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The Importance of District Energy in Building Resilient Cities

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ABSTRACT

Canadian families need energy to heat and cool their homes, offices, commercial, industrial and community recreational spaces. In 2010, the average Canadian home consumed 67% of its total energy for space heating.[1] Approximately one-half (53%)[2] of energy use in the industrial/commercial sectors is spent on space heating and cooling (i.e. thermal energy use). In aggregate, thermal energy use, mainly to cool and heat buildings, accounts for roughly one third of all energy consumed in the country. Becoming more efficient in the way that this energy is applied represents one of the highest impact ways to reduce energy consumption, and improve efficiency in Canada. This energy efficiency opportunity could be exploited through the application of District Energy thermal grid (DE) solutions. DE remains largely unexplored in Canada due to the unregulated market structure to which DE belongs. However, there are many reasons for Canada's current interest in the DE thermal network, most of all, its potential for energy efficiency gains and its ripple social and economic effects. The large potential for community-scale DE solutions to contribute to Canada's aspiration of becoming an energy superpower is largely untapped.

Nearly all the energy for space heating needs is now met by extremely high-grade energy sources (i.e., electricity, natural gas, oil). It is not efficient to be using a high-grade energy resource that burns at several hundred degrees Celsius in order to maintain a room or building between 20-23 degrees Celsius. Better to apply such energy forms for high-grade uses, such as running an elevator or operating a stove.

In most cases, individual home owners and businesses cannot avail themselves of local fuel resources, or waste heat resources. The application of DE solutions can facilitate the matching of lower quality energy sources to the job of meeting the heating and cooling requirements of communities across Canada. This makes the building of DE solutions an essential addition to the existing community energy

[1] The average Canadian household consumed 106 GJ of energy for use in the home in 2007 of which over 60% is used for space heating and cooling. http://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/showTable.cfm?type=CP&sector=res&juris=ca&rn=2&page=4&CFID=31395328&CFTOKEN=87e6577a24457d03-1C383035-9A93-A2DC-CF24BB81198976A6 and http://oee.nrcan.gc.ca/publications/statistics/sheu-summary07/space-heating.cfm

[2] Figure 4.3, "Energy Efficiency Trends in Canada 1990-2009", Natural Resources Canada, December 2011 http://oee.nrcan.gc.ca/publications/statistics/trends11/pdf/trends.pdf

infrastructure arsenal, and one worthy of engineers" and city planners" attention.

To accelerate DE implementation, Canada should take the opportunity to learn from, and catch up to, world-class DE leaders such as Denmark. The people of Denmark have enjoyed tremendous success in achieving energy savings through the construction of thermal grid networks throughout the country. Denmark is a particularly interesting case study because its weather climate conditions are comparable to much of Canada's climate. Many Canadian cities face some of the same energy challenges as experienced in Copenhagen, so understanding how these challenges were successfully overcome is instructive. In this chapter, the Danish approach of using DE solutions to heat and cool buildings is also examined to illustrate what is possible in our largest Canadian metropolis, the City of Toronto, and even more broadly, the Province of Ontario.

In jurisdictions such as Denmark, Sweden and Austria where DE implementation has been successful, this success has been supported and enabled by consistent political vision, legislation, regulation, and fiscal incentives. With the exception of British Columbia, and a few municipalities, Canada has not embraced this approach. Canada needs to change its approach and focus more on local energy planning, by ensuring at all levels of government, that:

1. A long-term thermal energy policy is established.
2. All levels of government adopt, or adhere to, legislation that includes thermal and electrical energy efficiency as key considerations in land use planning.
3. Supportive fiscal legislation and tools are put in place to help municipalities establish a DE network.
4. Supportive local building policies are in place to enable DE within communities.

Political leadership is needed to apply these tools and invest in Canada's vision of becoming a sustainable energy superpower.

Introduction

Every region of Canada has a rich history of constructing massive infrastructure projects to serve the energy needs of a relatively dispersed population over large and challenging geographic areas. There is little doubt that engineers in this country have added immense value to the capture, extraction, conversion and delivery of an abundance of natural energy resources. Indeed, the ability to extract, convert and transport these resources over large distances, efficiently and effectively, has been at the root of Canada's wealth.

Looking forward, many parts of Canada are considering large transformational energy supply projects. Aging energy infrastructure, rising energy prices, increasing urbanization, changing wealth patterns, and continued concerns regarding the building of new large energy infrastructure are driving changes to the country's energy planning environment. Engineers and planners can also work together to consider large, paradigm-shifting energy-use projects at the city and/or local community level. Long-term energy security and resilience requires that local resource stewardship be given much closer attention.

Municipalities are at the front lines of this transformation. There is an opportunity for city builders to endorse and/or invest in efficient municipal energy infrastructure, such as DE systems. These systems would facilitate efficiency and reduce community dependence on any one fuel source.

Local Resource Stewardship: The Case for DE

If Canada is to become a sustainable energy superpower, Canadian cities will need to be as focused on resource stewardship[3] and efficient management as they are on resource extraction and transport. Since municipal powers and energy policy are provincial matters, this will require that each province and local authority carefully consider community thermal energy needs, and enable the building of DE systems[4] to efficiently supply energy to meet those needs.

This approach has significant co-benefits. Reducing local consumption means that provinces with capacity to export energy will increase their export capacity and diversify their revenue

Toronto, Ontario

[3] Stewardship is used in this chapter to refer to the responsible planning and management of energy resources.

[4] In this paper, DE systems are also referred to as thermal grids, integrated local energy systems, and can include thermal recovery systems, small scale Combined Heat & Power (CHP) units and thermal storage.

sources. For provinces that are net importers of energy, the benefits will be even larger. These provinces need to be particularly strategic in managing their energy given that their energy deficits make them especially vulnerable to energy supply interruption, including severe weather and man-made supply events. For all Canadians, a renewed focus on energy stewardship ensures that the needs of future generations will be met in a more cost-effective and resource-responsible manner.

DE as an Integral Part of Community Energy Solutions

In 2010, the average Canadian home consumed 67% of its total energy for space heating.[5] If Canadians are serious about conserving energy, space heating is an obvious place to start.

While heating has broad potential across many Canadian towns and cities, District Cooling (DC) is attractive in areas of high density with peaking summer energy needs due to hot weather (e.g., the corridor between Windsor and the Greater Toronto Area). This opportunity is also sizeable. The "sub-region" of Toronto, which makes up about 49 percent of Ontario's population and over 19 percent of Canada's population, offers wide scope for DE implementation.[6] In addition to space air conditioning, DC is also attractive for process cooling applications such as data centres and for institutional applications such as in hospitals.[7]

In general, DC has economic challenges in that chilled water technology is more capital intensive than heating equipment.[8] Cooling pipes need to be large because of the relatively small temperature differences between supply and return water. It is for this reason that many DE Systems begin by laying a thermal grid foundation to supply heating in communities, and provided the density and cooling needs are present, these systems can evolve to offer cooling and electricity supply.

What is District Energy?

Distric Energy is a foundation for integrated community energy solutions that can optimize local fuel choices. DE is not new, and it is not a single technology. Rather, it is a network that deploys and integrates proven technologies in community-scale infrastructure to produce and distribute thermal energy. As an approach to community energy production and delivery, it is tried and tested, and widely deployed in many parts of Northern Europe.

DE is also being evaluated and implemented widely in select parts of this country. British Columbia (BC) is currently the most active Canadian market, driven largely by environmental legislation which has its foundations in efficient resource management and climate change mitigation. In BC, as in other parts of the country, DE has become an important component of sustainability plans allowing communities to achieve energy goals, environmental objectives and further economic competitiveness. DE implementation has often been facilitated by supportive land-use planning and building approaches.

A District Energy System (DES) is typically comprised of three components – an Energy Centre (EC), a thermal grid referred to as the Distribution Piping System (DPS), and the building Energy Transfer Station (ETS). Thermal energy (heating or cooling) is produced

[5] The average Canadian household consumed 106 GJ of energy for use in the home in 2007of which over 60% is used for space heating and cooling. http://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/showTable.cfm?type=CP&sector=res&juris=ca&rn=2&page=4&CFID=31395328&CFTOKEN=87e6577a24457d03-1C383035-9A93-A2DC-CF24BB81198976A6 and http://oee.nrcan.gc.ca/publications/statistics/sheu-summary07/space-heating.cfm

[6] http://www.canadafaq.ca/where+do+most+canadians+live/.

[7] Later in this chapter, the City of Toronto's DC system is considered which capitalizes on Lake Ontario's ("free") cool water supply to "fuel" the system. DC is also employed in Ottawa's Parliament Hill which makes use of natural cooling from the Ottawa River.

[8] The proportional split in costs between cooling and heating in combined heating and cooling DE systems is roughly 65/35 between cooling and heating costs.

at the central plant, the energy is then carried down through the DPS (usually steam, hot water, or chilled water), and exchanged at the building's ETS interface. DE systems have the capability to deliver heating and cooling to customers and to capture waste heat from buildings (i.e. data centres, treatment plants, etc.) and use that heat to produce needed thermal energy via a closed loop system.

Energy Centres

The EC is the source of thermal energy in a DES. Given that this thermal energy is transmitted to end users using water (or steam in legacy systems) as a medium, multiple fuel feedstock materials can be used to generate the thermal energy. These feedstocks can take many forms, including natural gas, biomass, solar, deep lake water, geothermal energy, thermal storage facilities and waste heat from adjacent industrial or commercial processes.

Having the thermal grid in place provides scale and scope, and allows communities to heat and cool their buildings by any fuel source, on a mass scale. A built-out thermal grid network, such as that which exists in Denmark and throughout many other European countries, has enabled the wide-scale use of renewables, in particular low-temperature district heating (e.g. solar heating, geothermal), which would not be possible with individual heating systems. The EC grid fortifies a community's energy security, and can reduce GHG emissions and fossil fuel consumption when combined with lower emitting feedstocks, and/or by substituting technologies over time as alternative fuels become more abundant, or as technology advances. Due to the design of a DES, rather than retrofitting thousands of homes, only a small number of centralized plants require updates to achieve widespread community benefits.

A DES also reduces communities' dependence on any one fuel, and allows them to respond to energy price and supply fluctuations over time. This is precisely what happened in Northern Europe after the oil shock of the 1970s, when countries such as Denmark, Sweden, Finland and Austria invested heavily in DE infrastructure.

Although the vast majority of thermal heating in Canada still comes from traditional fossil fuel sources, Canadians have experimented with renewable sources of energy in the DE systems that are in place.

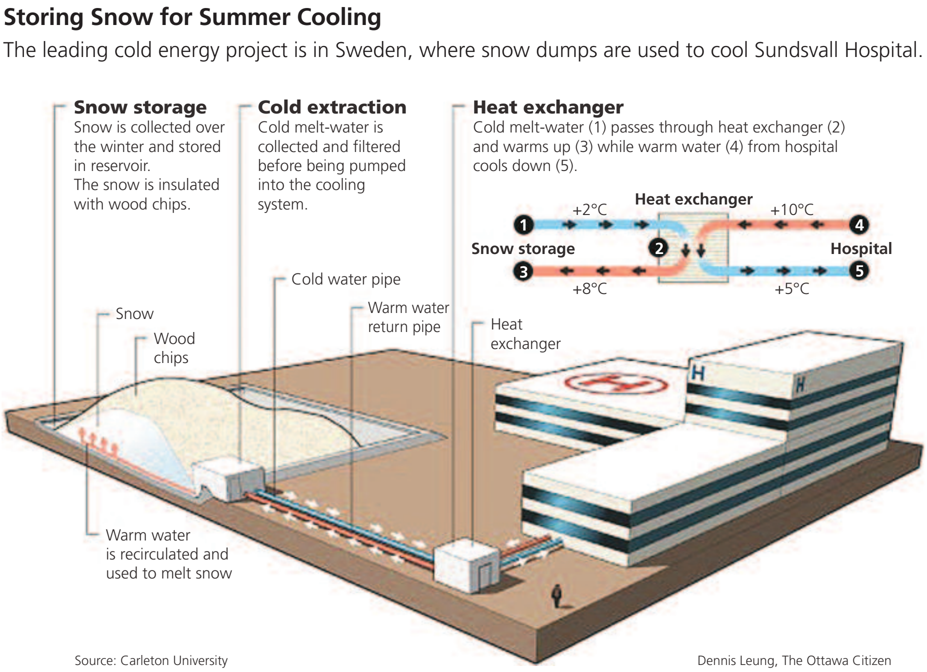
The Drake's Landing Solar Community is a master planned community in Okotoks, Alberta that uses solar as its primary source of heating for the DES. Ninety percent of space heating needs at Drake's Landing are met by solar thermal power. Relative to a "conventional approach" to development which relies on individual heating technology, and fossil fuels, Drake's Lading solar thermal community achieves a reduction of 5 tonnes of GHG per home every year.[9]

Other Canadian communities, like Revelstoke and Prince George, British Columbia, have turned sawmills into thermal energy sources. Waste from the mill is burned for electricity, and the thermal energy is recovered as "waste heat" which is used to heat buildings in the communities. In both of these cases, the EC is on the sawmill site and thermal energy is piped to the community. Using a similar line of thinking, Vancouver and Halifax have sewage heat recovery systems that take waste heat (ultimately a "free" fuel resource) from the city sewage system. Ouje-Bougoumou, Quebec uses forest biomass; and Charlottetown, PEI uses municipal solid waste and biomass to fuel their DE systems.

[9] http://www.dlsc.ca/

Figure 1
Schematic of Snow Cooling in Sundsvall

Image courtesy of IEA



Other countries, with more pervasive thermal grid infrastructure, have advanced even further in the stewardship and application of local resources to meet the energy needs of large populations in an economic manner. Sundsvall Hospital[10] in Sweden highlights the ingenuity of DE systems operating on locally available resources. The hospital uses the piles of snow shovelled from roads throughout winter as a source of cooling in the summer. The snow piles are thermally insulated by woodchips and the melt water is collected, filtered, and pumped into the cooling system. Environmental concerns continue to serve as important additional drivers in Danish policy, which motivated changes in the fuels used in the generation of thermal energy over time. The Danish thermal grid now relies heavily on both recycled heat sources that otherwise would be wasted (including surplus heat from electricity production (i.e., Combined Heat and Power systems - CHP), waste-to-energy plants, and industrial processes), and renewable heat sources (including forest-based biomass, geo-exchange, solar, wind and biogas). By utilizing surplus heat from industry and various renewable sources, the consumption of primary energy resources is reduced. By 2006, Denmark achieved energy self sufficiency, with CHP units delivering 47% of thermal electricity needs and 82% of District Heating needs.[11] Today, 98% of Copenhagen's population is served by DE systems that are fuelled by waste and renewable sources.

These are just a few examples of how other communities and countries are meeting their energy needs in a manner that reflects principles of stewardship, economic responsibility and innovation.

Distribution Piping System (DPS): The Thermal Grid

A DPS is a network of piping that brings hot water, steam, or chilled water from a centralized plant to a cluster of buildings. Distribution piping used in the Markham District Energy System can be seen in Figure 2. The buildings in turn use this heating/cooling source to meet the needs for space heating, cooling, or domestic hot water. It is analogous to the electricity transmission and distribution wires in an electricity grid. Akin to this grid (as discussed above),

[10] Image Courtesy of IEA: IEA, CHP/DHC Country Scorecard: Denmark, 2008 at http://www.iea.org/g8/chp/profiles/denmark.pdf.

[11] IEA, CHP/DHC Country Scorecard: Denmark, 2008 at http://www.iea.org/g8/chp/profiles/denmark.pdf.

Figure 2
District Energy Pipes in Markham, Ontario

Image courtesy of FVB Energy

multiple feedstocks can be used to create the energy that it transmits. It is typically the costliest part of the DES infrastructure; however, it is a critical component that links the central plant to its customer base. Where dense, more compact communities are planned, there are even more opportunities for efficiencies and cost savings in the building of this "thermal grid."

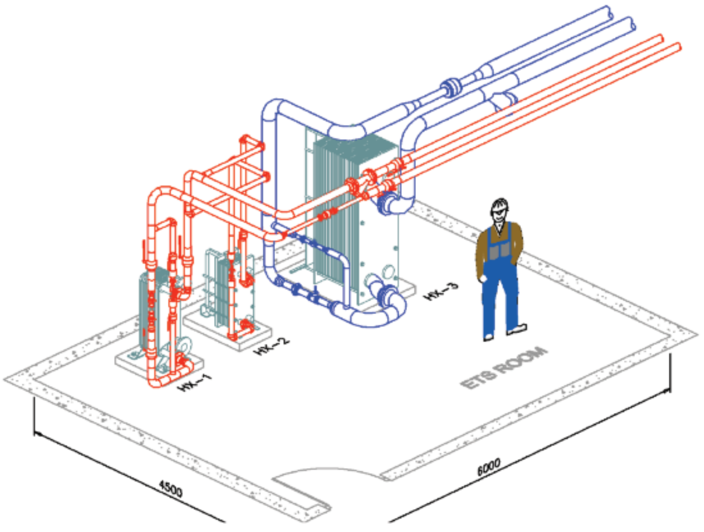
Like other municipal infrastructure, such as water and sewage, the DPS is usually underground (but can be above ground where permafrost is an issue) and will last a very long time. Canada's oldest steam system is in London, Ontario dating back over 100 years.

Energy Transfer Stations (ETS)

The ETS is the interface between the DPS and the building HVAC system.[12] Figure 3 depicts a typical ETS configuration. Buildings are connected to the central plant via underground pipes, and as water enters the system it interfaces with the building's Heat Exchanger (HX) sending ambient water back to the EC.

Figure 3
Typical ETS Configuration

Image courtesy of FVB Energy



[12] Though there is the possibility of a direct connection where the same water in the DPS runs through the building, it increases the chances of fouling the water amid other complications. Most DE system operators prefer that the DPS remain a closed system that simply interfaces with the building's system via the heat exchanger.

Benefits of District Energy: Delivering Value to Canadian Communities

Efficiency

Traditional energy delivery systems operate at much lower efficiencies than modern district energy systems. The efficiency of fossil-fuelled electricity generating plants is typically between 30 - 45%.[13] This means that nearly two-thirds of the energy produced during combustion at large centralized power stations is rejected into the atmosphere as "waste" heat during production.

Once the DE grid is installed, energy efficiencies can be further enhanced through the addition of "ancillary infrastructure", such as small-scale Combined Heat and Power (CHP),[14] which enables electricity to be generated closer to densely populated areas, with the rejected "waste heat" from the CHP system captured to heat buildings through closed-loop heat networks.[15] DES with CHP can achieve system efficiencies of 80% or more by the co-production of thermal and electrical energy. Efficiency gains are increased due to shorter transmission lines than associated with large-scale systems.[16] The reduced fuel consumption also results in commensurate reductions in carbon emissions.

The addition of thermal energy storage units can further optimize operating efficiencies, as can the use of proximate wasted heat from buildings and industry. Manufacturing processes often produce heat as a by-product. This heat is most commonly rejected into the atmosphere. Large-scale commercial applications, such as data centres, similarly produce rejected heat. A thermal grid would allow recovery of that heat which would otherwise be vented into the atmosphere, and the simultaneous delivery of cooler water to the manufacturing facility.

The City of Markham's DE systems have both CHP and thermal storage, achieving a 50% reduction in GHG emissions relative to business-as-usual practices.

There is a growing range of evidence that the wider development of small-scale CHP in association with DE infrastructure is a cost-effective means of accomplishing energy efficiency and GHG reduction goals in the near term. The US Environmental Protection Agency CHP Partnership in 2008 supported the installation of 335 CHP plants stating that this also achieved CO_2 emission reductions equivalent to taking 2 million cars off the road, or planting 2.4 million acres of forest.[18] Furthermore, in a study to assess the cost abatement policies in the Netherlands, CHP was identified as one of the least cost solutions, lower than building insulation, condensing boilers and wind power (Boonekamp et al, 2004).[18] In a 2013 study t o compare the cost-effectiveness of alternative strategies to reduce GHG emissions in Ontario, a 5 MW natural gas CHP facility was seen as four times less costly (capital dollars per GHG emission tonnes avoided) than a 250 kw Solar PV facility.[19]

When considering the efficiencies of DE/CHP systems, and the proportion of end-use energy consumption associated with space heating and cooling, the benefits of DE systems becomes apparent.[20]

[13] Gilmour, B., & Warren, J. (2008, January). The New District Energy: Building Block for Sustainable Community Development. Canadian District Energy Association. Toronto: Urban Energy Solutions. p. 20.

[14] Combined Heat and Power (CHP) burns a fuel (often natural gas but could easily be biofuel or solid waste) to produce electricity. This process is very heat intensive and requires the entire system to be cooled. This "rejected heat" can be put into the DE system and sent down the pipes to heat homes and offices rather than be vented to the atmosphere and wasted while having these other buildings burn their own natural gas for heat.

[15] King, M., & Shaw, R. (2010). Community Energy: Planning, Development and Delivery. Retrieved November 2012, from http://www.tcpa.org.uk/data/files/comm_energy_plandevdel.pdf, p. 2

[16] Gilmour, B., & Warren, J. (2008, January). The New District Energy: Building Block for Sustainable Community Development. Canadian District Energy Association. Toronto : Urban Energy Solutions. p. 20.

[17] International Energy Agency, Cogeneration and District Energy, 2009, p. 15

[18] Ibid.

[19] Remarks delivered at October 29, 2013 Combined Heat and Power Workshop by Bruce Ander, CEO, Markham District Energy.

[20] Natural Resources Canada. (2012, May 29). Science and Technology: The ecoENERGY Innovation Initiative. Retrieved April 1, 2013, from http://www.nrcan.gc.ca/energy/science/2003

Assigning the "Right Energy to the Work"

DE systems can play a key role in Canada's reduction of high grade energy use. For example, the energy required to heat a room or a building in winter is of lower quality than the electricity needed to bring a kitchen oven to 250 degrees Celsius. Electricity is the highest quality form of energy, and using it for space heating or cooling means taking energy that can maintain a stove operating at a couple hundred degrees and using it to maintain room temperature around 22 degrees Celsius. This is not an efficient use of high-grade energy. Optimizing energy entails using the right tool for a given job. In order to gain maximum efficiency, energy systems should be designed to address the demand for specific energy uses.

The economics of implementing the building infrastructure necessary to use "free" (or residual) waste heat or cooling would be very challenging. For example, it would be very difficult and expensive to run a pipe from a nearby lake to take advantage of the lake as a massive heat sink if it were only to service one building. With a DES however, only one point of heat exchange needs to be built and the entire community can take advantage of a relatively low cost source of heating or cooling.

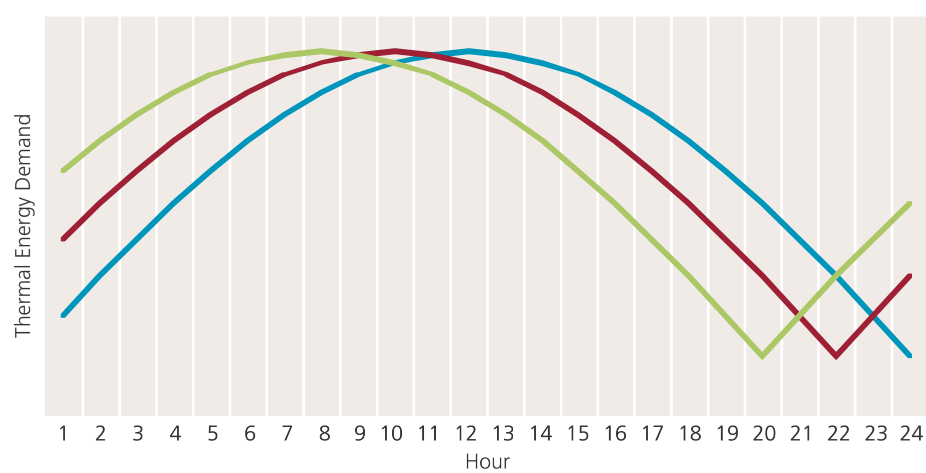
Energy stewardship means allocating electricity, one of the highest forms of energy, to appropriate uses. A DES enables beneficial use of surplus thermal energy from dispersed sources allowing us to tap into lower grade energy to condition a room or a building. Designing cities in a way that optimizes the use of waste heat can foster conditions wherein the overall need for energy is reduced and the "right energy is assigned to do the appropriate work."

Hitting the Sweet Spot

DE systems also take advantage of hitting a boiler and chillers' "sweet spot" or, in other words, operating efficiency.[21] This arises because there is a higher likelihood of equipment in a DES operating in the optimal efficiency range compared to stand-alone buildings. The lines in Figure 4 are meant to be illustrative of thermal energy load profiles of three buildings or institutions over a 24-hour period. Since different buildings will hit their peak loads at slightly different times, an integrated DE system is able to operate at a more consistent level, and closer to optimal efficiency, by tracking and managing the portfolio of building needs.

Peak energy use usually occurs only a few times a year for both heating and cooling – on the coldest and hottest days of the year, or of a multiple-year period. However, buildings are fitted

Figure 4
Conceptual Illustration of Staggered Loads with Three Hypothetical Buildings



[21] The City of Toronto's study of DE potential acknowledged the inherent inefficiency of the "Business As Usual" conventional build-out approach, in their 2010 Genivar study, and that this approach would cause them to miss their GHG targets. "While each type of building has different electrical and thermal load profiles, the heating and chilling equipment is generally sized to the ASHRAE 99% weather data for maximum rating and equipment selection of the facility – which is only needed for 1% of the year. For the balance of the year, the oversized conventional equipment typically operates in less efficient High – Low – Off mode. Hence, for example, boilers with performance datasheets quoting +80% efficiency (at peak load) are frequently only achieving 60 to 65% efficiency over the year. This is analogous to operating a car under stop and go city conditions. This is termed seasonal efficiency and is reflective of significant diversity of energy load through the day and the seasons.... it is agreed that continued development in BAU protocol will miss the 2050 GHG Target Emission Level by 14 Mega tonnes per year." Genivar, Potential District Energy Scan in the City of Toronto, September 2012 (http://bbptoronto.ca/wp-content/uploads/2012/06/FINAL-GENIVAR-Report-City-of-Toronto-District-Energy-September-4-12.pdf) , p. 10

New York: Where the Lights Stayed On

Unprecedented in its size and affecting 21 states, the total estimated cost of the impact of Sandy's wrath was over $70 billion. During Hurricane Sandy, it took days – and sometimes weeks – for utility workers to restore electric services across large swaths of New England and the Mid-Atlantic region, including New York City. Indeed, 8.5 million customers lost power during Sandy. Understanding where the lights stayed on during Sandy might provide valuable lessons to city leaders looking to mitigate the effects of increasingly frequent severe weather events. For example, in Co-op City, a 40 MW CHP/DE system continued to provide lights for more than 60,000 residents during and after Sandy's gale force winds and storm surge. And it wasn't just Co-Op City residents. For four days, the CHP system provided the 290 units in this Manhattan residential complex with all its heating, water, and electrical needs, including elevators, until the grid was back up. Though typically home to about 720 residents, the building nearly doubled its population after Sandy as those without power sought refuge among friends and family who lived there. Contrast that with New York City's public housing facilities, which are often well-suited for CHP, where residents went up to two weeks without electricity and over 15,000 of them were still dealing with no heat or hot water well after that. In the same way, a small number of other facilities – including hospitals, universities, and public service facilities – kept their power, heat, and critical equipment running.

Source: Drawn from American Council for an Energy Efficient Economy, December 6, 2012 "How CHP Stepped Up When the Power Went Out During Hurricane Sandy," By Anna Chittum, Senior Policy Analyst

http://www.aceee.org/blog/2012/12/how-chp-stepped-when-power-went-out-d; and "Lessons from where the Lights stayed on During Sandy," http://www.forbes.com/sites/williampentland/2012/10/31/where-the-lights-stayed-on-during-hurricane-sandy/

with systems that operate year-round to meet these peak needs. The advantage of the DES is that the boilers and chillers are aggregated in one place. In part-load conditions, the energy centre might only run two out of five boilers, but will run both very efficiently. Moreover, aggregating customer loads across a community can serve to "level out" the demand curve by combining different customers with different peak and off-peak demand periods. This contributes to further optimization of equipment operation.

Resilience and Security

A thermal grid, with small-scale CHP, also increases the reliability of the electricity generating system. Given trends in urban population growth, it is likely that future electricity supply facilities will need to be built to maintain electricity supply reliability (particularly at peak load times), and operate in targeted urban and electricity system-constrained areas.

DE systems can be built so that they can be "isolated" from the main electricity grid — continuing to provide thermal and electrical services to critical loads.

The experience of some New Yorkers during the 2012 Hurricane Sandy illustrates the immediate benefit that a DES brings to provide backup supply security, islanding capacity and such important services as black-start capability. During the hurricane, CHP/DE systems played an important role in providing local resilience in the face of worsening weather and grid outages caused by climate and man-made supply crises. This mitigated communities" vulnerability to the failure of grids that transmit power over long distances.

In late December 2013, the Toronto region experienced a record ice storm. Hundreds of thousands were without power for days and, in some cases, more than a week. Several deaths have been attributed to this ice storm as people desperate for heating brought outdoor devices inside the home, causing carbon monoxide poisoning.[22] The DES with CHP facility operating in Markham, Ontario had the ability to continue to provide power and heat to critical customers throughout this event (15 centres, and approximately 5 million square feet).[23]

Fuel Flexibility

DE systems offer the flexibility of fuel choice and upgrades over time, allowing Canadians to more easily modify the type of heating fuel used for space heating. Although the economics of renewable fuels may be questionable at the moment, given the low price of natural gas, future

[22] http://www.cbc.ca/news/canada/ice-storm-makes-christmas-a-dark-day-for-tens-of-thousands-1.2476164

[23] Conversation with Bruce Ander, President and CEO, Markham District Energy. The Markham DES capability was available, but never used, as the City did not officially declare a state of emergency during the 2013 Ice Storm.

prices are unpredictable. DE systems enable whole communities to switch from their individual natural gas furnaces to whatever heating source is available with minimal retrofits.

GHG Reduction

Energy plays a critical role in the quest to adapt, mitigate and reverse the impacts of climate change at a community level. According to a study released by the United Nations Human Settlements Programme (2010), 75% of commercial energy is consumed in urban and semi-urban areas. In addition, up to 60% of GHG emissions, which cause global climate change, originate from cities.[24] Nandi and Bose estimate that 70% of the global population will live in cities by the year 2050, further amplifying the strain placed on municipalities to provide energy services.[25] Interestingly, the International Energy Agency estimates that the proportion of global energy consumed in cities is greater than the proportion of the world's population living in cities – thus signalling that intervention is needed to reverse this trend.[26]

Considering the extent to which cities consume energy,[27] and the rate at which urbanization is taking place, reducing energy consumption in cities will be of paramount importance to combating climate change The way cities are planned and local energy systems are built has enormous potential to affect the efficiency with which energy is used, the type of local convertible fuels used (from proximate water or snow, to urban biomass and municipal solid waste), and the resulting quantity of GHG emissions.

A DES allows for optimized local fuel choices and increases the efficiency with which those fuels are converted to useful energy. Many DE systems in both Europe and Canada make use of local biomass materials (e.g., forest-based wood, urban-based forest materials, clean construction waste, etc.) to generate heat for their communities. In Europe, the use of municipal solid waste to generate heat is commonplace. Sophisticated systems, with advanced emission-mitigation technologies, are viewed as a sensible "closed system" approach to sustainability.

Economic Benefits

Communities can reap economic benefits from DES implementation, thereby providing the opportunity for local investment, jobs, and creation of local fuel resource supply chain development (e.g., urban forest biomass or clean construction wood waste).

Research undertaken in 2011[28] by Natural Resources Canada into the quantification of socio-economic benefits associated with DE investment in several Canadian communities indicated that there are positive economic multiplier effects for the dollars invested in terms of jobs and commercial activity. Using the District Energy Economic Model (DEEM),[29] the City of Markham was one of four systems studied. The DEEM results for Markham, although preliminary, indicate positive net economic benefits from local energy infrastructure investment, with every dollar invested by Markham in their DES generating economic impacts equal to $1.37 (i.e., GDP, tax base, wages). This does not include any return on equity of the DE investment itself.[30] A recent study of the City of Toronto also documented the potential economic benefits of district energy to that city.[31]

[24] El Sioufi, M. (2010). Climate Change and Sustainable Cities: Major Challenges Facing Cities and Urban Settlements in the Coming Decades, p. 5. UN-HABITAT, United Nations Human Settlements Programme. International Federation of Surveyors, p. 5

[25] Nandi, S. & Bose, R.K (2010). The Imperative of Efficient Energy Use in Cities: Analytical Approaches and Good Practices. In Bose, R.K. (Eds.), Energy Efficient Cities: Assessment Tools and Benchmarking Practices(pp. 1-20). Retrieved from http://www.esmap.org/node/271

[26] International Energy Agency. (2008). World Energy Outlook 2008. Retrieved February 7, 2013, from http://www.worldenergyoutlook.org/media/weowebsite/2008-1994/weo2008.pdf

[27] In 2006, the global primary energy use in cities was 7,900 Mtoe (million tonnes oil equivalent), or 67% of global demand; however, global city energy use is projected to grow by 1.9% per year, and make up 73% of global demand by 2030 (International Energy Agency, 2008, pp. 182, 184). Therefore, urban areas will continue to increase in importance as strategies for mitigating climate change are developed. Reducing urban energy demand and implementing local embedded energy solutions including district energy and distributed generation technologies must be a component of these strategies if climate change goals are to be realized. This positions our cities at the crux of the climate challenge where solutions to critical energy issues will have most significant impacts. Municipalities generally cannot adequately meet these complex challenges on their own.

[28] This pilot research is not yet publicly available.

[29] Bruce Ander, President and CEO, Markham District Energy, Presentation to QUEST Conference, November 12, 2013

[30] Bruce Ander, President and CEO, Markham District Energy, Presentation to QUEST Conference, November 12, 2013.

[31] Beck, T. et al. (2012). The Power to Grow: The Economic and Fiscal Benefits of Urban Development Facilitated by Local Generation, District Energy, and Conservation in an Electrically Constrained Scenario. University of Toronto Masters paper, prepared for the City of Toronto, Energy Efficiency Office and Department of Economic Development & Culture. Toronto.

Learning from DE Leaders

Denmark & Copenhagen

In just a few decades, Denmark has become a world leader in District Energy solutions. Its success story is based on a package of policies that evolved after the first Heat Supply Law was introduced in 1979, followed by a ban on electrical heating in buildings (1988), and national financial incentives to ensure the ongoing economic viability of CHP/DE.

The strategy was adopted as a result of the oil crisis that Denmark faced during the 1970s, at a time when more than 90% of Danish energy was met by oil imports. The energy crises of 1973 and 1979 resulted in long-term increases in energy prices and a heightened awareness for enhanced fuel flexibility. Emphasis was placed on having more secure energy supply and more efficient generation and use of energy, making CHP/DE a natural, competitive choice.[32]

The 1979 law required municipalities to carry out studies on their future needs for heating, and on the potential for district heating (DH) in their jurisdictions. It also allowed for the zoning of DH networks to replace individual oil boilers. Crucially, the expanded provision of DH was supported by a new power for local authorities to require households to connect to the networks.[33] The law created a clear strategic goal, and relied on strong local and municipal participation. Sharing responsibility and involving local authorities in this national planning process has been an effective way of creating an efficient heating network in Denmark.

A new planning system launched in 1990 mandated local authorities to convert DE providers to CHP providers. DE and CHP played a critical role in reducing Copenhagen's carbon footprint and securing fuel supply, primarily using local energy resources as feedstock. Power plants run as CHP stations where the steam is extracted from a turbine to heat water for large scale DH networks. Fiscal measures related to specific fuels have resulted in 35% of the CHP plant fuelled by surplus heat from waste incineration, and the remaining production of district heating is based on geothermal energy and fuels such as wood pellets, straw, straw pellets, natural gas, oil and coal.

Environmental concerns have been addressed by the ability to switch feedstock to lower emission fuels, and the addition of CHP.

More recently, the Danes have further benefitted by the synergistic opportunity of a holistic energy approach—one that realizes the value integrating their thermal planning more broadly with electricity planning. This has arisen because electricity system changes developed in isolation have resulted in a significant and increasing amount of intermittent electricity produced by wind. Rather than exporting surplus base load generation at a loss, at times when there is surplus (and non-dispatchable) renewable electricity available, the Danes are seeking integrative solutions to utilize the surplus electricity within the country by using the surplus to power heat pumps in DE systems using geo-exchange technology. The Danish investment in a geographically significant thermal grid has become a crucial part of the energy infrastructure, enabling utilization of fluctuating renewable energy sources.[34]

Denmark is a leader in DE/CHP, and it is important to learn from those who lead. The experience of Copenhagen illustrates the benefits to communities from utilizing DE/CHP to

[32] IEA, Cogeneration and District Energy, 2009, pp 18-19

[33] Danish Energy Authority, Heat Supply in Denmark Who What Where and Why, 2005, http://dbdh.dk/images/uploads/pdf-diverse/varmeforsyning%20i%20DK%20p%C3%A5%20engelsk.pdf

[34] Closer to home, this is not dissimilar to the Markham Ontario DE system, which is seen by the municipality as being their most strategic energy asset, facilitating their economic goals as well as meeting their energy and environmental goals. More detail on the Markham experience is contained below.

support local economic development, energy efficiency, energy security and resilience to unforeseen events.

Energy strategy is as much a city planning issue as a technical issue, and communities have been vital players in achieving greater scales of energy sustainability and increased economic value.

A Case Study: Applying the Danish Approach in the Province of Ontario

It is interesting to consider what would happen if Ontario followed the same path as other DE leaders and invested in building DE systems to salvage waste heat.

In Denmark, electricity generation facilities cannot be built unless a recipient for waste thermal energy is first identified for the waste heat. Closer to home, the City of Markham has been a leader in the deployment of DE in two growth nodes. As a result, since 2000, Markham District Energy has invested in four small-scale CHP units totalling 15 MW, and uses rejected heat to supply the thermal energy needs of its customers.

The province of Ontario could insert this requirement into energy policy, particularly with thermal generation stations that are built in proximity to communities. If Ontario were to recover all the "waste" heat generated by gas fired generators and use it for space heating purposes, the province could reduce its natural gas consumption by 4.6 billion cubic metres annually.[35] This is enough natural gas to heat 1.5 million Canadian homes[36] and is equivalent to reducing emissions by 864 Mega tonnes of CO2 annually.[37]

As illustrated in Figure 5,[38] Toronto is growing at an unprecedented rate and is leading in the construction of the most high-rise buildings in all of North America for 2012. The city is welcoming 178 high-rise construction projects, thereby further increasing the density of the city's built form and introducing a need to heat, cool and power a new stock of buildings.

Energy Challenges in the City of Toronto

Toronto, with a population of 2,615,060 (or 7.8% of Canada's population),[39] is already home to Canada's largest DES. The Enwave system currently keeps 200 downtown buildings air conditioned via a world-famous deep-lake water cooling system. As impressive as this system is, however, there has been remarkably little new investment in DE infrastructure over the last several decades despite Toronto facing growing energy challenges.

For Toronto, most of the energy supply is produced outside of the city, with approximately $4.5 billion spent on energy each year.[40] At the same time, the downtown core of Toronto is experiencing the highest growth rate in condominium development in North America. With industry moving out and condominiums moving in, population and energy intensification are predicted to continue. On average, two condo proposals add the equivalent of three 8000-person Ontario towns within a six block area.[41]

While demand for all types of energy is expected to increase in the city, the electrical capacity and reliability is of particular concern, especially in the downtown core which is supplied with electricity by just two transmission lines and one small central power plant.

[35] Electricity production data provided by the Ontario Independent Electricity System Operator. 28,750,000 MWH gas fired generation. 60% efficiency for combined cycle.

[36] Assuming that, on average, Canadians use 92 GJ of heating energy per household. http://www.statcan.gc.ca/pub/11-526-s/2010001/part-partie1-eng.htm

[37] Using emissions factor for Ontario http://www.ec.gc.ca/ges-ghg/default.asp?lang=En&n=AC2B7641-1

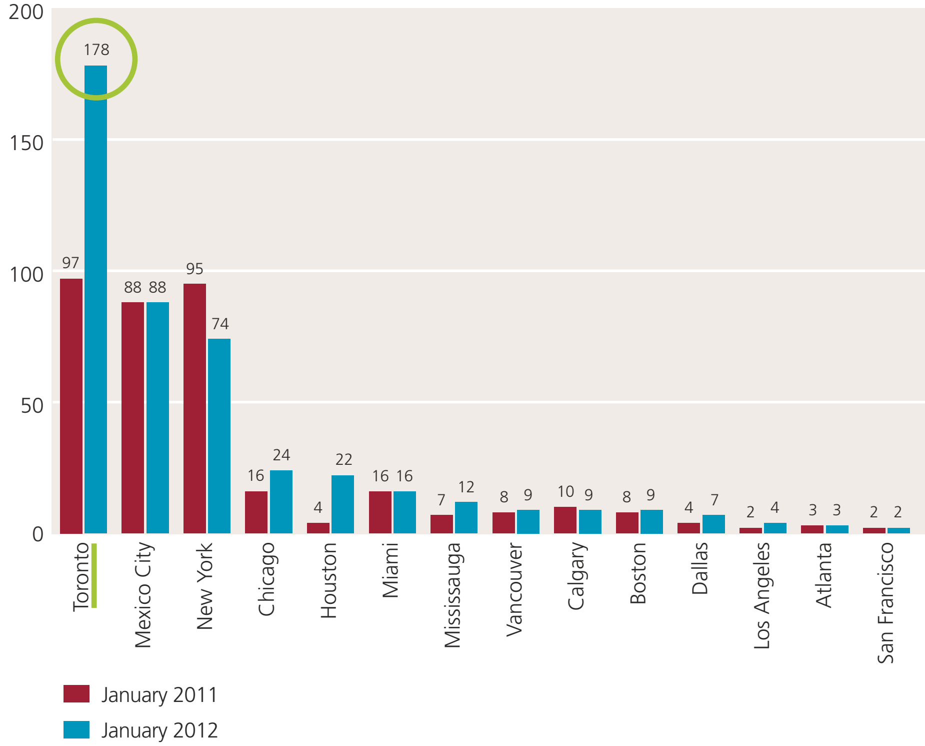
[38] Chart adapted from: Baxter, Jim, Director Environment and Energy Division, City of Toronto. "Energy Crunch in the City." QUEST Conference Presentation. November 13, 2013.

[39] Census Canada. (2012). 2011 Census: Population and Dwelling Counts. Retrieved from: http://www.toronto.ca/demographics/pdf/2011-census-backgrounder.pdf pp. 1

[40] Genivar, Potential District Energy Scan in the City of Toronto, September 2012 (http://bbptoronto.ca/wp-content/uploads/2012/06/FINAL-GENIVAR-Report-City-of-Toronto-District-Energy-September-4-12.pdf) , p. 3.

[41] Baxter, Jim, Director Environment and Energy Division, City of Toronto. "Energy Crunch in the City." QUEST Conference Presentation. November 13, 2013.

Figure 5
Bar Graph Depicting the Number of High-Rise Construction Projects in Major North American Cities



Electricity demand in downtown Toronto is approaching supply capacity, particularly at summer peaks, and fears of continued extreme weather events are growing. Adding large-scale generation and transmission infrastructure and even refurbishing or replacing aging electricity distribution infrastructure is difficult and expensive in the crowded right-of-way corridors of downtown Toronto. Large-scale refurbishment also often attracts significant community opposition.

Energy Savings Potential of Expanded District Cooling in Toronto

What would happen if Toronto followed the same path as Copenhagen and invested in building energy-saving thermal grids for District Heating and District Cooling in its growth nodes?

The Enwave system[42] in Toronto takes water from Lake Ontario in a deep part of the lakebed where the temperature is a constant 4 degrees Celsius year round. The cold water is used to pre chill Enwave's District Cooling system before being fed to the city's potable water system.[43]

The Enwave system is unusual in that it uses drinking water as the coolant. What would happen if Toronto decided to make a commitment to expand its use of the available cooling sources for all its space cooling needs? The city uses approximately 420 million litres of water daily. If the City expanded its system to use all of its potable water supply to extract thermal cooling energy, similar to Enwave's Deep Lake Water Cooling system, roughly 670,000 kWh of electricity per day could be reduced. This is equivalent to 121 million m3 of natural gas that could be conserved on an annual basis assuming 60% efficiency for combined cycle generation.[44]

[42] Enwave Energy Corporation, a private corporation owned by Brookfield Asset Management and formerly jointly owned by the City of Toronto municipal government and the Ontario Municipal Employees Retirement System, is one of the largest district energy systems in North America. Enwave was formed after the restructuring of the Toronto District Heating Corporation. Currently, 150 buildings in downtown Toronto are connected to the Enwave network.

[43] Cold water from the lake is passed through a heat exchanger to pre-chill the water being sent back from buildings before it re-enters the plant to be cooled and redistributed for space cooling purposes.

[44] Enwave is also evaluating options to expand the cooling capacity of their existing system through the use of underwater storage caverns.

Introduce a Long Term Thermal Energy Policy

Given the benefits of DE systems, it is important for Canadians to consider how DE implementation could be accelerated.

In jurisdictions where DE supplies a significant portion of the total heating and cooling needs, energy policy has explicitly included both thermal and electrical energy considerations and also included specific references to DE, with CHP. Public policy drivers have included: energy security; environmental issues; increased energy efficiency; and local economic development. Further, public policy goals are supported by enabling legislation, regulation and fiscal incentives to accelerate DE implementation. Left to itself, the market does not adequately recognize the broader public policy goals (i.e., energy prices do not adequately reflect long-term goals or externalities related to carbon).

There are many parallels between the public policy goals espoused in these other jurisdictions and those of most Canadian provinces with respect to environmental, economic and energy goals (e.g., Ontario's Green Energy and Economy Act, 2009).[45] Adding thermal policies in Canadian energy, environmental and land use planning legislation will allow provinces to accelerate the accomplishment of these goals.

Including Thermal and Electrical Energy as a Key Elements in Land-Use Planning Requirements

Land-use planning decisions guide the way cities look and grow. Most Canadian provinces lag behind leading jurisdictions in important land-use planning legislation. The political and practical decisions centre on shaping how and where our communities will grow, and have a direct impact on the social, economic and environmental performance of communities. Land-use planning is also considered a tool to curb sprawl as well as to support rational stewardship of resources by directing where residential, commercial, institutional, industrial, recreational and other infrastructure and essential services are located.

Municipalities are required to consider many types of essential infrastructure including water, transit, sewage, and recreational facilities, to ensure adequacy of supply to maximize the welfare of their citizens. Some provincial planning legislation considers certain kinds of electricity generation facilities. By adding thermal energy use and energy production in land-use legislation, land-use planning can also optimize the efficient use of local energy resources, including waste heat, in a way that increases energy efficiency, and reduces the draw on imported energy resources. Considering that thermal energy accounts for a significant portion of community energy needs, the lack of explicit thermal elements in land-use policies emerges as a startling gap that should be redressed through provincial legislation.

Supportive Fiscal Policy Regime

An investment in the Distribution Piping System (DPS) is capital-intensive with up-front expenditures yielding benefits over time as communities" thermal energy demands grow. Investment in thermal infrastructure is particularly challenging given the relative low price of competing alternatives, delivered through existing electricity and natural gas grid infrastructure. Unlike traditional energy delivery systems such as electrical systems with a

[45] In May 2009, the Ontario government passed the Green Energy and Economy Act ("GEA"), which further accelerated the implementation of renewable energy (i.e. electricity) and introduced the Feed-in Tariff program for renewable electricity generation. It was intended to expand renewable energy projects, promote a "green economy," and encourage all Ontarians to use energy efficiently. The GEA is best known for creating a number of feed-in tariff rates for different types of energy sources, and was focused exclusively on matters related to electricity. Prior to the introduction of the GEA, Ontario had enacted a number of different programs focused on electricity, introducing renewable energy or promoting conservation, including the Energy Conservation Leadership Act and the Energy Efficiency Act.

regulated rate base and recovery of incremental expenditures, there is no regulatory construct to support the up-front capital cost to transition communities to DE.

Many of the benefits of building DE grids are difficult to monetize for the municipal host (e.g., energy security, operating efficiency, economic development), and for many private sector investors, these benefits are irrelevant. Community resilience is becoming an increasing focus with every extreme weather event. Despite the benefit of greater local energy resilience, municipalities find it hard to fund capital to achieve the benefit. The private sector will not invest unless compensated for the incremental investment. Absent a carbon pricing regime, there is less financial motivation to migrate to non-conventional fuel sources. Without assured economic returns, DE projects will struggle to attract willing investors capable of bringing new DE projects forward. It will be difficult to attract large-scale investors, such as municipalities, utilities and pension funds capable of bearing the substantive up-front capital expenditures. If financing cannot be coordinated, developments will default to more conventional forms of energy delivery systems where long-term energy contracts and/or regulatory regimes provide revenue certainty, making financing easier.

It is for these reasons that public sector intervention has supported the growth of the DE industry in every jurisdiction in which it has grown. Fiscal incentives have taken the form of low interest loans, tax incentives, grants, and direct public investment.

A supportive fiscal framework will assist investors to overcome the fiscal challenge they face in building new thermal infrastructure. In the same way that Canadian electricity policy has been supported with appropriate fiscal policies, and executed through contracts and programs, DE/CHP systems need fiscal incentives or economic regulation. They are akin to other essential infrastructure.

Supportive Municipal Policies to Enable DE within Communities

Municipalities not only have the jurisdiction to drive a DE project, they also contribute to the longevity and success of a project. They have the authority to introduce progressive policy related to urban form, define growth nodes, determine areas and levels of density, and make developmental decisions with opportunities to blend residential, commercial, institutional, industrial or cultural uses through zoning bylaws.[46] All of these policy elements contribute to creating communities with the critical mass to support DE. Municipalities are responsible for local infrastructure, often own local utility companies, and are in a position to invest in DE projects, either directly or through a public/private partnership. Municipalities can facilitate DE through ensuring rights-of-way connections. They can also define DE areas where connection to an existing DH scheme is obligatory.[47] Municipalities have a key role in community consultation regarding energy options, communicating and positioning DE as a "green energy option" to key stakeholders. Municipalities can also influence developers to connect new builds to district energy or to incorporate community energy solutions through policy tools, moral suasion or by mandating connections.

For these reasons, provinces should support municipal planning tools to accelerate DE development. These planning tools have been used in many jurisdictions to great effect, positioning DE investment as a key part of essential municipal infrastructure, including:

[46] Compass Resource Management. (2010, July). Ontario Power Authority: District Energy Research Report. Retrieved October 2012, from http://www.powerauthority.on.ca/sites/default/files/news/16925_CRM_OPA_District_Energy_Research_Report_15July10.pdf.

[47] Such bylaws are in place in North Vancouver, Vancouver, Surrey and Richmond, British Columbia.

- Mandatory (or rewarded) connection
- DE-ready infrastructure
- Zoning bylaws
- Site plan control
- Use of local improvement charges to support grid investment
- Height and density bonusing and /or
- Expedited development permitting for DE connected buildings.

Conclusion

Like their European counterparts, Canadian communities and municipalities increasingly understand that local sustainable energy development will contribute to their economic, environmental and social objectives.

Conventional land-use planning approaches tackle energy at the end of the planning process, with energy considerations presently appearing secondary to building or community design. This approach misses the opportunity for increased efficiencies, the use of local energy fuels, and the application of other energy stewardship concepts. As such, the typical planning approach also fails to acknowledge the many tertiary benefits of including DE in city planning that are outlined above. This reactive approach promotes business-as-usual practices that result in conventional energy systems that lock communities into long-term, less adaptable energy scenarios.

Unfortunately, in many provincial jurisdictions, energy policies have focused primarily on electricity. Additionally, despite discussions of "smart grids," energy investment has predominately concentrated on large central electricity plants located hundreds of kilometres away from the communities they serve. This is not only an expensive approach, it condemns many provinces to the "status quo" approach for decades, one that is geared towards a "one-size-fits-all" model that is often out-of-sync with the needs of individual communities.

Community energy systems, including DE and small-scale CHP, are more responsive to community needs. These elements clearly affect communities and have the potential of facilitating greater local social acceptance by virtue of what they can contribute to local goals.

In jurisdictions such as Denmark, Sweden and Austria where DE implementation is successful, this success has been supported and enabled by consistent political vision, legislation, regulation, and fiscal incentives. With the exception of British Columbia, and a few municipalities, Canada has not embraced this approach. Canada needs to change its approach and focus more on local energy planning, by ensuring, at all levels of government, that:

1. A long-term thermal energy policy is established.
2. All levels of government adopt, or adhere to, legislation that includes thermal and electrical energy as key considerations in land use planning.
3. Supportive fiscal legislation and tools are put in place to help municipalities establish a DE network.
4. Supportive local building policies are in place to enable DE within communities.

Political leadership is needed to apply these tools and invest in Canada's vision of becoming a sustainable energy superpower.

It is time to focus on the full range of the energy cycle, and consider how energy is produced, delivered and used in order to support Canada's ambition to be a sustainable energy superpower. A tried and tested way to meet this ambition is to start with community-level District Energy Systems.

Biography

Terri Chu: Terri is project analyst at FVB energy. She has a particular interest in how the interaction of municipal infrastructure can be optimized to reduce overall energy consumption. Terri holds a bachelor's degree in aerospace engineering and a master's in civil engineering with a specialization in sustainable urban systems. Terri is the lead author of "How District Energy Systems can be used to reduce Infrastructure Costs and Environmental Burdens."

Mary Ellen Richardson: Mary Ellen's career in the oil, natural gas and electricity industries spans 30 years. Over the last 10 years, Mary Ellen has held executive positions with the Canadian District Energy Association (President), the Ontario Power Authority (Vice President Corporate Affairs) and the Association of Major Power Consumers in Ontario (President). Each of these roles entailed a broad geographic and sector reach, involving frequent interaction with private, public, academic and industry representatives from across Canada and Europe. More recently, Mary Ellen has contributed as a lead author in the Mowat Centre's report on energy planning. Mary Ellen has served on the management board of the Ontario Centre of Excellence in Energy, as a board member for EcoCanada, on Ontario Province's 2003 Electricity Conservation and Supply Task Force, on the Executive of the Stakeholders" Alliance for Competition and Customer Choice, on the Electric Power Engineering Education Consortium, and as a member of Hydro One's Customer Advisory Board. She has also been a member of both the City of Guelph's Mayor Advisory Task Force and the City of Vancouver Community Energy Advisory Committee. Mary Ellen has completed the Institute of Corporate Directors program at the University of Toronto.

Marlena Rogowska: Marlena Rogowska is an urban and regional planner with experience in both the public and non-profit sectors. Her experience in the public sector is focused on land-use planning and policy development, and climate adaptation strategies whereas her experience in the non-profit sector provides her with a unique lens of domestic and international approaches to city building and resource management. She has an interest in research exploring opportunities for energy efficiency gains with a focus on community energy planning and other embedded energy solutions. Marlena holds a Master of Planning degree in Urban Development from Ryerson University, and an Honours Bachelor of Arts in Environmental Studies and Political Science from the University of Toronto.

Chapter Reviewers

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Richard Damecour, P.Eng., MBA, Chief Executive Officer – FVB Energy Inc., is the International District Energy Association (IDEA)'s Chair of the Canadian Forum. He is the Chief Executive Officer of FVB Energy Inc., a consulting company specializing in district energy and CHP business development, engineering and marketing, with offices in Toronto, Edmonton and Vancouver. FVB also has offices in Minneapolis and Seattle in the US and various cities in Sweden. He has over 30 years of experience in the energy industry, including 12 years in oil and gas, and for the past 20 years has helped to develop at least 25 new district energy systems that have been successfully brought into service in North America and the Middle East. Richard is a registered professional engineer in the Province of Ontario and has an MBA from the University of Alberta.