carbontalks

What lies beneath:

Incorporating geoexchange in building retrofits

May 25, 2012

Toronto Atmospheric Fund

ACKNOWLEDGEMENTS

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Toronto Atmospheric Fund is an agency of the City of Toronto. TAF's mandate is to support local activities that achieve significant reductions in greenhouse gas and air pollution emissions. TAF undertakes an annual forum in the name of Dan Leckie, a former City of Toronto Councillor and Founder and Chair of TAF. Dan Leckie devoted his life to building an inclusive and healthy world, and favoured participatory approaches and bringing about change.

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CONTENTS

Introduction

On May 25, 2012 SFU's Carbon Talks and the Toronto Atmospheric Fund (TAF) are bringing together a small group of thought leaders, including engineering firms, utilities, finance experts, real estate owners, policy makers, and academics, to identify best practices, practical opportunities and challenges for more widespread adoption of geoexchange and related heat exchange technologies in the urban environment. This discussion guide will focus mainly on urban opportunities for geoexchange, and specifically retrofit applications in medium to large buildings.

The City of Toronto has set itself a big target: to reduce corporate and city-wide greenhouse gas emissions to 30% below 1990 levels by 2020, and 80% below 1990 levels by 2050[1]. It has implemented a number of important programs, including the Mayor's Tower Renewal, the Toronto Green Standard, energy efficiency retrofits of over 500 city facilities, and the creation of a fund for renewable energy and energy efficiency in not-for-profit and government buildings, among other programs. It has also benefitted from CO_2 reductions resulting from its ownership position in EnWave, methane gas capture, and the reduced carbon co-efficient resulting from the phase-out of coal in electricity generation in Ontario. The City of Toronto has reduced its emissions from its own operations to 40% below 1990 levels[2]. It still, however, has a long way to go to meet its city-wide reduction goals.

Energy efficiency in buildings is a critical piece of the puzzle for reducing greenhouse gas emissions in Toronto. Natural gas combusted for space and water heating is responsible for 43% of Toronto's greenhouse gas emissions[3]. Highrise apartments and condos represent 40% of the emissions coming from Toronto's residential sector, and they emit 20% more CO_2/m^2 than single-family homes[4].

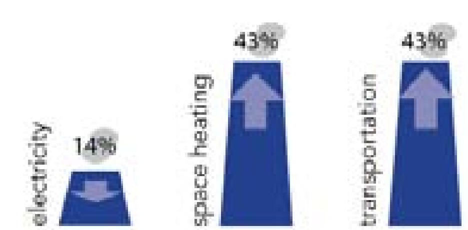
Natural gas used for space and water heating has a significant impact on Toronto's greenhouse gas emission profile. As a result, TAF is supporting initiatives that reduce natural gas, mainly through energy efficiency and the replacement of natural gas with less carbon intensive alternatives. Geoexchange is a technology that may present just such an opportunity. Geoexchange uses electricity to operate heat pumps that move heat to and from the earth, so no fossil fuels are directly combusted on site. They are very efficient: for every unit of electricity used to run the heat pump, up to four units of free, clean, renewable heat come from the ground. And since Ontario's electricity comes from relatively low-carbon sources, incorporating geoexchange more broadly in Toronto's buildings could offer an opportunity to create significant emissions reductions.

While geoexchange technology is not new – it has been used in Canada for several decades – the predominant deployment of the technology has been in rural, suburban and new-build situations. There is a growing interest in doing larger, more complicated inner-city projects, including retrofits of existing buildings. Paving the way for large scale, mainstream deployment of geoexchange in an urban setting will first require a thorough assessment of the opportunity, and also the technological, capacity, policy, and financial barriers to implementation.

This discussion guide is intended to serve as a resource that will lay out the background, relevant information, challenges and opportunities for the use of geoexchange in urban retrofits. It is intended to provoke discussion and debate on the greenhouse gas reduction opportunity, technical feasibility, implementation challenges, grid capacity issues, and possible business models and financing opportunities.

The ultimate goal of the Carbon Talks/TAF dialogue is to determine the significance of the opportunity that geoexchange can play in reducing greenhouse gas emissions in Toronto and, if this opportunity is deemed to be significant, to establish the necessary actions, stakeholders and appropriate roles to accelerate the use of geoexchange technologies and services in the City of Toronto and the Greater Toronto Area. TAF is especially interested in the opinion of the dialogue participants on what types of support the City of Toronto and TAF could best provide to accelerate alternative energy solutions in general, and geoexchange in particular.

Figure 1 - Emissions Profile, City of Toronto (TAF)



Context

The City of Toronto has set an aggressive target to reduce its emissions to 6% below 1990 levels by 2014, 30% by 2020, and 80% by 2050[5]. In 2007 it published its Climate Change, Clean Air and Sustainable Energy Action Plan, which set out recommendations for action on climate change.

Due to the significance of Toronto's building stock in the production of greenhouse gas emissions, tackling the efficiency of the City's buildings is critical to achieving the City's emission reduction targets. In particular, the City is interested in addressing the emission reduction opportunity associated with high-rise residential towers. Many of these were built in an era of cheap energy with no consideration given to conservation. A typical 200 unit building can contribute as much as 1,200 tonnes of greenhouse gases each year. Energy efficiency retrofits of these buildings – of which there are over 1,000 in Toronto built between the 1950s and the 1980s – can significantly help reduce emissions.

Toronto is also interested in supporting energy efficiency in all buildings, and in taking advantage of alternative energy sources and approaches to heating, such as solar thermal, air-to-air heat exchange, co- and tri-generation, waste heat capture, and district energy applications, in addition to geoexchange.

TAF has been working to reduce greenhouse gas and air pollution emissions in the city since the organization was established in 1991, with one of their core areas of focus being Toronto's buildings. As part of its program offerings, TAF identifies potential technologies and/or approaches that offer opportunities for improving efficiencies, and works with partners to test them in real world settings to assess performance, address financial and policy barriers and assess market readiness. By doing "trial runs" of various technologies and programs, TAF clarifies the processes and opportunities, enabling others to scale more rapidly without making costly mistakes. For example, TAF's TowerWise.ca project assists building owners in assessing energy efficiency opportunities and approaches; TAF's LightSavers.ca project assessed advanced outdoor lighting applications; and TAF's SolarCityPartnership.ca looks at the real-world performance and best practices associated with large solar energy installations in Toronto.

Opportunities for Reducing Emissions from Toronto's Buildings

There is a wide range of possible options when undertaking an HVAC retrofit of an existing commercial, institutional or multi-family residential building.

According to the most recent statistics available, there are 478,555 residential apartment units[6] in approximately 4,300 multi-family residential buildings in the City of Toronto. An estimated 2,000 of these buildings are high rise rental buildings, of which about half were built before 1984[7]. There are also approximately 2,300 condo corporations, of which about 25% of them are at least partially electrically heated[8]. Detailed and specific building data is not kept by Toronto Hydro, Enbridge or the City of Toronto but it is safe to assume that there are at least an equal number of commercial buildings.

Improving the greenhouse gas profile of buildings first requires aggressive demand reduction initiatives, following which the efficiency of heating and cooling systems can be addressed. Building efficiency can be achieved through a variety of measures, including envelope improvement and insulation, reducing plug load, and retro-commissioning. These measures offer a significant emission reduction opportunity, and they ensure that the HVAC system can then be made as small and efficient as possible.

There is a wide range of possible options when undertaking an HVAC retrofit of an existing commercial, institutional or multi-family residential building. There has been a long-term trend of converting buildings from electric heat, which is expensive to operate under current prices, to natural gas-fired equipment, which creates significantly more greenhouse gas emissions. High-efficiency boilers, chillers and heat pumps provide the same cooling and heating capacities as their standard counterparts but consume less energy by integrating high-efficiency components and controls.

Condensing Boilers

The most energy-efficient boilers are generally condensing boilers. Condensing boilers are high-efficiency water heaters in which the water vapour produced during combustion is condensed into water and used to pre-heat the cold water entering the boiler. Condensation occurs in the heat exchanger, where the hot gases transfer their heat to the system water being heated. Condensing boilers typically offer efficiencies of approximately 90%, compared to a maximum of 70% for traditional gas boilers, so replacing an existing boiler can create reductions in both operating costs and emissions.

Air Source Heat Pumps

Air source heat pumps use the outside air as a heat sink and/or source. In heating mode they take heat from the outside air and move it into the building; the process is reversed in cooling mode. In mild weather air source heat pumps can be an efficient option for space conditioning. However during temperature extremes the heat pumps have to work hard to operate effectively. There are currently a number of cold climate air source heat pumps being tested in Canada. For commercial applications air source gas absorption heat pumps that use a gas burner to drive the refrigeration cycle are an alternative.

Air source heat pumps can deliver 200% to 400% more heat than would be obtained from an equivalent electric resistance heating system[9]. Operating costs compared to electric baseboard heating can be reduced by up to 50%, depending on the operating conditions. Minimum efficiencies for air source heat pumps have improved by 5% to 10% over recent years, largely due to more efficient compressors, larger heat exchanger surfaces, and improved refrigerant flow[10].

High Efficiency Chillers

A chiller is a water-cooled air conditioning system. It chiller uses the evaporation of a refrigerant to cool the fluid through a heat exchanger. Chilled water is typically distributed to heat exchangers, or coils, in air handling units, or other types of terminal devices which cool the air, and then the chilled water is re-circulated back to the chiller to be cooled again. These cooling coils transfer heat from the air to the chilled water, thus cooling and usually dehumidifying the air stream.

Chillers used to cool commercial buildings are a major source of energy consumption, often making up between 35% and 50% of a building's annual energy use[11], and as much as 20% of all electrical power generated in North America[12]. In recent years, chillers have become much more efficient, using between 10% and 30% less energy than previous generations of equipment[13]. Most of today's new high-efficiency chillers have a full-load efficiency of about 0.50 kW/ton, compared to 0.80 to 0.90 kW/ton for older centrifugal chillers, 0.75 to 0.85 kW/ton for those that are 15 to 20 years old, or 0.60 to 0.70 kw/Ton for newer chillers that are between 10 and 15 years old. More importantly, new chillers have higher part-load efficiencies than older chillers. This is important since most chillers operate about 95% of the time under part-load conditions. Improved full-load and part-load operating efficiencies translate into bigger energy cost savings.

Geoexchange

Geoexchange systems (also referred to as "geothermal" or "ground source heat pumps") operate in a similar manner to air source heat pumps, except that instead of using the atmosphere as the heat sink/source they use the ground. Geoexchange systems provide space heating, cooling, and water heating using heat from the sun that is stored in the earth. The temperature of the earth below the frost line (about 4 feet deep in Toronto) remains relatively constant throughout the year. During cold seasons, the earth's natural heat is collected through a series of pipes, called a loop, which is installed below the surface of the ground, or alternatively it can be submersed in a pond or lake. Fluid, typically a water/ethanol mix, is circulated through the loop and carries the heat from the ground to the building. A heat pump system concentrates this low-grade heat and circulates the heated air through a standard duct system, or water through hydronic/radiant systems. In summer the process is reversed in order to provide air conditioning, with excess heat from the building expelled to the loop and used to re-charge the ground. The geoexchange system can also provide a portion of the domestic hot water.

All of the heating and cooling capacity of a geoexchange system comes from the ground, but electricity is required to run the heat pump. Each kWh of electricity used to operate a heat pump draws an equivalent of between 3 – 4 kWh of renewable heat energy from the ground, giving efficiencies of 300 - 400% when in heating mode. Efficiencies in cooling mode can be up to double that of standard air conditioning technology. Overall, geoexchange has the potential to reduce energy requirements for heating, cooling and hot water by up to 75%.

Geo-exchange - a Low-Carbon Opportunity?

The greenhouse gas impacts of geoexchange hinge on the source of the electricity used to operate the systems and, in a retrofit situation, the nature of the heating source being replaced.

Technology

Geoexchange technology has been used in both Europe and North America for decades. The technology is not complicated: A heat pump works like a refrigerator, moving heat from one place to another. Their overall efficiencies are largely determined by the efficiency of the compressor, the use of variable speed compressors, and the size of the heat exchanger. Ground source heat pumps currently on the market in North America claim coefficients of performance (COP) of between 2.5 and 5. The actual performance of the heat pump, though, is dependent on the operating conditions. The performance is best when the difference between the input and output temperatures is small. Heat pumps are often rated using ground temperatures in warmer climates, meaning the actual efficiencies achieved in Canada aren't as high as those claimed.

It has been reported that virtually every heat pump manufacturer is working on new vertical stacking units that can be used in multifamily residential installations. These units take up very little space within each unit, and enable each tenant to have control of their own space conditioning.

Drilling and Ground Loop

Land can be scarce in the inner city, so it can be challenging to find enough space for installation of a ground loop. Loop fields need to be adequately spaced to ensure there is enough heat available to supply the building. New drilling technology has recently become available that enables drilling under the footprint of existing buildings. This will help to mitigate this challenge, however for larger installations it is possible that the building footprint will not provide adequate area.

Geoexchange pipe is receiving higher pressure ratings, enabling holes to be drilled deeper. This can have value in certain applications, enabling loop installation within a smaller area.

Internal Distribution System

Converting from a gas-fired heating system to geoexchange is generally quite straightforward. The main challenge is with the sizing of the internal distribution system, since geoexchange delivers heat at a lower temperature than natural gas it is necessary to push more air through the system. It may be necessary to address the need for additional distribution capacity.

Converting from an electrically heated system to geoexchange, however, poses much larger challenges since those buildings generally have no ductwork through which the conditioned air can be distributed. There are spatial, structural and cost issues associated with this work. It is generally possible to resolve the technical challenges, however it may be cost prohibitive.

For electrically heated buildings without central air conditioning, an option is to replace electric baseboards with a hydronic, gas-fired heating system using a hybrid geoexchange/high efficiency boiler system. In this situation there would have to be space available to create a new boiler/mechanical room. This, however, can create a recharge issue for the ground loop, since the geoexchange system will be pulling heat from the ground during heating season, but there is no air conditioning load which would normally be put back into the ground to recharge it. The ground temperature would need to be recharged to ensure the temperature didn't fall too low, which is generally accomplished using natural gas boilers or solar thermal.

Design

One of the biggest challenges with ensuring the proper functioning of geoexchange systems is the lack of design expertise available. It can be quite difficult to find engineers with direct, proven experience in geoexchange design. The Canadian Geoexchange Coalition (CGC) has been working hard to create and deliver training programs for engineers, but the number of commercial installations in Canada is still small enough that there are only a handful of technical experts with a breadth and depth of experience in large-scale installations. Following completion of the CGC's Commercial Designers Course individual designers must complete five successful installations prior to being allowed to apply for accreditation from the CGC. Accreditation is voluntary, although several jurisdictions are now requiring proof that installations have been designed by an accredited professional.

Hybrid Geoexchange Systems

It is possible, and often financially and technically appealing, to create hybrid systems, where geoexchange is installed to carry the building's base load, and alternative options are used to meet peak needs. These alternatives could be conventional boilers/chillers, solar thermal, or another alternative source. This can be an option for bringing down the capital cost of the system (depending on technology chosen), and can also help to mitigate the perceived risk associated with converting to a 100% geoexchange system. Adding an extra heat source can also be an effective way to balance loads for buildings without air conditioning.

Ultimately, it comes down to determining the most efficient design based on balancing the capital cost with the operating cost, and the greenhouse gas profile of the various options. Situations where loads are properly balanced, and possibly creating "mini districts" where a small number of buildings with offsetting loads are grouped together on one common system, can create good opportunities to design optimally efficient systems and minimize upfront capital cost, long term operating costs and greenhouse gas emissions.

Installation

Ground loop drilling and installation can be a time consuming process, in large installations often taking several months. In new-build situations this can be a bottleneck since the drilling in commercial applications generally happens under the footprint of the building so the rest of the construction is on hold until the ground loop is installed. In retrofit applications it can be challenging to find adequate area to install the ground loop. New drilling technology is enabling drilling under the footprint of existing buildings, which will open up the opportunity to retrofit buildings that may previously have been too technically challenging.

Regulatory Requirements

There is currently very little difference in the permitting requirements in Toronto for geoexchange compared to traditional HVAC. For residential projects there is no permit fee, drawings are to be stamped by an engineer, and there is a 10-day turnaround. For commercial and multi-family residential, engineer-stamped drawings are also necessary, and the turnaround time is longer. The City is developing a checklist of requirements for geoexchange installations, but it has not yet been finalized. A number of municipalities, Toronto included, have been looking at the model established by the City of Calgary for inspecting and permitting geoexchange.

Calgary is one of the few municipalities examining how to successfully incorporate geoexchange into the city's buildings. It has chosen to focus on ensuring installations are done correctly by implementing an inspection and permitting program for all geoexchange systems installed in the city. This provides home and business owners with an objective, independent and standardized inspection of the systems. The systems are inspected three times as they are being installed: during installation of the ground loop; following completion of the headers but prior to backfilling; and following commissioning. Larger projects may also require "progress inspections". This initiative is a first step in helping to raise the confidence of the general population.

It has been said that inspection per se doesn't do anything to improve the success of the systems -- inspectors are looking only at parts of the installation and not assessing the effectiveness of the design on performance. In order to encourage widespread energy efficiency retrofits of existing buildings a number of municipalities are reviewing the permitting system, moving from prescriptive or predictive compliance to performance-focused, with flexibility to pursue retrofit strategies to achieve a pre-negotiated performance target. Metering, monitoring and reporting of energy consumption would be mandatory. If combined with appropriate policy, such as targeted incentives to encourage retrofits of the worst performing buildings and requiring sub-metering, these changes to code could drive retrofit opportunities and change tenant behaviour.

Access to Public Land

When the developers of Planet Traveller, an inner city traveller's hotel, wanted to install a geoexchange system they had a problem: their building took up the entire property and had no private land available to install the ground loop. Owners Tom Rand and Anthony Aarts lobbied the city to allow them access to the public laneway that ran beside the property, which was granted with a number of conditions.

Figure 2 - Drilling in the public laneway at Planet Traveller

Several follow-up discussions have been held with relevant stakeholders to identify the conditions necessary to enable future geoexchange projects to use public land for ground loop installation, but to date they have not yet resulted in any streamlined policy or process.

Operation and Maintenance

Maintenance requirements, and hence costs, are lower for geoexchange than for conventional heating and air conditioning systems, as the conditions under which systems operate are less severe. Since heat pumps have no outdoor components, they are not exposed to dirt, rain, snow and extreme temperatures, and as such are not susceptible to deterioration due to weather or vandalism. As there is no combustion in a heat pump the temperatures they experience are much less extreme than the flames of a fossil fuel furnace, putting less stress on the equipment. The loop is buried underground so very little stress is placed on it, making it essentially maintenance-free. The standard warranty for pipe is 50 years, with a much longer expected life. There is also no burner to clean out. Other than the routine changing of air filters (as in any system), geoexchange heating and cooling systems operate virtually maintenance-free and can be relied upon to deliver their rated performance over long periods.

Performance

There is widespread experience with conventional HVAC technologies, which leads to confidence in the systems to perform according to specifications and energy models. This, however, is not the case with geoexchange. While geoexchange systems have been in use in Canada for decades, there is virtually no public data on how those systems are actually working. Systems are finely engineered, yet very few organizations do follow-up modeling to determine, based on verifiable operating data, whether the system is performing as predicted by the computer simulation. Without this data it is essentially impossible to state with real knowledge the actual performance, efficiency, and GHG reductions of these buildings. Geoexchange systems aren't like conventional HVAC where you can simply oversize a system with little added cost. Excess drilling significantly increases the capital cost of the system and therefore reduces the economic efficiency.

To remedy this situation, several years ago the Canadian Geoexchange Coalition implemented a national metering program. The goal was to meter and monitor large installations for corporate, municipal and utility clients. Due to the technical specifications of the meters, however, the usefulness of the program was limited. The meters could only be installed on one inch pipe, which is not commonly used in large installations. They also could only be installed on systems where the loop temperature did not drop below $0^{\circ}C$, which ruled out their use on many ground loops. According to the CGC's press release on February 16, 2009, appropriate systems include open loop, natural gas driven heat pumps, water-water (internal) loops, or hydronic systems. These are not as commonly used in commercial installations, which unfortunately limits the value of this program.

This lack of independently verified analysis proving energy, emissions and operating cost savings is one of the key challenges to advancing geoexchange systems, and would be required for various types of building and heating and/or cooling conditions.

Greenhouse Gas Emissions

There are no publicly available studies that specifically address the greenhouse gas emissions reduction opportunities of geoexchange in a broader range of building types, nor specifically in retrofit applications.

The greenhouse gas impacts of geoexchange hinge on the source of the electricity used to operate the systems and, in a retrofit situation, the nature of the heating source being replaced. Ontario has been phasing out coal-fired power generation, making its energy mix significantly cleaner. To date over 70% of the coal capacity has been shut down, and they are expected to be completely phased out by 2014.

According to Canada's most recent UNFCCC National Inventory Report, Ontario's CO_2 intensity was 170g/kWh in 2008 and it was estimated at 100 g/kWh in 2009. Ontario Power Generation's most recent Sustainable Development report indicates that its gross CO_2 emissions were 24Mt in 2008, 10Mt in 2009 and 12.7Mt in 2010. Since four more coal-fired plants were taken offline in 2010 and additional capacity from renewables has been added, the current emissions figures are lower but have not yet been published.

Geoexchange has long been seen as a technology that can help reduce greenhouse gas emissions in locations where the electricity is generated from low carbon sources. This is especially true when they are used for both heating and air conditioning. A geoexchange system typically uses between 40% to 70% less energy than a conventional system14. The National Renewable Energy Laboratory in the US notes that geoexchange systems can reduce energy consumption by up to 72% compared to electric resistance heating with standard air conditioning equipment[15], resulting in a commensurate reduction in emissions of up to 72% for electrically heated and cooled buildings. When efficiencies are broken down into heating and cooling modes, heating efficiencies are 50% to 70% higher than other heating systems and cooling efficiencies are 20% to 40% above available air conditioners[16].

The Canadian Geoexchange Coalition undertook a study that assessed the GHG benefits of geoexchange in single family homes[17]. The study limited itself exclusively to looking at the benefits of heating with geoexchange, ignoring the opportunities for additional GHG reductions from using geoexchange to heat water and cool air since the use of desuperheaters and air conditioners were not consistently used across their study area. The report showed that geoexchange systems present an opportunity to reduce greenhouse gas emissions in Ontario. It stated that with a 2% market penetration geoexchange systems could reduce emissions by 27,455 tons of CO_2 compared with baseboard electric heating, and 143,544 tons compared with natural gas heating (this doesn't take into account benefits from air conditioning, and looks only at single family homes).

The following table presents an example of potential emissions reductions from geoexchange, using a residential example. This model would need to be scaled for each larger building being analyzed, but gives an idea of the emissions reductions that are available through geoexchange.

Table 1 – Emissions Reductions for Geoexchange vs. Natural Gas (Residential)

Heating, Cooling, Hot Water Needs	Natural Gas System	Geoexchange System	Emission Reduction
Electricity (MWh)	4.4	14.1	
Natural Gas (eMWh)	50.8	0	
Emissions (tonnes)	14.156	1.41	90.0%

Based on 94% high efficiency gas furnace with 3 ton 15 SEER AC versus 4 ton geothermal heat pump. Emissions factors used were 100kg/MWh for electricity, as per Ontario's 2009 UNFCCC submission, and 270kg/MWh as per the Biomass Energy Centre.

The Business Case

Geoexchange is a rare example of a renewable energy technology that is currently economically feasible, even without incentives. There are a variety of factors that influence the business case.

The Price of Natural Gas and Electricity

The payback periods when converting from natural gas have recently been substantially extended due to the drop in the price of natural gas, which is at lows not seen since the mid-1990s. Prices are generally expected to remain low in the near term due in large part to the growth in shale gas supplies in the US. Unseasonably warm winter heating seasons in North America and decreased economic activity have also played a part. It is inevitable that prices will again increase, but it is uncertain when that will be.

As with any HVAC system, operating costs are linked to the building's location, standard of construction, type, use, and size. Table 2 on page 14 shows potential energy savings for a geoexchange system versus natural gas in the Greater Toronto Area, using a residential example.

Incentives for Peak Reduction

While low natural gas prices weaken the economic case for geoexchange, there is still a case given Ontario's overall energy picture. Specifically, in the past ten years, high rates of air conditioning have led to summer peaking with needs of approximately 27,000 MW[18]. This is driving the province to purchase electricity from Quebec, Manitoba, Michigan and New York State, and to build natural gas peaking plants.

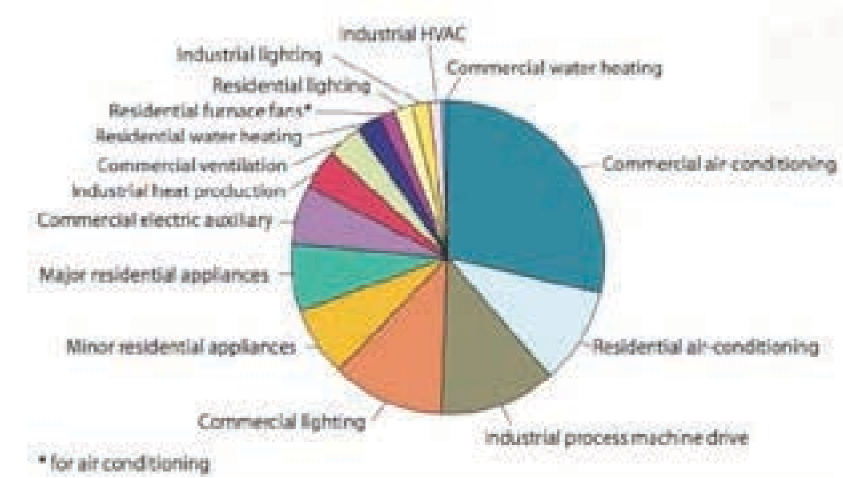
As can be seen in Figure 3, residential and commercial air conditioning is responsible for 40.2% of electricity consumption at the time of a summer peak. Since geoexchange can reduce electricity consumption from air conditioning by between 20% and 40% it could have an impact on reducing summer peak consumption, helping the IESO to reduce its energy imports and better manage the grid. Conventional cooling technologies do not offer the same benefits. Since geoexchange systems use less electricity during

Table 2 – Energy Consumption For Natural Gas and Geoexchange

Heating, Cooling, Hot Water Needs	Natural Gas System	Geoexchange System	Energy Savings	Cost Savings
Electricity (MWh)	4.4	141	-220%	$(892.40)
Natural Gas (eMWh)	50.8	0	100%	$1,210.01
Total	55.2	14.1	74%	$317.61

Based on 94% high efficiency gas furnace with 3 ton 15 SEER AC versus 4 ton geothermal heat pump. Energy pricing uses incremental electricity rate of 0.092 $/kWh and natural gas rate of 0.2382 $/m^3 (Just Energy's 5 year fixed rate using Enbridge's deregulated gas price)

Figure 3 – Ontario's Electricity Consumption by End Use on Summer Peak Demand



Source: Ontario Clean Air Alliance, 2006. Air Quality Issues Fact Sheet #24

peak pricing periods based on Time Of Use rates, the operating cost will be lower during these months.

Notwithstanding recent summer peaks, there is still a significant electrical demand during the winter months, with a difference of only about 2,000MW between the winter and summer peaks. Since large-scale installation of geoexchange could increase the amount of electricity being used in the winter it could push the province back towards a winter peak.

Demand Response Opportunities

When provincial electricity consumption goes over a particular threshold, the price of power rises steeply. One of the ways in which the province encourages reduced electricity consumption during peak demand periods is through demand response programs. Customers sign up for these programs, which allow the local distribution companies (LDCs) to shut down specific equipment during times of peak electricity demand.

For buildings that sign up for these programs, the utility has the option of shutting down HVAC equipment in the building during times of critical energy use. These requests can happen when the when the wholesale market price for electricity is high, power system is experiencing large peaks in demand, and/or there is a greater risk to the reliability of the electricity grid. The temperature in the building may creep up over the period of the shutdown, but on average the impacts on comfort are negligible and the benefits on peak reduction can be significant.

In addition to the direct reductions coming from using geoexchange for air conditioning there is also an opportunity to reduce peak energy consumption by automatically incorporating geoexchange into a demand management program. This could play a role in the Ontario Power Authority meeting its challenging target of shaving peak energy demand by 6,300MW by 2025[19].

Capital Cost

Geoexchange systems cost about twice as much as a conventional system. In general, the cost of the equipment inside the building is on par with other HVAC technologies. However the ground loop cost about the same, essentially doubling the price of the system.

If modifications also need to be made to the air distribution system, as would be the case in buildings previously using electric baseboard heating, the costs increase again. Given both the split incentive problem and a lack of awareness and confidence in the attainment of modeled energy savings, both described below, building owners are often very wary of moving ahead with a geoexchange installation.

Maintenance Costs

As already discussed, maintenance costs for geoexchange systems are lower than for conventional systems. This helps to lower the lifecycle costs of the systems. Table 3 compares annual maintenance, repair and corrective action costs between geoexchange and several chiller/boiler HVAC options.

Average PM Costs, Repair, Service, and Corrective Action Costs, and Total Maintenance Costs				
School	Preventive Maintenance Costs per Year per ft² (¢/yr • ft²)	Repair, Service, and Corrective Action Costs per Year per ft² (¢/yr • ft²)	Total Maintenance Costs per Year per ft² (¢/yr •	Total Maintenance Costs per Year per Cooling ft² (¢/yr • cool ft²)
Geothermal Heat Pumps	7.14	2.13	9.27	9.27
Air-Cooled Chiller and Gas-Fired Hot Water Boiler	5.87	2.88	8.75	10.43
Water-Cooled Chiller and Gas-Fired Steam Boiler	9.82	3.73	13.54	18.68
Water-Cooled Chiller and Gas-Fired Hot Water Boiler	12.65	6.07	18.71	20.71

Table 3 – Maintenance Costs, Geoexchange vs. Boiler/Chiller[20]

Access to and Cost of Capital

Despite a strong case for energy efficiency retrofits, financing remains far below the level needed to truly transform the existing built environment. The same will hold true for geo-exchange. Even if a building owner or tenant wants to install efficiency measures, most lenders do not have the expertise to understand the systems to the extent required to de-risk the loans, develop reasonable rates or generate the terms of the contract. Credit has been even harder to come by since the start of the economic downturn in 2008. There are very few sources of traditional financing available since there is very little real understanding among these players of energy efficiency technologies and the associated risks and opportunities. Having a financial return linked to energy savings requires specialized financial structures and knowledge of the underlying technology in order to ensure the reliability of expected savings. Having solid knowledge of, and confidence in, the rigour of the modeled savings is critical.

Split Incentives

Split incentives happen when those responsible for paying the energy bills are not the same parties responsible for making the capital investment decisions. Under a conventional commercial lease, the building owner pays for upgrades to the structure, but the tenant pays the majority of the operating costs such as lighting, heating and air conditioning. Owners, therefore, have little incentive to retrofit their building's infrastructure because the savings primarily accrue to the tenant. This issue applies for all energy efficiency measures, but due to the high upfront capital cost of geoexchange the challenge is amplified.

Technology Risk

Geoexchange systems that are properly designed and installed work well and save building owners money for decades; those that are not can cause endless headaches and expenditures trying to resolve problems. Poorly designed systems will be inefficient at best, and non-functional at worst. There are several installations in the Toronto area that have become well-known failures, and these often carry more weight than the hundreds of properly operating systems.

There is also a lack of confidence because planned installations are getting larger and more complex, and there are few examples of similar installations to point to. There are also far fewer engineers with a strong track record of successfully undertaking larger projects. It takes a motivated building owner to take a "leap of faith" and become one of the first to install a system in a different type or size of application.

In addition to the general lack of confidence in the design and installation, there is also uncertainty in the modeled energy savings. Since the return on investment is heavily dependent on the energy savings, until more installations are completed and monitored, it is going to remain difficult to convince owners of the possible benefits.

Possible Financial Mechanisms

Incentives and Rebates

There have been a number of government programs and grants that have had some success in shortening the simple payback to a time range that helps to make the projects financially viable (*e.g.,* the EcoEnergy grants and matching provincial grants), but they are not permanently available sources of capital (*e.g.,* the cancellation of the EcoEnergy Retrofit program).

As part of the province's demand management program, the Saskatchewan Research Council administers a program, funded by SaskPower Eneraction, to encourage installation of geoexchange systems by the business community. This program, the Commercial Geothermal Rebate – a 15% rebate up to $100K for the installation of a geoexchange system. The program is targeted at buildings without access to natural gas and buildings currently heated by sources other than natural gas.

At the end of 2011 the UK government initiated a Renewable Heat Incentive (RHI). This program is designed to increase the installation/usage of renewable heat technologies by providing incentive payments to non-domestic sectors (commercial, industrial, not-for-profit, etc.). The RHI offers businesses an income over periods up to 20 years, which will help offset the initial installation costs, for green heating systems including solar thermal equipment, biomass boilers and heat pumps.

Green Loans

The SFU Community Trust and Vancity Enterprises teamed up to develop a unique building called Verdant in the UniverCity neighbourhood on Burnaby Mountain near Simon Fraser University. The geoexchange system in the building has been financed by Vancity Capital Corporation through a "green loan." The loan has a term of 25 years, essentially the term of a typical mortgage, and covers the capital cost of both the geoexchange and radiant heating systems. Loan payments are incorporated into the monthly strata budget and are paid by each strata owner as part of their monthly fees[21]. In order to make this work each member of the strata had to take personal responsibility for the loan in the sales agreement, since the strata corporation itself has no assets so Vancity would have had no recourse had there been a default on the loan.

Similarly, the Toronto Atmospheric Fund has developed the Green Condo Loan. This loan is intended to resolve the split incentive problem between the owner, who pays the capital cost, and the tenant, who benefits from lower operating costs. The loan is taken on by the developer but is then transferred to the condo corporation, which makes the payments. Under these conditions condo developers are able to build much more efficient buildings without raising the price of the units. This could be applied to geoexchange. The ground loop could be considered the portion of the project that creates added capital costs. TAF (or a similar institution) could finance this extra cost and have the loan transferred to the condo corporation.

Utility Models

Financing geoexchange systems creates an issue with collateral that is not a problem for most other energy efficiency measures. The ground loop generally accounts for approximately half the cost of a geoexchange system, but it is not an asset that has resale value should the borrower default on the loan – it is expensive to install, but the actual pipe has very little value and is not going to be dug up, removed, and sold. That makes it an asset that is essentially impossible to directly finance through traditional lenders.

FortisBC (previously Terasen) is a British Columbia-based utility, but rather than managing traditional energy assets they provide alternative energy systems, including geoexchange. They have financed, for example, the Pomaria, a 30-storey condo tower located in Vancouver's Yaletown neighbourhood, and Waterstone Pier in Richmond, a 144 unit multifamily residential development. The heating, cooling and hot water for the buildings is supplied by geoexchange. Terasen owns and operates the systems, which takes both the capital cost and the risk away from the developers. In return, the building's occupants are charged a utility fee, which pays for the energy used to run the system, the capital costs, and a return for Fortis.

Corix Utilities, which is also Vancouver-based, owns and operates ground loops as a utility. One of their key projects is Sun Rivers, in Kelowna. When the home is being built the homeowner pays the cost of the heat pump and inside work, and Corix installs the separate vertical ground loop systems for each lot. The company recovers its investment in the ground loop through a monthly "geothermal ground loop access fee". The homeowners pay their monthly electricity bill separately, which includes the energy used to run the heat pumps.

TAF has participated with Glenbarra Energy Management Corp. in the creation of a solar thermal utility. This model could be expanded to the geoexchange situation as well. Glenbarra installed, owns and operates the solar thermal systems that were installed to provide hot water to three City of Toronto facilities under a long-term purchase agreement. The water is supplied at the same price as the City would have paid for fossil fuel-heated water, but they do not have to pay the upfront cost, or deal with operating and maintaining the system. TAF provided the commercial financing for the project. This approach helps to create awareness of solar thermal technology and provides the operating information necessary to begin de-risking this type of investment for traditional lenders, while making a competitive financial return for TAF.

Energy Service Companies

An energy service company, or ESCO, will design, install, finance and operate projects that reduce energy consumption in buildings in exchange for a fixed term energy supply agreement that is based on the actual energy savings achieved. The ESCO is responsible for operating, maintaining and replacing equipment for the life of the contract. Under this model the ESCO assumes both the financial and performance risk of the system. Customers have guaranteed energy costs and no unexpected repair or maintenance charges.

Examples of buildings that have used geoexchange under the ESCO model are the Strata and Ironstone condominiums, both in Burlington. Ironstone is a 16 storey, 210 unit, 200,000 square foot building, and Strata is a 21 storey, 186 unit, 275,000 square foot building.

Energy Savings Purchase Agreements

TAF has also developed a new financing product called TAF's Energy Savings Performance Agreements, which remove the upfront cost of part or all of an energy efficiency upgrade by pre-purchasing a portion of the utility cost savings. The agreement will cover up to the full cost of the retrofit, and then TAF shares in the resulting energy savings until it has recovered its capital and made a return. After that all of the savings flow to the building owner. This method could be used to finance the cost of the ground loop, or the entire geoexchange system.

Utility or Tax Bill Financing

On-bill financing, a tool that allows customers to pay for energy efficiency investments through their utility bills, are in their infancy but are gaining traction in various locations across North America. These programs can address financing gaps that have not been addressed by traditional funding mechanisms. With on-bill financing, the utility pays the capital cost for the efficiency investment, which is then repaid over a given term by the customer on their monthly utility bill. Like with the green loans, the energy savings are often sufficient to cover the monthly payments, so the monthly charge is actually less than or equal to the pre-investment amount.

The Property Assessed Clean Energy (PACE) program, which was started in California in 2008, is similar to the on-bill financing model except that the loan is held by a municipality rather than a utility. The municipality sells bonds, the proceeds of which are loaned to home and building owners to finance energy efficiency retrofits. The loan is paid back over time through increased property tax payments. To enable retrofits that would have a payback that is longer than the expected length of tenure, the loan is attached to the property and is therefore transferred to the new owner with the sale of the property. This is yet another up-and-coming tool that would enable property owners to finance geoexchange installations and retrofits by removing the upfront capital cost.

Green Bonds

Green bonds are an idea floated by a group of passionate Canadians to address the lack of low-cost capital available to renewable energy producers. They are a government-backed financial instrument designed to engage the public by raising capital to accelerate renewable energy production[22]. Essentially, Canadians would have the opportunity to buy a government-backed bond (just like a Canada Savings Bond) and the proceeds would go towards providing low-cost debt financing to renewable energy providers.

Conclusion

This discussion guide is provided as a way to "kick start" thinking on whether geoexchange offers a significant, viable opportunity to reduce greenhouse gas emissions in Toronto's urban context, especially in the retrofit market.

While geoexchange has been used in Canada for decades and is being implemented in various in new-build applications, the challenges of retrofitting existing buildings has limited its use in high density, inner-city retrofit applications.

Overall, the sector is emerging, the understanding of performance and emission reduction potential is weak, and there many barriers and outstanding questions remain.
Among the questions to be addressed are:

- Does geoexchange offer an adequate GHG reduction opportunity? How should this be modeled, metered and monitored?
- What are the pros, cons and bottlenecks of retrofitting urban buildings with geoexchange as a way to reduce emissions for heating and cooling? Are the challenges addressable?
- Are there technological advances in the works that will enable more cost effective installations?
- Are there opportunities to profitably finance urban geoexchange installations?
- What are the conditions under which a geoexchange system should be considered?
- What policy considerations are important to breaking down barriers to geoexchange?
- What types of buildings offer the best opportunity for geoexchange, considering the need for both a financial return and emissions reductions? Are these types of "ideal" cases common, or uncommon?
- Under what types of scenarios could building owners be encouraged to undertake energy efficiency, and specifically geoexchange, retrofits?
- What types of partnerships are necessary to move this agenda forward? Who needs to be at the table?

The discussion and questions posed in this document represent a starting point for the discussion at the dialogue session on May 25. Carbon Talks and TAF look forward to the opportunity to engage experts and thought-leaders in a thoughtful, respectful, constructive, and fruitful dialogue on if and how Toronto can become a GeoCity.

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