize where and how municipalities use energy and identify where particular solutions may fit best. Energy mapping can be thought of as a spatial approach to CEP and it can be used for such things as identifying opportunities for conservation, locating distribution infrastructure and integrating renewable energy technologies (Miller et al., 2011). Geographic Information Systems (GIS) are a common tool in urban planning and, to a certain extent, energy planning. However, as energy planning shifts from the large, centralized system to the community level, the way in which this tool is applied is changing (Reiter & Wallemacq, 2011). While a GIS may have traditionally been used at the regional level to map the locations of power stations and electricity transmission infrastructure, community energy mapping operates at the scale of city blocks and urban districts. Mapping at this scale allows for the visualization of detailed energy data on individual buildings, which is necessary for this emerging approach to urban energy planning (Reiter & Wallemacq, 2011). Furthermore, a GIS can also throughput datasets on land uses, physical specifications of buildings and socio-demographic data, providing a nuanced analysis of the relationships between energy, land use, built form and even consumer behaviour (Miller et al., 2011). This simultaneous visualization of quantitative and qualitative data creates a powerful decision-assisting tool.

The City of Guelph was one of four Ontario municipalities that was part of the Canadian Urban Institute's *Integrated Energy Mapping* project. By projecting energy consumption to areas where future growth is expected (Figure 11), they were able to suggest where a DE study is

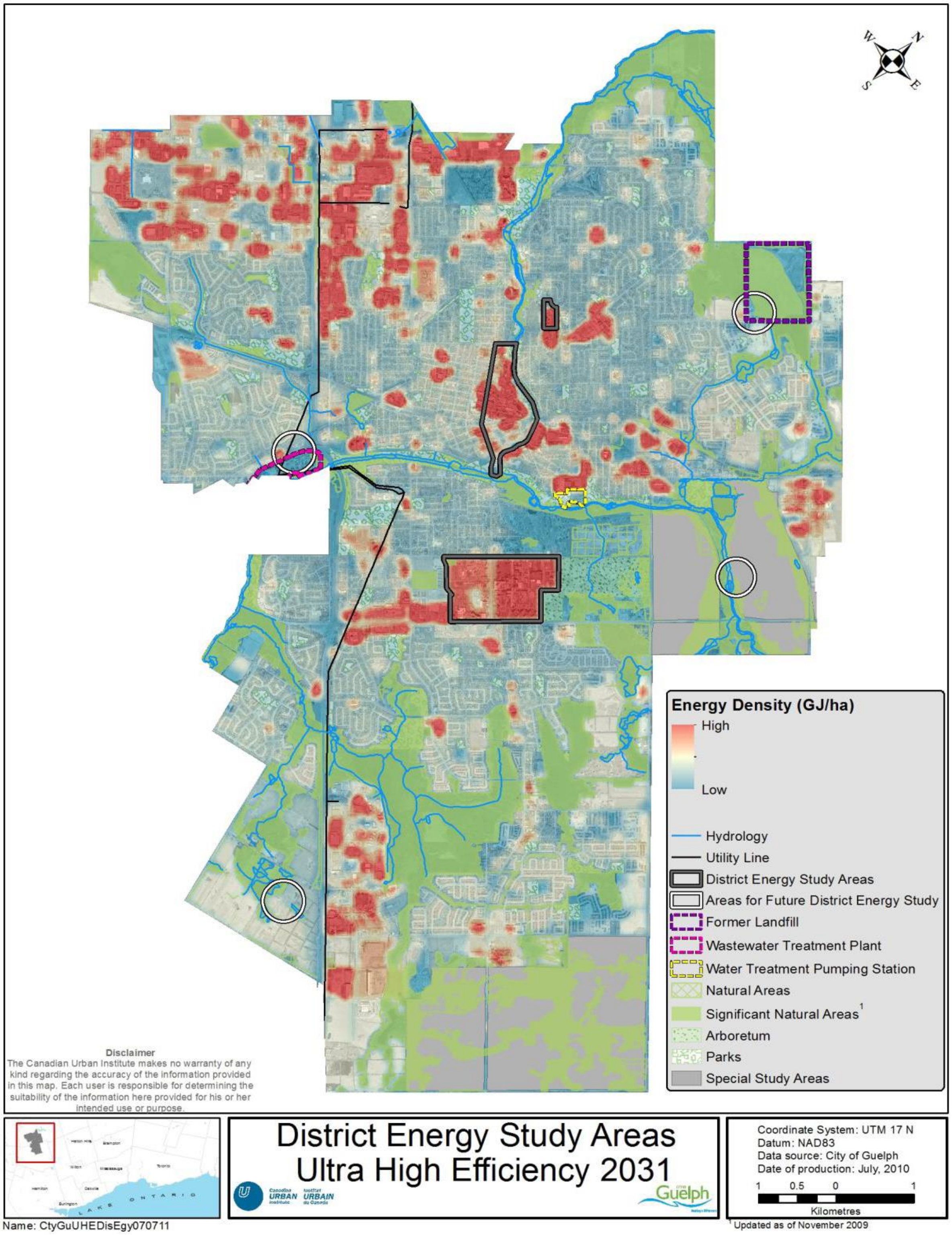


Figure 11. DE study areas identified in the City of Guelph Energy Mapping project. (Gilmour et. al., 2010).

warranted based on locations with substantial energy density (Gilmour et al., 2010). At a high level, the exercise helped planners begin to appreciate the scale of CEP (MS 3, 2013). This also provides the lead time needed to conduct relevant studies and ensure that energy-conscious land use decisions are made going forward. In fact, it assisted with articulation of the DE zones that are now being carried forward into Official Plan policy (MS 2, 2013). However, at the scale of an entire municipality, much of the finer detail necessary to begin planning for DE is unavailable. Energy mapping of clusters of individual buildings is useful for more accurate delineation of the “energy opportunity” (TE 2, 2013). An energy map at the scale of the Keele Campus, for example, would allow for consideration of where to locate the initial thermal plants and possible pipe routes.

3.21. The need for data

CEP and energy mapping are data-driven exercises and the difficult task for municipalities is acquisition of this data from local utilities. At a high level, metered data can be aggregated so as to avoid any intrusion on customer privacy. However, for the purposes of planning for DE, the need for data on individual buildings presents a challenge for planners. The case study of the Keele Campus relied on “door knocking” to obtain electricity and natural gas billing information from the third-party owned buildings, though in some cases building owners could not or would not provide the information. The scale and diverse ownership at the block scale of urban municipalities would make this approach untenable.

As was used in the CUI energy mapping project, energy planners must often rely on a combination of actual (i.e. metered) and estimated data – standardized values for energy consumption, demand and GHG emissions. This was the approach used in the case study of the

Keele Campus, where coefficients were applied to the potential floor area of new development to project the energy performance of the buildings. DE planning can be challenged by the limited availability of metered thermal data on connected buildings, which tends to be proprietary. Though some interviewees were initially skeptical of the use of coefficients, they agreed that energy projections developed in the case study were within an acceptable range for the purpose of a high level analysis such as this, though a business case would require much more accurate numbers.

4. Lessons Learned and Recommendations

DE is not a new technology, but as urban growth, extreme weather events and political interference raise concerns about the centralized approach to energy planning, a new context is creating an emerging opportunity for DE in southern Ontario. Though DE systems bring numerous benefits to the communities they are located in, the sharing of infrastructure sets DE apart from other energy solutions. DE system are resilient: the buried distribution network is physically robust and the local approach to planning for DE avoids the political interference of centralized energy planning. DE systems provide a platform for fuel switching: the economies of scale offer fuel choices, including renewables, to individual buildings that would otherwise be uneconomic with standalone equipment. DE systems contribute to local economic development: energy expenditures that would normally leave the jurisdiction are recirculated locally and security of energy supply is an attractive proposition to certain businesses.

Planning for DE also faces several challenges. The perception of DE as a new utility implies that it must be proven against the electricity and gas utilities, which have a long history of entrenchment in Ontario. Furthermore, as planning for DE is an emerging practice for municipalities, there is a need to build internal expertise. Finally, though not a prerequisite for success, there is no thermal energy policy at the provincial level and DE utilities are unregulated, which furthers misconceptions and uncertainty among municipalities. In addition to these challenges, the organizational complexity of DE also requires precise integration with community planning and land development in order to move towards implementation. In terms of technical parameters, higher density, mixed use developments improve the feasibility of DE systems. However, DE is also a major infrastructure commitment and so it benefits from early integration with plans for other municipal infrastructure. Furthermore, given the substantial capital required for DE and the uncertainty associated with land development, plans must be flexible to mitigate risk to both building developers and DE system developers.

In consideration of the above, it is clear that municipal leadership is essential to the growth of DE systems in Ontario. Notwithstanding that the provincial government appears to be moving towards more substantive municipal involvement in energy planning, policy and regulation is not liable to change in the short term and energy planning, while perhaps less centralized, will continue to be led by the province. As such, successful DE system implementation in Regent Park and the cities of Markham and Guelph highlight the importance of municipal commitment. This commitment can be further entrenched by connecting DE to strategic priorities and a community energy plan is a useful vehicle through which to do so.

It is also clear that planning for DE can facilitate implementation. In areas where growth is anticipated, planning for DE can provide much of the preliminary information necessary to begin conceptual design work and financial analysis that decision makers will require in order to make a commitment. Also, when plans for DE can be incorporated into community plans and the land development process up front, there is less uncertainty and less risk for building developers, DE system developers and potential investors and an opportunity for public input. However, given that planning for DE will be a new venture for many municipalities, there is also a need for disseminating practical approaches to planners and other municipal staff. The modern approach to DE is to develop nodes, starting with a limited number of buildings and connecting new buildings in increments. Campuses are important locations to initiate nodes because they tend to have consolidated land ownership. Planning policy can be utilized to require studies or DE-ready buildings as part of the planning process, though it cannot be used to require connection. Energy mapping is a useful spatial approach to energy planning and it can assist with identifying locations for DE nodes and, depending on the availability of data, preliminary network design.

The primary goal of this project was to use lessons learned from the case study of the Keele Campus to inform municipal DE development in Ontario. In retrospect, the literature and the interviewees' experiences with DE, especially in Markham, Guelph and Regent Park, also served as a substantial resource of information for consideration of DE expansion at the Keele Campus. Furthermore, the interviews suggest that there is indeed a substantial opportunity to expand the Keele Campus DE network and that the approach utilized in the case study is useful as a means of identifying and communicating the opportunity. Though more detailed analysis will follow this preliminary case study, there are nonetheless several important lessons that can help inform municipal DE development in Ontario. In many ways, the Keele Campus is a microcosm of a municipality and this section summarizes the lessons learned that are applicable to both the campus and urban municipalities in Ontario. .

The following are some of the steps that municipalities can take to facilitate the implementation of DE, though some will apply to universities as well.

1) *Incorporate thermal grid policy into Official Plans, especially with respect to areas where growth is anticipated*

Official Plans often include policies to direct certain actions and direction for development of thermal grids, especially in growth areas, can be incorporated as well. Though planning policy cannot be used to mandate connection to a system in Ontario, identifying a commitment at the highest official level signals to developers and planners that DE is being pursued in certain areas and should be considered. Supportive policies, such as requirement for a study as part of a development application or designing DE-ready buildings can further advance opportunities to develop DE nodes in growth areas.

2) *Engage and educate the public/community on DE*

This includes efforts to communicate the opportunity for DE to residents (current and future) and the broader community during the required public consultations that accompany a development proposal. In areas where DE has been identified as feasible, such outreach would enhance prospects for implementation by offering opportunities to express concerns or support and it would also being more visibility to DE. Though the technology is not new, this embedded approach to energy solutions requires public support as it must compete with incumbent utilities that have a long history of entrenchment.

3) *Align DE with strategic municipal priorities*

Given the lack of provincial policy and regulatory support for DE as well the lack of enabling planning legislation to mandate connection to a DE system, aligning DE with strategic municipal priorities can facilitate implementation by elevating DE beyond a technology option or energy solution. For instance, policies might include ensuring that communities are designed so that a local building serves as a public refuge should the electricity grid fail. Such a building would require reliable power as well as thermal energy, and DE would be a viable way to provide these services.

4) *Consider using existing assets to establish DE nodes*

With a long-term view and access to capital, municipalities can establish DE nodes by leveraging existing assets. For example, replacing an existing boiler with a larger unit in a municipal building and distributing heat to a neighbouring building.

5) *Develop energy maps, especially in growth areas*

As part of community energy plans, an energy map can be a useful visual tool to plan for various energy solutions, including DE. With respect to existing buildings, energy maps can identify opportunities for conservation or retrofit connections. For new development, they can suggest where locating thermal plants and/or CHP would make the most sense.

6) *Work with local utilities to share data on energy use and infrastructure constraints*

Community energy plans and energy maps rely on high quality data, most of which is held by the local gas and electricity utilities. Obtaining this data, especially for individual buildings, can be difficult given privacy concerns. Collaborating with utilities to share data without revealing personal information will help advance CEP and DE.

5. Directions for Future Work

The intent of this research project was to identify and discuss conceptual and practical approaches to planning for DE as a means to reduce its inherent organizational complexity and thereby facilitate implementation. Drawing on scholarly literature, key informant interviews, and a case study of the opportunity to expand the Keele Campus DE network, it is clear that planning for DE does have a role in facilitating implementation and that there is a strong rationale for doing so, but more work is needed in order to fully explore these relationships.

The benefits of DE were emphasized in this paper, but there is a need for further quantification, especially with respect to the value of resilience and to the extent that DE can help avoid the costs associated with extreme weather events. The value of fuel switching is well documented in literature and a current initiative of Natural Resources Canada will see the release of a District Energy Economic Multiplier (DEEM) model in the near future, which will assist with further quantifying the local economic value of DE. However, in light of the substantial costs of Hurricane Sandy in the northeastern United States, the avoidance of such costs should be calculated in terms of the present value of a DE system, if at all possible.

Developer perspectives were also mentioned in this report, though more information is needed to assess the variety of perspectives among different developers. Findings were counterintuitive to the general consensus that the principal-agent problem would dissuade developers from considering DE and as such, more research is needed to understand how developers perceive DE.

While energy mapping has become well-established in practice, it can be improved by through access to utility data at the individual building level. Data can be treated in various ways so as not to infringe on customer privacy without compromising the quality of the maps. However, utilities are not required to share this data and it remains a challenge to deliver energy maps that are building specific. Further efforts must be made to acquire this data, which may mean finding improved ways to protect customer privacy or establishing some sort of framework that allows for customers to opt in to a data sharing program.

With respect to the Keele Campus, the findings suggest that there is an opportunity to expand the DE network and next steps would be engineering studies that examine various scenarios of system design, ideally including detailed projections of phasing and built form. This would involve coordination with YUDC and CSBO (Energy Management) to understand how the new development will interface with the existing infrastructure, if at all. Concomitant with this would be a business case that establishes the costs, financial parameters and ownership options. Such a business case is essential to attract investors, which the research indicates would be necessary given that York University is not in the business of selling energy services. The attraction of DE investors would also be facilitated by the guaranteeing of customers and as such, efforts should be directed to gauging the reaction of building developers to mandatory connections and whether this could pose a challenge.

Furthermore, students, faculty and staff must be engaged in such a plan as part of the rationale for expansion is the opportunity to build curriculum. Given the importance of the subway and the subsequent development to the university's and possibly the broader community's future, public participation will be substantial. It would seem prudent to include DE in that process as expansion would benefit students and community residents alike.

Finally, it would be worthwhile to look for opportunities to expand beyond the Keele Campus. Significant development is anticipated immediately north of the campus along Steeles Avenue West and these buildings would represent a large thermal load to connect, notwithstanding the challenges of crossing a major arterial road and the fact that York Region is a different jurisdiction (Map 1). Looking even more broadly, the Keele Campus is positioned between the future Vaughan Metropolitan Centre and Downsview Park, both of which are expected to be large developments. Expansion at the Keele Campus could act as the anchor to a much larger DE node.

Steeles West - Potential New Development

Map 1. Potential new development along Steeles Avenue West (Adapted from &Co Architects & Dillon Consulting, 2013).

Part II: District Energy Planning in Practice

1. Executive Summary

The history of development of the Keele Campus, with respect to both buildings and energy infrastructure, provides important insights into the unique situation that the campus faces today. With the original Master Plan never realized due to a 1972 provincial moratorium on campus development and subsequent funding shortfall, campus development has proceeded through infill projects in the campus core, resulting in substantial land holdings (approximately 153 acres) at the edge of campus that are considered surplus to academic needs. With the York University Development Corporation tasked to monetize the holdings, the Spadina subway extension has provided the impetus necessary to develop these lands at a scale not seen in the university's history.

The Concept Plan for the campus identifies the potential for over 1.4 million square metres of residential, office, retail and institutional uses surrounding the academic core. The new development expected for the edge of campus lands might possibly be secured through land leases with private developers, which means that any connection to DE must either be specified in lease agreements or negotiated with the developers. The university would not assume control of the buildings for decades, if at all, but if the administration accepts a long-term view then the university leaves itself vulnerable to high fuel prices and expensive infrastructure development in the future by not pursuing connection.

With commercial development guided by academic goals, there is a clear opportunity to integrate land development, energy infrastructure and academic curriculum. Furthermore, with some of the existing infrastructure approaching a half century in age, future plans for reinvestment will hinge on available funding. This may come from land leases, but there is also an opportunity to earn revenue through new energy infrastructure, including DE, as identified in the recent Master Plan. Beyond revenue, there is an emerging pressure for universities to innovate with respect to teaching and research. DE can provide a platform for multidisciplinary, experiential education and the development of new curricula.

The results of the analysis and key informant interviews indicate that by expanding the DE network to potential new development, carbon dioxide emissions would be reduced by at least 8,000 tonnes per year and, depending on the operating strategy, 15-25 MW of combined heat and power could be embedded within the campus. Furthermore, by expanding the DE network to potential new development, it may allow for the connection of existing buildings that are not currently connected. Next steps would involve completion of detailed engineering studies and a business case.

2. Introduction

The MUSH (municipal, university, school and health care) sector is often referred to as an important area in which to foster the growth of DE systems because, in general, they: are large institutions; have long expected life spans; consume substantial amounts of energy; have somewhat centralized control over land development; and in the cases of universities and hospitals, often include missions critical operations (e.g. laboratories and life support systems) that cannot fail. Hence the reason why many initial university campus plans included infrastructure for steam distribution and provision for future cooling and electrical distribution –

it was logical to invest the necessary capital in order to reap the future benefits of long-term operational savings and reliability.

However, the above rationale applies only to those buildings operated by the university, not to those that are owned and operated by third parties notwithstanding that they are located on university land. Such is the situation that the York University administration is faced with at the Keele Campus – academic buildings and uses ancillary to university operations are moving forward as infill projects, while development on edge of campus lands is expected to be delivered by third parties through land lease agreements. The following section will outline the history of the development of buildings and infrastructure at the Keele Campus. Understanding the internal and external forces that have shaped the campus and led to this land development scenario will provide insight into the future opportunity to expand the DE network.

2.1. Building and DE development at the Keele Campus

In 1962 the provincial government endowed York University with 457 acres of land at the southwest corner of Keele Street and Steeles Avenue West in the former borough of North York (City of Toronto et al., 2008). Then, in 1963, the first Master Plan was developed for the Keele Campus by a group of consulting firms organized under the title UPACE (University Planners Architects and Consulting Engineers). According to their initial report, UPACE identified the early 1960s as a crucial time for campus planning due to expected enrollment increases in the near future as many baby boomers start to reach enrollment age. While the Master Plan was based on an anticipated population of 15,000 by 1980, it included expansion provisions for up to 25,000 people (UPACE, 1963). Land availability was the primary concern expressed by UPACE regarding future expansion, noting that in order to still accommodate green space and surface parking, it would be necessary to increase the heights and densities of buildings in the central core of the campus through multi-storey towers and parking garages (UPACE, 1963). The plan called for closely spaced buildings of modest heights, which were design features intended to address the climate extremes of the area. A ring road would separate the interior academic buildings from the exterior parking and uses that were ancillary to academic functions, including the central plant (UPACE, 1963).

The Central Utilities Building (CUB) is located at the northeast corner of the campus and is connected to the core buildings through a network of underground tunnels that house the steam, chilled water and electricity distribution infrastructure (Figure 12). The CUB boilers initially utilized heavy fuel oil to create steam as there was no natural gas connection available during initial development and fuel oil boilers were less expensive than coal-fired units. The high viscosity of heavy fuel oil meant that it had to be heated in storage tanks in order to be combusted in the boilers and it was problematic to work with. Given these challenges, it was common practice to centralize these boiler plants so that several large boilers, storage tanks and other equipment could be operated in one location by trained staff rather than in each building. This reduced staffing requirements and expenses through economies of scale and it also meant that emissions were centralized, away from the academic buildings where the student population concentrated.

The initial master services plan for the university was based on the anticipated floor area growth as per population projections in the 1963 Master Plan – 15,000 people by 1980. However, considering that by 1971 there were 20,000 students enrolled (almost half in full-time

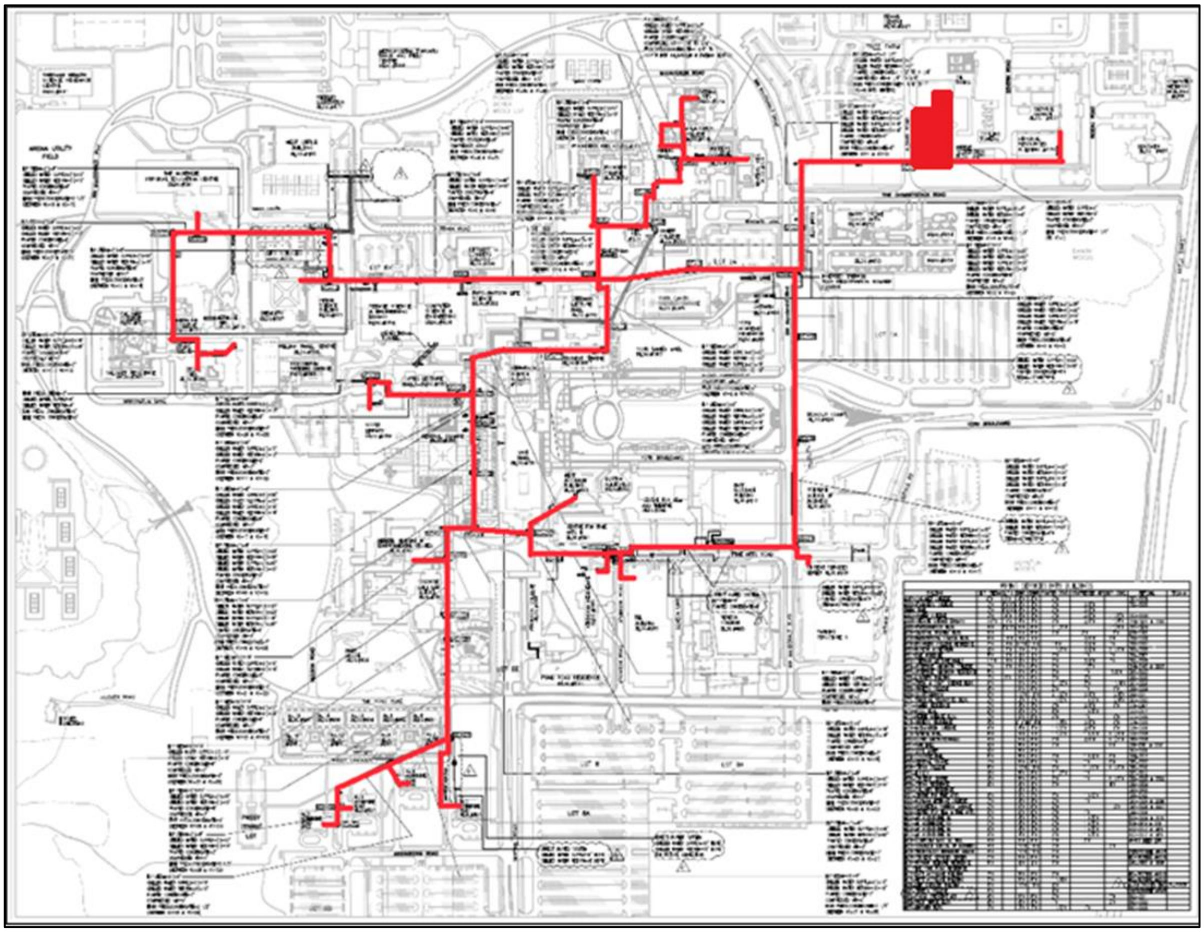


Figure 12. The Central Utilities Building and tunnel network (Adapted from York U Facilities Services (2013) Mechanical Distribution Services and Tunnel drawing.)

programs) it was essential that the master services plan was flexible (Lyles & Dale, 1971). Equipment was added in a modular fashion at the CUB and the DE network expanded as projections for future growth changed. Capital investments were made only once there was a risk that the available capacity of the CUB would not meet current demand (Lyles & Dale, 1971). Two crucial decisions were made in the initial designs of the CUB and the distribution network: 1) provisions for natural gas fired boilers and; 2) installation of a 13.8 kV microgrid that would distribute electricity on campus from the 27.6 kV distribution system operated by the utility. In the mid-1970s, once a natural gas pipeline was extended to the Keele Campus, the oil boilers were converted to combust natural gas, a fuel which is less complex to work with, less emission-intensive and cheaper when supply is based on an interruptible contract. A dedicated natural gas supply also allowed the university to begin generating electricity with high-efficiency CHP turbines. During initial campus development, it was not considered economical to generate electricity at the CUB given the costs of fuel and the means by which electricity rates were structured (Lyles & Dale, 1971). However, as electricity rates increased at 10-15% per year in the 1990s it became economical to use natural gas to generate electricity for use in campus buildings. In 1997 and again in 2002, a 5 MW gas turbine was installed in the CUB. Steam is fed into the thermal distribution pipes, which allows for the boilers to be used less and electricity is fed into the campus microgrid, which allows for less electricity to be imported from the local distribution grid.

2.2. Growth and Fiscal Pressures

While it is important to understand how the existing CUB and distribution network came to be, they did not inform campus design or land use; rather energy and infrastructure considerations were the result of growth and development that accelerated and decelerated at the influence of both, internal and external pressures. For the Keele Campus, the 1972 moratorium on Ontario university campus development issued by the Ministry of Colleges and Universities proved to be very disruptive as it occurred during the crucial formative years of the campus (Lapp, 1985). However, enrollment remained high and space was limited – by 1985, 32, 000 students were enrolled at the Keele Campus despite only half of the originally planned buildings having been constructed and the resulting space shortfall was in excess of 500, 000 square feet (Lapp, 1985). Of those buildings, the built form envisioned in the 1963 Master Plan was never realized and the current Keele Campus was, and is, often lamented for exposure to extreme weather and long walking distances – the antitheses to the dense, urban and sheltered designs in the original Master Plan (Lapp, 1985). With no public funds being administered by the Ministry, the university administration recognized that it could only grow by monetizing its existing land assets.

In 1982, MMM Group was hired to complete a *Lands Study* and provide actionable recommendations for the administration. They found that: hotel/motel, residential and institutional uses would provide the greatest returns, with research, retail and recreational uses being less valuable; the administration should utilize a separate entity with university affiliation to proceed with real estate matters and liaise with municipal planning authorities; and the university should clearly delineate design and development criteria regarding non-university uses (Lapp. 1985). During completion of this study, the administration expressed several concerns regarding commercial land development, in particular its relationship with academic planning and the notion that academic needs should drive land use decisions above all else (Lapp, 1985). Faculty Deans suggested that buildings should include university and non-university uses to engender commercial research initiatives and that communication with the broader York community would be essential (Lapp, 1985).

Overall, it was suggested that campus development proceed in one of two ways: 1) with university and non-university uses physically separate as per the 1963 Master Plan and; 2) mixed university and non-university development through infill, which would require a new Master Plan. Lapp (1985), arguing that a new Master Plan was required, proposed that future campus land-use development be guided by three objectives: “to generate a revenue stream to finance physical facilities for University use; to improve the aesthetic and physical environment of the campus and; to attract industrial, commercial and other socially relevant users onto the campus that support academic goals and objectives, or that enhance campus life" (p. 43).

It became evident that infill development would be necessary to achieve a high quality built form and that university buildings would be financed through land leases that included non-university uses, both beyond the scope of the 1963 Master Plan (Lapp, 1985). In 1988, the university created a new Master Plan and helping to manage this process was the York University Development Corporation (YUDC). Established as the real estate development entity of the university (York being its sole shareholder) by the Board of Governors in 1985, YUDC was tasked with ensuring that population growth was accommodated and that the university received a return from the monetization of land assets. The 1988 Master Plan included provisions for the addition of over 5 million square feet of floor space, room enough for an estimated student population of 60,000.

A significant change from the previous plan was the addition of secondary roads to the ring-road that surrounds the campus. This was intended to make a greater number of smaller parcels available for other development, including non-academic uses, the development of which was to be coordinated by YUDC. This altered campus development from the intent of the original 1963 Master Plan and would become the basis for future development (City of Toronto et al., 2008). Of note were the desires to further increase the density of built form (through taller buildings and infill), increase the population of students living in campus residences, improve transit accessibility to campus and develop precincts beyond the academic core.

Not long after this, a Secondary Plan was produced for the university in 1991 to guide development in specific precincts. The University Core would be preserved for institutional uses, including student housing; the North Precinct would include both institutional and commercial uses given the strategic location along Steeles Avenue; the Southwest Precinct would be primarily residential; and the Southeast Precinct mixed-use, including residential, retail and office space. When the 2002 Official Plan was appealed by the university over concerns about how the Institutional Areas policies in the OP would affect the Secondary Plan area, the Secondary Plan was never approved by the Ontario Municipal Board (City of Toronto et al., 2008). Nevertheless, the idea of a core surrounded by non-university precincts would carry over into future planning initiatives.

2.3. A New Planning Framework

Anticipation of significant changes to the Keele Campus – driven by the York University-Spadina subway extension – necessitated an update of the 1991 Secondary Plan (City of Toronto, 2009). Approved by City Council in 2009, the new Secondary Plan will ensure the protection of university priorities and continuity with the existing community as development intensifies around the subway nodes and leads to population and employment as well as infrastructure requirements. The Secondary Plan projects an eventual population of 24,000 residents and 21,000 jobs in the six precincts surrounding the campus core.

The City of Toronto emphasizes the importance of Environmental Stewardship and Sustainable Design in the Secondary Plan. The Toronto Green Standard is a city-wide performance standard that encourages the reduction of GHGs through sustainable design, energy efficiency and the use of renewable energy sources. The Secondary Plan draws from this and policy 3.8.1 states that: “Sustainability strategies will be developed at the precinct planning stage that will identify the mechanisms and techniques, such as community energy plans, district heating/cooling, renewable energy…to be used for mitigating environmental impacts of development on a precinct wide basis” (p. 25). Furthermore, policy 3.8.3 states that: District heating and cooling with geothermal technology will be encouraged as a means to reduce greenhouse gas emissions and conserve energy” (p.25). Precinct Plans and Context Plans will be used to implement the policies within Secondary Plan and the forthcoming Master Plan will provide further guidance once in place.

Currently, YUDC, working with the Planning Partnership and Greenberg Consultants, is updating the 1988 Master Plan in order to create a long-term vision for the Keele Campus. The potential revenue from available land to be developed is being positioned as a means to realize the original vision of the Keele Campus as an urban university (YUDC, 2013). Initial consultation with students, faculty and staff indicated that sustainability needed to be a key part of the Master Plan, building on previous initiatives by including provisions for energy efficiency, renewable fuel sources and improved infrastructure among other ideas. Proposed new projects, including building development and presumably including energy infrastructure, will be evaluated based on integration with the Master Plan.

One of the 7 Pillars of the Master Plan is to “Become recognized leaders in environmental sustainability” (p. 19). York University has maintained an excellent reputation as a leader in environmental sustainability and was one of the first universities to be a signatory to the Talloires Declaration – a global initiative that aims to incorporate sustainability into the academic and operational components of universities. The university has taken significant strides to reduce energy consumption and personal vehicle travel, but with diminishing returns of energy efficiency initiatives and the sheer scale of development envisioned in the Master Plan, sustainability efforts with respect to energy efficiency and GHG emissions will require innovative solutions that address new growth. For example, Green Infrastructure is one of the key components of the Master Plan: "The University is exploring opportunities to build upon its existing infrastructure to a district energy system that will continue to treat all campus buildings, and potentially serve adjacent urban neighbourhoods" (p. 29). The intent is that as the university moves forward with development, considerations of district energy would be included in Precinct Plans.

2.4. Aging Infrastructure and "Differentiation"

Though DE is poised to contribute to the universities environmental objectives, it can also address some of the more immediate challenges that the university will face in the short term. Some sections of the CUB and distribution network are approaching a half-century of operation and concerns about the longevity of the infrastructure are evident on the part of the administration. It was just three years ago that the entire campus was evacuated following a boiler fire at the CUB. One mistake by a single contractor disrupted steam service to the entire campus in December of 2010, forcing the rescheduling of exams and the temporary relocation of thousands of students by the university. As rare as they are, events such as that are a stark reminder of the vulnerability of an aging asset and the need for consistent reinvestment.

Yet the reality is that all public universities in Ontario, including York, will face tremendous fiscal pressures in the short term as the province scales back funding in order to reduce its own deficit. In an effort to more efficiently allocate the available funds, the province is encouraging universities to differentiate – to focus on the specific areas of teaching and research that play to the university's strengths – which could be a detriment to other areas (Bradshaw, 2013). The 1972 moratorium forced York University to consider other means to raise revenue, which it pursued through monetization of land assets. It will continue to do this, but amidst this challenge there is an opportunity to develop innovative curricula that drive enrollment and attract research grants and partnerships going forward.

2.5. Summary

Owing to its difficult history of development, the Keele Campus has a unique opportunity to extract revenue from land development at the perimeter while expanding academic functions with infill development in the core. The extension of the Spadina subway provides the necessary incentive and a new Secondary Plan and Master Plan will guide this development in the future. The university has gone to great lengths to practice environmental sustainability and related goals are evident in these plans. Yet aging infrastructure and the pressure to differentiate will represent major challenges for the university going forward. Expansion of the campus DE network with new development has the potential to generate revenue, improve resilience and contribute to academic innovation.

3. Analytical methods

The following section outlines the specific methods used in the case study analysis, including data collection, assumptions and relevant contextual literature. Figure 13 outlines the methodological workflow followed.

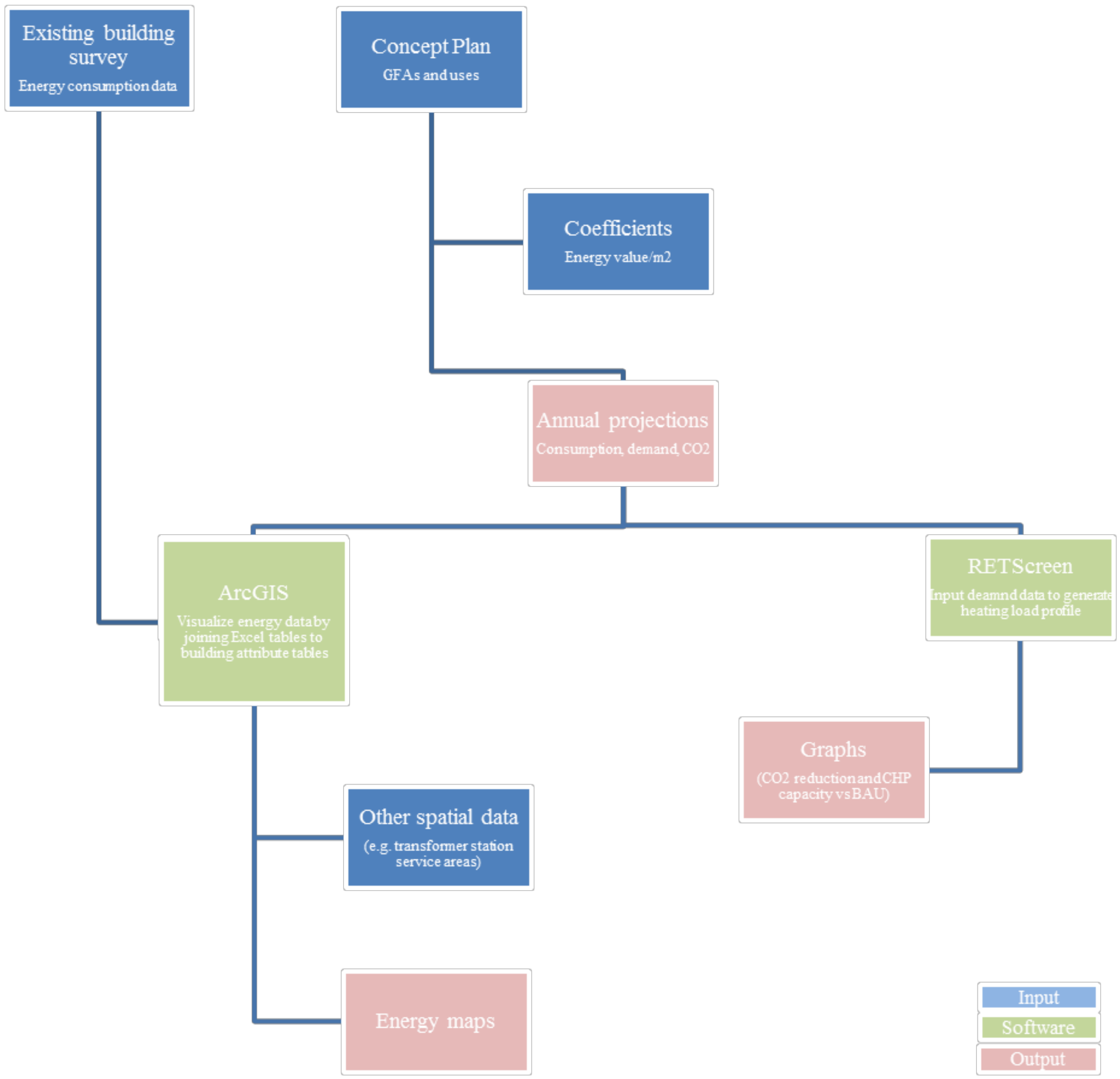


Figure 13. Methodological workflow of Part II

3.1. Existing Building Survey

Though new development is the driver for expanding the Keele Campus DE network, planning for expansion must begin with an account of existing conditions, specifically the buildings on campus that are not connected to the DE network. There reason for doing so is that while connection may not have been feasible when the building was first constructed, an expanded system may allow for these buildings to be connected. However, the buildings are unique with respect to ownership, energy consumption and equipment age, which may complicate potential retrofits. In order to identify where a future retrofit may and may not be feasible, a Building Survey is used to collect the necessary information to make such recommendations. The Building Survey (Appendix A) was adapted from one used by the Energy Efficiency Office (City of Toronto) to examine opportunities for various energy performance improvements in existing buildings, including potential for DE connections. The survey is designed to collect data on the metrics that the feasibility of a retrofit is most sensitive to, including:

3.1.1. Ownership

Of the existing buildings on the Keele Campus not connected to the DE network, some are owned and managed by third parties through lease agreements with the university, while others are York University buildings. With the university being the decision maker in this case, the prospects of a retrofit are simpler when the building is owned by the university. Information on ownership was collected through conversations with YUDC – responsible for negotiation of land leases – and through site visits to the existing buildings.

3.1.2. Physical specifications

The use and size of a building are also important factors that will come to bear when a potential retrofit is considered. A low density, residential building is less amenable to connection than a higher density building that might include multiple uses, such as office and retail. Furthermore, it is essential to characterize the type of heating and/or cooling distribution system used in the building. Centralized, hydronic (water-based) distribution systems are a prerequisite for connection to DE. Buildings that utilize forced air systems or electric baseboard heaters are not amenable to connection; a substantial retrofit of the in-building distribution system would be required first. For this project, information on physical specifications was collected through conversations with YUDC, the CSBO Drafting Office and through site visits with staff from Energy Management.

3.1.3. Energy consumption

In general, buildings that use minimal amounts of energy are less likely to be connected as it becomes difficult to justify the cost of connecting relative to the small load. In this case, data on energy consumption was obtained from Energy Management (for York University buildings) and through authorized access to electricity and gas utility bills for non-York buildings.

3.1.4. Mechanical equipment

The age and location of heating and cooling equipment are also important determinants of connection opportunities. As new boilers and chillers are not likely to be replaced, connection to DE benefits from timing the deployment of infrastructure with replacement of equipment at the end of its operating life. Also, when equipment is located in the penthouse or on the roof of a building, it means that longer piping is necessary to connect it compared to equipment located below or at grade. Longer piping runs equal more cost and connection is difficult if equipment is located above grade.

3.2. Characterizing new development

3.2.1. Distribution of uses

The Concept Plan forms the basis for analysis of the opportunity to expand the DE network to new development. However, the Concept Plan does not provide the necessary level of detail on individual buildings – the floor area and uses are aggregated into building clusters. In order to characterize each building, it was necessary to approximate how uses might be distributed throughout the clusters. The approach taken was to assign uses – residential, office, retail and institutional – to each building and then use a weighted average to estimate the floor area for each use (See Appendix B for sample calculation.) The weighted average is the same proportion of how the uses are distributed for each cluster as per the Concept Plan. While the weighted average method may overestimate some uses in certain buildings and clusters, it ensures that the total gross floor area is consistent with the initial Concept Plan. Furthermore, given that the development envisioned in the Concept Plan is likely to change, this method is reasonable at such an early stage of planning.

3.2.2. Coefficients

In order to make projections about the energy performance of the potential new development, values (normalized to floor area) are needed for various energy metrics that correspond to each of the different building uses. These energy metrics are referred to here as coefficients and they include values for energy consumption, energy demand and carbon dioxide emissions per square metre of floor area (Appendix C). They will differ based on the building use and in this case, all buildings are assumed to meet Tier 1 of the new Toronto Green Standard, which is equivalent to 35% better than the 1997 Model National Energy Code for Buildings (MNECB) used in the Building Code. The specific set of coefficients utilized in this project was obtained from the engineering consulting firm, Halsall Associates Limited, who have developed several community energy plans on behalf of the City of Toronto. These coefficients are derived from a combination of metered and modeled data on existing buildings, benchmark values provided by Natural Resources Canada and general engineering rules of thumb. While it would be ideal to develop a set of coefficients specific to the Keele Campus, that is an exercise that requires extensive experience with building science as well as databases of building information. Since neither of those could be acquired in the time frame of this project, the coefficients used here provide a reasonable estimate of the energy performance of potential future development and they can be substituted with more precise values when available.

3.2.3. Development phasing

One of the most important and most challenging aspects of DE planning is predicting the phasing of building development. Projecting the timing of loads is essential in determining the timing of required capital outlays and infrastructure work. At the Keele Campus, where there is an existing network, phasing is even more important as the opportunity to connect the first new buildings will depend on how far they are located from the existing central plant. Phasing is a function of market demand and there is no guarantee that the loads will be added in a way that is conducive to expanding the system. That being said, it is also very challenging to predict how phasing will occur at this early stage of the process. However, in order to illustrate how phasing of development would affect electricity demand, a generic phasing schedule was used. It begins with the most attractive sites (highest densities) and expands outwards to fill in remaining space over a 30 year period. At the Keele Campus there are existing uses on some of the lands (athletic fields and surface parking as well as some buildings) and YUDC will have responsibility deciding how lands are parcelled off, so to develop a detailed phasing schedule at this point would not add to the analysis.

3.2.4. RETScreen Clean Energy Project Analysis Software

RETScreen is a free software program developed by Natural Resources Canada. It functions as a decision support tool and it is designed to reduce the expenditures on time and resources in the preliminary stages of an energy project. In other words, it can assist with informing decisions as to the feasibility of a particular project. Based on selected user inputs, each particular module can provide a basic energy model, estimates of financial performance and risk analyses. Despite being designed for use by individuals of various disciplines, RETScreen requires specific engineering knowledge in order to develop a detailed model. The program was used in this project to validate some of the assumptions made previously. A detailed energy model, costing and financial analysis requires significant expertise and given that this project is in its infancy, an in-depth analysis is prone to error. However, as a means to identify, validate and communicate the high level opportunity to expand DE at the Keele Campus, RETScreen is quite useful.

3.2.5. Assumptions

Load diversification factor

The load profile of a particular building is a function of the buildings use – different building uses will have varying load profiles and peak demands will occur at different times (Compass Resource Management, 2010). Since a DE network aggregates these diverse loads, it has the effect of reducing the peak demand and flattening the overall load profile. The numerical value that represents this change is referred to as the load diversification factor. For the purposes of the project a factor of 85% was chosen for the thermal load, meaning that the diversified peak load of the connected buildings will be 85% of the total peak load if each building had standalone equipment. Though diversification does not change the total amount of energy consumed, by reducing peak demand it allows for reduction in equipment and infrastructure size, which reduces capital costs (TE 1, 2013).

Boiler seasonal efficiency

The efficiency of a boiler describes the heat output relative to the fuel input and manufacturer ratings for modern units can reach more than 90%. However, the rated efficiency represents the maximum for a particular point in time. A more realistic measure is the seasonal efficiency, which accounts for variations in seasonal temperatures and the effects of part-load operation (Genivar Consultants, 2010). The seasonal efficiency of a boiler will be lower than the rated efficiency, more likely somewhere between 65-75%. There is no obvious consensus in literature, but for the purpose of this analysis 70% was confirmed to be a reasonable value (TE 2, 2013).

Central plant efficiency

Since DE networks aggregate multiple, diverse loads and operate at full load for a greater portion of the year, the efficiency of a well-operated plant should be better than a standalone boiler. Central plants can achieve operating efficiencies in the 80-90% range, so an average value of 85% represents a 15% improvement relative to a standalone boiler (TE 1; TE 2, 2013). This 15% improvement in energy efficiency corresponds to a 15% reduction in fuel use and an equivalent reduction in GHG emissions.

Base DHW demand

While demand for space heating varies with seasonal temperature fluctuations, the demand for domestic hot water (DHW) is more consistent throughout the year. DHW demand is a factor of building use – while in an office tower, DHW demand will be minimal (e.g. hand washing), a multi-unit residential building will be much higher as residents require hot water for showering, cooking, laundry, etc. RETScreen suggests that the base DHW demand of an office building might be approximately 10%. For a multi-unit residential building, 25% is more appropriate (CMHC, 2005). Based on the use mix for the Keele Campus (primarily residential), a base DHW demand of 20% was assumed.

Sizing CHP

There are different approaches to integrating CHP with DE. One approach is to size the thermal output of the unit to match the minimum annual thermal demand, which equates to the demand for DHW in the month of July (Genivar Consultants, 2010). The advantage of this strategy is that the unit can theoretically operate at full load for the entire year. The disadvantage is that the unit will be undersized relative to the peak thermal demand, which will require increased backup boiler capacity. Furthermore, it also means that less electricity will be generated over the course of the year, which means either less revenue earned (by virtue of exporting less electricity to the grid) or a greater reliance on imported grid electricity. There are numerous operating strategies that can be employed to allow for greater CHP capacity (e.g. rejecting heat; thermal storage), but this strategy was chosen in order to be able to verify calculated values by comparison with those used in reviewed documents.

3.3. Energy Mapping

A GIS is particularly useful for DE development. By visualizing the energy-specific datasets of existing and new buildings and then overlaying them on any existing energy infrastructure, the GIS can assist with decisions regarding: the potential to connect existing buildings via retrofit based on their proximity to future buildings; where to locate thermal plants (e.g.. boilers) based on the thermal demand of buildings; and the location of generation and distribution infrastructure and any potential conflicts. In this project, spatializing qualitative Building Survey data and quantitative projections of energy performance allow for in-depth insights into planning approaches for expanding the DE network. The workflow employed to carry out the GIS analysis is depicted in Figure 14. ArcGIS 10.1, developed by Environmental Systems Research Institute (ESRI), was utilized for this project. In general, the mapping process consisted of four main steps:

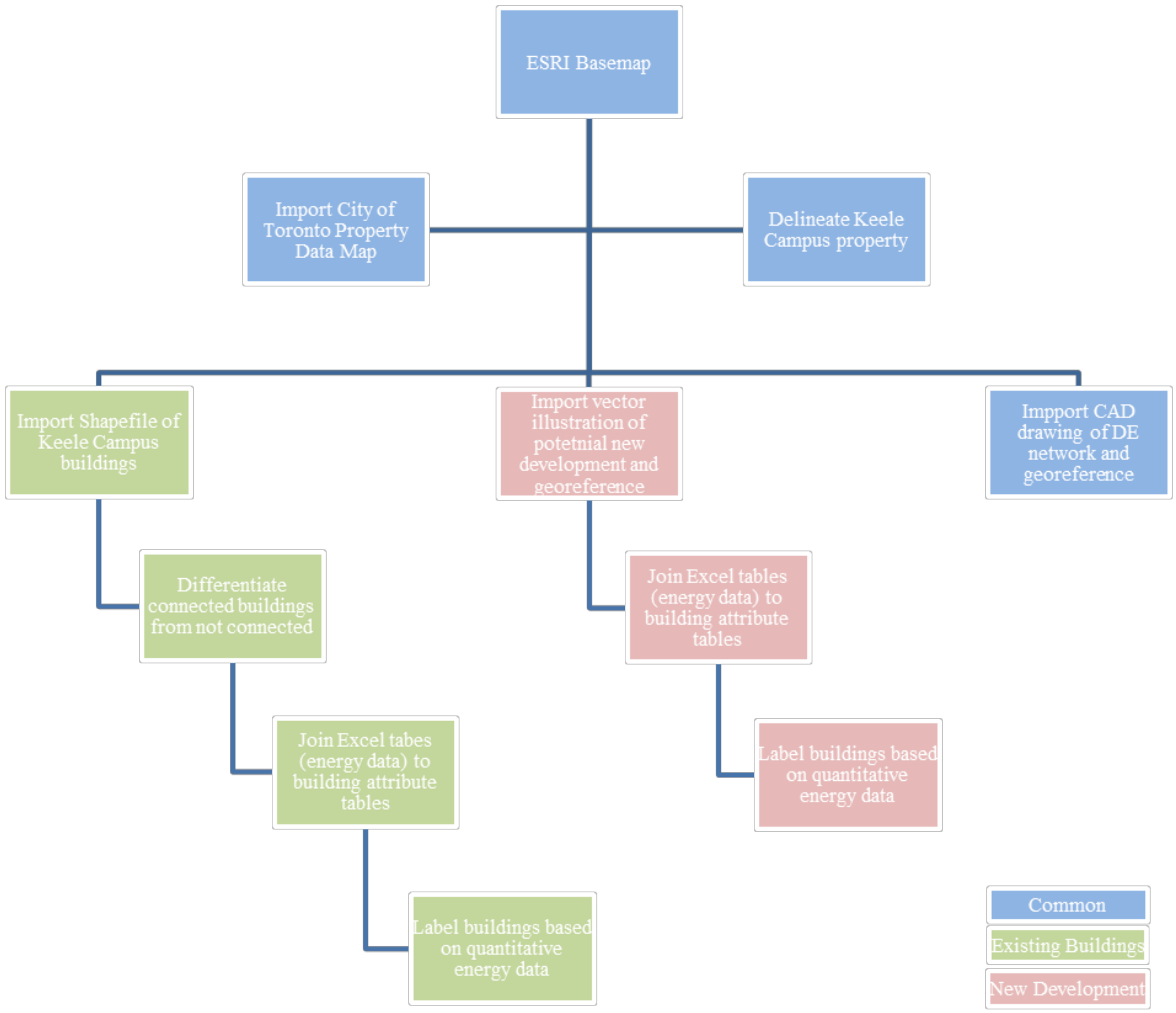


Figure 14. Energy mapping workflow

3.3.1. Establish boundaries and physical infrastructure

Beginning with a basemap of the world provided by ESRI, a subsequent City of Toronto Property Data Map (PDM) layer – obtained from the York University Map Library – is overlaid in order to delineate the Keele Campus boundaries. Since the PDM applies to the entire city, the initial steps involved selecting only the land owned by York University. In order to map the existing infrastructure, a CAD (computer-aided design) drawing of the DE network was obtained from CSBO and imported into the GIS. Since the CAD file did not have a coordinate system, the GIS was not able to map it according to its actual location and the DE network had to be georeferenced (manually located according to specified points) in order to ensure that it was in the correct location.

3.3.2. Import existing and potential new buildings

A spatial layer of the existing Keele Campus buildings was obtained from the Map Library and imported into the GIS. Buildings were then differentiated based on whether or not they are connected to the DE network. The spatial layer for potential new buildings first had to be created by tracing over an image of the Concept Plan in Adobe Illustrator. This program allows for the drawing of vectored images (images with spatial information) as opposed to importing a raster image of the Concept Plan into the GIS. This intermediate step was necessary so that the potential new buildings could be further analyzed using the GIS in subsequent steps.

3.3.3. Join energy data to building data

Though not executed using the GIS, tables of energy data (metered consumption for existing buildings and projections of consumption, demand and GHG emissions for potential new buildings) were created using Microsoft Excel. Next, in the GIS, the Excel tables were joined to the building attribute tables that contain information on physical specifications such as GFA, density and age. The process of joining, where unique identifiers in one table are matched to a set of identifiers in another table, allows for expanded analysis of a particular spatial layer – in this case, the energy data of existing and potential new buildings.

3.3.4. Visualize the energy data

The above process allows for the quantitative labelling of individual buildings based on the energy data. There are numerous ways in which the GIS can quantitatively label buildings and each classification presents the data in a different way. The Natural Breaks (Jenks) method is the default setting in ArcGIS and it optimizes the classification by maximizing the difference between the classes. A colour gradient is assigned to the range of values whereby increasing values are progressively darker and this particular style is referred to as choropleth mapping. A series of maps were created that show, for example, electricity intensity (consumption per square metre) of existing buildings and projected thermal demand (kW per year) of potential new buildings.

4. Findings and Preliminary Conclusions

4.1. Existing buildings

The following is a summary of the data gathered on physical specifications, energy use and mechanical systems (Table 4) for the existing buildings on campus not connected to the DE network. It is not intended to serve as a feasibility analysis; rather, it is to be understood as a screening process designed to identify candidates for connection.

York University - Keele Campus
Existing buildings not connected to the district energy system (2011 data except where indicated)

Building Data

Building No.	Name	Address	Main use(s)	Year of occupancy	GFA (m2)	Contact	Ownership
203	Bookstore (connected to central chilled water)	80A York Boulevard	Retail	1991		[redacted]	
383	Office (connected to central chilled water)		Office				
442	Retail		Retail and Food service				
SUBTOTAL	York Lanes				13,981.10		
375	Colonnade				2,064.58		
397	Stadium Field House	190 Northwest Gate	Sports facility	2000	1,745.02		
440	Rexall Centre (Tennis Canada)	1 Shoreham Drive	Sports facility	2004	15,800		
441	Sherman Health Research Building	180 Ian Macdonald Boulevard	Institutional	1968 (Renovated 2009)	2,808.75		
443	190 Albany Road (YUDC + Tennis Centre)	190 Albany Road; 3111 Steeles Ave W	Office	1985 (Currently being renovated)	900.00		
444	City of Toronto Track & Field Centre (connected to cogen electricity)	130 Ian Macdonald Boulevard	Sports facility	1979	28,414.10		
445	Seneca at York (connected to cogen steam)	70 The Pond Road	Institutional	1999	25,851.24		
448	Canlan Ice Gardens	989 Murray Ross Pkwy	Sports facility	1998	35,178.77		
452	Harry Sherman Crowe Housing Co-op Apt. (connected to cogen electricity)	51 The Chimneystack Road	Residential apartments	1993	12,311.00		
453	Harry Sherman Crowe Housing Co-op- South	51 The Chimneystack Road	Residential townhomes	1993	3,313.70		
454	Harry Sherman Crowe Housing Co-op-East	51 The Chimneystack Road	Residential townhomes	1993	1,434.64		
455	Harry Sherman Crowe Housing Co-op-West	51 The Chimneystack Road	Residential townhomes	1993	1,434.65		
456	Harry Sherman Crowe Housing Co-op-Southeast	51 The Chimneystack Road	Residential townhomes	1993	2,831.40		
484	Archives of Ontario Building	134 Ian Macdonald Boulevard	Office	2009	10,512.18		
485	York Academic-Research Building (YRT)	74 York Boulevard	Office	2009	11768.94		
488	Computer Methods Research Facility	4850 Keele Street	Data centre	1987	1,686.38		
TOTALS	**Campus buildings not connected to DE**				**172,036.45**		

Equipment Data

Building No.	HVAC System	Space Heating	Fuel	Total Heating Capacity (kW)	Age	Location	DHW	Fuel	Total DHW Capacity (kW)	Age	Location
203	Hydronic	Air Handling Units (x7) for common space/Single loop heat pump system for office and retail space	AHUs: Natural gas/Heat pumps: Electric	AHUs: 246-352; Heat pumps: 3.5-18	AHUs = Less than 1 year	AHUs = Rooftop/Heat pumps = Main Floor	One hot water heater for each commerical retail unit/office space/Bookstore	Natural gas			Main Floor
383											
442											
SUBTOTAL											
375	NA	ION Unit	Natural gas	246	Installed 2012	2nd Floor	None				
397	Electric		Electricity				Hot water heater	Natural gas			
440	Hydronic	Heat pumps (x5)/Heating boilers (x2)	Heat pumps: Electric; Boilers: Natural gas	566.4 (Heat pumps: 11.24 kW (avg); Boilers: 227)	Installed 2004	At or above grade	Hot water heater (x2)	Primary heater: Natural Gas; Secondary heater: Electric	26.4	Installed 2004	At or above grade
441	Hydronic	Heating boiler (x2)	Natural gas	395	n.d. (last 3 years?)	Main Floor	Hot water heater (x2)	Natural gas	117.2	n.d. (last 3 years?)	Main Floor
443	Hydronic	Hot water boiler	Natural gas	63	n.d. (after 2007)	Basement	Hot water heater	Electric	30	Manufactured 2009	Basement
444	Hydronic	Hot water boiler (x4)	Natural gas	138	Manufactured 2010	Main Floor	Hot water heater	Natural gas	430	n.d. (last 5 years?)	Main floor
445	Hydronic	Central Plant									
448	Hydronic										
452	Hydronic	Heating boiler (x2) for tenant space/Air handling units (x2) for common space	Natural gas	1117 (Heating boiler: 309; Make up units: 220-250)	Boilers: Installed 2011	Rooftop	Hot water heater (x2 - at least)	Natural gas	440	Installed 2011	Rooftop
453	Hydronic	Individual Furnaces	Natural gas								
454	Hydronic	Individual Furnaces	Natural gas								
455	Hydronic	Individual Furnaces	Natural gas								
456	Hydronic	Individual Furnaces	Natural gas								
484	Hydronic		Natural gas			4th Floor		Natural gas		n.d. (last 3 years?)	4th Floor
485	Hydronic	Heating boiler (x3)	Natural gas	1,922	n.d. (last 3 years?)	4th Floor	Hot water heater	Natural gas	44	n.d. (last 3 years?)	4th Floor
488	Electric										
TOTALS											

Equipment Data (continued) and Utility Data

Building No.	Cooling	Fuel	Total Cooling Capacity (kW)	Age	Location	Electricity: Consumtpion (kWh)	Electricity: EUI (ekW/hm2)	Natural Gas: Consumption (m3)	Natural Gas: Consumption (ekWh)	Natural Gas: EUI (ekWh/m2)
203	Central plant for building/Heat pump for tenants (Bookstore is considered a tenant)	Electric heat pumps			Main floor	553,319.00		51,110.20	532,397.92	
383						681,251.00		49,607.20	516,741.67	
442						2,296,717.00		143,268.70	1,492,382.29	
SUBTOTAL						3,531,287.00	252.58	243,986.10	2,541,521.88	181.78
375	None							No readings yet		
397						126,531.00	72.51	22,296.00	232,250.00	133.09
440	Heat pumps (x5); Cooling tower	Electric	45.8	Installed 2004	At or above grade	2,372,166.00	150.14	900,000.00	9,375,000.00	593.35
441	Air cooled chillers (1 for building, 1 for MRI)	Electric	133 (Building: 84; MRI: 49)	n.d. (last 3 years?)	Main Floor	1,123,778.00	400.10	59,491.00	619,697.92	220.63
443	Chiller	Electric	106	Manufactured 1985	Basement Compressor; Rooftop Condenser	97,833.00	108.70	16,518.10	172,063.54	191.18
444	Chiller	Electric	18-35			760,999.00	26.78	85,151.00	886,989.58 (David: 2012 billing cycle)	31.22
445									Minimal lab/cafeteria uses only	
448										
452	Window unit AC	Electric	N/A	N/A	N/A	1,768,786.00	143.68	263,429.00	2,744,052.08 (David: 2012 billing cycle)	222.89
453										
454										
455										
456										
484										
485	Chiller	Electric	1341	n.d. (last 3 years?)	4th Floor	1,571,698.41	133.55	113,669.00	1,184,052.08	100.61
488						1,048,386.00	621.68		0.00	
TOTALS						**12,401,464.41**	**202.74**	**1,704,540.20**	**17,755,627.08**	**202.39**

Table 4. Characterization of existing buildings not connected to the district energy network.

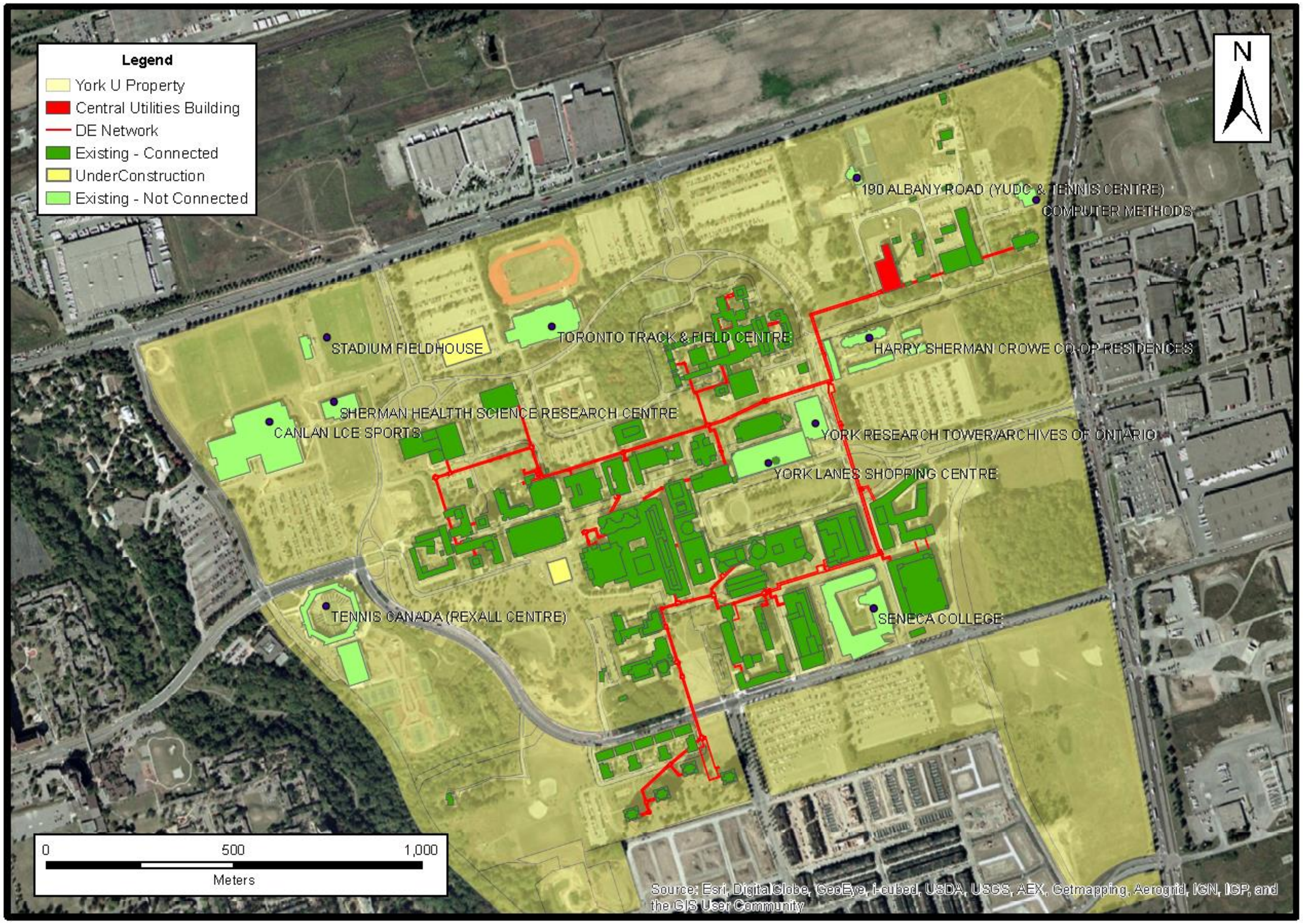
4.1.1. Overview

There are 17 buildings/spaces not connected (Map 2), or at least not connected to all the services provided by the DE network at the moment (for example, some are connected to chilled water only). These buildings/spaces comprise a total of approximately 172,000 m^2. The buildings vary by year of occupancy and some have been renovated in recent years as part of the university's capital improvements plan. Some of the buildings are owned and operated by the university while other sites are leased from York.

Electricity and natural gas consumption data was derived either from utility bills (with permission of the building owner) or from meter readings performed by CSBO staff. Most of the data correspond to 2011 measurements, though some datasets were generated from 2012 measurements where available. The existing campus loads not captured by the DE system are approximately 12.4 million kWh of electricity and 17.7 million equivalent kWh of natural gas. Maps 3 and 4 depict electricity and natural gas consumption (per square metre of floor area), respectively.

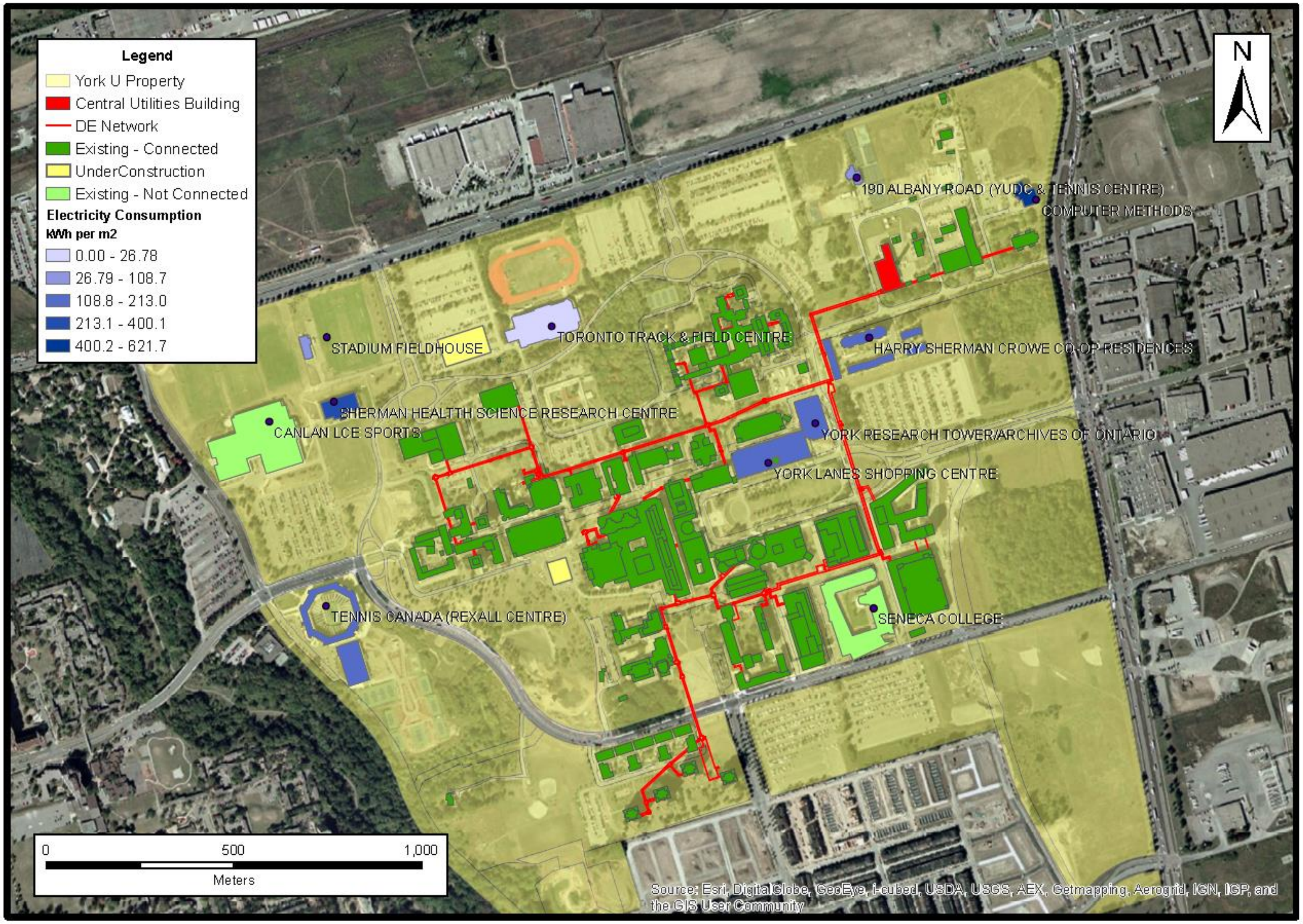
The inventory of the current primary energy supply equipment indicates that with only two exceptions, the HVAC systems are all hydronic. In general, the majority of the equipment is new, either because the building was recently constructed or equipment was replaced. Overall, the equipment specifications and locations vary from building to building.

Existing Buildings and District Energy Network



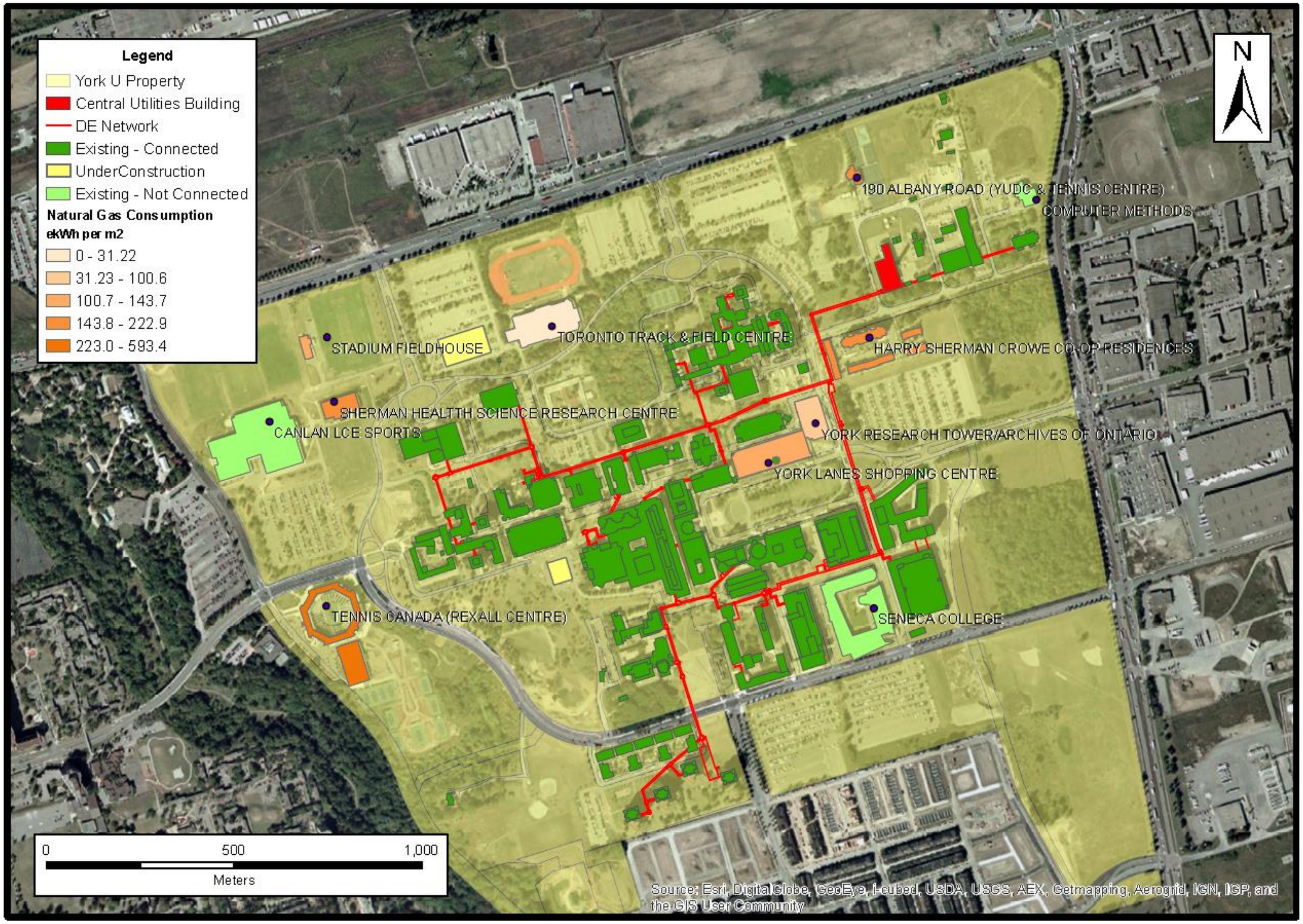
Map 2. Existing buildings not connected to the district energy network.

Existing Buildings (not connected) - Electricity Intensity



Map 3. Electricity intensity of existing buildings not connected to the district energy network.

Existing Buildings (not connected) - Nautral Gas Intensity



Map 4. Natural gas intensity of existing buildings not connected to the district energy network.

4.1.2. Findings

Colonnade (York Lanes section only)

Of the walkway that spans the length of the central bus loop, the section that runs parallel to York Lanes (including the Bookstore) is a heated space, but is not cooled. The ION unit that supplies space heating was installed last year and so far, no baseline measure of natural gas use for the unit has been established and no data on electricity use for the Colonnade is available. However, it will be difficult to ascertain the precise heating load for that particular area because the Colonnade is an open space. In other words, the ION unit does not heat a fully enclosed area. As such and given that the equipment is very new, the Colonnade is an unlikely candidate for connection.

York Lanes

York Lanes comprises the offices, retail spaces and the Bookstore between the Student Centre and the York Research Tower. The common spaces and the Bookstore are cooled by chilled water supplied by the central plant chillers, but as a large space (~ 14,000 m^2) with many individual tenants, electricity and natural gas consumption is significant: over 3.5 million kWh of electricity and 2.5 million ekWh of natural gas (a portion of which is used for restaurant needs). However, the connection potential of York Lanes is complicated for several reasons. First, the site is leased from the university. Second, tenants have individual heat pumps for space heating and cooling and individual hot water tanks for DHW needs. Finally, the air handling units that provided common space heating are only about one year old.

Stadium Field House

The Stadium Field House has the smallest GFA of the unconnected buildings and given its seasonal use, electricity and natural gas consumption is also less than the other buildings. Furthermore, it lacks a hydronic HVAC system, which would necessitate substantial renovations to connect to the steam supply. Also, at a significant distance from the existing tunnel system (~ 300 metres from the existing connection at the Tait McKenzie Centre), its connection would likely depend on the connection of the Sherman Health Research building.

Rexall Centre (Tennis Canada)

The stadium is at the western edge of campus, approximately 260 metres from the existing tunnel system. It uses electrical heat pumps to provide heating and cooling needs, with natural gas boilers for additional heating. The primary DHW unit is electric, with a secondary natural gas heater. The 15,800 m^2 of heated/cooled floor space includes a building with indoor-courts and some office and other athletic uses. The stadium is open air and usage is restricted to the warmer months. Given that the facilities were first occupied in 2004, the building equipment is not likely to be replaced in the near future.

Sherman Health Research Building

The Sherman Health Research Building is close to the existing tunnel system at approximately 175 metres from the Tait McKenzie Centre and it consumes a significant amount of electricity and natural gas. At approximately 2,800 m^2 it is also a large space and given its previous function as a hockey arena, the energy supply equipment is located on the main floor –

ideal for connection. However, extensive renovations were undertaken in 2009-10 and most of the equipment is less than four years old.

190 Albany Road

190 Albany Road is one of the smallest candidate buildings and has the lowest electricity and natural gas consumption totals. While it is close to the existing tunnel system (approximately 175 metres north of the Central Utilities Building) and most energy supply equipment is located in the basement, the boiler was installed after 2007 and the DHW heater in 2009. However, the electrical chiller was manufactured in 1985 and is potentially approaching the end of its useful life. Long term, there will be significant new development in close proximity to the building and it may be more feasible to pursue connection once nearby development occurs.

City of Toronto Track and Field Centre

While the central plant supplies electricity to the building, space heating is provided by four natural gas-fired boilers and DHW via electric hot water heaters. Given that the interior of the building is dominated by the large field house, there is only a small chiller for space cooling of the offices. While the building is close to the existing tunnel system (less than 200 metres away) and equipment is located in the basement, the boilers were manufactured in 2010. The new Pan Am Stadium – which will be connected to the DE network – will be constructed adjacent to the Track and Field Centre and connection may be justifiable in the future.

Seneca @ York

The Seneca College building uses steam from the central plant to provide space heating, but no information on DHW, cooling equipment or energy use is available. The building has a direct natural gas feed for laboratory and food uses (and possibly for DHW), but given that the primary uses are academic, consumption is likely not substantial. The Seneca building merits further consideration once consumption data and equipment specifications have been established.

Canlan Ice Sports

The Canlan building is at the western edge of campus and is furthest from the existing tunnel system at over 300 metres. No data on energy use and building equipment is available at the moment, but the facilities manager indicated that a significant amount of electricity and natural gas is consumed in operations, which occur year round. In addition to the athletic (ice hockey) uses, there is some office and restaurant space.

Harry Sherman Crowe Housing Co-op Complex

The complex includes the apartment building as well as the townhouses that surround it and the property is leased from York University. The townhouses each have individual natural gas furnaces and hot water heaters, making connection difficult to justify. The apartment building (less than 100 metres from the nearest tunnel), which is already supplied with electricity from the central plant, consumes a significant amount of natural gas in order to provide space heating and DHW – 263,429 m^3 in 2012. However, new boilers and hot water heaters were installed in 2011 and tenant space cooling is provided by electric window units. The equipment is located in a mechanical penthouse. Worth noting are the Solar Walls installed on the east and west facades of the building, which likely supplements the common space heating provided by the rooftop air handling units.

Archives of Ontario

The Archives building, which is comprised of the four floors that function as the podium for the York Research Tower, is a new building (occupied in 2009) with state of the art mechanical systems. Despite its connection to YRT, it has an individual mechanical room with equipment for space heating and cooling. To date, no information on equipment specifications or energy consumption has been acquired and it is not clear how ownership and management of the building is structured. Despite the limited available data, pursuing connection will likely be challenging.

York Research Tower

The YRT, which is the six floors that sit atop the Archives, was also occupied in 2009. Despite its proximity to the existing network, the YRT has individual electrical and natural gas feeds. With over 11,000 m^2 of GFA of office and academic uses, electricity and natural gas consumption is quite substantial. However, given the advanced mechanical equipment in the building, connection to the central steam and chilled water was never pursued. Instead, natural gas boilers and an electric chiller supply space heating and cooling, respectively, with a single hot water heater used to provide DHW. The mechanical room is located on the fourth floor, separating the Archives from YRT.

Computer Methods Building

Computer Methods, which is leased privately (no details available), does not have a hydronic HVAC system. Instead, the building is heated electrically, which would explain the substantial electrical consumption – over 1 million kWh. Staff from CSBO has indicated that there is a propane tank present on site, which likely functions as a backup heating fuel. The large electrical load could be explained by the computing uses, potentially as a data center. In either case, connection would be very challenging given the retrofits necessary. Furthermore, while York is responsible for electrical meter readings, it is not clear that the building and uses are affiliated with the university in any way.

4.1.3. Preliminary conclusions

Overall, while there are some building-specific factors that are favourable to connection, the majority of the buildings have new primary energy supply equipment, meaning that reinvestment is unlikely in the near future. For connection to be feasible, the buildings should ideally be very close to the existing tunnel system so as to minimize the infrastructure costs associated with connection.

The buildings that can be ruled out immediately are Computer Methods and the Stadium Field House. Given their lack of a hydronic HVAC system, the cost of the retrofits necessary to establish connection to the network would be substantial. Sherman Health, the Track and Field Centre and Canlan Ice Sports are the most likely candidates for connection. While they have new mechanical equipment, their proximity to each other, to the anticipated new development and to the existing tunnel system suggests that further analysis is warranted.

Given their recent construction and modern HVAC systems, the YRT and Archives of Ontario are poor candidates for connection to the network. Conversations with CSBO staff indicate that during construction the decision was made not to connect given the additional equipment that would be necessary to interface between the central plant steam and building hot water distribution.

The Rexall Centre, York Lanes, Seneca @ York and the Harry Sherman Crowe apartment building merit further consideration and a more detailed analysis to determine feasibility. At this point the data suggests that justifying connection will be challenging, but more data must be acquired before a final recommendation can be provided.

In terms of the impact on central plant operations, conversations with plant staff indicate that no additional capacity will need to be added to supply these buildings with steam, though chilled water supply is less certain. Thermal demand peaked at approximately 50 MW in January 2012, but only 2 out of the 6 available boilers were being used to produce steam (in addition to the steam provided by the heat recovery steam generators attached to the cogeneration turbines). Only on the hottest summer days are all 8 chillers operational, which was two days in the summer of 2011 (there were no such days in the summer of 2012). As part of plan to allow more efficient turbine operation in the summer, a new 2800 tonne, steam-driven chiller will replace an existing electric chiller.

As for electricity, the 10 MW of electrical output from the turbines provides approximately half of peak campus electricity demand (21 MW) and new connections would mean that the more electricity would be imported from the local distribution grid. However, the added DHW loads of new connections would also allow for more efficient operation of the turbine in the summer and if capacity is available, new chilled water supply to electrically connected buildings (Harry Sherman Crowe and Track & Field) would reduce campus peak electrical demand.

4.2. Potential new development

Notwithstanding that the case study is meant to help inform municipal DE development by drawing on lessons learned, it is also meant to facilitate DE expansion at the Keele Campus. However, the analysis used herein is not a formal approach to DE planning – it combines various methods and assumptions and as such, interviewees were asked to critique the approach based on their particular expertise. The following section, drawing on interviews and relevant literature, will discuss the findings of the case study.

4.2.1. Overview

The height and density testing in the Concept Plan for the Keele Campus indicates the potential for approximately 54 new buildings at a total GFA of 1,424,550 square metres. They would range from 2-17 stories and have a 1-4 X Floor Space Index (FSI). The overall use mix is 54% residential, 23% office, 16% institutional and 7% retail.

Based on the applied coefficients, the projected energy performance is approximately: 145 million ekWh of natural gas consumed; 82 MW peak thermal demand; 149 million kWh electricity consumed; 47 MW peak electrical demand; and 61,000 tonnes of CO_2 emissions (all values annual).

If all new buildings are connected to a thermal network, carbon dioxide emissions reductions would be approximately 8,000-10,000 tonnes per year. The potential for CHP is estimated to be between 3-4 MW when sized to meet the minimum annual thermal demand and though this value is consistent with approaches in literature, it is likely that 15-25 MW is a more appropriate capacity for CHP. Though not quantified in this report, capturing the waste heat from the CHP plant for distribution through the thermal network would further reduce emissions.

4.2.2. Findings

Concept Plan

The Concept Plan for the Keele Campus and potential development yields (Table 5), specifically the potential GFAs and uses, provides the basis from which the analysis is executed. However, recalling the analytical methods, a weighted average was used to estimate the distribution of uses for each individual building as opposed to the entire cluster as a single cluster often includes multiple buildings. The rationale behind this approach is that the coefficients are based on building use and in some cases (e.g. residential vs. office), values can be very different. In large, mixed-use clusters such as those outlined in the Concept Plan, this approach is likely to be more accurate than if a single average coefficient was applied.

Although the Concept Plan is currently the best available projection of potential new development (LD 2, 2013), the reality is that the ultimate built form is likely to look different than is envisioned in the Concept Plan (MS 1, 2013). This has obvious implications for projections of energy values, but it also means that at this early stage, the weighted average

Potential development yields

Cluster	Base FSI	Walking Distance to Subway (m)	Block Area (h)	Block Area (m^2)	% Site Coverage	Gross Floor Area (m^2)	Ground Floor Area (m^2)	Average Building Heights (storeys)	Residential GFA (m^2)	Office GFA (m^2)	Commercial GFA (m^2)	Research GFA (m^2)
A	3.0	250-500	0.64	6,400	41	19,200	2,522	8	16,678	1,261	1,261	0
B1	2.5	250-500	7.36	73,600	33	184,000	23,046	8	160,954	11,523	11,523	0
B2	2.0	250-500+	5.03	50,300	39	100,600	18,549	5	82,052	9,274	9,274	0
C	2.0	250-500+	8.09	80,900	48	161,800	36,964	4	62,418	62,418	36,964	0
D	1.5	500+	0.57	5,700	40	8,550	2,186	4	6,364	0	2,186	0
E	1.0	500+	0.86	8,600	48	8,600	3,936	2	4,664	0	3,936	0
F1	1.0	500+	0.96	9,600	48	9,600	4,496	2	5,104	0	4,496	0
F2	1.0	500+	1.79	17,900	53	17,900	8,968	2	8,932	0	8,968	0
G1	2.0	250-500+	2.34	23,400	48	46,800	10,592	4	0	23,400	0	23,400
G2	2.5	500+	3.84	38,400	46	96,000	16,894	6	0	48,000	0	48,000
H	2.5	250-500+	9.44	94,400	56	236,000	50,184	5	0	118,000	0	118,000
I	3.0	250-500	2.48	24,800	40	74,400	9,468	8	0	37,200	0	37,200
J	4.0	0-250	4.06	40,600	25	162,400	9,485	17	145,657	12,000	4,743	0
K	4.0	0-250	3.92	39,200	29	156,800	10,979	14	139,311	12,000	5,489	0
L	3.0	250-500	4.73	47,300	37	141,900	16,416	9	136,975	0	4,925	0
TOTAL	**2.33**		**56.11**	**561,100**	**42**	**1,424,550**	**224,685**	**7**	**769,109**	**335,076**	**93,765**	**226,600**

Table 5. Potential development yields as per the Concept Plan for the Keele Campus (Adapted from Brook McIlroy Inc., 2009).

approach is appropriate given the level of uncertainty (LD 2, 2013). Changing land values, market demand, revised planning goals and other internal and external factors can interact such that the ultimate development could be very different.

Coefficients

Coefficients for energy consumption, energy demand and CO_2 emissions were obtained from the consulting engineering firm, Halsall Associates Limited (Appendix C). In working with the City of Toronto Energy Efficiency Office to develop community energy plans for the Lawrence-Allen, Mimico by the Lake and Scarborough Centre Secondary Plan Areas, the consultants were tasked with providing estimates of the energy performance of the existing and new building stock. These coefficients are derived from databases of metered buildings, energy models, government statistics and engineering rules of thumb. With each community energy plan, the coefficients are revised to reflect updated databases and changing building codes and the values used in this project are from the most recent community energy plan for Scarborough Centre.

The coefficients are estimates of a particular energy performance metric per unit area and each number is specific to a particular use. For example, the electricity consumption of a residential building built to Tier 1 of the TGS is 96 kWh/m2. For this project, the coefficients chosen were based on the assumption that new buildings on the Keele Campus would reach, at a minimum, Tier 1 of the forthcoming revision of the Toronto Green Standard (TGS). This equates to an energy performance standard that is 35% than the Model National Energy Code for Buildings (MNECB) 1997. A revised MNECB is forthcoming in the near future and these coefficients will be updated to reflect this change.

With the information on GFA and use provided by the Concept Plan, one selects for the proper coefficient and it is straightforward arithmetic to project the energy performance for a particular building. Referring to the above coefficient for residential electricity consumption, a 10,000 square metre building would then consume 960,000 kWh of electricity per year (96 x 10,000). Though this approach is tedious, Microsoft Excel expedites the process and the advantage of using a spreadsheet is that updated projections of GFA or revised coefficients can be incorporated as they become available. Appendix D depicts the projected energy performance of all 54 potential new buildings.

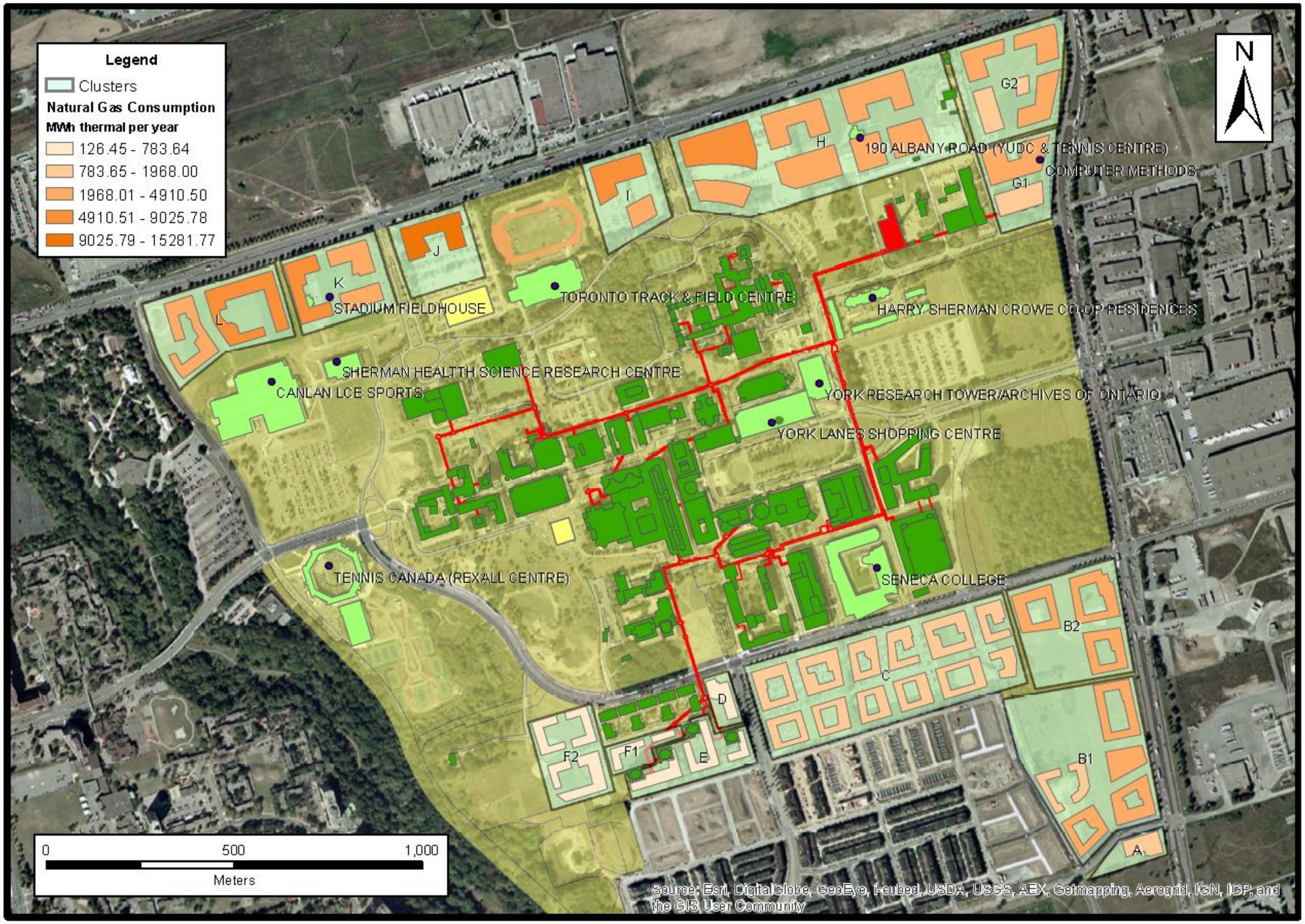
Projections of energy performance

Projected energy performance is summarized in Table 6 and mapped in Maps 5-9. Metered data from existing buildings would be ideal, but interviewees indicated that projections are within an acceptable range for a high level analysis. For example, one interviewee suggested that the projected peak thermal demand of 82 MW would likely be closer to 90 MW, which is within 10% of the original projection (TE 1, 2013). To put this number into perspective, the Markham Centre network (which serves approximately 604,000 square metres) peaked at 26 MW this past winter (TE 2, 2013). This equates to approximately 43 W/m^2. At the Keele Campus, the diversified load of 70 MW over 1,424,550 m^2 equates to approximately 49 W/m^2. Furthermore, the projected peak electrical demand of 47 MW (32.99 W/m^2) is also consistent with the current campus peak demand of 21 MW (32.29 W/m^2). Though there are differences in the building performance and mix of uses between the Keele Campus and Markham Centre, for the purpose of identifying the opportunity to expand DE, the projections are reasonable and merit more detailed analysis as further information becomes available.

		Business as Usual		
		North campus	South campus	Total campus
GFA (sq m)	Residential	421,943	347,166	769,109
	Office	250,600	84,476	335,076
	Retail	15,157	78,608	93,765
	Institutional	226,600	0	226,600
	Total	**914,300**	**510,250**	**1,424,550**
Natural Gas Consumption (kWh thermal)	Residential	40,506,528	33,327,936	73,834,464
	Office	19,296,200	6,504,652	25,800,852
	Retail	1,197,403	6,210,032	7,407,435
	Institutional	38,295,400	0	38,295,400
	Total	**99,295,531**	**46,042,620**	**145,338,151**
Total Thermal Demand (kW thermal)	Residential	22,912	18,851	41,763
	Office	15,136	5,102	20,239
	Retail	728	3,773	4,501
	Institutional	16,066	0	16,066
	Total	**54,841**	**27,727**	**82,568**
Electricity Consumption (kWh)	Residential	40,506,528	33,327,936	73,834,464
	Office	28,819,000	9,714,740	38,533,740
	Retail	2,212,922	11,476,768	13,689,690
	Institutional	23,339,800	0	23,339,800
	Total	**94,878,250**	**54,519,444**	**149,397,694**
Electricity Demand (kW)	Residential	10,760	8,853	19,612
	Office	10,124	3,413	13,537
	Retail	593	3,074	3,666
	Institutional	10,197	0	10,197
	Total	**31,673**	**15,339**	**47,013**
GHG Emissions (tCO2)	Residential	16,878	13,887	30,764
	Office	10,275	3,464	13,738
	Retail	728	3,773	4,501
	Institutional	12,690	0	12,690
	Total	**40,569**	**21,123**	**61,693**

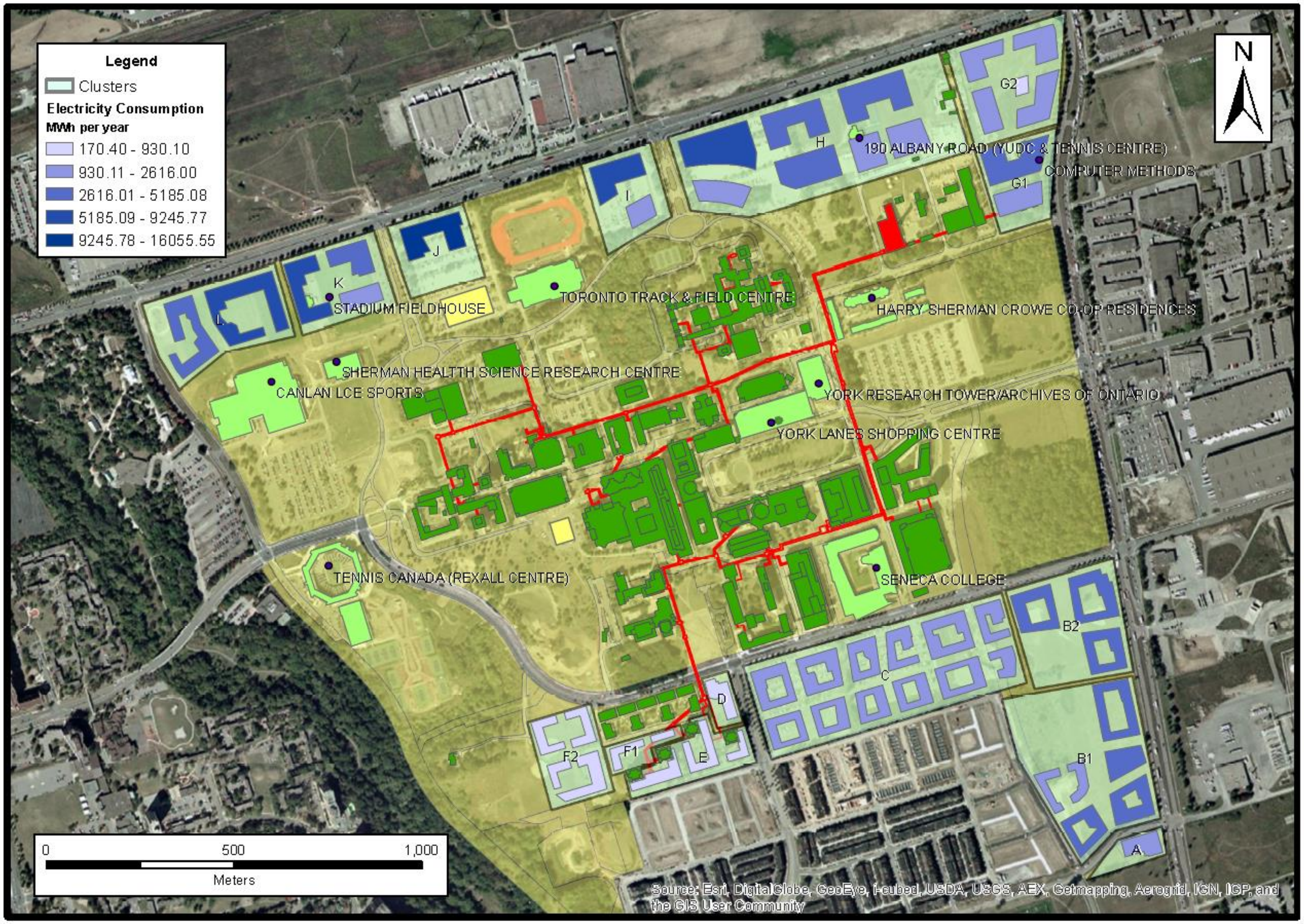
Table 6. Summarized projections of energy performance of potential new development.

Natural Gas Consumption - Potential New Development

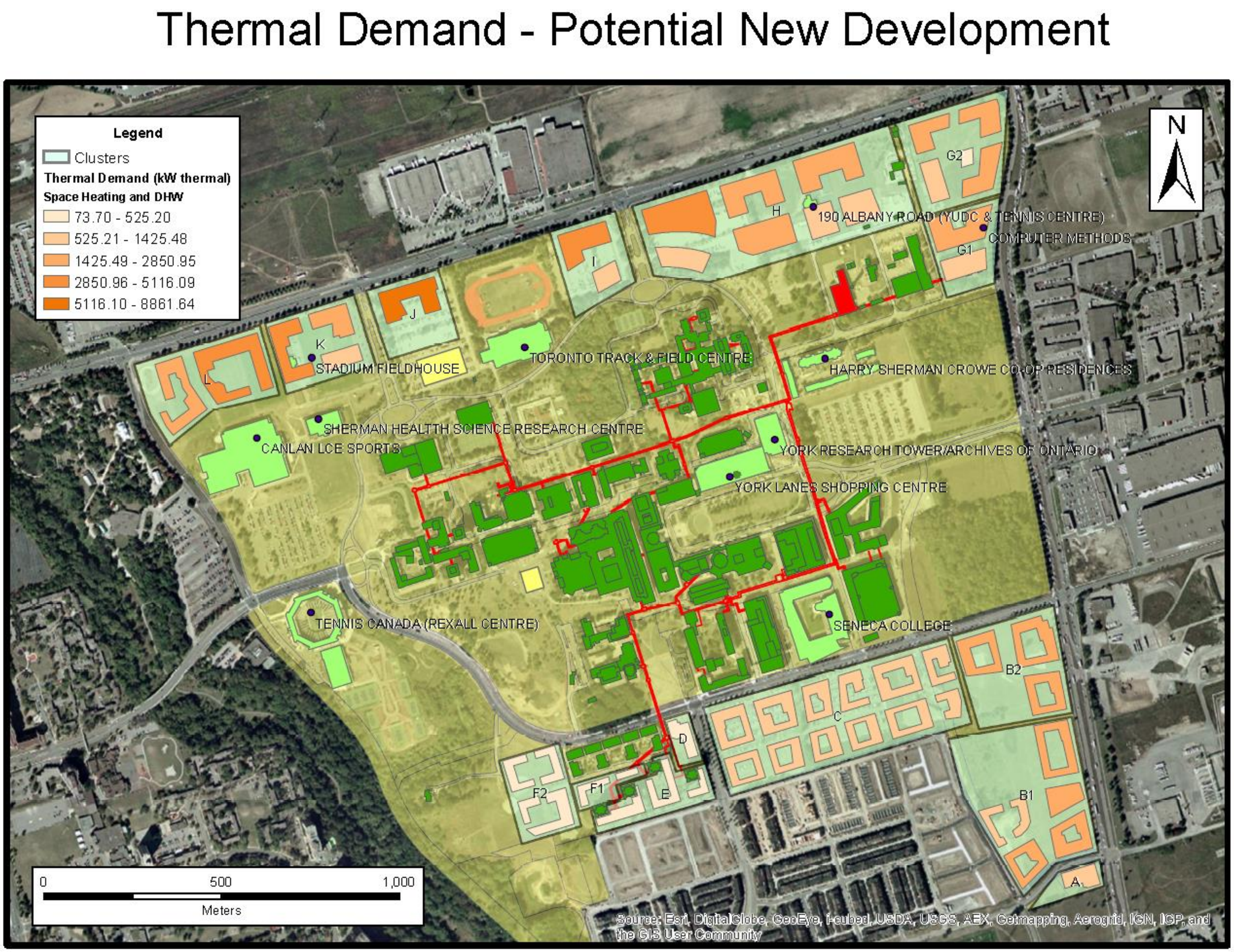


Map 5. Projected natural gas consumption of potential new development.

Electricity Consumption - Potential New Development

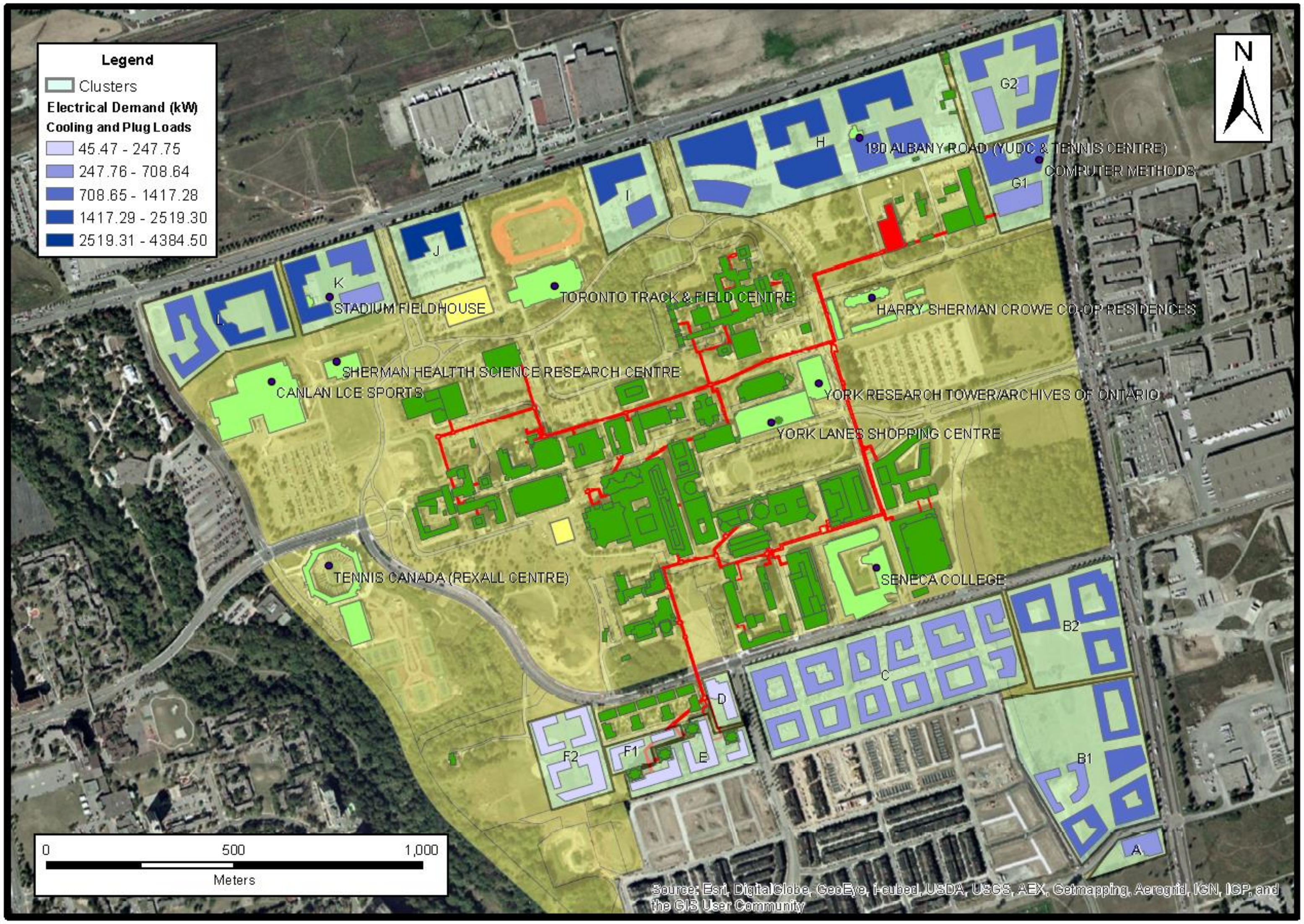


Map 6. Projected electricity consumption of potential new development.



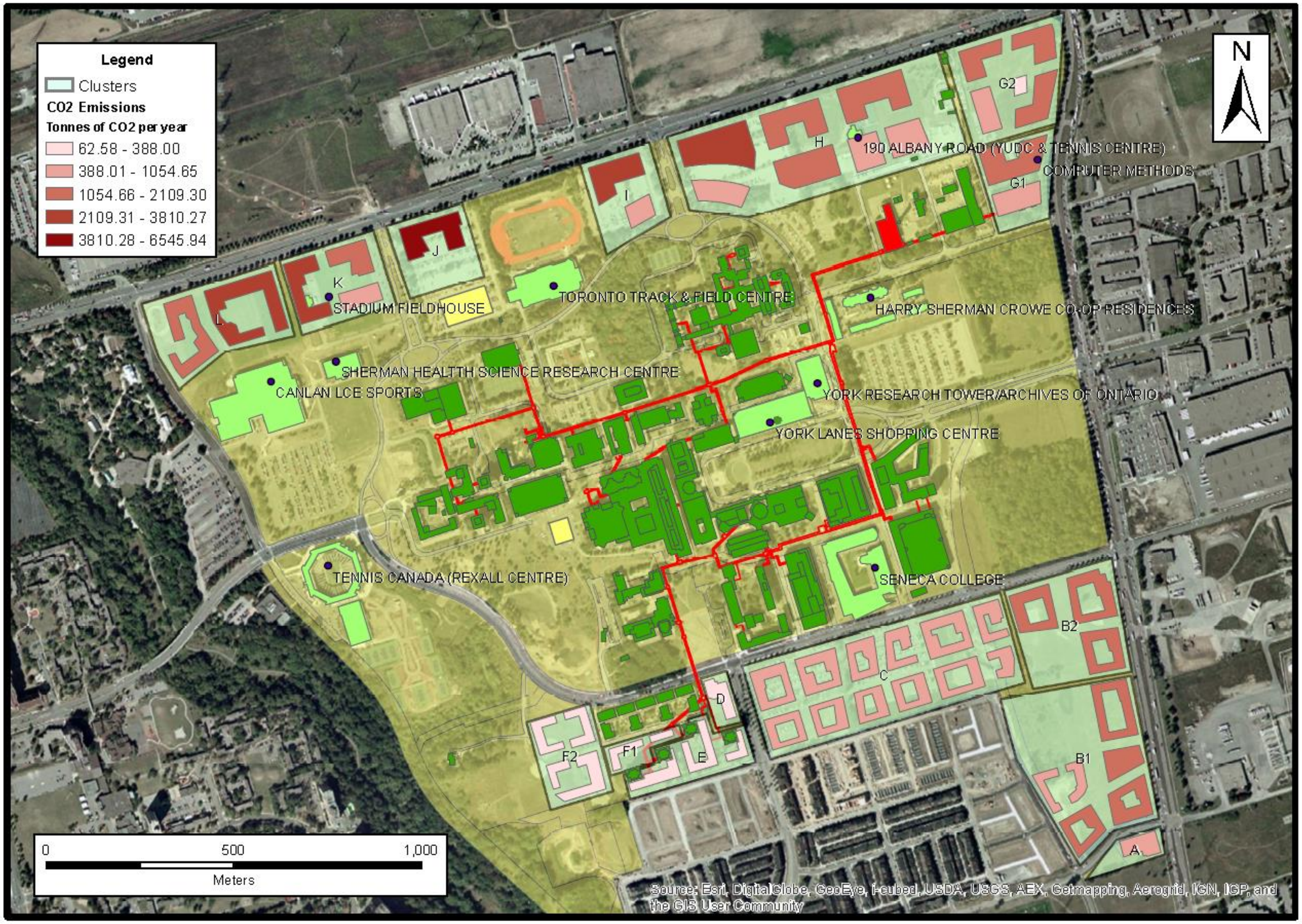
Map 7. Projected thermal demand of potential new development.

Electrical Demand - Potential New Development



Map 8. Projected electrical demand of potential new development.

Carbon Dioxide Emissions - Potential New Development



Map 9. Projected carbon dioxide emissions of potential new development

Breakdown of development and phasing

The histograms in Figure 15 depict how the potential new development will be distributed on campus. At the north end of the campus, fronting Steeles Avenue West, is the potential for approximately 914,000 square metres of GFA and the majority of uses are non-residential. Institutional and office uses account for more than 50% of the total development at the north end of the campus with the bulk of the density allocated around the future Pioneer Village subway station.

The south end of the campus, approximately 510,000 square metres, has a more residential character in keeping with the existing uses and transitioning to the low density subdivision (The Village). It is over 2/3 residential with some office and retail-at grade uses. Heights and densities are much lower with the exception of the southernmost building, which is closest to the future Finch West subway station.

Though there is a consistent demand for mid to high-rise residential development in Toronto, office and institutional uses are the largest variables (LD 2, 2013). At nearly 40% of the total campus development, significant changes to the total office and institutional GFA would have a large influence on the energy profile of the development. For example, with a small retail component, scaled back office and institutional uses would mean that residential uses would increase. Though it would likely reduce overall energy consumption and demand, it would also mean that the load profile would be more “peaky”. The point here is to illustrate how changes to the built form will have ramifications for sizing of infrastructure and operation of the equipment, hence the importance of flexibility in the analysis of any plans for expansion.

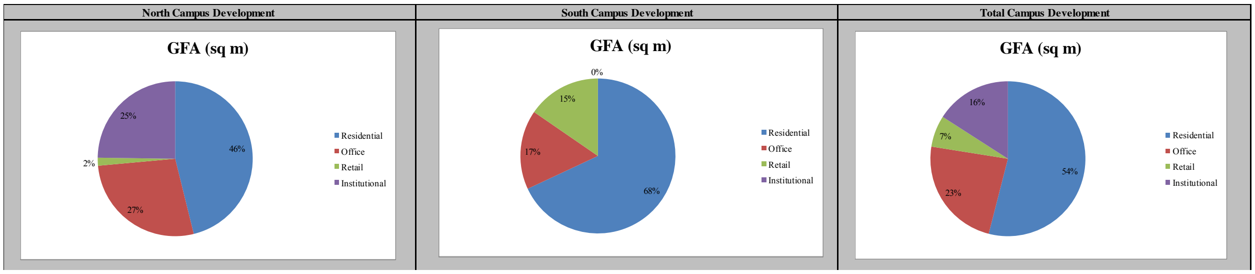


Figure 15. Use distribution of potential new development.

Though it the most difficult to predict, development phasing is a crucial determinant for DE (TE 1; UO 2, 2013). As one interviewee stated,

> "Well this business is an art – trying to guess where development will be. You do not want to overbuild the asset – the energy system – in the wrong place. Lots of people that don't really understand our business ask me instead of building three plants, if you own the property here why don't you just build one massive plant and then you're done. Besides losses being huge, we might be in the wrong location" (TE 2, 2013).

The challenge is one of timing because once a DE operator is aware of a development, it must build a plant and connect the building(s) in a timely fashion. From that point forward, expansion is a matter of extending the infrastructure to new buildings. Such is the case for the Pan Am Stadium and Lassonde Engineering building currently being constructed at the Keele Campus.

At the Keele Campus, the existing central plant, though it reduces the initial capital that would be required to expand the network, presents an added complication. If the first buildings to be constructed are at the opposite end of the campus, it would involve a significant capital outlay for piping with very little return until additional customers begin adding to the linear heat density along that pipe. With respect to capital expenditures, the density of a particular building is a secondary consideration to its location (UO 2, 2013). In this case, it could very well be more economical to build a smaller thermal plant to serve the new development (TE 2, 2013), provided of course that the university is willing to forgo the value of the land that the new plant would occupy. Though the piping is often the bulk of the investment for DE, the plant can be more expensive depending on the configuration of a particular system and the value of land (TE 1, 2013).

It is too early to predict the phasing at the Keele Campus. There are numerous factors involved – changes to the Master Plan, how YUDC arranges land parcels, market demand for particular uses, developer interest (LD 2; MS 1, 2013). However, DE can be implemented incrementally, with the network expanded as buildings are constructed and capacity added as necessary. However, for illustrative purposes, the analysis applies a generic phasing schedule (Table 7) and specifies 30 years as a reasonable time frame for full build out, though it could be shorter or longer depending on various factors (LD 2, 2013).

Emissions reductions and embedded generation

Growth of CO_2 emissions and electricity demand were graphed over 30 years comparing the business-as-usual approach (standalone equipment) to DE, assuming that all buildings are connected (Figure 16). The graphs indicate the choices available to the administration: the BAU approach would lead to over 60,000 tonnes of annual CO_2 emissions, while an expanded DE network would reduce that to just over 50,000 tonnes based only on the improved efficiency of a central plant versus individual boilers. To put that in perspective, 2011 CO_2 emissions for the campus were approximately 55,000 tonnes (Ministry of the Environment, 2013).

Phasing

Year	Phases Complete	GFA (m2)	Cumulative GFA Growth	GHGs (tCO2)	Cumulative GHG Growth - BAU	Cumulative GHG Growth - District Heat	Electricity Demand (kW)	Cumulative Electricity Demand Growth - BAU	Cumulative Electricity Demand Growth - CHP (4MW)	Cumulative Electricity Demand Growth - CHP (16MW)
2015	0	0	0	0	0	0	0	0	0	0
2020	A, J, G2	277,600	277,600	7,705.15	7,705.149	6549.37665	9,009.24	9,009.24	9,009.24	9,009.24
2025	B1, G1, K	387,600	665,200	16,061.42	23,766.568	20201.5828	11,270.62	20,279.86	20,279.86	16,279.86
2030	B2, H, L	478,500	1,143,700	24,625.11	48,391.675	41132.92375	16,592.24	36,872.10	32,872.10	24,872.10
2035	C, I	236,200	1,379,900	10,438.53	58,830.205	50005.67425	8,735.52	45,607.62	41,607.62	29,607.62
2040	D, E	17,150	1,397,050	734.98	59,565.181	50630.40385	520.58	46,128.20	42,128.20	26,128.20
2045	F1, F2	27,500	1,424,550	1,207.71	60,772.893	51656.95905	884.36	47,012.56	43,012.56	27,012.56
TOTAL		**1,424,550**		**60,772.89**			**47,012.56**			

Table 7. Generic phasing schedule for new potential development over 30 years.

Phased energy projections

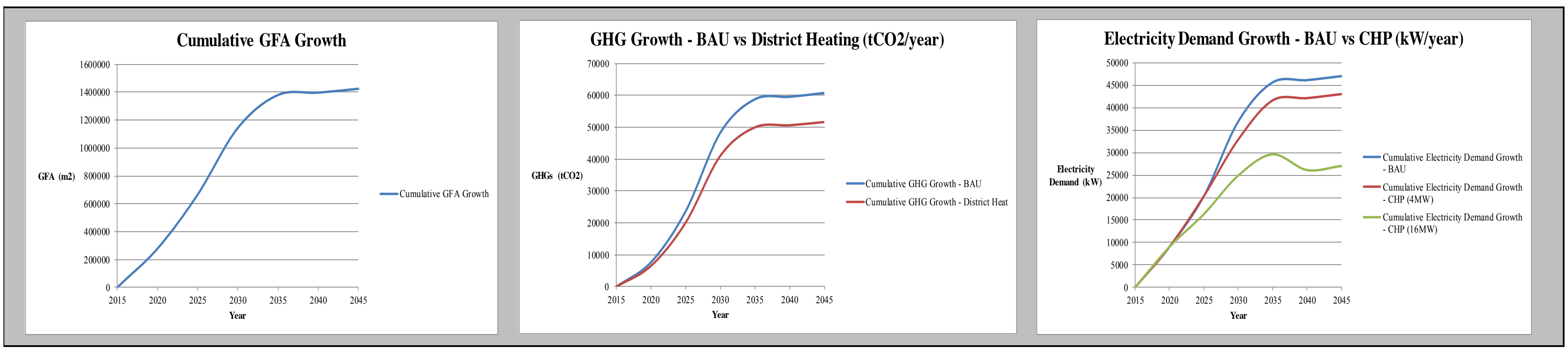


Figure 16. Projected emissions and electricity demand growth comparing business-as-usual to district energy and combined heat and power.

With respect to electricity demand, grid imported electricity would increase over the 30 year period in the BAU scenario. However, if CHP is added in 4 MW increments (for a total of 16 MW) as the load increases, the ultimate campus peak demand would be approximately 40% lower upon full build out.

In planning terms, 30 years is a short time period, notwithstanding that much can change in that time. Though an 8,000 – 10,000 tonne annual reduction seems inconsequential, this would only be the result of the efficiency gained by consolidating boiler operation to a central location, approximately 15%. The addition of CHP, by virtue of capturing waste heat from the electricity generation process, would reduce the use of boilers and could reduce emissions by an additional 30-40% (TE 1, 2013). Though no one from Toronto Hydro was interviewed for this project, one interviewee indicated that there is interest from the utility in more embedded generation within the distribution grid (UO 2, 2013). CHP has the potential to reduce the peak electricity demand, which could have a profound effect on load management at the Keele Campus given possible constraints at the Bathurst Transformer Station.

Sizing CHP

The approach to estimating the potential CHP capacity that could be added on campus was to equate the maximum output of the engine to the minimum thermal demand in the summer, which is for domestic hot water (DHW). Whereas space heating demand is seasonal, demand for DHW is steadier and sizing to this minimum allows for the steadiest operation of the units. This was the method used in the *Node Scan* for DE in Toronto (2010) and the results are similar. For a 1,035,000 square metre node, the *Node Scan* indicated the potential for approximately 4 MW of CHP. For the 1,424,550 square metres of new development at the Keele Campus, the potential size of CHP was estimated to be 3.1 MW after a load diversification factor of 85% was applied (Figure 17).

However, several of the interviewees indicated that 3-4 MW of CHP is undersized relative to the projected 47 MW electricity demand. Though CHP is sized based on the thermal demand, there are strategies that can be used to allow for more electrical output without significantly affecting overall efficiency, such as adding hot water storage or rejecting some heat in the summer (TE 1, 2013). The interviewees held different perspectives on estimating the appropriate CHP capacity and rough estimates ranged from approximately 15-25 MW for the Keele Campus. As a safe rule of thumb, it was suggested that 1 MW per 1 million square feet is reasonable, which would equate to approximately 15 MW for the potential new development (TE 2, 2013). 1/3 to ½ of the diversified thermal load was also suggested as another means to estimate the capacity, which would equate to 23-35 MW in total (TE 2, 2013).

This past summer, the thermal demand for the Keele Campus reached a minimum of approximately 6 MW, which meant that one of the turbines was shut down for a period of time so as to avoid wasting the heat generated. The trade-off is that there is less electrical output occurring at a time when electricity demand is typically highest owing to the use of air conditioners. The addition of CHP, regardless of total capacity, should be incremental and modular so that it allows for the most operational flexibility. Hence the addition of CHP in 4MW increments as used in the assumptions regarding phasing and build out - as the load increases, reciprocating engines can be added in stages.

Base case load characteristics

Month	Heating average load kW
January	47,531
February	39,909
March	29,621
April	18,125
May	9,264
June	3,109
July	3,109
August	3,109
September	5,474
October	14,341
November	22,766
December	34,975
Peak load - annual	70,183

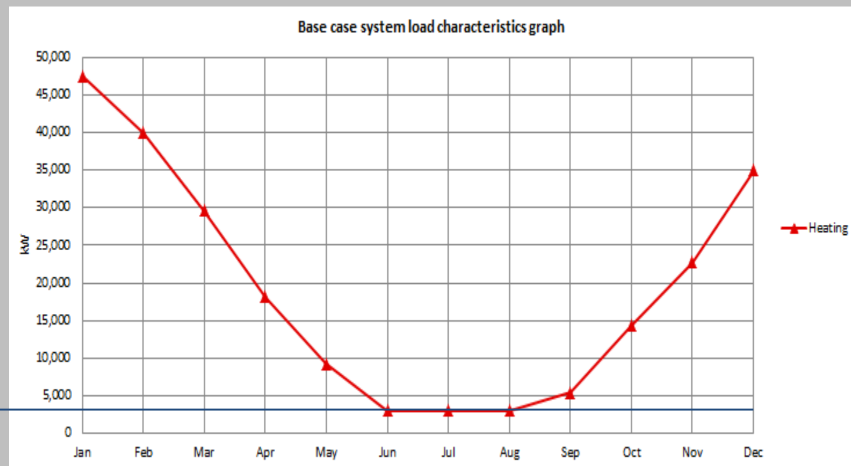


Figure 17. Estimated CHP capacity for potential new development.

Table 8 provides a comparison of the Keele Campus system (existing and potential) to the Markham Centre system. Given the capacity of CHP in the Markham Centre and existing Keele Campus systems relative to the floor area served, it suggests that 16 MW is still a conservative estimate.

Energy Maps

DE has a considerable spatial component and energy maps were helpful to many of the interviewees in considering expansion at the Keele Campus. A GIS can assist with decision making in many intuitive ways such as: overlaying rights of way and zoning; identifying conflicts with other infrastructure; and indicating suitable locations for a central plant. However, by including projections of energy performance, a GIS can deliver a robust map through which

	Markham Centre	Keele Campus (existing)	Keele Campus Potential (not including existing)
Number of plants	3	1	?
Number of buildings	32	90	54
Length of network (km)	20	3.5	?
GFA served (sq m)	604, 000	650, 000	1, 424, 550
Diversified peak thermal demand (MW)	26	37	70
CHP capacity (MW)	**11.5 (4 x 2.5-3.5 MW)**	**10 (2 x 5 MW)**	**16 (4 x 4 MW)**
Other	40 MWh hot water storage	Steam system	Hot water system

Table 8. Markham Centre DE system versus the Keele Campus (exiting and potential) DE system.

to explore various scenarios for DE opportunities. For example, consider Maps 3 and 4 that depict electricity and natural gas intensity of existing buildings that are not connected to the network, respectively. By overlaying energy intensity with the existing DE infrastructure, the maps can help assess the feasibility of connecting an existing building by identifying the candidates that consume significant amounts of energy and are in close proximity to the distribution network. Qualitative data can further narrow down the potential candidates by eliminating buildings without hydronic HVAC systems or those with new mechanical equipment.

With respect to new buildings, the maps are used to tell a different story. Assuming that all new buildings will be connected, the energy maps can assist with decisions regarding the location of infrastructure, for example. In the case of the Keele Campus, the existing central plant would be the ideal thermal source for the first new buildings. However, if the first buildings are constructed at the opposite end of the campus and it is too costly to connect them to the

Existing plant, then consideration of thermal demand (Map 7) becomes important. The buildings with the highest thermal demand – those adjacent to the future Pioneer Village subway station – would be the ideal location for the deployment of a second thermal plant. Furthermore, though provincial regulation of electricity distribution is not a consideration on campus (notwithstanding that the distribution grid does cross some public rights of way), it is a challenge in most situations of mixed land ownership. In order to comply with regulation, any electricity generated must either be exported to the local distribution grid or used within a single property, which is sometimes referred to as "behind the meter generation". When considering the inclusion of CHP, a map of electrical demand can assist with identifying the ideal area to locate a CHP unit based on which building has the largest demand.

A caveat is warranted with respect to the use of a GIS for energy mapping. The software itself does not intuit on behalf of the user and assumptions and biases will be carried forward and displayed spatially. With respect to energy mapping, how the energy data is normalized (how a particular value is displayed per unit of another value) can change the analysis and choice of normalization depends on the story that the maps are intended to tell. For example, consider the map of electricity intensity of existing buildings, specifically the Computer Methods building and the Rexall Centre. If the map was intended to communicate which buildings consume the most electricity, the Rexall Centre (2,372,166 kWh) would be darker than Computer Methods (1,048,386 kWh). However, in order to compare their efficiency, one must eliminate the influence of building size. The GFA of the Computer Methods building is 1,686 m^2, while the Rexall Centre is nearly 10 times larger at 15,800 m^2. When electricity consumption is normalized to floor area, however, Computer Methods is much darker. The reason for this distinction is based on the use: Computer Methods being a data centre, has a large electrical load, while the Rexall Centre being an athletic facility with some office uses, has a much smaller electrical load.

Analysis of the maps of potential new development is slightly different. Consider the map of thermal demand. The coefficients that were used to project the thermal demand of the building are already normalized values per unit floor area. The projection of the thermal demand of a particular building is a function of the coefficient multiplied by the floor area. If the projected value was then divided again by the floor area, the value would simply be the coefficient and each building would be the same shade of orange. Of course, the difference between existing and new buildings is that the metered consumption data of the existing buildings includes all the aspects of operations that influence energy performance, such as user behaviour, equipment variations and seasonal temperatures. The fact is that uses and built form have yet to be determined, so the energy maps will look different if redone in the future. While one cannot use this map to compare the performance of potential new buildings, it can suggest where the significant demand is likely to be in order to start considering preliminary network design.

4.2.3. Preliminary conclusions

The analysis indicates that expansion of the DE network to potential new development would reduce CO_2 emissions by 8,000-10,000 tonnes per year and could accommodate at least 3-4 MW of CHP (once full build out is reached). Depending on the network design and operation, it is likely that the capacity of CHP could be increased to a total of 15-25 MW. This would further reduce CO_2 emissions as more waste heat is captured and distributed through the network.

Although development phasing cannot be accurately established at this stage, the generic phasing schedule applied indicates that by expanding the network and adding CHP incrementally, the campus arrives at very different destinies with respect to emissions and embedded generation. Given that the Keele Campus may be in an electricity-constrained scenario, reducing peak electricity demand by approximately 40% should be attractive to both the university and Toronto Hydro.

The results are based on a number of assumptions and opinions on their validity differ both in literature and among interviewees. Furthermore, many of the assumptions are based on parameters that will change and the analysis will change. How development phasing proceeds will have a significant influence as the location of the first buildings will determine whether network expansion proceeds from the existing central plant or a new, secondary thermal plant.

Overall, this analysis provides a very high level identification of the opportunity to expand DE at the Keele Campus and although interviewees did confirm that the opportunity is indeed favourable, more in-depth analyses will be required to determine the feasibility of various scenarios.

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Appendix A – Building Survey (City of Toronto, Energy Efficiency Office)

Building Survey Information

Date:

Surveyed by: Energy Efficiency Office City of Toronto

BETTER BUILDINGS PARTNERSHIP

CONTACT INFORMATION	
BUILDING NAME	
ADDRESS	
POSTAL CODE	
CITY	
OWNER	
CONTACT NAME	
Phone #	
E-mail	
MAINTENANCE CONTRACT (Y/N)	
IF YES, PROVIDE CONTACT NAME	
Phone #	
E-mail	

BUILDING GENERAL INFORMATION	
MAIN USE	
(Office, Apartment, Retail, School, Hotel, Hospital)	
BUILLDING FOOT-PRINT, [sq.ft. or sq.m]	
GROSS FLOOR AREA (GFA) [sq.ft or sq.m] OR LEASEABLE FLOOR AREA (LFA) (please indicate which)	
YEAR OF CONSTRUCTION or projected occupancy date (for new development)	
NUMBER OF STOREYS ABOVE GRADE	
NUMBER OF STOREYS BELOW GRADE	
BELOW GRADE PARKING	
(HOTEL OR APT) NO. OF UNITS:	
Hours of Facility operation:	
WATER BASED (HYDRONIC) CENTRALIZED HVAC (Y/N)	

ENERGY DATA	
Energy Audit/Energy Management Company – (Y/N) (Year completed.)	
Can you provide a copy of the audit?	
<u>HEATING SYSTEM</u>	
FUEL USED (Gas/Electricity)	
No. of Boilers and boiler capacity (MBH or Btu/hr or kW)	

Building Survey Information

BETTER BUILDINGS PARTNERSHIP

Date:
Surveyed by: Energy Efficiency Office City of Toronto

Indicate make/model (if known)	
Total Installed Capacity	
Age of Equipment	
Equipment Location (Basement/Roof)	
Is the heating system sufficient to meet the buildings needs? How many boilers operate on the coldest day?	

<u>**DHW HEATING SYSTEM**</u>	
FUEL USED (Gas/Electricity)	
No. of Boilers and Boiler Capacity (MBH or Btu/hr or kW)	
Age of Equipment	
Equipment Location (Basement/Roof)	

<u>**COOLING**</u>	
FUEL USED (Gas/Electricity)	
No. of chillers and chiller capacity (tons)	
Indicate make/model (if known)	
Age of Equipment	
Equipment Location (Basement/Roof)	
Is the cooling system sufficient to meet the buildings needs? How many chillers operate on the hottest day?	

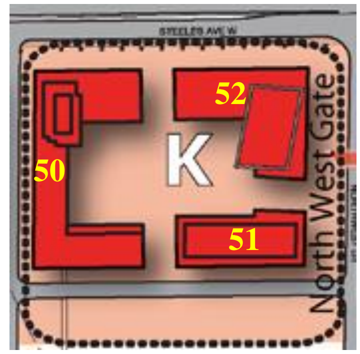
<u>**MAKE UP AIR/ROOF TOP UNITS**</u>	
FUEL USED (Gas-fired heating/Electric-DX coil cooling/Other-hot water/chilled water coils)	
Are there any other uses of natural gas in the building (i.e. kitchen, laundry, pool heating etc.)	

The information you provide will be used by the EEO to improve existing programs and design new programs. You can be sure that any information you provide will be kept in the utmost confidence and is for internal use only.

☑ The City appreciates your assistance in this project. Please return attached form with available details as soon as possible.

Appendix B – Sample Calculation of Weighted Average Use Distribution Method

Consider building cluster K: the concept plan depicts three buildings (image at right) within the cluster, which has a block (lot) area of 39, 200 m^2 and a total gross floor area of 156, 800 m^2 (see development yields below). Although the building heights are likely to differ, for this calculation they are assumed to be



Cluster	Base FSI	Walking Distance to Subway (m)	Block Area (h)	Block Area (m^2)	% Site Coverage	Gross Floor Area (m^2)	Ground Floor Area (m^2)	Average Building Heights (storeys)	Residential GFA (m^2)	Office GFA (m^2)	Commercial GFA (m^2)	Research GFA (m^2)
K	4.0	0-250	3.92	39,200	29	156,800	10,979	14	139,311	12,000	5,489	0

equal. The first step is to estimate the lot area for each building. Building 50 roughly occupies half of the cluster so the lot area for Building 50 was estimated to be 19, 600 m2 (see Building Data at right). At a density of 4.0 FSI, the total GFA of Building 50 would be 78,400.0 m2 as density is the ratio of GFA to lot area.

$$4.0 = X\ m^2 / 19,600\ m^2$$

$$X = 19,600\ m^2 \times 4$$

$$X = 78,400.0\ m^2$$

Building Data					
Cluster	**Building**	**Use**	**Lot Area (m2)**	**Gross Floor Area (m2)**	**Base Density (FSI)**
K	50-1	Residential	19,600.0	69,655.50	4.0
	50-2	Office		6,000.00	
	50-3	Retail		2,744.50	
	50-4	Research/ Instituional		0.00	
	Subtotal			**78,400.00**	
	51-1	Residential	6,533.3	23,218.50	4.0
	51-2	Office		2,000.00	
	51-3	Retail		914.83	
	51-4	Research/ Instituional		0.00	
	Subtotal			**26,133.33**	
	52-1	Residential	13,066.7	46,437.00	4.0
	52-2	Office		4,000.00	
	52-3	Retail		1,829.67	
	52-4	Research/ Instituional		0.00	
	Subtotal			**52,266.67**	
	TOTAL		**39,200.0**	**156,800.00**	

However, given that the coefficients differ by building use, it is necessary to assume the quantity of floor area devoted to each particular use within each building in a mixed-use cluster such as cluster K. The weighted average approach to use distribution begins by dividing building 50 into the four possible uses: residential (50-1), office (50-2), retail (50-3) and research/institutional (50-4). The percentage of GFA assigned to a particular use in each building is the same as the total percentage of GFA for a particular use assigned to the cluster. For cluster K, the percentage of residential floor space

= (residential GFA / total GFA) X 100%

= (139,311 m2 / 156,800 m2) X 100%

= 89%.

For building 50-1, the residential GFA

= percentage of cluster residential floor space X total GFA of building 50

= 0.89 X 78,400 m2

= 69,655.50 m2

The same method is followed for buildings 51 and 52 and when summed, the total GFA for each use and for each building equals the totals for the cluster as per the development yields of the concept plan. The weighted average approach is a simplified method and as such, it may overestimate or underestimate some of the GFAs. However, given that the ultimate built form will differ from the concept plan, such an approach is reasonable at this early stage.

Appendix C – Coefficients (Adapted from Halsall Associates Limited)

Consumption Energy Use Intensities

	Scarborough existing								
	NRCan Ontario Statistics								
	Apartments	Offices	Retail Trade	Parking	Arts, Entertainment and Recreation	Transportation and Warehousing	Accomodation and Food Services	Educational Services	Residential (single attached)
Reference	[redacted]								
Total EUI (ewkWh/m2)	222	352	523	3.2	461	358	619	417	222
EUI Fossil Fuel (ewkWh/m2)	164	188	264	0	237	207	329	215	164
EUI Electricity (ewkWh/m2)	58	164	259	3.2	225	152	287	202	58
Heating	108	166	157	0	203	204	261	183	134
DHW	70	29	10	0	41	14	69	37	47
Cooling (Electricity)	6	27	13	0	35	26	51	34	31
Lighting, plug, other electricity	39	131	94	3.2	182	114	236	163	9
Total	222	353	274	3.2	461	358	617	417	222

	Scarborough new (25% better than MNECB)								
	Halsall's Database/MNECB								
	Residential	Office	Retail/Misc	Parking	Arts, Entertainment and Recreation	Transportation and Warehousing	Accomodation and Food Services	Educational Services	Residential (single attached)
Reference	[redacted]								
Total EUI (ewkWh/m2)	221	221	259	3.2	330		373	314	
EUI Fossil Fuel (ewkWh/m2)	133	89	91	0	205		131	195	
EUI Electricity (ewkWh/m2)	89	133	168	3.2	125		243	119	
Heating	100	84	186	0	198		123	188	
DHW	33	4	85	0	7		7	7	
Cooling (Electricity)	18	22	5	0	26		56	24	
Lighting, plug, other electricity	71	111	39	3.2	99		187	95	
Total	247	221	130	3.2	330		373	314	

	Scarborough new - Tier 1 TGS (35% better than MNECB)								
	Halsall's Database/MNECB								
	Residential	Office	Retail/Misc	Parking	Arts, Entertainment and Recreation	Transportation and Warehousing	Accomodation and Food Services	Educational Services	Residential (single attached)
Reference	[redacted]								
Total EUI (ewkWh/m2)	192	192	224	2.1	286		324	272	
EUI Fossil Fuel (ewkWh/m2)	96	77	79	0	178		113	169	
EUI Electricity (ewkWh/m2)	96	115	146	2.1	108		210	103	
Heating	77	73	74	0	172		107	163	
DHW	19	4	4	0	6		6	6	
Cooling (Electricity)	15	19	29	0	22		42	21	
Lighting, plug, other electricity	81	96	117	2.1	86		168	82	
Total	192	192	224	2.1	286		324	272	

	Scarborough new - Tier 2 TGS (50% better than MNECB)								
	Halsall's Database/MNECB								
	Residential	Office	Retail/Misc	Parking	Arts, Entertainment and Recreation	Transportation and Warehousing	Accomodation and Food Services	Educational Services	Residential (single attached)
Reference	[redacted]								
Total EUI (ewkWh/m2)	148	148	173	2	220		249	209	
EUI Fossil Fuel (ewkWh/m2)	59	59	60	0	137		87	130	
EUI Electricity (ewkWh/m2)	89	89	112	2	83		162	79	
Heating	44	56	57	0	132		82	125	
DHW	15	3	3	0	5		5	5	
Cooling (Electricity)	15	15	22	0	17		32	16	
Lighting, plug, other electricity	74	74	90	2	66		129	63	
Total	148	148	173	2	220		249	209	

Demand Energy Use Intensities

	Existing buildings			
	Rules of thumb			
	Residential	Office	Retail	Institutional
Reference	Residential Models	Office Models	Retail Models	Institutional Models
Heating (w/m2)	62.6	76	58.4	137.2
DHW (w/m2)	11.9	2.9	1.7	4
Electricity (w/m2)	8.4	14	19.7	20.9
Cooling (w/m2)	23	45.6	36.7	44
Total (w/m2)	105.9	138.6	116.5	206.1

	New baseline - 25% better than MNECB			
	Rules of thumb			
	Residential	Office	Retail	Institutional
Reference	Residential Models	Office Models	Retail Models	Institutional Models
Heating (w/m2)	51.2	64.1	50.4	88.1
DHW (w/m2)	8.5	1.2	0.9	2.6
Cooling (w/m2)	8	12.3	15.1	15.6
Electricity (w/m2)	19.1	33.6	29	35.1
Total (w/m2)	86.9	111.2	95.3	141.5

	New buildings - Tier 1 TGS (35% better than MNECB)			
	Rules of thumb			
	Residential	Office	Retail	Institutional
Reference	Residential Models	Office Models	Retail Models	Institutional Models
Heating (w/m2)	46.7	59.4	47.2	68.5
DHW (w/m2)	7.6	1	0.8	2.4
Cooling (w/m2)	7.9	11.6	13.2	13.4
Electricity (w/m2)	17.6	28.8	25.9	31.6
Total (w/m2)	79.8	100.8	87.1	115.9

	New buildings - Tier 2 TGS (50% better than MNECB)			
	Rules of thumb			
	Residential	Office	Retail	Institutional
Reference	Residential Models	Office Models	Retail Models	Institutional Models
Heating (w/m2)	39.8	52.2	42.4	39.1
DHW (w/m2)	4.2	0.6	0.4	1.3
Cooling (w/m2)	7.7	10.5	10.5	10.2
Electricity (w/m2)	15.3	21.6	21.2	26.2
Total (w/m2)	67	84.9	74.5	76.9

Greenhouse Gas Emissions

	Scarborough existing NRCan Ontario statistics							
	Residential (apartments)	Office	Retail Trade	Parking	Arts, Entertainment and Recreation	Transportation and Warehousing	Accomodation and Food Services	Educational Services
Reference								
Total (ton CO2/m2)	0.045	0.074	0.09	0.00074	0.097	0.074	0.13	0.087
Fossil Fuel (ton CO2/m2)	0.031	0.036	0.041	0	0.045	0.039	0.063	0.041
Electricity (ton CO2/m2)	0.013	0.038	0.048	0.00074	0.052	0.035	0.066	0.046
Heating (ton CO2/m2)	0.02	0.032	0.035	0	0.039	0.039	0.05	0.035
DHW (ton CO2/m2)	0.013	0.005	0.007	0	0.008	0.003	0.013	0.007
Cooling electricity (ton CO2/m2)	0.001	0.006	0.009	0	0.008	0.006	0.012	0.008
Lighting, plug, other electricity (tCO2/m2)	0.009	0.03	0.038	0.00074	0.042	0.026	0.054	0.038

	Scarborough new (25% better than MNECB) Halsall's Database/MNECB							
	Residential (apartments)	Office	Retail Trade	Parking	Arts, Entertainment and Recreation	Transportation and Warehousing	Accomodation and Food Services	Educational Services
Reference								
Total (ton CO2/m2)	0.046	0.047	0.056	0.00074	0.068			0.056
Fossil Fuel (ton CO2/m2)	0.025	0.017	0.017	0	0.039			0.032
Electricity (ton CO2/m2)	0.02	0.031	0.039	0.00074	0.029			0.024
Heating (ton CO2/m2)	0.019	0.016	0.016	0	0.038			0.031
DHW (ton CO2/m2)	0.006	0.001	0.001	0	0.001			0.001
Cooling electricity (ton CO2/m2)	0.004	0.005	0.009	0	0.006			0.005
Lighting, plug, other electricity (tCO2/m2)	0.016	0.025	0.03	0.00074	0.023			0.019

	Scarborough new - Tier 1 TGS(35% better than MNECB) Halsall's Database/MNECB							
	Residential (apartments)	Office	Retail Trade	Parking	Arts, Entertainment and Recreation	Transportation and Warehousing	Accomodation and Food Services	Educational Services
Reference								
Total (ton CO2/m2)	0.04	0.041	0.048	0.00048	0.059			0.056
Fossil Fuel (ton CO2/m2)	0.018	0.015	0.015	0	0.034			0.032
Electricity (ton CO2/m2)	0.022	0.026	0.034	0.00048	0.025			0.024
Heating (ton CO2/m2)	0.015	0.014	0.014	0	0.033			0.031
DHW (ton CO2/m2)	0.004	0.001	0.001	0	0.001			0.001
Cooling electricity (ton CO2/m2)	0.004	0.004	0.007	0	0.005			0.005
Lighting, plug, other electricity (tCO2/m2)	0.019	0.022	0.027	0.00048	0.02			0.019

	Scarborough new - Tier 2 TGS (50% better than MNECB) Halsall's Database/MNECB							
	Residential (apartments)	Office	Retail Trade	Parking	Arts, Entertainment and Recreation	Transportation and Warehousing	Accomodation and Food Services	Educational Services
Reference								
Total (ton CO2/m2)	0.032	0.032	0.037	0.00046	0.045			0.043
Fossil Fuel (ton CO2/m2)	0.011	0.011	0.011	0	0.026			0.025
Electricity (ton CO2/m2)	0.02	0.02	0.026	0.00046	0.019			0.018
Heating (ton CO2/m2)	0.008	0.011	0.011	0	0.025			0.024
DHW (ton CO2/m2)	0.003	0.001	0.001	0	0.001			0.001
Cooling electricity (ton CO2/m2)	0.003	0.003	0.005	0	0.004			0.004
Lighting, plug, other electricity (tCO2/m2)	0.017	0.017	0.021	0.00046	0.015			0.014

Appendix D – Projected Energy Performance of New Development)

Building Data						Coefficients											Calculated Energy Values												
Cluster	Building	Use	Lot Area (m2)	Gross Floor Area (m2)	Base Density (FSI)	Natural Gas EUI (kWh/m2)	Electricity EUI (kWh/m2)	Total EUI (kWh/m2)	Gas Demand (W/m2)	DHW Demand (W/m2)	Cooling Demand (W/m2)	Electricity Demand (W/m2)	Total Demand (W/m2)	GHGs from Natural Gas EUI (tCO2/m2)	GHGs from Electricity EUI (tCO2/m2)	Total GHGs EUI (tCO2/m2)	Natural Gas Consumption (kWh)	Electricity Consumption (kWh)	Total Consumption (kWh)	Gas Demand (kW thermal)	DHW Demand (kW thermal)	Total Thermal Demand (kW thermal)	Cooling Demand (kW electric)	Electricity Demand (kW electric)	Total Electricity Demand (kW)	Total Demand (kW)	GHGs from Natural Gas (tCO2)	GHGs from Electricity (tCO2)	Total GHGs (tCO2)
A	1-1	Residential	6,400.0	16,678.00	3.0	96	96	192	46.7	7.6	7.9	17.6	79.8	0.018	0.022	0.04	1,601,088.00	1,601,088.00	3,202,176.00	778.86	126.75	905.62	131.76	293.53	425.29	1,330.90	300.204	366.916	667.12
	1-2	Office		1,261.00		77	115	192	59.4	1	11.6	28.8	100.8	0.015	0.026	0.041	97,097.00	145,015.00	242,112.00	74.90	1.26	76.16	14.63	36.32	50.94	127.11	18.915	32.786	51.701
	1-3	Retail		1,261.00		79	146	224	47.2	0.8	13.2	25.9	87.1	0.015	0.034	0.048	99,619.00	184,106.00	282,464.00	59.52	1.01	60.53	16.65	32.66	49.31	109.83	18.915	42.874	60.528
	1-4	Research/ Instituional		0.00		169	103	272	68.5	2.4	13.4	31.6	115.9	0.032	0.024	0.056	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	Subtotal			**19,200.00**													**1,797,804.00**	**1,930,209.00**	**3,726,752.00**	**913.29**	**129.02**	**1,042.31**	**163.03**	**362.51**	**525.54**	**1,567.85**	**338.03**	**442.58**	**779.35**
	TOTAL		**6,400.0**	**19,200.00**													**1,797,804.00**	**1,930,209.00**	**3,726,752.00**	**913.29**	**129.02**	**1,042.31**	**163.03**	**362.51**	**525.54**	**1,567.85**	**338.03**	**442.58**	**779.35**
B1	2-1	Residential	12,266.7	32,190.80	3.0	96	96	192	46.7	7.6	7.9	17.6	79.8	0.018	0.022	0.04	3,090,316.80	3,090,316.80	6,180,633.60	1,503.31	244.65	1,747.96	254.31	566.56	820.87	2,568.83	579.4344	708.1976	1287.632
	2-2	Office		2,304.60		77	115	192	59.4	1	11.6	28.8	100.8	0.015	0.026	0.041	177,454.20	265,029.00	442,483.20	136.89	2.30	139.20	26.73	66.37	93.11	232.30	34.569	59.9196	94.4886
	2-3	Retail		2,304.60		79	146	224	47.2	0.8	13.2	25.9	87.1	0.015	0.034	0.048	182,063.40	336,471.60	516,230.40	108.78	1.84	110.62	30.42	59.69	90.11	200.73	34.569	78.3564	110.6208
	2-4	Research/ Instituional		0.00		169	103	272	68.5	2.4	13.4	31.6	115.9	0.032	0.024	0.056	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	Subtotal			**36,800.00**													**3,449,834.40**	**3,691,817.40**	**7,139,347.20**	**1,748.98**	**248.80**	**1,997.78**	**311.46**	**692.62**	**1,004.08**	**3,001.86**	**648.57**	**846.47**	**1,492.74**
	3-1	Residential	12,266.7	32,190.80	3.0	96	96	192	46.7	7.6	7.9	17.6	79.8	0.018	0.022	0.04	3,090,316.80	3,090,316.80	6,180,633.60	1,503.31	244.65	1,747.96	254.31	566.56	820.87	2,568.83	579.4344	708.1976	1287.632
	3-2	Office		2,304.60		77	115	192	59.4	1	11.6	28.8	100.8	0.015	0.026	0.041	177,454.20	265,029.00	442,483.20	136.89	2.30	139.20	26.73	66.37	93.11	232.30	34.569	59.9196	94.4886
	3-3	Retail		2,304.60		79	146	224	47.2	0.8	13.2	25.9	87.1	0.015	0.034	0.048	182,063.40	336,471.60	516,230.40	108.78	1.84	110.62	30.42	59.69	90.11	200.73	34.569	78.3564	110.6208
	3-4	Research/ Instituional		0.00		169	103	272	68.5	2.4	13.4	31.6	115.9	0.032	0.024	0.056	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	Subtotal			**36,800.00**													**3,449,834.40**	**3,691,817.40**	**7,139,347.20**	**1,748.98**	**248.80**	**1,997.78**	**311.46**	**692.62**	**1,004.08**	**3,001.86**	**648.57**	**846.47**	**1,492.74**
	4-1	Residential	6,133.3	16,095.40	3.0	96	96	192	46.7	7.6	7.9	17.6	79.8	0.018	0.022	0.04	1,545,158.40	1,545,158.40	3,090,316.80	751.66	122.33	873.98	127.15	283.28	410.43	1,284.41	289.7172	354.0988	643.816
	4-2	Office		0.00		77	115	192	59.4	1	11.6	28.8	100.8	0.015	0.026	0.041	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	4-3	Retail		1,152.30		79	146	224	47.2	0.8	13.2	25.9	87.1	0.015	0.034	0.048	91,031.70	168,235.80	258,115.20	54.39	0.92	55.31	15.21	29.84	45.05	100.37	17.2845	39.1782	55.3104
	4-4	Research/ Instituional		0.00		169	103	272	68.5	2.4	13.4	31.6	115.9	0.032	0.024	0.056	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	Subtotal			**17,247.70**													**1,636,190.10**	**1,713,394.20**	**3,348,432.00**	**806.04**	**123.25**	**929.29**	**142.36**	**313.12**	**455.49**	**1,384.78**	**307.00**	**393.28**	**699.13**
	5-1	Residential	6,133.3	16,095.40	3.0	96	96	192	46.7	7.6	7.9	17.6	79.8	0.018	0.022	0.04	1,545,158.40	1,545,158.40	3,090,316.80	751.66	122.33	873.98	127.15	283.28	410.43	1,284.41	289.7172	354.0988	643.816
	5-2	Office		0.00		77	115	192	59.4	1	11.6	28.8	100.8	0.015	0.026	0.041	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	5-3	Retail		1,152.30		79	146	224	47.2	0.8	13.2	25.9	87.1	0.015	0.034	0.048	91,031.70	168,235.80	258,115.20	54.39	0.92	55.31	15.21	29.84	45.05	100.37	17.2845	39.1782	55.3104
	5-4	Research/ Instituional		0.00		169	103	272	68.5	2.4	13.4	31.6	115.9	0.032	0.024	0.056	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	Subtotal			**17,247.70**													**1,636,190.10**	**1,713,394.20**	**3,348,432.00**	**806.04**	**123.25**	**929.29**	**142.36**	**313.12**	**455.49**	**1,384.78**	**307.00**	**393.28**	**699.13**
	6-1	Residential	12,266.7	32,190.80	3.0	96	96	192	46.7	7.6	7.9	17.6	79.8	0.018	0.022	0.04	3,090,316.80	3,090,316.80	6,180,633.60	1,503.31	244.65	1,747.96	254.31	566.56	820.87	2,568.83	579.4344	708.1976	1287.632
	6-2	Office		2,304.60		77	115	192	59.4	1	11.6	28.8	100.8	0.015	0.026	0.041	177,454.20	265,029.00	442,483.20	136.89	2.30	139.20	26.73	66.37	93.11	232.30	34.569	59.9196	94.4886
	6-3	Retail		2,304.60		79	146	224	47.2	0.8	13.2	25.9	87.1	0.015	0.034	0.048	182,063.40	336,471.60	516,230.40	108.78	1.84	110.62	30.42	59.69	90.11	200.73	34.569	78.3564	110.6208
	6-4	Research/ Instituional		0.00		169	103	272	68.5	2.4	13.4	31.6	115.9	0.032	0.024	0.056	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	Subtotal			**36,800.00**													**3,449,834.40**	**3,691,817.40**	**7,139,347.20**	**1,748.98**	**248.80**	**1,997.78**	**311.46**	**692.62**	**1,004.08**	**3,001.86**	**648.57**	**846.47**	**1,492.74**
	7-1	Residential	24,533.3	32,190.8	3.0	96	96	192	46.7	7.6	7.9	17.6	79.8	0.018	0.022	0.04	3,090,316.80	3,090,316.80	6,180,633.60	1,503.31	244.65	1,747.96	254.31	566.56	820.87	2,568.83	579.4344	708.1976	1287.632
	7-2	Office		4,609.2		77	115	192	59.4	1	11.6	28.8	100.8	0.015	0.026	0.041	354,908.40	530,058.00	884,966.40	273.79	4.61	278.40	53.47	132.74	186.21	464.61	69.138	119.8392	188.9772
	7-3	Retail		2,304.6		79	146	224	47.2	0.8	13.2	25.9	87.1	0.015	0.034	0.048	182,063.40	336,471.60	516,230.40	108.78	1.84	110.62	30.42	59.69	90.11	200.73	34.569	78.3564	110.6208
	7-4	Research/ Instituional		0.00		169	103	272	68.5	2.4	13.4	31.6	115.9	0.032	0.024	0.056	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	Subtotal			**39,104.60**													**3,627,288.60**	**3,956,846.40**	**7,581,830.40**	**1,885.87**	**251.10**	**2,136.98**	**338.19**	**758.99**	**1,097.19**	**3,234.16**	**683.14**	**906.39**	**1,587.23**
	TOTAL		**73,600.0**	**184,000.00**													**17,249,172.00**	**18,459,087.00**	**35,696,736.00**	**8,744.90**	**1,243.99**	**9,988.90**	**1,557.31**	**3,463.10**	**5,020.41**	**15,009.30**	**3,242.86**	**4,232.37**	**7,463.71**
B2	8-1	Residential	16,766.7	27,350.67	2.0	96	96	192	46.7	7.6	7.9	17.6	79.8	0.018	0.022	0.04	2,625,664.00	2,625,664.00	5,251,328.00	1,277.28	207.87	1,485.14	216.07	481.37	697.44	2,182.58	492.312	601.7146667	1094.026667
	8-2	Office		3,091.33		77	115	192	59.4	1	11.6	28.8	100.8	0.015	0.026	0.041	238,032.67	355,503.33	593,536.00	183.63	3.09	186.72	35.86	89.03	124.89	311.61	46.37	80.37466667	126.7446667
	8-3	Retail		3,091.33		79	146	224	47.2	0.8	13.2	25.9	87.1	0.015	0.034	0.048	244,215.33	451,334.67	692,458.67	145.91	2.47	148.38	40.81	80.07	120.87	269.26	46.37	105.1053333	148.384
	8-4	Research/ Instituional		0.00		169	103	272	68.5	2.4	13.4	31.6	115.9	0.032	0.024	0.056	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	Subtotal			**33,533.33**													**3,107,912.00**	**3,432,502.00**	**6,537,322.67**	**1,606.81**	**213.43**	**1,820.24**	**292.74**	**650.47**	**943.20**	**2,763.44**	**585.05**	**787.19**	**1,369.16**
	9-1	Residential	16,766.7	27,350.67	2.0	96	96	192	46.7	7.6	7.9	17.6	79.8	0.018	0.022	0.04	2,625,664.00	2,625,664.00	5,251,328.00	1,277.28	207.87	1,485.14	216.07	481.37	697.44	2,182.58	492.312	601.7146667	1094.026667
	9-2	Office		3,091.33		77	115	192	59.4	1	11.6	28.8	100.8	0.015	0.026	0.041	238,032.67	355,503.33	593,536.00	183.63	3.09	186.72	35.86	89.03	124.89	311.61	46.37	80.37466667	126.7446667
	9-3	Retail		3,091.33		79	146	224	47.2	0.8	13.2	25.9	87.1	0.015	0.034	0.048	244,215.33	451,334.67	692,458.67	145.91	2.47	148.38	40.81	80.07	120.87	269.26	46.37	105.1053333	148.384
	9-4	Research/ Instituional		0.00		169	103	272	68.5	2.4	13.4	31.6	115.9	0.032	0.024	0.056	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	Subtotal			**33,533.33**													**3,107,912.00**	**3,432,502.00**	**6,537,322.67**	**1,606.81**	**213.43**	**1,820.24**	**292.74**	**650.47**	**943.20**	**2,763.44**	**585.05**	**787.19**	**1,369.16**
	10-1	Residential	16,766.7	27,350.67	2.0	96	96	192	46.7	7.6	7.9	17.6	79.8	0.018	0.022	0.04	2,625,664.00	2,625,664.00	5,251,328.00	1,277.28	207.87	1,485.14	216.07	481.37	697.44	2,182.58	492.312	601.7146667	1094.026667
	10-2	Office		3,091.33		77	115	192	59.4	1	11.6	28.8	100.8	0.015	0.026	0.041	238,032.67	355,503.33	593,536.00	183.63	3.09	186.72	35.86	89.03	124.89	311.61	46.37	80.37466667	126.7446667
	10-3	Retail		3,091.33		79	146	224	47.2	0.8	13.2	25.9	87.1	0.015	0.034	0.048	244,215.33	451,334.67	692,458.67	145.91	2.47	148.38	40.81	80.07	120.87	269.26	46.37	105.1053333	148.384
	10-4	Research/ Instituional		0.00		169	103	272	68.5	2.4	13.4	31.6	115.9	0.032	0.024	0.056	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	Subtotal			**33,533.33**													**3,107,912.00**	**3,432,502.00**	**6,537,322.67**	**1,606.81**	**213.43**	**1,820.24**	**292.74**	**650.47**	**943.20**	**2,763.44**	**585.05**	**787.19**	**1,369.16**
	TOTAL		**50,300.0**	**100,600.00**													**9,323,736.00**	**10,297,506.00**	**19,611,968.00**	**4,820.44**	**640.29**	**5,460.73**	**878.21**	**1,951.40**	**2,829.61**	**8,290.33**	**1,755.16**	**2,361.58**	**4,107.47**

C	11-1	Residential	6,741.7	10,403.00	2.0	96	96	192	46.7	7.6	7.9	17.6	79.8	0.018	0.022	0.04	998,688.00	998,688.00	1,997,376.00	485.82	79.06	564.88	82.18	183.09	265.28	830.16	187.254	228.866	416.12
	11-2	Office		0.00		77	115	192	59.4	1	11.6	28.8	100.8	0.015	0.026	0.041	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	11-3	Retail		3,080.33		79	146	224	47.2	0.8	13.2	25.9	87.1	0.015	0.034	0.048	243,346.33	449,728.67	689,994.67	145.39	2.46	147.86	40.66	79.78	120.44	268.30	46.205	104.7313333	147.856
	11-4	Research/ Instituional		0.00		169	103	272	68.5	2.4	13.4	31.6	115.9	0.032	0.024	0.056	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	Subtotal			**13,483.33**													**1,242,034.33**	**1,448,416.67**	**2,687,370.67**	**631.21**	**81.53**	**712.74**	**122.84**	**262.87**	**385.72**	**1,098.46**	**233.46**	**333.60**	**563.98**
	12-1	Residential	6,741.7	10,403.00	2.0	96	96	192	46.7	7.6	7.9	17.6	79.8	0.018	0.022	0.04	998,688.00	998,688.00	1,997,376.00	485.82	79.06	564.88	82.18	183.09	265.28	830.16	187.254	228.866	416.12
	12-2	Office		0.00		77	115	192	59.4	1	11.6	28.8	100.8	0.015	0.026	0.041	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	12-3	Retail		3,080.33		79	146	224	47.2	0.8	13.2	25.9	87.1	0.015	0.034	0.048	243,346.33	449,728.67	689,994.67	145.39	2.46	147.86	40.66	79.78	120.44	268.30	46.205	104.7313333	147.856
	12-4	Research/ Instituional		0.00		169	103	272	68.5	2.4	13.4	31.6	115.9	0.032	0.024	0.056	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	Subtotal			**13,483.33**													**1,242,034.33**	**1,448,416.67**	**2,687,370.67**	**631.21**	**81.53**	**712.74**	**122.84**	**262.87**	**385.72**	**1,098.46**	**233.46**	**333.60**	**563.98**
	13-1	Residential	6,741.7	10,403.00	2.0	96	96	192	46.7	7.6	7.9	17.6	79.8	0.018	0.022	0.04	998,688.00	998,688.00	1,997,376.00	485.82	79.06	564.88	82.18	183.09	265.28	830.16	187.254	228.866	416.12
	13-2	Office		0.00		77	115	192	59.4	1	11.6	28.8	100.8	0.015	0.026	0.041	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	13-3	Retail		3,080.33		79	146	224	47.2	0.8	13.2	25.9	87.1	0.015	0.034	0.048	243,346.33	449,728.67	689,994.67	145.39	2.46	147.86	40.66	79.78	120.44	268.30	46.205	104.7313333	147.856
	13-4	Research/ Instituional		0.00		169	103	272	68.5	2.4	13.4	31.6	115.9	0.032	0.024	0.056	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	Subtotal			**13,483.33**													**1,242,034.33**	**1,448,416.67**	**2,687,370.67**	**631.21**	**81.53**	**712.74**	**122.84**	**262.87**	**385.72**	**1,098.46**	**233.46**	**333.60**	**563.98**
	14-1	Residential	6,741.7	10,403.00	2.0	96	96	192	46.7	7.6	7.9	17.6	79.8	0.018	0.022	0.04	998,688.00	998,688.00	1,997,376.00	485.82	79.06	564.88	82.18	183.09	265.28	830.16	187.254	228.866	416.12
	14-2	Office		0.00		77	115	192	59.4	1	11.6	28.8	100.8	0.015	0.026	0.041	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	14-3	Retail		3,080.33		79	146	224	47.2	0.8	13.2	25.9	87.1	0.015	0.034	0.048	243,346.33	449,728.67	689,994.67	145.39	2.46	147.86	40.66	79.78	120.44	268.30	46.205	104.7313333	147.856
	14-4	Research/ Instituional		0.00		169	103	272	68.5	2.4	13.4	31.6	115.9	0.032	0.024	0.056	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	Subtotal			**13,483.33**													**1,242,034.33**	**1,448,416.67**	**2,687,370.67**	**631.21**	**81.53**	**712.74**	**122.84**	**262.87**	**385.72**	**1,098.46**	**233.46**	**333.60**	**563.98**
	15-1	Residential	6,741.7	10,403.00	2.0	96	96	192	46.7	7.6	7.9	17.6	79.8	0.018	0.022	0.04	998,688.00	998,688.00	1,997,376.00	485.82	79.06	564.88	82.18	183.09	265.28	830.16	187.254	228.866	416.12
	15-2	Office		0.00		77	115	192	59.4	1	11.6	28.8	100.8	0.015	0.026	0.041	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	15-3	Retail		3,080.33		79	146	224	47.2	0.8	13.2	25.9	87.1	0.015	0.034	0.048	243,346.33	449,728.67	689,994.67	145.39	2.46	147.86	40.66	79.78	120.44	268.30	46.205	104.7313333	147.856
	15-4	Research/ Instituional		0.00		169	103	272	68.5	2.4	13.4	31.6	115.9	0.032	0.024	0.056	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	Subtotal			**13,483.33**													**1,242,034.33**	**1,448,416.67**	**2,687,370.67**	**631.21**	**81.53**	**712.74**	**122.84**	**262.87**	**385.72**	**1,098.46**	**233.46**	**333.60**	**563.98**
	16-1	Residential	6,741.7	10,403.00	2.0	96	96	192	46.7	7.6	7.9	17.6	79.8	0.018	0.022	0.04	998,688.00	998,688.00	1,997,376.00	485.82	79.06	564.88	82.18	183.09	265.28	830.16	187.254	228.866	416.12
	16-2	Office		0.00		77	115	192	59.4	1	11.6	28.8	100.8	0.015	0.026	0.041	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	16-3	Retail		3,080.33		79	146	224	47.2	0.8	13.2	25.9	87.1	0.015	0.034	0.048	243,346.33	449,728.67	689,994.67	145.39	2.46	147.86	40.66	79.78	120.44	268.30	46.205	104.7313333	147.856
	16-4	Research/ Instituional		0.00		169	103	272	68.5	2.4	13.4	31.6	115.9	0.032	0.024	0.056	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	Subtotal			**13,483.33**													**1,242,034.33**	**1,448,416.67**	**2,687,370.67**	**631.21**	**81.53**	**712.74**	**122.84**	**262.87**	**385.72**	**1,098.46**	**233.46**	**333.60**	**563.98**
	17-1	Residential	6,741.7	0.00	2.0	96	96	192	46.7	7.6	7.9	17.6	79.8	0.018	0.022	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	17-2	Office		10,403.00		77	115	192	59.4	1	11.6	28.8	100.8	0.015	0.026	0.041	801,031.00	1,196,345.00	1,997,376.00	617.94	10.40	628.34	120.67	299.61	420.28	1,048.62	156.045	270.478	426.523
	17-3	Retail		3,080.33		79	146	224	47.2	0.8	13.2	25.9	87.1	0.015	0.034	0.048	243,346.33	449,728.67	689,994.67	145.39	2.46	147.86	40.66	79.78	120.44	268.30	46.205	104.7313333	147.856
	17-4	Research/ Instituional		0.00		169	103	272	68.5	2.4	13.4	31.6	115.9	0.032	0.024	0.056	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	Subtotal			**13,483.33**													**1,044,377.33**	**1,646,073.67**	**2,687,370.67**	**763.33**	**12.87**	**776.20**	**161.34**	**379.39**	**540.72**	**1,316.92**	**202.25**	**375.21**	**574.38**
	18-1	Residential	6,741.7	0.00	2.0	96	96	192	46.7	7.6	7.9	17.6	79.8	0.018	0.022	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	18-2	Office		10,403.00		77	115	192	59.4	1	11.6	28.8	100.8	0.015	0.026	0.041	801,031.00	1,196,345.00	1,997,376.00	617.94	10.40	628.34	120.67	299.61	420.28	1,048.62	156.045	270.478	426.523
	18-3	Retail		3,080.33		79	146	224	47.2	0.8	13.2	25.9	87.1	0.015	0.034	0.048	243,346.33	449,728.67	689,994.67	145.39	2.46	147.86	40.66	79.78	120.44	268.30	46.205	104.7313333	147.856
	18-4	Research/ Instituional		0.00		169	103	272	68.5	2.4	13.4	31.6	115.9	0.032	0.024	0.056	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	Subtotal			**13,483.33**													**1,044,377.33**	**1,646,073.67**	**2,687,370.67**	**763.33**	**12.87**	**776.20**	**161.34**	**379.39**	**540.72**	**1,316.92**	**202.25**	**375.21**	**574.38**
	19-1	Residential	6,741.7	0.00	2.0	96	96	192	46.7	7.6	7.9	17.6	79.8	0.018	0.022	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	19-2	Office		10,403.00		77	115	192	59.4	1	11.6	28.8	100.8	0.015	0.026	0.041	801,031.00	1,196,345.00	1,997,376.00	617.94	10.40	628.34	120.67	299.61	420.28	1,048.62	156.045	270.478	426.523
	19-3	Retail		3,080.33		79	146	224	47.2	0.8	13.2	25.9	87.1	0.015	0.034	0.048	243,346.33	449,728.67	689,994.67	145.39	2.46	147.86	40.66	79.78	120.44	268.30	46.205	104.7313333	147.856
	19-4	Research/ Instituional		0.00		169	103	272	68.5	2.4	13.4	31.6	115.9	0.032	0.024	0.056	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	Subtotal			**13,483.33**													**1,044,377.33**	**1,646,073.67**	**2,687,370.67**	**763.33**	**12.87**	**776.20**	**161.34**	**379.39**	**540.72**	**1,316.92**	**202.25**	**375.21**	**574.38**
	20-1	Residential	6,741.7	0.00	2.0	96	96	192	46.7	7.6	7.9	17.6	79.8	0.018	0.022	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	20-2	Office		10,403.00		77	115	192	59.4	1	11.6	28.8	100.8	0.015	0.026	0.041	801,031.00	1,196,345.00	1,997,376.00	617.94	10.40	628.34	120.67	299.61	420.28	1,048.62	156.045	270.478	426.523
	20-3	Retail		3,080.33		79	146	224	47.2	0.8	13.2	25.9	87.1	0.015	0.034	0.048	243,346.33	449,728.67	689,994.67	145.39	2.46	147.86	40.66	79.78	120.44	268.30	46.205	104.7313333	147.856
	20-4	Research/ Instituional		0.00		169	103	272	68.5	2.4	13.4	31.6	115.9	0.032	0.024	0.056	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	Subtotal			**13,483.33**													**1,044,377.33**	**1,646,073.67**	**2,687,370.67**	**763.33**	**12.87**	**776.20**	**161.34**	**379.39**	**540.72**	**1,316.92**	**202.25**	**375.21**	**574.38**
	21-1	Residential	6,741.7	0.00	2.0	96	96	192	46.7	7.6	7.9	17.6	79.8	0.018	0.022	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	21-2	Office		10,403.00		77	115	192	59.4	1	11.6	28.8	100.8	0.015	0.026	0.041	801,031.00	1,196,345.00	1,997,376.00	617.94	10.40	628.34	120.67	299.61	420.28	1,048.62	156.045	270.478	426.523
	21-3	Retail		3,080.33		79	146	224	47.2	0.8	13.2	25.9	87.1	0.015	0.034	0.048	243,346.33	449,728.67	689,994.67	145.39	2.46	147.86	40.66	79.78	120.44	268.30	46.205	104.7313333	147.856
	21-4	Research/ Instituional		0.00		169	103	272	68.5	2.4	13.4	31.6	115.9	0.032	0.024	0.056	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	Subtotal			**13,483.33**													**1,044,377.33**	**1,646,073.67**	**2,687,370.67**	**763.33**	**12.87**	**776.20**	**161.34**	**379.39**	**540.72**	**1,316.92**	**202.25**	**375.21**	**574.38**
	22-1	Residential	6,741.7	0.00	2.0	96	96	192	46.7	7.6	7.9	17.6	79.8	0.018	0.022	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	22-2	Office		10,403.00		77	115	192	59.4	1	11.6	28.8	100.8	0.015	0.026	0.041	801,031.00	1,196,345.00	1,997,376.00	617.94	10.40	628.34	120.67	299.61	420.28	1,048.62	156.045	270.478	426.523
	22-3	Retail		3,080.33		79	146	224	47.2	0.8	13.2	25.9	87.1	0.015	0.034	0.048	243,346.33	449,728.67	689,994.67	145.39	2.46	147.86	40.66	79.78	120.44	268.30	46.205	104.7313333	147.856
	22-4	Research/ Instituional		0.00		169	103	272	68.5	2.4	13.4	31.6	115.9	0.032	0.024	0.056	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	Subtotal			**13,483.33**													**1,044,377.33**	**1,646,073.67**	**2,687,370.67**	**763.33**	**12.87**	**776.20**	**161.34**	**379.39**	**540.72**	**1,316.92**	**202.25**	**375.21**	**574.38**
	TOTAL		**80,900.0**	**161,800.00**													**13,718,470.00**	**18,566,942.00**	**32,248,448.00**	**8,367.25**	**566.37**	**8,933.62**	**1,705.08**	**3,853.56**	**5,558.64**	**14,492.26**	**2,614.25**	**4,252.84**	**6,830.13**
D	23-1	Residential	5,700.0	6,364.00	1.5	96	96	192	46.7	7.6	7.9	17.6	79.8	0.018	0.022	0.04	610,944.00	610,944.00	1,221,888.00	297.20	48.37	345.57	50.28	112.01	162.28	507.85	114.552	140.008	254.56
	23-2	Office		0.00		77	115	192	59.4	1	11.6	28.8	100.8	0.015	0.026	0.041	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	23-3	Retail		2,186.00		79	146	224	47.2	0.8	13.2	25.9	87.1	0.015	0.034	0.048	172,694.00	319,156.00	489,664.00	103.18	1.75	104.93	28.86	56.62	85.47	190.40	32.79	74.324	104.928
	23-4	Research/ Instituional		0.00		169	103	272	68.5	2.4	13.4	31.6	115.9	0.032	0.024	0.056	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	Subtotal			**8,550.00**													**783,638.00**	**930,100.00**	**1,711,552.00**	**400.38**	**50.12**	**450.49**	**79.13**	**168.62**	**247.75**	**698.25**	**147.34**	**214.33**	**359.49**
	TOTAL		**5,700.0**	**8,550.00**													**783,638.00**	**930,100.00**	**1,711,552.00**	**400.38**	**50.12**	**450.49**	**79.13**	**168.62**	**247.75**	**698.25**	**147.34**	**214.33**	**359.49**

E	24-1	Residential	2,866.7	1,554.67	1.0	96	96	192	46.7	7.6	7.9	17.6	79.8	0.018	0.022	0.04	149,248.00	149,248.00	298,496.00	72.60	11.82	84.42	12.28	27.36	39.64	124.06	27.984	34.20266667	62.18666667
	24-2	Office		0.00		77	115	192	59.4	1	11.6	28.8	100.8	0.015	0.026	0.041	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	24-3	Retail		1,312.00		79	146	224	47.2	0.8	13.2	25.9	87.1	0.015	0.034	0.048	103,648.00	191,552.00	293,888.00	61.93	1.05	62.98	17.32	33.98	51.30	114.28	19.68	44.608	62.976
	24-4	Research/ Instituional		0.00		169	103	272	68.5	2.4	13.4	31.6	115.9	0.032	0.024	0.056	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	Subtotal			**2,866.67**													**252,896.00**	**340,800.00**	**592,384.00**	**134.53**	**12.87**	**147.39**	**29.60**	**61.34**	**90.94**	**238.34**	**47.66**	**78.81**	**125.16**
	25-1	Residential	4,300.0	2,332.00	1.0	96	96	192	46.7	7.6	7.9	17.6	79.8	0.018	0.022	0.04	223,872.00	223,872.00	447,744.00	108.90	17.72	126.63	18.42	41.04	59.47	186.09	41.976	51.304	93.28
	25-2	Office		0.00		77	115	192	59.4	1	11.6	28.8	100.8	0.015	0.026	0.041	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	25-3	Retail		1,968.00		79	146	224	47.2	0.8	13.2	25.9	87.1	0.015	0.034	0.048	155,472.00	287,328.00	440,832.00	92.89	1.57	94.46	25.98	50.97	76.95	171.41	29.52	66.912	94.464
	25-4	Research/ Instituional		0.00		169	103	272	68.5	2.4	13.4	31.6	115.9	0.032	0.024	0.056	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	Subtotal			**4,300.00**													**379,344.00**	**511,200.00**	**888,576.00**	**201.79**	**19.30**	**221.09**	**44.40**	**92.01**	**136.41**	**357.51**	**71.50**	**118.22**	**187.74**
	26-1	Residential	1,433.3	777.33	1.0	96	96	192	46.7	7.6	7.9	17.6	79.8	0.018	0.022	0.04	74,624.00	74,624.00	149,248.00	36.30	5.91	42.21	6.14	13.68	19.82	62.03	13.992	17.10133333	31.09333333
	26-2	Office		0.00		77	115	192	59.4	1	11.6	28.8	100.8	0.015	0.026	0.041	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	26-3	Retail		656.00		79	146	224	47.2	0.8	13.2	25.9	87.1	0.015	0.034	0.048	51,824.00	95,776.00	146,944.00	30.96	0.52	31.49	8.66	16.99	25.65	57.14	9.84	22.304	31.488
	26-4	Research/ Instituional		0.00		169	103	272	68.5	2.4	13.4	31.6	115.9	0.032	0.024	0.056	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	Subtotal			**1,433.33**													**126,448.00**	**170,400.00**	**296,192.00**	**67.26**	**6.43**	**73.70**	**14.80**	**30.67**	**45.47**	**119.17**	**23.83**	**39.41**	**62.58**
	TOTAL		**8,600.0**	**8,600.00**													**758,688.00**	**1,022,400.00**	**1,777,152.00**	**403.59**	**38.60**	**442.18**	**88.80**	**184.03**	**272.83**	**715.01**	**142.99**	**236.43**	**375.49**
F1	27-1	Residential	7,200.0	3,828.00	1.0	96	96	192	46.7	7.6	7.9	17.6	79.8	0.018	0.022	0.04	367,488.00	367,488.00	734,976.00	178.77	29.09	207.86	30.24	67.37	97.61	305.47	68.904	84.216	153.12
	27-2	Office		0.00		77	115	192	59.4	1	11.6	28.8	100.8	0.015	0.026	0.041	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	27-3	Retail		3,372.00		79	146	224	47.2	0.8	13.2	25.9	87.1	0.015	0.034	0.048	266,388.00	492,312.00	755,328.00	159.16	2.70	161.86	44.51	87.33	131.85	293.70	50.58	114.648	161.856
	27-4	Research/ Instituional		0.00		169	103	272	68.5	2.4	13.4	31.6	115.9	0.032	0.024	0.056	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	Subtotal			**7,200.00**													**633,876.00**	**859,800.00**	**1,490,304.00**	**337.93**	**31.79**	369.72	**74.75**	**154.71**	**229.46**	**599.18**	**119.48**	**198.86**	**314.98**
	28-1	Residential	2,400.0	1,276.00	1.0	96	96	192	46.7	7.6	7.9	17.6	79.8	0.018	0.022	0.04	122,496.00	122,496.00	244,992.00	59.59	9.70	69.29	10.08	22.46	32.54	101.82	22.968	28.072	51.04
	28-2	Office		0.00		77	115	192	59.4	1	11.6	28.8	100.8	0.015	0.026	0.041	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	28-3	Retail		1,124.00		79	146	224	47.2	0.8	13.2	25.9	87.1	0.015	0.034	0.048	88,796.00	164,104.00	251,776.00	53.05	0.90	53.95	14.84	29.11	43.95	97.90	16.86	38.216	53.952
	28-4	Research/ Instituional		0.00		169	103	272	68.5	2.4	13.4	31.6	115.9	0.032	0.024	0.056	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	Subtotal			**2,400.00**													**211,292.00**	**286,600.00**	**496,768.00**	**112.64**	**10.60**	**123.24**	**24.92**	**51.57**	**76.49**	**199.73**	**39.83**	**66.29**	**104.99**
	TOTAL		**9,600.0**	**9,600.00**													**845,168.00**	**1,146,400.00**	**1,987,072.00**	**450.57**	**42.39**	**492.96**	**99.67**	**206.28**	**305.95**	**798.90**	**159.31**	**265.15**	**419.97**
F2	29-1	Residential	2,983.3	1,488.67	1.0	96	96	192	46.7	7.6	7.9	17.6	79.8	0.018	0.022	0.04	142,912.00	142,912.00	285,824.00	69.52	11.31	80.83	11.76	26.20	37.96	118.80	26.796	32.75066667	59.54666667
	29-2	Office		0.00		77	115	192	59.4	1	11.6	28.8	100.8	0.015	0.026	0.041	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	29-3	Retail		1,494.67		79	146	224	47.2	0.8	13.2	25.9	87.1	0.015	0.034	0.048	118,078.67	218,221.33	334,805.33	70.55	1.20	71.74	19.73	38.71	58.44	130.19	22.42	50.81866667	71.744
	29-4	Research/ Instituional		0.00		169	103	272	68.5	2.4	13.4	31.6	115.9	0.032	0.024	0.056	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	Subtotal			**2,983.33**													**260,990.67**	**361,133.33**	**620,629.33**	**140.07**	**12.51**	**152.58**	**31.49**	**64.91**	**96.40**	**248.98**	**49.22**	**83.57**	**131.29**
	30-1	Residential	5,966.7	2,977.33	1.0	96	96	192	46.7	7.6	7.9	17.6	79.8	0.018	0.022	0.04	285,824.00	285,824.00	571,648.00	139.04	22.63	161.67	23.52	52.40	75.92	237.59	53.592	65.50133333	119.0933333
	30-2	Office		0.00		77	115	192	59.4	1	11.6	28.8	100.8	0.015	0.026	0.041	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	30-3	Retail		2,989.33		79	146	224	47.2	0.8	13.2	25.9	87.1	0.015	0.034	0.048	236,157.33	436,442.67	669,610.67	141.10	2.39	143.49	39.46	77.42	116.88	260.37	44.84	101.6373333	143.488
	30-4	Research/ Instituional		0.00		169	103	272	68.5	2.4	13.4	31.6	115.9	0.032	0.024	0.056	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	Subtotal			**5,966.67**													**521,981.33**	**722,266.67**	**1,241,258.67**	**280.14**	**25.02**	**305.16**	**62.98**	**129.82**	**192.80**	**497.96**	**98.43**	**167.14**	**262.58**
	31-1	Residential	4,475.0	2,233.00	1.0	96	96	192	46.7	7.6	7.9	17.6	79.8	0.018	0.022	0.04	214,368.00	214,368.00	428,736.00	104.28	16.97	121.25	17.64	39.30	56.94	178.19	40.194	49.126	89.32
	31-2	Office		0.00		77	115	192	59.4	1	11.6	28.8	100.8	0.015	0.026	0.041	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	31-3	Retail		2,242.00		79	146	224	47.2	0.8	13.2	25.9	87.1	0.015	0.034	0.048	177,118.00	327,332.00	502,208.00	105.82	1.79	107.62	29.59	58.07	87.66	195.28	33.63	76.228	107.616
	31-4	Research/ Instituional		0.00		169	103	272	68.5	2.4	13.4	31.6	115.9	0.032	0.024	0.056	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	Subtotal			**4,475.00**													**391,486.00**	**541,700.00**	**930,944.00**	**210.10**	**18.76**	**228.87**	**47.24**	**97.37**	**144.60**	**373.47**	**73.82**	**125.35**	**196.94**
	32-1	Residential	4,475.0	2,233.00	1.0	96	96	192	46.7	7.6	7.9	17.6	79.8	0.018	0.022	0.04	214,368.00	214,368.00	428,736.00	104.28	16.97	121.25	17.64	39.30	56.94	178.19	40.194	49.126	89.32
	32-2	Office		0.00		77	115	192	59.4	1	11.6	28.8	100.8	0.015	0.026	0.041	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	32-3	Retail		2,242.00		79	146	224	47.2	0.8	13.2	25.9	87.1	0.015	0.034	0.048	177,118.00	327,332.00	502,208.00	105.82	1.79	107.62	29.59	58.07	87.66	195.28	33.63	76.228	107.616
	32-4	Research/ Instituional		0.00		169	103	272	68.5	2.4	13.4	31.6	115.9	0.032	0.024	0.056	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	Subtotal			**4,475.00**													**391,486.00**	**541,700.00**	**930,944.00**	**210.10**	**18.76**	**228.87**	**47.24**	**97.37**	**144.60**	**373.47**	**73.82**	**125.35**	**196.94**
	TOTAL		**17,900.0**	**17,900.00**													**1,565,944.00**	**2,166,800.00**	**3,723,776.00**	**840.41**	**75.06**	**915.47**	**188.94**	**389.47**	**578.41**	**1,493.89**	**295.30**	**501.42**	**787.74**
G1	33-1	Residential	7,800.0	0.00	2.0	96	96	192	46.7	7.6	7.9	17.6	79.8	0.018	0.022	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	33-2	Office		7,800.00		77	115	192	59.4	1	11.6	28.8	100.8	0.015	0.026	0.041	600,600.00	897,000.00	1,497,600.00	463.32	7.80	471.12	90.48	224.64	315.12	786.24	117	202.8	319.8
	33-3	Retail		0.00		79	146	224	47.2	0.8	13.2	25.9	87.1	0.015	0.034	0.048	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	33-4	Research/ Instituional		7,800.00		169	103	272	68.5	2.4	13.4	31.6	115.9	0.032	0.024	0.056	1,318,200.00	803,400.00	2,121,600.00	534.30	18.72	553.02	104.52	246.48	351.00	904.02	249.6	187.2	436.8
	Subtotal			**15,600.00**													**1,918,800.00**	**1,700,400.00**	**3,619,200.00**	**997.62**	**26.52**	**1,024.14**	**195.00**	**471.12**	**666.12**	**1,690.26**	**366.60**	**390.00**	**756.60**
	34-1	Residential	15,600.0	0.00	2.0	96	96	192	46.7	7.6	7.9	17.6	79.8	0.018	0.022	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	34-2	Office		15,600.00		77	115	192	59.4	1	11.6	28.8	100.8	0.015	0.026	0.041	1,201,200.00	1,794,000.00	2,995,200.00	926.64	15.60	942.24	180.96	449.28	630.24	1,572.48	234	405.6	639.6
	34-3	Retail		0.00		79	146	224	47.2	0.8	13.2	25.9	87.1	0.015	0.034	0.048	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	34-4	Research/ Instituional		15,600.00		169	103	272	68.5	2.4	13.4	31.6	115.9	0.032	0.024	0.056	2,636,400.00	1,606,800.00	4,243,200.00	1,068.60	37.44	1,106.04	209.04	492.96	702.00	1,808.04	499.2	374.4	873.6
	Subtotal			**31,200.00**													**3,837,600.00**	**3,400,800.00**	**7,238,400.00**	**1,995.24**	**53.04**	**2,048.28**	**390.00**	**942.24**	**1,332.24**	**3,380.52**	**733.20**	**780.00**	**1,513.20**
	TOTAL		**23,400.0**	**46,800.00**													**5,756,400.00**	**5,101,200.00**	**10,857,600.00**	**2,992.86**	**79.56**	**3,072.42**	**585.00**	**1,413.36**	**1,998.36**	**5,070.78**	**1,099.80**	**1,170.00**	**2,269.80**

	35-1	Residential		0.00		96	96	192	46.7	7.6	7.9	17.6	79.8	0.018	0.022	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	35-2	Office		8,000.00		77	115	192	59.4	1	11.6	28.8	100.8	0.015	0.026	0.041	616,000.00	920,000.00	1,536,000.00	475.20	8.00	483.20	92.80	230.40	323.20	806.40	120	208	328
	35-3	Retail	6,400.0	0.00	2.5	79	146	224	47.2	0.8	13.2	25.9	87.1	0.015	0.034	0.048	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	35-4	Research/ Instituional		8,000.00		169	103	272	68.5	2.4	13.4	31.6	115.9	0.032	0.024	0.056	1,352,000.00	824,000.00	2,176,000.00	548.00	19.20	567.20	107.20	252.80	360.00	927.20	256	192	448
	Subtotal			**16,000.00**													**1,968,000.00**	**1,744,000.00**	**3,712,000.00**	**1,023.20**	**27.20**	**1,050.40**	**200.00**	**483.20**	**683.20**	**1,733.60**	**376.00**	**400.00**	**776.00**
	36-1	Residential		0.00		96	96	192	46.7	7.6	7.9	17.6	79.8	0.018	0.022	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	36-2	Office		4,000.00		77	115	192	59.4	1	11.6	28.8	100.8	0.015	0.026	0.041	308,000.00	460,000.00	768,000.00	237.60	4.00	241.60	46.40	115.20	161.60	403.20	60	104	164
	36-3	Retail	3,200.0	0.00	2.5	79	146	224	47.2	0.8	13.2	25.9	87.1	0.015	0.034	0.048	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	36-4	Research/ Instituional		4,000.00		169	103	272	68.5	2.4	13.4	31.6	115.9	0.032	0.024	0.056	676,000.00	412,000.00	1,088,000.00	274.00	9.60	283.60	53.60	126.40	180.00	463.60	128	96	224
	Subtotal			**8,000.00**													**984,000.00**	**872,000.00**	**1,856,000.00**	**511.60**	**13.60**	**525.20**	**100.00**	**241.60**	**341.60**	**866.80**	**188.00**	**200.00**	**388.00**
	37-1	Residential		0.00		96	96	192	46.7	7.6	7.9	17.6	79.8	0.018	0.022	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	37-2	Office		12,000.00		77	115	192	59.4	1	11.6	28.8	100.8	0.015	0.026	0.041	924,000.00	1,380,000.00	2,304,000.00	712.80	12.00	724.80	139.20	345.60	484.80	1,209.60	180	312	492
	37-3	Retail	9,600.0	0.00	2.5	79	146	224	47.2	0.8	13.2	25.9	87.1	0.015	0.034	0.048	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
G2	37-4	Research/ Instituional		12,000.00		169	103	272	68.5	2.4	13.4	31.6	115.9	0.032	0.024	0.056	2,028,000.00	1,236,000.00	3,264,000.00	822.00	28.80	850.80	160.80	379.20	540.00	1,390.80	384	288	672
	Subtotal			**24,000.00**													**2,952,000.00**	**2,616,000.00**	**5,568,000.00**	**1,534.80**	**40.80**	**1,575.60**	**300.00**	**724.80**	**1,024.80**	**2,600.40**	**564.00**	**600.00**	**1,164.00**
	38-1	Residential		0.00		96	96	192	46.7	7.6	7.9	17.6	79.8	0.018	0.022	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	38-2	Office		12,000.00		77	115	192	59.4	1	11.6	28.8	100.8	0.015	0.026	0.041	924,000.00	1,380,000.00	2,304,000.00	712.80	12.00	724.80	139.20	345.60	484.80	1,209.60	180	312	492
	38-3	Retail	9,600.0	0.00	2.5	79	146	224	47.2	0.8	13.2	25.9	87.1	0.015	0.034	0.048	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	38-4	Research/ Instituional		12,000.00		169	103	272	68.5	2.4	13.4	31.6	115.9	0.032	0.024	0.056	2,028,000.00	1,236,000.00	3,264,000.00	822.00	28.80	850.80	160.80	379.20	540.00	1,390.80	384	288	672
	Subtotal			**24,000.00**													**2,952,000.00**	**2,616,000.00**	**5,568,000.00**	**1,534.80**	**40.80**	**1,575.60**	**300.00**	**724.80**	**1,024.80**	**2,600.40**	**564.00**	**600.00**	**1,164.00**
	39-1	Residential		0.00		96	96	192	46.7	7.6	7.9	17.6	79.8	0.018	0.022	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	39-2	Office		12,000.00		77	115	192	59.4	1	11.6	28.8	100.8	0.015	0.026	0.041	924,000.00	1,380,000.00	2,304,000.00	712.80	12.00	724.80	139.20	345.60	484.80	1,209.60	180	312	492
	39-3	Retail	9,600.0	0.00	2.5	79	146	224	47.2	0.8	13.2	25.9	87.1	0.015	0.034	0.048	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	39-4	Research/ Instituional		12,000.00		169	103	272	68.5	2.4	13.4	31.6	115.9	0.032	0.024	0.056	2,028,000.00	1,236,000.00	3,264,000.00	822.00	28.80	850.80	160.80	379.20	540.00	1,390.80	384	288	672
	Subtotal			**24,000.00**													**2,952,000.00**	**2,616,000.00**	**5,568,000.00**	**1,534.80**	**40.80**	1,575.60	**300.00**	**724.80**	1,024.80	**2,600.40**	**564.00**	**600.00**	**1,164.00**
	TOTAL		**38,400.0**	**96,000.00**													**11,808,000.00**	**10,464,000.00**	**22,272,000.00**	**6,139.20**	**163.20**	**6,302.40**	**1,200.00**	**2,899.20**	**4,099.20**	**10,401.60**	**2,256.00**	**2,400.00**	**4,656.00**
	40-1	Residential		0.00		96	96	192	46.7	7.6	7.9	17.6	79.8	0.018	0.022	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	40-2	Office		9,833.33		77	115	192	59.4	1	11.6	28.8	100.8	0.015	0.026	0.041	757,166.67	1,130,833.33	1,888,000.00	584.10	9.83	593.93	114.07	283.20	397.27	991.20	147.5	255.6666667	403.1666667
	40-3	Retail	7,866.7	0.00	2.5	79	146	224	47.2	0.8	13.2	25.9	87.1	0.015	0.034	0.048	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	40-4	Research/ Instituional		9,833.33		169	103	272	68.5	2.4	13.4	31.6	115.9	0.032	0.024	0.056	1,661,833.33	1,012,833.33	2,674,666.67	673.58	23.60	697.18	131.77	310.73	442.50	1,139.68	314.6666667	236	550.6666667
	Subtotal			**19,666.67**													**2,419,000.00**	**2,143,666.67**	**4,562,666.67**	**1,257.68**	**33.43**	**1,291.12**	**245.83**	**593.93**	**839.77**	**2,130.88**	**462.17**	**491.67**	**953.83**
	41-1	Residential		0.00		96	96	192	46.7	7.6	7.9	17.6	79.8	0.018	0.022	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	41-2	Office		19,666.67		77	115	192	59.4	1	11.6	28.8	100.8	0.015	0.026	0.041	1,514,333.33	2,261,666.67	3,776,000.00	1,168.20	19.67	1,187.87	228.13	566.40	794.53	1,982.40	295	511.3333333	806.3333333
	41-3	Retail	15,733.3	0.00	2.5	79	146	224	47.2	0.8	13.2	25.9	87.1	0.015	0.034	0.048	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	41-4	Research/ Instituional		19,666.67		169	103	272	68.5	2.4	13.4	31.6	115.9	0.032	0.024	0.056	3,323,666.67	2,025,666.67	5,349,333.33	1,347.17	47.20	1,394.37	263.53	621.47	885.00	2,279.37	629.3333333	472	1101.333333
	Subtotal			**39,333.33**													**4,838,000.00**	**4,287,333.33**	**9,125,333.33**	**2,515.37**	**66.87**	**2,582.23**	**491.67**	**1,187.87**	**1,679.53**	**4,261.77**	**924.33**	**983.33**	**1,907.67**
	42-1	Residential		0.00		96	96	192	46.7	7.6	7.9	17.6	79.8	0.018	0.022	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	42-2	Office		9,833.33		77	115	192	59.4	1	11.6	28.8	100.8	0.015	0.026	0.041	757,166.67	1,130,833.33	1,888,000.00	584.10	9.83	593.93	114.07	283.20	397.27	991.20	147.5	255.6666667	403.1666667
	42-3	Retail	7,866.7	0.00	2.5	79	146	224	47.2	0.8	13.2	25.9	87.1	0.015	0.034	0.048	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	42-4	Research/ Instituional		9,833.33		169	103	272	68.5	2.4	13.4	31.6	115.9	0.032	0.024	0.056	1,661,833.33	1,012,833.33	2,674,666.67	673.58	23.60	697.18	131.77	310.73	442.50	1,139.68	314.6666667	236	550.6666667
	Subtotal			**19,666.67**													**2,419,000.00**	**2,143,666.67**	**4,562,666.67**	**1,257.68**	**33.43**	**1,291.12**	**245.83**	**593.93**	**839.77**	**2,130.88**	**462.17**	**491.67**	**953.83**
	43-1	Residential		0.00		96	96	192	46.7	7.6	7.9	17.6	79.8	0.018	0.022	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	43-2	Office		9,833.33		77	115	192	59.4	1	11.6	28.8	100.8	0.015	0.026	0.041	757,166.67	1,130,833.33	1,888,000.00	584.10	9.83	593.93	114.07	283.20	397.27	991.20	147.5	255.6666667	403.1666667
	43-3	Retail	7,866.7	0.00	2.5	79	146	224	47.2	0.8	13.2	25.9	87.1	0.015	0.034	0.048	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
H	43-4	Research/ Instituional		9,833.33		169	103	272	68.5	2.4	13.4	31.6	115.9	0.032	0.024	0.056	1,661,833.33	1,012,833.33	2,674,666.67	673.58	23.60	697.18	131.77	310.73	442.50	1,139.68	314.6666667	236	550.6666667
	Subtotal			**19,666.67**													**2,419,000.00**	**2,143,666.67**	**4,562,666.67**	**1,257.68**	**33.43**	**1,291.12**	**245.83**	**593.93**	**839.77**	**2,130.88**	**462.17**	**491.67**	**953.83**
	44-1	Residential		0.00		96	96	192	46.7	7.6	7.9	17.6	79.8	0.018	0.022	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	44-2	Office		29,500.00		77	115	192	59.4	1	11.6	28.8	100.8	0.015	0.026	0.041	2,271,500.00	3,392,500.00	5,664,000.00	1,752.30	29.50	1,781.80	342.20	849.60	1,191.80	2,973.60	442.5	767	1209.5
	44-3	Retail	23,600.0	0.00	2.5	79	146	224	47.2	0.8	13.2	25.9	87.1	0.015	0.034	0.048	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	44-4	Research/ Instituional		29,500.00		169	103	272	68.5	2.4	13.4	31.6	115.9	0.032	0.024	0.056	4,985,500.00	3,038,500.00	8,024,000.00	2,020.75	70.80	2,091.55	395.30	932.20	1,327.50	3,419.05	944	708	1652
	Subtotal			**59,000.00**													**7,257,000.00**	**6,431,000.00**	**13,688,000.00**	**3,773.05**	**100.30**	**3,873.35**	**737.50**	**1,781.80**	**2,519.30**	**6,392.65**	**1,386.50**	**1,475.00**	**2,861.50**
	45-1	Residential		0.00		96	96	192	46.7	7.6	7.9	17.6	79.8	0.018	0.022	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	45-2	Office		19,666.67		77	115	192	59.4	1	11.6	28.8	100.8	0.015	0.026	0.041	1,514,333.33	2,261,666.67	3,776,000.00	1,168.20	19.67	1,187.87	228.13	566.40	794.53	1,982.40	295	511.3333333	806.3333333
	45-3	Retail	15,733.3	0.00	2.5	79	146	224	47.2	0.8	13.2	25.9	87.1	0.015	0.034	0.048	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	45-4	Research/ Instituional		19,666.67		169	103	272	68.5	2.4	13.4	31.6	115.9	0.032	0.024	0.056	3,323,666.67	2,025,666.67	5,349,333.33	1,347.17	47.20	1,394.37	263.53	621.47	885.00	2,279.37	629.3333333	472	1101.333333
	Subtotal			**39,333.33**													**4,838,000.00**	**4,287,333.33**	**9,125,333.33**	**2,515.37**	**66.87**	**2,582.23**	**491.67**	**1,187.87**	**1,679.53**	**4,261.77**	**924.33**	**983.33**	**1,907.67**
	46-1	Residential		0.00		96	96	192	46.7	7.6	7.9	17.6	79.8	0.018	0.022	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	46-2	Office		19,666.67		77	115	192	59.4	1	11.6	28.8	100.8	0.015	0.026	0.041	1,514,333.33	2,261,666.67	3,776,000.00	1,168.20	19.67	1,187.87	228.13	566.40	794.53	1,982.40	295	511.3333333	806.3333333
	46-3	Retail	15,733.3	0.00	2.5	79	146	224	47.2	0.8	13.2	25.9	87.1	0.015	0.034	0.048	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	46-4	Research/ Instituional		19,666.67		169	103	272	68.5	2.4	13.4	31.6	115.9	0.032	0.024	0.056	3,323,666.67	2,025,666.67	5,349,333.33	1,347.17	47.20	1,394.37	263.53	621.47	885.00	2,279.37	629.3333333	472	1101.333333
	Subtotal			**39,333.33**													**4,838,000.00**	**4,287,333.33**	**9,125,333.33**	**2,515.37**	**66.87**	**2,582.23**	**491.67**	**1,187.87**	**1,679.53**	**4,261.77**	**924.33**	**983.33**	**1,907.67**
	TOTAL		**94,400.0**	**236,000.00**													**29,028,000.00**	**25,724,000.00**	**54,752,000.00**	**15,092.20**	**401.20**	**15,493.40**	**2,950.00**	**7,127.20**	**10,077.20**	**25,570.60**	**5,546.00**	**5,900.00**	**11,446.00**
	47-1	Residential		0.00		96	96	192	46.7	7.6	7.9	17.6	79.8	0.018	0.022	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	47-2	Office		0.00		77	115	192	59.4	1	11.6	28.8	100.8	0.015	0.026	0.041	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	47-3	Retail	6,200.0	0.00	3.0	79	146	224	47.2	0.8	13.2	25.9	87.1	0.015	0.034	0.048	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	47-4	Research/ Instituional		18,600.00		169	103	272	68.5	2.4	13.4	31.6	115.9	0.032	0.024	0.056	3,143,400.00	1,915,800.00	5,059,200.00	1,274.10	44.64	1,318.74	249.24	587.76	837.00	2,155.74	595.2	446.4	1041.6
	Subtotal			**18,600.00**													**3,143,400.00**	**1,915,800.00**	**5,059,200.00**	**1,274.10**	**44.64**	**1,318.74**	**249.24**	**587.76**	**837.00**	**2,155.74**	**595.20**	**446.40**	**1,041.60**
I	48-1	Residential		0.00		96	96	192	46.7	7.6	7.9	17.6	79.8	0.018	0.022	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	48-2	Office		37,200.00		77	115	192	59.4	1	11.6	28.8	100.8	0.015	0.026	0.041	2,864,400.00	4,278,000.00	7,142,400.00	2,209.68	37.20	2,246.88	431.52	1,071.36	1,502.88	3,749.76	558	967.2	1525.2
	48-3	Retail	18,600.0	0.00	3.0	79	146	224	47.2	0.8	13.2	25.9	87.1	0.015	0.034	0.048	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	48-4	Research/ Instituional		18,600.00		169	103	272	68.5	2.4	13.4	31.6	115.9	0.032	0.024	0.056	3,143,400.00	1,915,800.00	5,059,200.00	1,274.10	44.64	1,318.74	249.24	587.76	837.00	2,155.74	595.2	446.4	1041.6
	Subtotal			**55,800.00**													**6,007,800.00**	**6,193,800.00**	**12,201,600.00**	**3,483.78**	**81.84**	**3,565.62**	**680.76**	**1,659.12**	**2,339.88**	**5,905.50**	**1,153.20**	**1,413.60**	**2,566.80**
	TOTAL		**24,800.0**	**74,400.00**													**9,151,200.00**	**8,109,600.00**	**17,260,800.00**	**4,757.88**	**126.48**	**4,884.36**	**930.00**	**2,246.88**	**3,176.88**	**8,061.24**	**1,748.40**	**1,860.00**	**3,608.40**

	49-1	Residential		145,657.00		96	96	192	46.7	7.6	7.9	17.6	79.8	0.018	0.022	0.04	13,983,072.00	13,983,072.00	27,966,144.00	6,802.18	1,106.99	7,909.18	1,150.69	2,563.56	3,714.25	11,623.43	2621.826	3204.454	5826.28
	49-2	Office		12,000.00		77	115	192	59.4	1	11.6	28.8	100.8	0.015	0.026	0.041	924,000.00	1,380,000.00	2,304,000.00	712.80	12.00	724.80	139.20	345.60	484.80	1,209.60	180	312	492
	49-3	Retail	40,600.0	4,743.00	4.0	79	146	224	47.2	0.8	13.2	25.9	87.1	0.015	0.034	0.048	374,697.00	692,478.00	1,062,432.00	223.87	3.79	227.66	62.61	122.84	185.45	413.12	71.145	161.262	227.664
J	49-4	Research/ Instituional		0.00		169	103	272	68.5	2.4	13.4	31.6	115.9	0.032	0.024	0.056	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	Subtotal			**162,400.00**													**15,281,769.00**	**16,055,550.00**	**31,332,576.00**	**7,738.85**	**1,122.79**	**8,861.64**	**1,352.50**	**3,032.01**	**4,384.50**	**13,246.14**	**2,872.97**	**3,677.72**	**6,545.94**
	TOTAL		**40,600.0**	**162,400.00**													**15,281,769.00**	**16,055,550.00**	**31,332,576.00**	**7,738.85**	**1,122.79**	**8,861.64**	**1,352.50**	**3,032.01**	**4,384.50**	**13,246.14**	**2,872.97**	**3,677.72**	**6,545.94**
	50-1	Residential		69,655.50		96	96	192	46.7	7.6	7.9	17.6	79.8	0.018	0.022	0.04	6,686,928.00	6,686,928.00	13,373,856.00	3,252.91	529.38	3,782.29	550.28	1,225.94	1,776.22	5,558.51	1253.799	1532.421	2786.22
	50-2	Office		6,000.00		77	115	192	59.4	1	11.6	28.8	100.8	0.015	0.026	0.041	462,000.00	690,000.00	1,152,000.00	356.40	6.00	362.40	69.60	172.80	242.40	604.80	90	156	246
	50-3	Retail	19,600.0	2,744.50	4.0	79	146	224	47.2	0.8	13.2	25.9	87.1	0.015	0.034	0.048	216,815.50	400,697.00	614,768.00	129.54	2.20	131.74	36.23	71.08	107.31	239.05	41.1675	93.313	131.736
	50-4	Research/ Instituional		0.00		169	103	272	68.5	2.4	13.4	31.6	115.9	0.032	0.024	0.056	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	Subtotal			**78,400.00**													**7,365,743.50**	**7,777,625.00**	**15,140,624.00**	**3,738.85**	**537.58**	**4,276.43**	**656.11**	**1,469.82**	**2,125.93**	**6,402.35**	**1,384.97**	**1,781.73**	**3,163.96**
	51-1	Residential		23,218.50		96	96	192	46.7	7.6	7.9	17.6	79.8	0.018	0.022	0.04	2,228,976.00	2,228,976.00	4,457,952.00	1,084.30	176.46	1,260.76	183.43	408.65	592.07	1,852.84	417.933	510.807	928.74
	51-2	Office		2,000.00		77	115	192	59.4	1	11.6	28.8	100.8	0.015	0.026	0.041	154,000.00	230,000.00	384,000.00	118.80	2.00	120.80	23.20	57.60	80.80	201.60	30	52	82
	51-3	Retail	6,533.3	914.83	4.0	79	146	224	47.2	0.8	13.2	25.9	87.1	0.015	0.034	0.048	72,271.83	133,565.67	204,922.67	43.18	0.73	43.91	12.08	23.69	35.77	79.68	13.7225	31.10433333	43.912
K	51-4	Research/ Instituional		0.00		169	103	272	68.5	2.4	13.4	31.6	115.9	0.032	0.024	0.056	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	Subtotal			**26,133.33**													**2,455,247.83**	**2,592,541.67**	**5,046,874.67**	**1,246.28**	**179.19**	**1,425.48**	**218.70**	**489.94**	**708.64**	**2,134.12**	**461.66**	**593.91**	**1,054.65**
	52-1	Residential		46,437.00		96	96	192	46.7	7.6	7.9	17.6	79.8	0.018	0.022	0.04	4,457,952.00	4,457,952.00	8,915,904.00	2,168.61	352.92	2,521.53	366.85	817.29	1,184.14	3,705.67	835.866	1021.614	1857.48
	52-2	Office		4,000.00		77	115	192	59.4	1	11.6	28.8	100.8	0.015	0.026	0.041	308,000.00	460,000.00	768,000.00	237.60	4.00	241.60	46.40	115.20	161.60	403.20	60	104	164
	52-3	Retail	13,066.7	1,829.67	4.0	79	146	224	47.2	0.8	13.2	25.9	87.1	0.015	0.034	0.048	144,543.67	267,131.33	409,845.33	86.36	1.46	87.82	24.15	47.39	71.54	159.36	27.445	62.20866667	87.824
	52-4	Research/ Instituional		0.00		169	103	272	68.5	2.4	13.4	31.6	115.9	0.032	0.024	0.056	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	Subtotal			**52,266.67**													**4,910,495.67**	**5,185,083.33**	**10,093,749.33**	**2,492.57**	**358.38**	**2,850.95**	**437.40**	**979.88**	**1,417.28**	**4,268.24**	**923.31**	**1,187.82**	**2,109.30**
	TOTAL		**39,200.0**	**156,800.00**													**14,731,487.00**	**15,555,250.00**	**30,281,248.00**	**7,477.70**	**1,075.15**	**8,552.86**	**1,312.21**	**2,939.64**	**4,251.85**	**12,804.71**	**2,769.93**	**3,563.47**	**6,327.91**
	53-1	Residential		45,658.33		96	96	192	46.7	7.6	7.9	17.6	79.8	0.018	0.022	0.04	4,383,200.00	4,383,200.00	8,766,400.00	2,132.24	347.00	2,479.25	360.70	803.59	1,164.29	3,643.54	821.85	1004.483333	1826.333333
	53-2	Office		0.00		77	115	192	59.4	1	11.6	28.8	100.8	0.015	0.026	0.041	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	53-3	Retail	15,766.7	1,641.67	3.0	79	146	224	47.2	0.8	13.2	25.9	87.1	0.015	0.034	0.048	129,691.67	239,683.33	367,733.33	77.49	1.31	78.80	21.67	42.52	64.19	142.99	24.625	55.81666667	78.8
	53-4	Research/ Instituional		0.00		169	103	272	68.5	2.4	13.4	31.6	115.9	0.032	0.024	0.056	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	Subtotal			**47,300.00**													**4,512,891.67**	**4,622,883.33**	**9,134,133.33**	**2,209.73**	**348.32**	**2,558.05**	**382.37**	**846.11**	**1,228.48**	**3,786.52**	**846.48**	**1,060.30**	**1,905.13**
L	54-1	Residential		91,316.67		96	96	192	46.7	7.6	7.9	17.6	79.8	0.018	0.022	0.04	8,766,400.00	8,766,400.00	17,532,800.00	4,264.49	694.01	4,958.50	721.40	1,607.17	2,328.58	7,287.07	1643.7	2008.966667	3652.666667
	54-2	Office		0.00		77	115	192	59.4	1	11.6	28.8	100.8	0.015	0.026	0.041	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	54-3	Retail	31,533.3	3,283.33	3.0	79	146	224	47.2	0.8	13.2	25.9	87.1	0.015	0.034	0.048	259,383.33	479,366.67	735,466.67	154.97	2.63	157.60	43.34	85.04	128.38	285.98	49.25	111.6333333	157.6
	54-4	Research/ Instituional		0.00		169	103	272	68.5	2.4	13.4	31.6	115.9	0.032	0.024	0.056	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
	Subtotal			**94,600.00**													**9,025,783.33**	**9,245,766.67**	**18,268,266.67**	**4,419.46**	**696.63**	**5,116.10**	**764.74**	**1,692.21**	**2,456.95**	**7,573.05**	**1,692.95**	**2,120.60**	**3,810.27**
	TOTAL		**47,300.0**	**141,900.00**													**13,538,675.00**	**13,868,650.00**	**27,402,400.00**	**6,629.19**	**1,044.95**	**7,674.14**	**1,147.11**	**2,538.32**	**3,685.43**	**11,359.57**	**2,539.43**	**3,180.90**	**5,715.40**
TOTAL/ AVERAGE			**1,074,900.0**	**1,424,550.00**	**2.3**	**105.25**	**115**	**220**	**55.45**	**2.95**	**11.525**	**25.975**	**95.9**	**0.02**	**0.0265**	**0.04625**	**145,338,151.00**	**149,397,694.00**	**294,642,080.00**	**75,768.71**	**6,799.16**	**82,567.87**	**14,236.98**	**32,775.58**	**47,012.56**	**129,580.43**	**27,527.78**	**34,258.78**	**61,692.80**

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