ONTARIO'S LOW CARBON FUTURE:

GEOTHERMAL HEAT PUMPS

Evidence for the Ontario Energy Board

in the Generic Proceeding

EB-2016-0004 Community Expansion of Natural Gas

from the

Ontario Geothermal Association

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TABLE OF CONTENTS

1 EXECUTIVE SUMMARY

Union Gas Limited and Enbridge Gas Distribution Inc. are proposing uneconomic expansions into many Ontario communities. During the lifetime of the current proposed expansions, emissions are likely to exceed ***4,000,000 tonnes of carbon*** just for these expansions alone. In the context of a provincial policy of reducing carbon emissions, this is a concern, especially if there are alternatives that can deliver the same energy functionality, at a lower cost, and without those emissions. Geothermal energy is such an alternative.

Geothermal Energy

Geothermal systems[1] utilize the natural storage functions of the earth to produce heating (of space or water) and cooling more efficiently than any known alternative.

Any heat pump has as its function the pumping of heat from one place to another (e.g. into a building in the winter, and out of a building in the summer). The efficiency of the heat pump is driven by the temperature differential between those two places. Most air conditioners, for example, are "air-source heat pumps", in that they pump heat from the inside of a house or building to the outside air. Air source heat pumps can also be used for heating, working in reverse. The thermal energy exchange process can utilize air, water or earth as the storage medium.

Below about 3 metres, the ground is a relatively constant temperature all the time, around 10-15°C. This is because the ground stores heat for a long time. It increases its temperature, due to solar gain, only very slowly, and it loses that temperature, due to radiative effects, just as slowly. For all practical purposes, it is the same temperature all day, every day, all year round. In this respect, it is an infinitely renewable energy resource.

A geo heat pump transfers heat from the building to the ground in the summer, and from the ground to the building in the winter. Because the temperature differential between building and ground is lower than between building and air, the geo system is by its nature more efficient than an air-source system.

In all but a few exceptional cases, geo systems can provide all of the space heating, space cooling, and water heating needs of Ontario buildings, at a typical efficiency[2] of about 400% for heating and 800% for cooling. That is not a typo. For every unit of energy used, about four units of heat is added to the space or eight units of heat are removed from the space (cooled).

[1] Also called ground source heat pumps, earth energy, geoexchange, GSHP, Geo HP. All of these are referred to in this report as "Geo" for short.
[2] Using Coefficient of Performance (COP) as the standard measure for heating.

<u>The Geothermal Industry</u>

Ontario has an active and mature network of contractors trained and experienced in installing geo systems. The industry has, over the years, developed accepted official standards, such as CSA 448 and HDPE 4710, and strong training and certification programs. It continues to lack economies of scale, though, meaning that geo systems tend to be expensive relative to conventional systems. It also means that they have the potential to drop in price, in much the same way as solar photovoltaic systems in recent years (although likely not as much).

Geothermal also suffers from the fact that competitors, such as natural gas, already have extensive built infrastructure, which has been amortized over many years. Geo systems require pipes in the ground, much like natural gas, but for the most part the geo pipes are not yet built. Of course, where natural gas infrastructure is being expanded into new communities with marginal or negative economics, geothermal's infrastructure disadvantage is reduced.

<u>Government Policy</u>

The Ontario government has announced its commitment to a low-carbon future, and its intent to be part of the Western Climate Initiative, a cap and trade program for carbon. The price of carbon for natural gas use in Ontario is expected to increase to at least $80 per tonne by 2030, and substantially more by 2050. Some other jurisdictions, such as New York, already peg the societal cost of carbon at US$128 per tonne or more in 2017.

In order to achieve Ontario's low-carbon goals, natural gas use must decrease by about 40% by 2030, with bigger reductions by 2050. The Ontario electricity system, on the other hand, has been largely de-carbonized, with only limited gas generation remaining, largely as a transitional measure.

The Ontario government has announced its support of <u>rational</u> natural gas expansion into communities not yet served, in order to promote economic development, and has agreed to provide $30 million in subsidies, and $200 million in loans. The government has not made any statements supporting additional subsidies by local municipalities, or ratepayers, or anyone else.

<u>Head to Head Comparisons</u>

Geo is a low carbon alternative to natural gas. Where the currently proposed community expansions by Union and Enbridge would likely produce about 4 Mt of carbon by 2050, serving the same communities with geothermal energy, at a lower cost, would produce about 0.2 Mt of carbon over the same period (i.e. about 5% of the natural gas emissions), and maybe less if the carbon content of the electricity sector continues to decline.

Though geothermal relies on electricity as an input (to power the pump), a geothermal system actually reduces electricity demand in the summer, and increases it in the winter, relative to traditional methods of heating and cooling (heating with fossil fuels and cooling with traditional AC systems). For Ontario, a summer peaking jurisdiction, a greater reliance on geothermal would reduce peaking power needs and also reduce surplus baseload generation. Coincidentally, the load profile of a geo system is similar to the production profiles of Ontario wind energy facilities.

Geothermal, of course, provides significant environmental benefits relative to electric resistance, propane, oil, LNG, and other heating and cooling energy alternatives. And the thermal energy from the ground is endlessly renewable, making the technology highly sustainable.

In addition, over the lifecycle of the systems, geothermal systems in the areas of proposed expansion would, on average, cost no more than 85% of the cost of natural gas expansion at current cost levels, and a lower percentage as natural gas costs increase and geothermal costs decline. That differential would vary by community, and it is not certain that geothermal would be the lowest cost alternative in every case.

The economic activity to provide these energy needs with geothermal, vs. natural gas, is more heavily weighted to Ontario rather than other jurisdictions, because geothermal does not rely on a fuel – natural gas – that is imported into Ontario.

What Should the Board Do?

The Ontario Geothermal Association believes that the Ontario Energy Board should reach two conclusions in this case:

1. Natural gas community expansion should only be approved with a Profitability Index (PI), for each proposed expansion, of 1.0 or better.

2. Each time Union or Enbridge proposes an expansion into a new community, one of the mandatory criteria should be evidence demonstrating that:

    a. Before any subsidies (from any level of government, or from ratepayers, or from contributions in aid of construction), natural gas expansion is more cost effective in most reasonable scenarios than the unsubsidized cost of any alternatives, including geothermal; and

    b. Natural gas expansion is either preferable to, or equal to, those alternatives from an environmental point of view, including carbon emissions.

2 GEOTHERMAL ENERGY

2.1 *Introduction*

There are several terms used to describe these highly efficient and clean heating and cooling systems: GeoExchange, Earth Energy or Earth Exchange, Ground Source Heat Pump and Geothermal Heat Pump systems. They all mean the same thing. In this report, we use the terms "Geothermal Heat Pump" and "Geothermal Heat Pump System" and their abbreviations, "Geo HP" and "Geo System".

Geo Systems are a relatively mature technology, but are continuing to improve. There are more than 1,000,000 Geo Systems installed in North America and close to 100,000 in Canada.

2.2 *How Does It Work?*

Heat energy naturally flows from a higher temperature medium to a lower temperature medium. However, to get heat energy from a lower temp to a higher temp, it must be "pumped" by a mechanical device called a "heat pump". Heat pumps use a refrigerant compression-expansion cycle to do this.

Heat pumps use electrical energy to run the pump and compressor. This is the same principle that is used in refrigerators and air conditioners. In a refrigerator, heat is pumped out of the box and into the kitchen. An air conditioner pumps heat out of the house and into the ambient air around it.

The lower the temperature difference between the source of heat energy and the load, the less energy it takes to transfer or "pump' it. Geothermal systems are the most efficient method currently known to use electrical energy to heat and cool buildings and other spaces, because they minimize the temperature difference between the source and the load.

For every unit of energy (electricity) used to operate it, a Geo HP will transfer a total of 3 to 5 units of thermal energy into a building – so at least 2/3rds and as much as 4/5ths of the thermal energy provided is coming from the ground. That's 300% to 500% efficiency. This compares with heating systems using fossil fuels (natural gas, oil and propane) which, at best, can only approach 100% efficiency.

For the cooling of buildings, Geo HP's use about half the electricity to operate compared to air source heat pumps and AC systems, and, geo's electrical demand doesn't spike as it gets hot outside, since the ground loop temperature remains relatively unchanged. They can reduce the "heat wave" electricity system demand spikes by up to 75%.

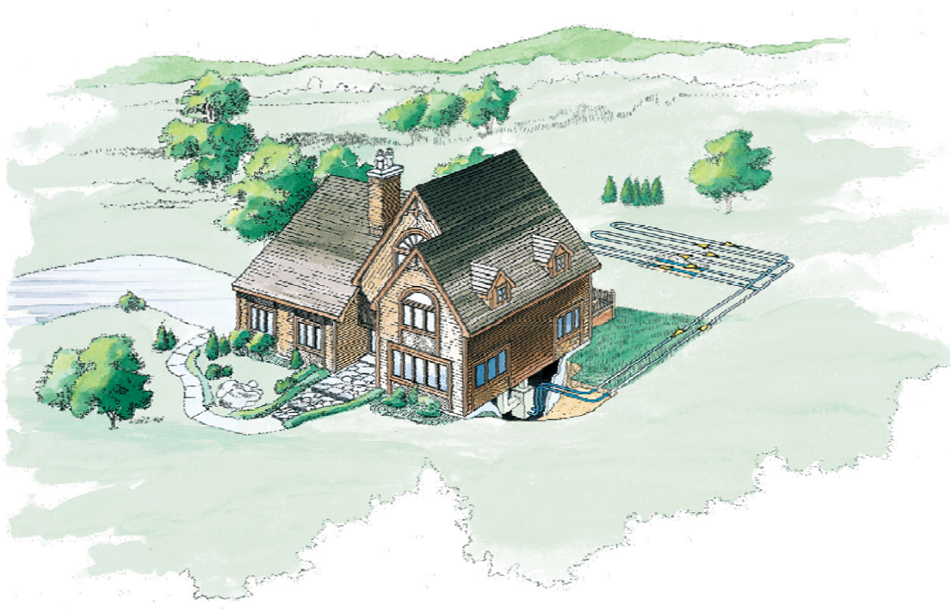
2.3 *Geothermal Systems*

A geo HP system consists of three main components: compressor inside the building to draw heat from a liquid; a ground (or, in a few cases, water) loop outside the house to act as the heat exchanger with the ground, and a pump to circulate the liquid between one and the other. They also have control systems, and, like any other heating/cooling system, a method of circulating the hot or cold air within the building.

The most unique feature of GeoHP systems is the ground loop. This is a loop of pipe, quite similar to natural gas distribution pipes, that is embedded in the ground to allow the liquid within the loop to exchange heat with the ground. If there is sufficient surface area (for example, in rural settings, or under a parking lot), the ground loop can be horizontal, installed through trenching only a few metres below the surface. In more urban or space-constrained areas, the ground loop is vertical, installed by drilling to a depth of up to 200 metres. Vertical loops are installed much like well drilling, but with a much smaller bore size.

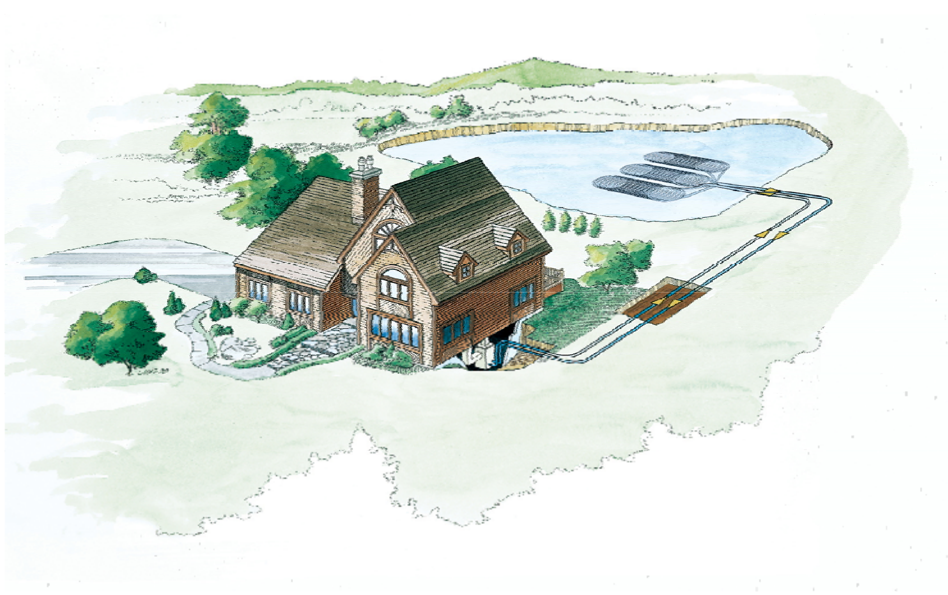
The cost to install a vertical loop can be up to twice as much as a horizontal loop. However, the loops typically last 50 years or more, so the cost differential is not as significant on a lifecycle basis.

Horizontal Ground Loop



Vertical Ground Loop

Pond/Lake Loop



The efficiency of geothermal systems is enhanced by increased ground loop length. A longer ground loop means that the temperature of the fluid as it returns to the house is higher in the winter, and lower in the summer, because it will have gained or lost more heat through the ground loop cycle. Standards have been developed to size ground loops to maximize efficiency relative to cost. Typically horizontal ground loops are 90 metres in length (supply-return) per ton capacity, while vertical ground loops are 50 metres in length (supply-return) per ton capacity.

With a few notable exceptions (such as the Enwave deep water system in Toronto), geothermal has not yet been used in district energy applications. This is a likely future evolution, particularly in greenfield situations such as new subdivisions, where the cost to install the ground loop can be dramatically reduced. While this report focuses on stand-alone geo HP systems, future district energy systems using geothermal can be expected to play a significant role in thermal storage in combination with other energy alternatives such as combined heat and power (CHP), passive solar, bio, and excess electrical generation.

2.4 *Environmental Benefits of Geothermal*

At its simplest, switching from fossil fuels to geothermal generates environmental benefits two ways.

First, the amount of input energy used in geothermal is significantly less than the alternatives to deliver a given amount of heating or cooling. Efficiency of 400% is better than 95%.

Second, the input energy used is electricity instead of combustion of fossil fuels. The environmental impacts of the energy function are those of Ontario's mostly decarbonized electricity system, as opposed to the environmental impacts of a combustion technology like natural gas.

Carbon is the most obvious example of that. The use of geo systems in Ontario's buildings instead of conventional heating systems, fueled by natural gas, oil or propane, and inefficient AC systems will reduce their annual GHG emissions by between 4.1 and 7.1 tonnes per average household to less than 0.5 tonnes per household.

2.5 *Electricity System Benefits of Geothermal*

Geothermal systems, because their efficiency is largely unaffected by outside temperature, provide reasonably smooth electrical power consumption relative to air-source heat pumps or air conditioners.

For cooling, geothermal heat pumps operate at EER (btu/W) of approximately 27 even on the hottest day of the summer. Because the geothermal heat pumps are normally sized for heating, and peak cooling loads are significantly smaller than peak heating loads, the geothermal heat pumps normally run at second-stage for cooling and achieve very high EER. Air conditioners operate at EER numbers of around 8-10 on the hottest days of summer. A geothermally cooled house uses approximately 0.5 kW/ton less than an air conditioned house which equates to approximately 1.0 kW less for a 1500 sq ft house. SEER ratings do not reflect peak power demand requirements because they are seasonal average numbers, not reflective of the demand on the hottest days.

Figure 1 shows the daily power consumption for a geothermal system with a COP[3] of 4 and EER[4] of 27 versus an air conditioner with an EER of 9 (assuming 38 C or 100 F on hottest day). The hourly heating and cooling loads are based on simulated loads for a typical 1500 sq. ft. single detached home in Southern Ontario. For the sake of calculation, the two systems are assumed to operate at a constant efficiency regardless of load or outside air temperature. The purpose of the comparison is to provide a load profile with representative peak loads rather than provide exact numbers since the efficiency of both systems would vary depending on load and temperature. The geothermal system provides both heating and cooling while the air conditioner provides only cooling.

Figure 1 shows that peak electrical loads in the summer are reduced, because geothermal provides cooling more efficiently than air-source systems like conventional air conditioners. A new electrical peak load is added in the winter, because geothermal uses electricity instead of combustion for heating. The overall annual peak will be higher for the geothermal system (2.9 kW) than for the air conditioning (1.4 kW), and that the peak shifts from summer to winter when going from air conditioning to geothermal (LHS axis). Total annual electrical consumption also increases with geothermal from 810 kWh for air to 3520 kWh for geothermal[5]. Note that power consumption does not reflect costs of running the fan for gas heating or electric hot water.

Figure 1 also shows the monthly average power generation for 3 small wind farms in Ontario (RHS axis). The power output profile of wind is much better suited to the load profile for geothermal systems than it is to conventional air conditioning where minimum wind power generation coincides with maximum power requirements.

[3] COP, or coefficient of performance, is the standard method of comparing energy efficiency in many applications, and it is the most common way of comparing systems that use different energy sources. It divides energy outputs by energy inputs for a given application. It is used for comparing heating systems, where one is combustion and the other is electrical.

[4] EER, or energy efficiency ratio, is the standard method of comparing cooling efficiency. It measures the ratio of cooling output in BTUs to the electrical energy input in watt-hours. A higher EER is better. The US Department of Energy often uses the term SEER, which means seasonal energy efficiency ratio, and is the same calculation with an adjustment for seasonal variations.

[5] Total energy consumption (not shown on Figure 1) declines, of course, because the combustion component is removed. Geothermal is more energy efficient in both winter (vs. natural gas) and summer (vs. conventional air conditioning).

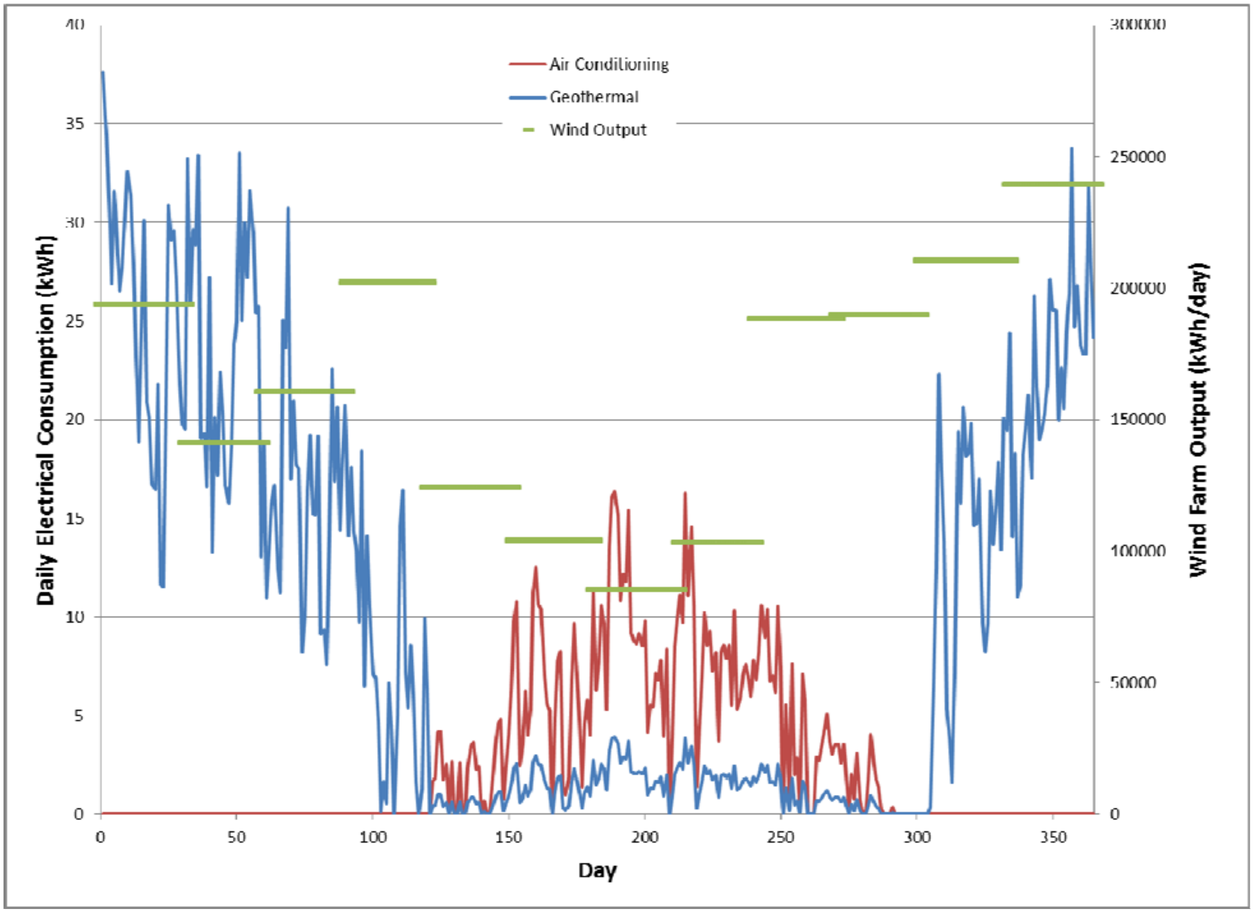


Figure 1. Comparison of daily electrical consumption for a geothermal system (both heating and cooling) versus an air conditioner (cooling only) for a 1500 sq ft typical house (LHS axis). Consumption is based on simulated hourly loads from EQuest. Also shown is the power production (averaged monthly) for three small wind farms in Southern Ontario (RHS axis).

Table 2
Estimated Heating Equipment Conversion/Replacement Costs[8]

Heating Equipment and Fuel	Distribution	Estimated Conversion Cost	Assumptions
Oil Boiler	32%	$4,200	$4,000 + $200 to remove oil tank
Oil Forced Air	3%	$4,200	$4,000 + $200 to remove oil tank
Propane Boiler	1%	$4,000	
Propane Forced Air	12%	$1,525	75% can be converted at $700; remainder replaced at $4,000
Propane Space Heater	2%	$3,500	Replaced with a fireplace
Electric Baseboard	6%	$11,000	
Electric Forced Air	12%	$4,000	
Electric Heat Pump /Hydronic	4%	$4,000	
Wood (assumed wood stove)	28%	$3,500	Replaced with a fireplace
Weighted Average	**100%**	**$4,068**	

Effect on Peak

The effect of changing all homes to geothermal on aggregated peak power demand can be calculated using the distribution of heating equipment and fuel systems provided in Table 2 of Union Gas Exhibit A Tab 1 (reproduced above). The calculation assumes all houses are air conditioned (or eventually will be) and all houses are reasonably well represented by the load profiles shown in Figure 1. For existing systems, peak electrical load in winter is assumed to be negligible for all systems other than for electric heating. For electric heating, the peak load is assumed to be 4 times that of a geothermal system or 11.6 kW per system. During summer peak load is assumed to be 1.4 kW per system for all systems excluding heat pumps (i.e. all homes have air conditioning or eventually will). Heat pump systems are assumed to have a peak winter and summer loads of 2.9 kW and 0.37 kW, respectively.

With existing systems, the calculated aggregate average peak electrical load for HVAC in winter is approximately 2.2 kW per household and in summer 1.4 kW. For 100% geothermal the aggregate average peak electrical consumption for HVAC in winter would be 2.9 kW per household and in summer 0.4 kW. By switching all systems to geothermal, the aggregate electrical peak is then expected to increase 0.7 kW/household in winter and decrease 1.0 kW in summer.

Ontario is presently summer peaking, which would suggest that a switch to geothermal would help reduce the summer peak. The increase in winter demand would not be problematic. Wind generation is also higher in winter, so geothermal would allow higher utilization of wind power.

Effect on Total Power Consumption

The effect of changing all homes to geothermal from existing systems on total power consumption can also be calculated. For all existing systems except the electric heat pump systems, the power consumption related to air conditioning is assumed to be 810 kWh/yr. Electric heat pumps systems are assumed to be geothermal with an existing consumption of 4450 kWh/yr. Electrical systems are expected to consume four times the amount of geothermal for heating, giving a total for air conditioning and heating of 14,350 kWh/yr. Following conversion to geothermal, all systems would use 4,450 kWh/yr.

The aggregate average electrical consumption per household for HVAC would increase from 3400 kWh/yr to 4450 kWh/yr by switching all homes to geothermal.

3 THE GEOTHERMAL INDUSTRY

3.1 *Introduction*

The residential geothermal industry is largely made up of small to midsized heating and refrigeration contractors, many of the same contractors that install natural gas furnaces and air conditions. Those contractors with specialized geothermal training complete the bulk of the heat pump installations, including sizing of the systems, and installation of the geothermal loops if installed horizontally or in lakes or ponds. Vertical geothermal loops are generally installed by well contractors or specialized geothermal drilling companies.

During the ecoEnergy rebate program for geothermal heat pumps from 2006-2011, annual installations in Ontario reached a high of approximately 9000 residential geothermal retrofits[6]. Over 8000 installers were certified by the CGC training program, many of which are in Ontario. Installation rate increased rapidly during the ecoEnergy rebate program, showing the ability of the industry to respond to the increased demand for heat pumps.

3.2 *History*

Geo HP systems were first offered commercially in North American in 1979, and became a preferred technology for the US Department of Energy in the oil crisis of the 1980s. This dramatically increased the nascent industry's growth, leading to the first "boom-and-bust" segment of the industry's history.

As technical standards and training caught up to demand, Ontario Hydro offered a significant rebate program for geothermal HP systems in 1991. This led to another major industry expansion, as well as further training of contractors in Ontario. That program was axed suddenly in 1995, and the Ontario industry saw its market largely evaporate.

Throughout North America the lull in the late 1990s allowed the industry to consolidate, improve technical standards further, and form common industry organizations. Geothermal continued to be a preferred technology for the US federal government, and many states.

The industry experienced a substantial expansion once more in both Canada and the United States in the early 2000s. The Canadian federal government promoted geothermal systems as part of the ecoEnergy program, and in the US a 30% tax credit (still in effect) reduced the capital cost different for geo systems.

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[6] Based on information from the Canadian Geoexchange Coalition (CGC).

Approximately 8000 individuals were trained by the CGC to install heat pumps during the ecoEnergy grant program from 2006 to 2011. Of those, many are from Ontario.

The ecoEnergy grant program for geothermal heat pumps resulted in very rapid growth of the residential geothermal market and led to the entry of many new companies looking to capitalize on the grant program.

Geothermal was a popular EnerGuide choice for Canadian buildings under the ecoEnergy program, but that program was abruptly cancelled in 2010.

Since that time, changes have occurred within the Ontario geothermal industry, and the industry as a whole, that have led to improved quality of installations. One key change was the affiliation of the Ontario Geothermal Association with the Heating Refrigeration Air-conditioning Institute (HRAI) in 2014. HRAI provides a vetting process for all its member companies to ensure proper training and certification. HRAI now is able to ensure that member geothermal installation companies will have proper geothermal design and installation training. Training courses are offered through the International Ground Source Heat Pump Association (IGSHPA). These training courses incorporate the latest CSA 448 bi-national standard "Design and Installation of Ground Source Heat Pump Systems for Commercial and Residential Buildings". All HRAI member geothermal companies will be required to ensure that their personnel have this training in the future[7].

Adoption of CSA 448 standards for geothermal pipe manufacturing and installation has led to very high pipe quality and very low pipe failure rates. The move to 100% fused (plastic welded) joints has removed the issues of occasional geothermal loop failure seen in installations from the early 1990's related to mechanical joints. The move to high quality geothermal pipe manufacturing through adoption of NSF and CSA standards for geothermal pipe has drastically reduced pipe failure found in some installations completed in the 2002-2004 time frame. CSA 448 is very specific on type of pipe resin used.

More recent industry wide adoption of HDPE 4710 resins in manufacture of geothermal pipe and fittings, prefabricated factory-made pressurized vertical u-loops, and continued tightening of industry standards and training all are continuing to improve the quality and longevity of geothermal loops. Expectation for geothermal loops longevity is now in excess of 50 years, where longevity of HDPE 4710 loops is expected to exceed 100 years.

[7] In addition to applicable trade licences (refrigeration, electrical, plumbing, etc.), business insurance, and WSIB coverage.

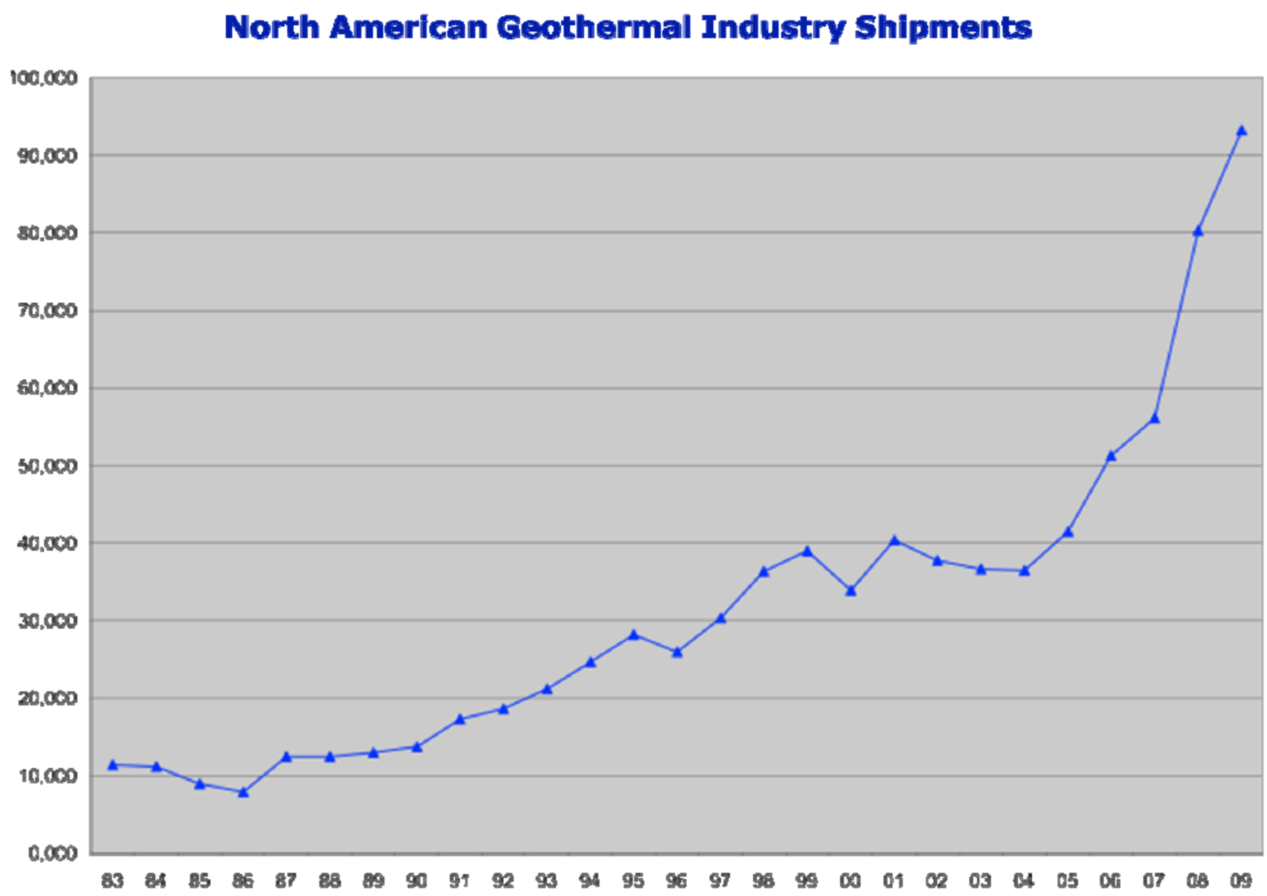

Figure 2[8]

3.3 ***The Industry Today***

Union's proposal to complete 29 projects to provide natural gas service to approximately 18,000 homes and businesses in 34 communities could alternatively be provided through geothermal heat pump installations. Local heat pump contractors exist in most of the proposed areas, already providing new installations and servicing to existing geothermal customers in those communities. From Union's proposal, approximately 4% of customers already have electric heat pump installations many of which would be geothermal heat pump installations. This indicates significant penetration of geothermal installations in some of these communities already.

[8] Extracted from presentation by Dan Ellis to US Congress.

Similar proposals from Enbridge will, given the Enbridge service territories, also be in areas already served today by experienced geothermal contractors. Those contractors – who in many cases are the same companies that would be converting customers in the community expansion areas to natural gas, if that were the direction taken – have the capacity and expertise to convert those customers to geothermal on a similar time frame to natural gas conversion.

4 GOVERNMENT POLICY

4.1 *Introduction*

Conversion of the heating and cooling sources for Ontario communities is driven by a number of related government policies. The Board is aware of those policies, so in this section the Ontario Geothermal Association is only providing a summary of the highlights.

4.2 *Low Carbon Future*

The Ontario government has adopted a policy imperative of a low-carbon future. The Minister of Environment and Climate Change describes that future this way[9]:

> *"By 2050, we envision Ontarians will be using less energy and the energy we do use will be from low-carbon sources. Communities will be climate-resilient, complete and compact. More people will choose electric or other zero-emission vehicles and transit to get swiftly and efficiently where they need to go. Agricultural lands, natural areas and ecosystems will be better protected for the benefit and enjoyment of all, including First Nations and Métis peoples who rely on our shared natural environment for sustainment and spiritual benefit."*

The Province has agreed to join the Western Climate Initiative, and starting in 2017 Ontario will have a cap and trade system to internalize the cost of carbon. Ontario's target is to reduce emissions by 80% relative to 1990 levels. All carbon-emitting energy sources will be affected.

On March 10, 2016, the OEB announced a consultation to consider how to deal with cap and trade in the context of natural gas regulation. In announcing EB-2015-0363, the Board said in part:

> *"On February 24, 2016, the Government of Ontario proposed Bill 172, the <u>Climate Change and Low-carbon Economy Act, 2016</u>. The government also released draft regulation – The Cap and Trade Program – on February 25, 2016, which provides details about the proposed Cap and Trade program…*
>
> *Under the proposed legislation, natural gas distributors will be required to comply with the Cap and Trade program. This will include activities such as GHG abatement and purchasing emissions credits. These activities will be*

[9] Ontario's Climate Change Strategy, p. 3, "Message from the Minister".

> *described in the natural gas distributors' Cap and Trade Compliance Plans. The OEB is responsible for assessing these Plans for the purpose of cost recovery from ratepayers."*

The introduction of cap and trade will have an important impact on the cost-effectiveness, and appropriateness, of building new carbon-emitting infrastructure in the Province of Ontario.

4.3 ***Natural Gas Community Expansion***

Another provincial government policy is to promote "rational" expansion of natural gas into communities not currently served by gas infrastructure. In her mandate letter to the Minister of Energy, the Premier spelled out the overriding priority for the Minister, and later talked about two economic development programs, as follows[10]:

> *"Helping the Minister of Economic Development, Employment and Infrastructure establish and implement a new Natural Gas Access Loan. Our government will provide up to $200 million over two years through this program to help communities partner with utilities to extend access to natural gas supplies.*
>
> *Helping the Minister of Economic Development, Employment and Infrastructure establish and implement a $30 million Natural Gas Economic Development Grant to accelerate projects with clear economic development potential."*

On February 17, 2015, the Minister of Energy wrote to the Board in this regard, saying[11]:

> *"I am writing to you today to encourage the Board to continue to move forward on a timely basis on its plans to examine opportunities to facilitate access to natural gas services to more communities, and to reiterate the government's commitment to that objective. I appreciate your continued support to ensure <u>the rational expansion</u> of the natural gas transmission and distribution system for all Ontarians." [emphasis added]*

This proceeding is a direct result of the government's policy initiative in this area. It is clear that the focus is on expansion for the purpose of economic development, and all such expansion must be in the public interest.

[10] EB-2015-0179, Exhibit A, Tab 1, App. N.
[11] EB-2015-0179, Exhibit A, Tab 1, App. A

4.4 ***Geothermal***

In the context of its recent Climate Change Strategy, the Ontario government has sought to reiterate its support for geothermal heat pumps as a preferred heating and cooling option, highlighting geothermal as follows[12]:

> *"Geothermal heating and cooling systems, often called geoexchange or ground source heat pumps (GSHPs), are an efficient way to heat buildings. When paired with low-carbon electricity, this technology can be virtually emissions free. Switzerland, for example, has more than 25,000 GSHP systems in operation, and is estimated to have the highest installed density in the world. Swiss public utilities have used a system called energy contracting to effectively provide an incentive for the adoption of GSHPs, which involves planning, installing, operating, and maintaining GSHP systems at their own cost and selling the heat (or cold) to the property owner at a contracted price in cents per kilowatt hour."*

In the context of the low carbon future, Ontario has recognized that geothermal will play an important role in achieving that future. For example, the graphic below, from the Ontario government's website, shows the link between low carbon homes and ground source heat pumps.

[12] Ontario's Climate Change Strategy, p. 23

The OGA is aware that the government is currently considering the appropriate methods to promote geothermal – as well as other low-carbon energy sources – as part of its comprehensive strategy to implement cap and trade and reduce Ontario's carbon footprint. However, the details of the government's incentives and other policy steps have not been finalized or announced.

However, it is clear that the climate change direction will entail a rethinking of policies promoting fossil fuels, as the policy says[13]:

> *"Ontario will take the following actions to achieve these goals:*
>
> ***…2. Review and make recommendations regarding existing policies and programs that support fossil fuel use and fossil fuel intensive technologies.*** *Our strategy recognizes the negative impact of fossil fuels on the climate. We will look at removing existing initiatives that support fossil fuel use, which could free up funds to better support sustainable development and clean technologies and energy. We will communicate to users that moving away from fossil fuels makes financial sense since the cost of renewable energies such as solar and wind is dropping significantly. "*

In the United States, geothermal continues (since the mid-90s) to be considered the most efficient method of heating and cooling buildings currently available for most applications and geographic regions. It is subject to a 30% tax credit, and state support in many areas of the US. Some references that show the views of US federal and state governments with respect to geothermal are the following:

US Department of Energy:

http://energy.gov/energysaver/geothermal-heat-pumps

US Environmental Protection Agency:

https://www.epa.gov/rhc/geothermal-heating-and-cooling-technologies

Californian Energy Commission:

http://www.consumerenergycenter.org/residential/heating_cooling/geothermal.html

Oak Ridge Laboratory:

[13] Ontario's Climate Change Strategy, p. 24

http://greenbuildingelements.com/2015/03/20/new-geothermal-heat-pump-uses-50-less-energy/

New York State:

http://www.nyserda.ny.gov/Cleantech-and-Innovation/Power-Generation/Geothermal-Heat-Pumps

New York City:

http://www.nyc.gov/html/planyc/downloads/pdf/publications/2015_Geothermal.pdf
http://www.renewableenergyworld.com/articles/2016/01/new-york-city-council-gives-a-thumbs-up-to-geothermal-heat-pumps.html

Tennessee Valley Authority:

https://www.tva.gov/Energy/EnergyRightSolutions/EnergyRight-Solutions-for-Home/Rebated-Upgrades/Heat-Pumps/Geothermal

National Renewable Energy Laboratory (NREL):

http://www.nrel.gov/geothermal/guidebooks/heating_cooling/state_policies.html

5 HEAD TO HEAD COMPARISONS

5.1 *Introduction*

This section compares the cost and environmental impacts of serving Ontario communities with natural gas vs. geothermal. What the comparison shows is that, in most cases, geothermal is the preferred energy source for heating and cooling buildings in a low-carbon Ontario, both on the basis of cost and on the basis of emissions.

A key component of this analysis is carbon differentials. The numbers are pretty clear. Carbon emissions from heating a typical home, per annum:

- Natural Gas 5.10 Tonnes
- Propane 4.90 Tonnes
- Oil 5.90 Tonnes
- Electric 1.37 Tonnes
- Geo .45 Tonne

5.2 *Subject Communities - Natural Gas vs. Geothermal*

Cost. Several assumptions are being made when calculating the lifecycle cost of natural gas systems versus geothermal systems over the period 2017 to 2050. The following assumptions are used:

- The retrofit costs of representative gas and geothermal systems are reasonably reflected by the cost calculations in Appendix B, namely $10,975 for gas and $15,050 for geo, respectively.
- The cost of operation of each of the systems is equal to the analysis provided by annual costs shown in Appendix B. The house size is approximately 1200-1500 sq ft.
- The cost of the gas connection is the capital cost for the respective projects spread over the number of forecast customers rather than potential customers. The 4 projects with highest PI would then have a connection cost of $8,801/house and the Kincardine et al. project would have a connection cost of $15,588/house. See Appendix B.
- Carbon pricing is reflected in the cost of using gas and that it increases linearly from $30/tonne in 2017 to $80/tonne in 2030 and continues to escalate at that rate to 2050, in equivalent 2017 dollars
- Inflation rate is 2%, used for net present value calculations, cost of future equipment replacement, cost of carbon, cost of gas, and cost of electricity
- Carrying costs of loans are not considered

- Equipment is replaced after 20 years of service [14]
- Geothermal equipment is replaced with variable heat pump technology when replaced at 20 years
- Fixed rate electrical charge for distribution reaches 100% in 2020

A lifecycle cost comparison for the top 4 PI projects and the Kincardine et al. projects[15] from Union Gas is provided in Table 1. Net present values, reflected in annual cost, are shown for where the connection charges to the gas main or geothermal loop are included and excluded. A scenario is also considered where after 20 years, at the end of equipment life, the gas furnace, water heater, and air conditioner are replaced with a geothermal system (all costs included). In all instances, the lifecycle cost of a gas system is greater than that of geothermal system, regardless of whether the cost of connection to gas is included or not included. The conversion to geothermal after 20 years also has a lower lifecycle cost because significant carbon cost is avoided. The large difference in lifecycle cost is very much related to the cost of carbon. Table 2 also compares the top 4 PI projects with carbon price is excluded. Without carbon pricing, geothermal systems still have a slightly lower lifecycle cost.

Table 1. Lifecycle Cost expressed as Annual Cost Based on Net Present Value of Expenses Associated with Natural Gas and Geothermal Systems (no increase in commodity cost)

	to natural gas		to geothermal		to geothermal after 20 yrs
	with connection	w/out connection	with loop	w/out loop	with gas connection and loop at year 20
top 4 PI projects	$ 2,414.01	$ 2,160.23	$ 1,820.58	$ 1,633.15	$ 2,303.70
top 4 PI without carbon	$ 2,052.60	$ 1,798.62	$ 1,820.58	$ 1,633.15	$ 2,136.27
Kincardine etc	$ 2,609.71	$ 2,160.23	$ 1,820.58	$ 1,633.15	$ 2,499.40

Without increases in cost of either gas or electricity, the cost of operating a typical house in 2050 will remain about $1,975/yr for natural gas but decrease to about $640/yr for geothermal because of technology improvements and changes in distribution charges on electricity (in 2016 equivalent $CDN). This represents a savings of about $1300/yr by 2050 for geothermal.

The lifecycle costs of different size systems will vary. The analysis shown in Table 1 is for a house about 1200-1500 sq ft. Smaller houses, townhouses, or apartments may show a more favourable lifecycle cost for geothermal because less gas is used so the cost per unit volume of

[14] Equipment life is assumed to be approximately 20 years for the mechanical equipment being installed, either gas furnace, air conditioner, and hot water heater, or geothermal heat pump and hot water heater.
[15] This term refers to the four largest projects. See Appendix B.

gas goes up (fixed monthly charge) and the connection cost remains the same. On the other hand, geothermal systems require a smaller loop and therefore initial connection costs are reduced. Operational cost ratios would remain about the same. The opposite is true for larger homes, where the geothermal loop costs would increase while gas connection remains similar.

The conclusion of the lifecycle cost analysis is that geothermal systems are competitive with natural gas in the proposed communities, particularly when carbon costs are considered. The variables such as house size, geology, ability to put in horizontal geothermal loops for the geothermal system, and cost of putting in gas mains for gas systems will determine which system has a better overall lifecycle cost. Geothermal will certainly be more competitive in some communities than others.

This set of scenarios assumes that both the cost of electricity and the cost of natural gas increase with inflation only. That is not likely to be correct. In most jurisdictions, it is expected that in the long term the real cost of natural gas will increase at a higher rate than electricity.

In the US, the federal government's Energy Information Administration (EIA), for example, forecasts that, between now and 2040, natural gas costs will increase annually by inflation plus 1.75%, while electricity costs will increase annually by inflation plus 0.63%. While Ontario costs for natural gas will likely mirror North American prices, it is not clear that the Ontario electricity system, already decarbonized, will see increasing prices at the same levels as the US. It is likely, however, that comparisons of geothermal to natural gas that build in future price scenarios will show that geothermal has a bigger advantage than using current price levels.

What is undisputed is that natural gas heated houses are subject to significant cost risks from both commodity prices and carbon prices. By utilizing low carbon alternatives such as geothermal that rely on low carbon electricity, the risk of price increases is reduced dramatically.

Carbon Emissions. Ontario's power generation has largely been decarbonized which implies that use of electricity for space heating is a low carbon solution. Various options for space heating exist including electrical resistance, air-source heat pumps, and geothermal heat pumps. Geothermal systems are the most efficient and operationally cost effective electrically based space heating technology, followed by air-source heat pumps, and last electric resistance.

Cost increases within the electrical sector over the last few years already reflect the cost of switching to low carbon generation technologies. This has not yet occurred in the natural gas sector, and consequently all natural gas based space heating.

For the 29 proposed Union Gas projects, burner tip CO_2 emissions are estimated to be approximately 48,000 tonnes/yr. From 2017 to 2050, cumulative emissions would be approximately 1.6 megatonnes. Based on 2030 estimates of carbon cost at $80/tonne eCO_2, annual cost of carbon is approximately $3.9M or approximately $425/yr per customer. Actual cost will depend on the price of carbon.

Assuming that the Enbridge projects are about 150% of the total size of the Union projects, the cumulative Enbridge emissions from community expansion projects would be 2.4 Mt., for a total under this set of expansions of about 4.0 Mt.

Geothermal systems do not emit CO_2 emissions at point of use. Emissions are associated with electrical power generation. Presently Ontario's power generation mix provides approximately 40-50 g/kWh based on 2015 data. Emissions from added electrical power requirements (approximately 3,800 kWh/house/yr) for geothermal systems would equate to 2,200 tonnes/yr. Cumulative emissions for geothermal systems from 2017 to 2050 (2200 tonnes per year for 34 years) would be approximately 0.075 megatonnes. Cost of carbon for geothermal systems will be negligible and represent no long-term price risk to the consumer.

Essentially all carbon emissions associated with burning natural gas or displaced fuels presently used in these communities for space heating and hot water will be eliminated.

Stranded Assets. The gas utilities recognize the risk to their volumes associated with Ontario's low carbon future. At a presentation to the OEB on January 15, 2016 (EB-2015-0237), Enbridge said:

> *"EGD will need to re-imagine infrastructure and business model*
> – *Residential, commercial, institutional NG consumption could need to decline by ~40% by 2030*
> – *Even if protection afforded industrial emitters consumption will need to decline by 20 – 30%*
> – *No net increase in NG consumption for electricity generation*
> – *Electrification of transport and buildings"*

Continued expansion of natural gas infrastructure ties customers to long-term use of natural gas for their heating source, and to the associated carbon emissions. As Ontario moves forward with its Climate Change Strategy, efforts to reduce carbon emissions from burning fossil fuels will intensify, with target reductions as high as 80% by 2050. Reduction of carbon emissions from building space heating is readily achieved because the technology to do so is already available and is reasonably cost effective. The options for carbon reduction in transportation (particularly air transport), forestry, fishery, farming, manufacturing, shipping, and cement sectors are not as well-developed, and therefore achieving reductions in those areas is going to be more difficult and costly.

Investment into low carbon technology solutions will continue to occur to achieve targets and it is certainly possible gas infrastructure may become highly underutilized as building space heating is transitioned to low carbon electric based heating technologies such as heat pumps. The recovery on capital investment on natural gas infrastructure will need to occur over smaller and smaller volumes of gas, increasing the cost of the gas delivery with time. This will be of particular concern to industrial users sensitive to energy input costs.

The cost of infrastructure expansion for the 29 projects identified by Union Gas is $134M. The cost to retrofit each of the houses to gas is suggested to be approximately $37M for forecast customers and up to $75M for potential customers. If air conditioning, hot water tanks, and gas plumbing are included and more realistic numbers are used for the retrofitting of these buildings, the cost of retrofitting to gas with air conditioning will be upwards of $100M for forecast customers and $202M for potential customers. Total cost for the conversion to natural gas would then be in range of $171M to $336M depending on cost of conversion and number of conversions completed.

If carbon emissions are to be drastically reduced, very little of this infrastructure will remain viable. How much life remains in the gas infrastructure and associated home retrofit equipment will depend on when conversion to low carbon emission equipment is required. The gas delivery infrastructure would not be useable if gas can no longer be burned, gas furnaces and water heaters will need to be replaced, and air conditioners would be redundant if air-source or geothermal heat pumps are used to provide space heating.

Alternatively, if the gas infrastructure continues to be used, cost of carbon is expected to be in range of $3.7M/yr by 2030 for the customers served by the 29 projects, equivalent to approximately $425/yr per customer. If carbon cost trend continues to 2050, that cost will be approximately $1000/yr per customer. Without any other increases in gas prices, carbon would more than double the cost of space heating by 2050, in 2016 dollars. The total cost of carbon by 2050 customers would be in range of $146M. Also, if these homes are not converted to low-carbon emission technology, they will continue to pay these costs as long as carbon costs apply.

The details of the Enbridge projects are not yet known. When that information is available, OGA will provide an update that replicates these calculations for the Enbridge projects.

5.3 ***Other Energy Alternatives***

Natural gas is generally preferred on a cost and/or environmental basis to oil, propane and electric resistance technologies. In each case, geothermal is also preferred to those technologies, and by a higher differential.

6 WHAT SHOULD THE BOARD DO?

The Ontario Geothermal Association believes that the Ontario Energy Board should reach two conclusions in this case:

1. Natural gas community expansion projects should only be approved with a Profitability Index (PI), for each proposed expansion, of 1.0 or better.

2. Each time Union or Enbridge proposes an expansion into a new community, one of the mandatory criteria should be evidence demonstrating:

    a. Before any subsidies (from any level of government, or from ratepayers, or from contributions in aid of construction), natural gas expansion is more cost effective in most reasonable scenarios than the unsubsidized cost of any alternatives, including geothermal; and

    b. Natural gas expansion is either preferable to, or equal to, those alternatives from an environmental point of view, including carbon emissions.

The Board should, of course, retain the discretion to approve projects that fall slightly short of these tests, if there is specific and credible evidence of economic development opportunities available to a community that depend on the expansion of natural gas infrastructure.

6.1 *Amend the EBO 188 Formula*

The purpose of using a cost/benefit ratio for gas expansions of less than 1.0 is to recognize the non-financial benefits of providing gas distribution to local communities: environmental benefits, and increased economic development. In a low-carbon future, it is not currently clear that there are net non-financial benefits to gas in many cases. While there are advantages to reducing coal, oil and propane combustion, and potential economic development advantages arising from access to natural gas, those are likely offset, or even more than offset, by environmental costs, including in particular carbon emissions, by the risk of future stranded assets, and by the favourable economic development impacts of alternatives with higher levels of Ontario content.

The OGA therefore believes that the Ontario Energy Board should reconsider whether to allow any community expansion projects that do not have a net PI of 1.0 or better.

6.2 *Additional Test for Expansions*

When a gas utility expands its system, its interest is, and can only be:

a. To make a net long-term profit for the shareholders, and

b. To ensure that its existing ratepayers are not burdened with a net cost to subsidize the new ratepayers.

These goals can be accomplished by proceeding only with PI +1.0 projects, or by adjusting the economics of projects that are below 1.0 through contributions in aid of construction, local, regional or provincial government contributions, local rate riders, and, as proposed in this proceeding, subsidies from existing customers of that gas utility or others.

From a regulatory point of view, however, the question is not whether the given community expansion is, or can be made to be, cost-effective. The regulator must be concerned with whether the expansion is in the public interest. That requires reviewing whether there are other alternatives to natural gas expansion that would serve the public interest better.

There are two main ways to measure energy supply options against each other: cost (including cost risks), and environmental impacts.

OGA believes that, for a natural gas community expansion, the expansion should be compared to alternatives from a cost point of view without any subsidies or contributions, both for natural gas and for the alternative. The assessment should be on a completely level playing field, comparing the net present value of all lifecycle costs, including appropriate consideration of cost risks, and any differential between those risks. The process is not dissimilar to the comparison of futures using the total resource cost (TRC) test, or the societal cost test (SCT), for DSM programs.

In addition, even alternatives that have similar costs should be compared based on environmental impacts. Options such as natural gas expansion that have known environmental disadvantages should be approved only where there are no cost-effective alternatives with a lesser environmental footprint.

Exceptions should be made where there are specific economic development opportunities available, but even in those cases the Board should balance, in the public interest, the economic development impacts with the environmental impacts, and should seek alternatives that maximize the positive impacts of both.

7 APPENDIX A – HISTORY OF THE GEOTHERMAL INDUSTRY

Based upon water source heat pump from Florida of 1950's
Ground loop development using iron and copper loops 1930's and 40's. PB and PE pipe made viable in late 1970's.
Three regions of development in 1979:

- Oklahoma State University - J. Bose Phd, J. Partin Phd, G. Parker Phd
- Ontario - Dave Hatherton
- Ft Wayne, IN - Dan Ellis

Mid - Late 70's-Early 1980's

Energy crisis:
Fossil fuel shortages and price shocks

Dependence began shift to electricity
WaterFurnace founded in Canada 1980
WaterFurnace International founded in US
Opportunity builds for geothermal technology
Technical competence develops in the industry

Mid 1980's
Electric utilities experiencing "peak demands"
DSM (demand side management) becomes a strategic planning tool
Extensive monitoring reveals geothermal efficiency and market potential
Geothermal becomes recognized as DSM planning tool
DSM Rebates mandated by states
IGSHPA founded - OSU
Ontario Hydro becomes aware of tech and begins R&D
Ontario Hydro promotes tech to customer base

Late 1980's
CSA 445 Performance Standards established for geothermal systems, adopted in US
Canadian Earth Energy Association founded collaboration of MOE, NRCan and WF
Training programs developed based on CSA 445
Negotiations begin with Ontario Hydro to launch incentive program
Support grows from regulators, research groups and utilities
Substantial performance in utility DSM programs
A proven technology competitive with conventional fuels

Early - Mid 1990’s
Geothermal recognized as key technology to reduce greenhouse gases
EPA and DOE release reports confirming industry growth potential
Government, utility, and industry consortium formed to assist in the development of the geothermal market
Ontario Hydro Incentive Program launched 7,000 systems installed
1995 Hydro cancels Program industry retreats
WF closes Canadian operations

Late 1990’s – 2000
Geothermal becomes recognized as a major renewable energy source on an international scale
GeoExchange™ systems increase in performance and
NRCan, MOE, EPA , DOE , EPRI , NRECA and EEI recognize the potential for GeoExchange™
Utility GeoExchange™ DSM programs begin implementation
Major international accord to reduce greenhouse gas emissions signed & ignored
MOU Signed between NRCan and GHPC/DC
NextEnergy Founded - Begin rebuilding Canadian Market

Early 2000’s -Year 2010
NextEnergy/NRCan calculate CO2 reduction
US introduces 30% tax credit - still in force
GSHPs adopted into EnerGuide Program grant levels set
Many Provinces match grant - Approx. $9,000 per
Harper adopts EnerGuide rebrands to EcoEnergy
Harper gets majority pulls out of Kyoto, cancels program
Industry retracts by 75%

8 APPENDIX B – GEOTHERMAL VS. NATURAL GAS CONVERSION

There are three components to the cost comparison:

- Cost to retrofit the mechanical systems in the home
- Cost to connect to the gas system, vs. the cost to install the ground loop
- Annual operating costs over the lifecycle of the system

The three components can then be combined using net present value methodology to get a directly comparable cost for natural gas vs. geothermal. See Section 5.2 of the main report.

Cost to Retrofit Mechanical System

The comparison below is for a typical 1500 sq ft house where a forced air oil furnace is replaced with a natural gas furnace and water heater and electric air conditioner in one case and with a geothermal heat pump and pre-heat water tank in the other. In both cases, the connection of service (gas or geothermal loop) is excluded. The two mechanical replacement systems provide the same functionality, namely space heating and cooling and hot water. Similar costs are expected for all other systems except the conversion of electric baseboard and propane forced air furnaces that can readily be converted to natural gas. The example therefore represents about 80% of conversions. The cost analysis will vary with house size and mechanical system being replaced.

From oil to gas with (high efficiency) gas water heater and electric air conditioner

Specifics:
Gas service within house $900
Removal of oil tank $650
97% efficient, two-stage with ECM blower furnace $4,250
50 Gal Power vent natural gas water heater $1,875
15 SEER 2.0 Ton air-conditioner $3,300
Total $10,975

Versus

From oil to geothermal (36,000 btu/hr) with pre-heat water tank

Specifics:
Electrical breaker and disconnect $900
3 ton 2-stage ground source heat pump sytem with ECM blower $11,000
Circulation pump $1,000
Removal of oil tank $650
Preheat 40 Gal insulated water tank – connect to existing electric water tank $1,500
Total $15,050

Cost to Connect

Natural Gas

The cost to connect new customers on main is relatively low. That is not true for these community expansion projects. For the 4 highest PI communities the estimated cost per potential customer to connect to gas is $5,554. The cost per forecast customer is $8,802. For the top 29 projects identified by Union Gas, the cost to connect per potential customer is $7,343 and the cost per forecast customer is $14,815. For the largest of the projects, Kincardine, Tiverton, Paisley, and Chesley[16], the cost per potential customer is $7,952 and the cost per forecast customer is $15,588.

Geothermal

The cost of geothermal connection is the construction of the geothermal ground loop and its connection into the house. The cost of the ground loop is closely related to the size of the house or more accurately, the peak heating load of the house. The ground loop can be constructed either as horizontal loops installed in trenches or horizontal drilling or vertical u-loops, installed in drilled boreholes. The space requirement for horizontal loops is approximately 100 m^2 per ton of heating capacity at a completed cost of approximately $1500/ton. Vertical u-loops require a minimum of approximately 5 m^2 per ton and can readily be placed either under the building for new construction or in or beside the driveway, front lawn, back lawn etc for retrofit. Ability to provide angled boreholes further decreases surface space requirements for vertical u-loops (angled in this case). Vertical u-loops can be used to service most buildings where space constraints exist. Cost for vertical u-loops is approximately $2500/ton and range from $2000-$3000/ton depending on geology, site conditions, and size of project. Combination of vertical and horizontal loops may be possible to blend costs.

[16] These four projects are referred to as a group, throughout, as "Kincardine et al".

The typical gas customer identified by Union Gas is used for typical geothermal cost calculations. A house that uses 2,200 m^3 of gas annually for heating and domestic hot water is equivalent to a house with a peak heating load of approximately 30,000 btu/hr (2.5 ton). The cost of a horizontal loop for that house would be approximately $3750 and a vertical u-loop would be $6,250.

<u>Total Capital Costs for Typical House</u>

Table 2. Cost Comparison of Conversion From Oil to Natural Gas or Geothermal for Various Scenerios

	to natural gas		to geothermal			forecast customers vs 75/25
	potential customers	forecast customers	100% vertical	100% horizontal	75 vert/25 horz	
top 4 PI projects	$16,529	$19,777	$21,300	$18,800	$20,675	-$898
Kincardine etc	$18,927	$26,563	$21,300	$18,800	$20,675	$5,888
29 projects	$18,318	$25,790	$21,300	$18,800	$20,675	$5,115

Table 2 compares the all in cost of a conversion from oil to natural gas versus geothermal for the various projects considered by Union Gas[17]. Also provided is a comparison of cost for either all customers or forecast customers connecting to the gas infrastructure. The capital cost for the gas main expansion is assumed to be the same whether only forecast customers or potential customers connect to the gas infrastructure, an unlikely assumption but no further detail was provided on those costs. Geothermal costs are provided for both 100% vertical u-loop,100% horizontal loop, and a 75%/25% vertical u-loop to horizontal loop ratio. The final column in Table 2 is the difference in cost between the natural gas conversion for forecast customers and geothermal conversion for the 75%/25% loop mix.

For the top 4 PI projects, the conversion to natural gas on average will be about $900 less than for geothermal. For the Kincardine, et al projects, the cost of the natural gas conversion will be approximately $5,900 more per customer than geothermal. For the top 29 projects considered, the cost of the natural gas conversion will be approximately $5,100 more than geothermal.

The connection cost of geothermal installation is on average less costly than installation of natural gas for all projects considered. Put another way, if the geothermal installations received the same subsidies as the natural gas companies are proposing, geothermal is the cheaper option on a connection basis alone. This does not take into account the impact of full lifecycle costs, discussed below.

[17] A similar analysis for the Enbridge projects will be prepared when the Enbridge project data is available.

<u>Operational Cost of Geothermal versus Natural Gas</u>

A comparison is made on the energy costs for a geothermal system with hot water and a natural gas system with hot water and electric air conditioning for a house that would use approximately 2,200 m^3 of gas per annum. Various scenarios are considered to see how cost of operation may vary with time or market conditions. GeoDesigner® from ClimateMaster is used for the analysis to provide the comparison. Weather data for the analysis is from Wellington County, selected to represent average conditions for some of the areas being considered for natural gas service.

Case 1 (Natural Gas and Air Conditioner Today)
Case 1 is using today's natural gas and electricity prices with the typical gas furnace and air conditioner equipment used today. Electrical price delivered is approximately $0.18/kWh and natural gas delivered is approximately $0.36/$m^3$. Electrical cost does not include the monthly fixed distribution charge, because that cost will occur regardless of whether geothermal is included or not (for further comparison). Natural gas cost does include the monthly fixed charge, since that could be eliminated if geothermal is used.

A 95% efficient gas furnace with ECM fan, a 15 SEER air conditioner, and a power vent gas water heater would be considered standard conventional equipment.

Case 2 (Natural Gas with Carbon Price and Air Conditioner)
Case 2 now includes the price of carbon in 2030, estimated to be $80/ton eCO_2, or $0.14/$m^3$ of natural gas, and with existing price of electricity. Base cost of both electricity and natural gas are expected to increase more or less equally with inflation, so for sake of comparison, electricity remains $0.18/kWh and natural gas is $0.50/$m^3$ to reflect added price of carbon.

Case 3 (Geothermal System Using Today's Heat Pump Equipment and Fixed Electrical Distribution Cost)
Case 3 uses a two-stage geothermal heat pump with ECM fan, a pre-heat water tank, and electrical water heater which would be considered today's standard geothermal equipment. Electricity assumes all fixed charge for distribution. Today`s weighted average time of use cost for electricity is $0.135/kWh and this would represent the incremental cost when fixed distribution cost is charged. No cost of natural gas is included.

Case 4 (Geothermal System Using Next Generation Heat Pump Equipment)
Case 4 uses the same price of utilities as in Case 1 but now looks at what happens to the cost of operation when geothermal equipment continues to improve moving from 2-stage compressors to variable speed compressors and pumps along with hot water generation. The latest ClimateMaster heat pump, the Trilogy® Q-mode 930, utilizes a variable speed Mitsubishi

compressor, variable speed circulation pumps, domestic hot water tank control, and smart logic with integrated outdoor temperature sensor for predicting and learning building loads in response to outside temperature. The unit can be controlled to utilize time of use electrical pricing and thermal storage with phase change material. This heat pump system represents the next generation of heat pump technology and will be the new standard for geothermal installations in the decade to come.

Figure 3 provides a comparison of all the cases.

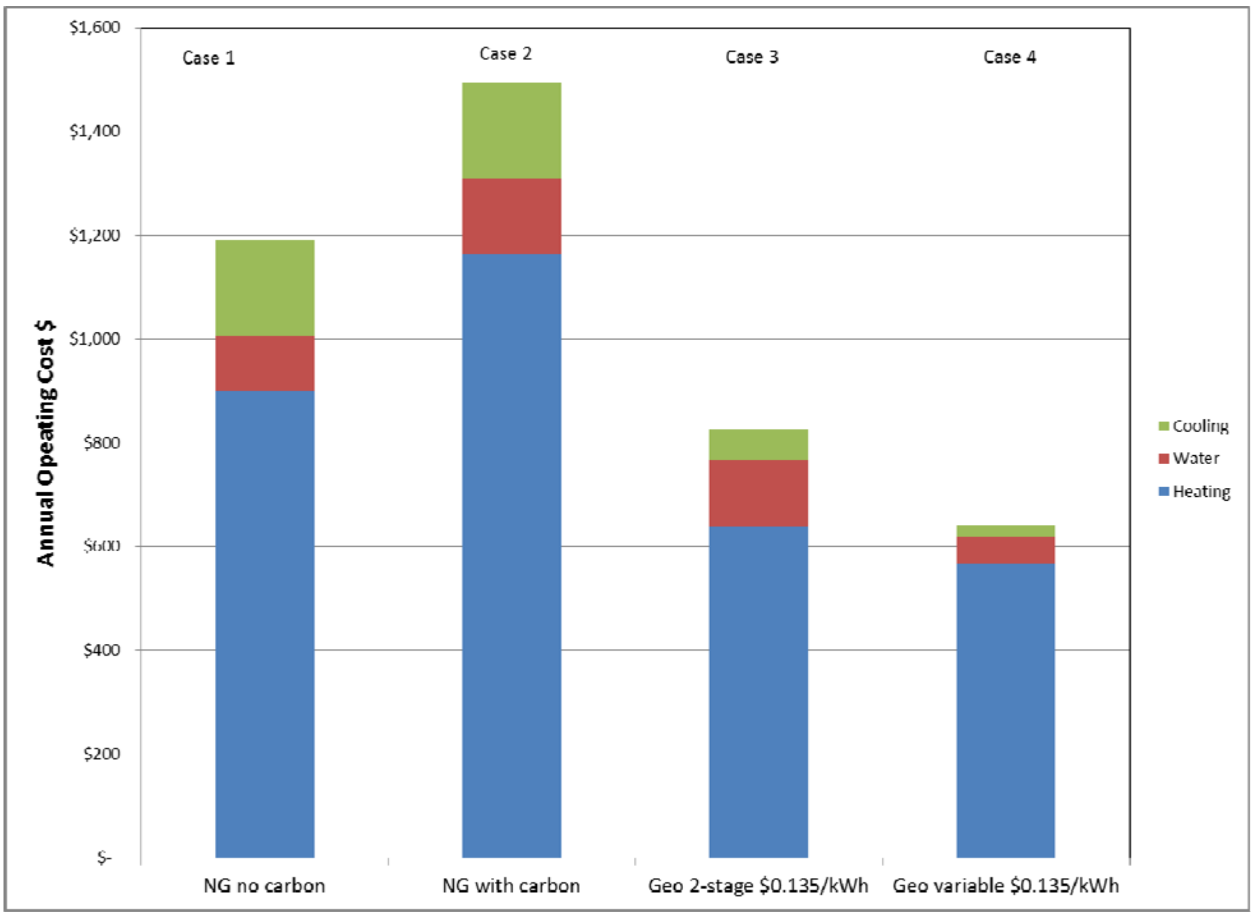

Figure 3. Comparison of annual operating costs of natural gas and geothermal systems under the various cases. Case 1 through 6 are shown from left to right.

From Figure 3, it can be seen that with today's utility prices, and assuming fixed charge for electricity distribution, and today's equipment, natural gas operating costs are about 50% more than geothermal (Case 1 versus Case 3). With the cost of carbon being added to natural gas (Case 2), the cost of operating natural gas systems is approximately 80% more than today's geothermal systems (Case 2 versus Case 3). When next generation geothermal systems are utilized (Case 4), natural gas operational costs (Case 1) are approximately 95% more than geothermal. With carbon costs on natural gas (Case 2), this moves operating costs of natural gas almost 130% more than next generation geothermal equipment.

Improving Cost and Performance

Natural gas systems are a fully mature technology with very little room for efficiency gains and cost reductions with increased volume. On the other hand, geothermal systems have continued room for efficiency gains, as well as equipment cost reduction with increased manufacturing volume.

Figure 4 shows the EER rating for WaterFurnace from various heat pumps over the years. While comparison is somewhat difficult with changing standards, efforts were made to compare heat pumps under similar conditions. Comparisons were made on a nominal capacity of 4-ton units with entering water temperature (EWT) at 30 ^{0}F on full heating, 40 ^{0}F on partial heating, 80 ^{0}F on full cooling and 70 ^{0}F on part cooling, 1550 cfm air flow on full capacity and 1350 cfm on partial capacity, and 12 gpm loop flow rate on full capacity and 11 gpm loop flow rate on partial capacity. Testing followed ARI standard 13256-1. Figure 5 shows COP performance versus year for heating.

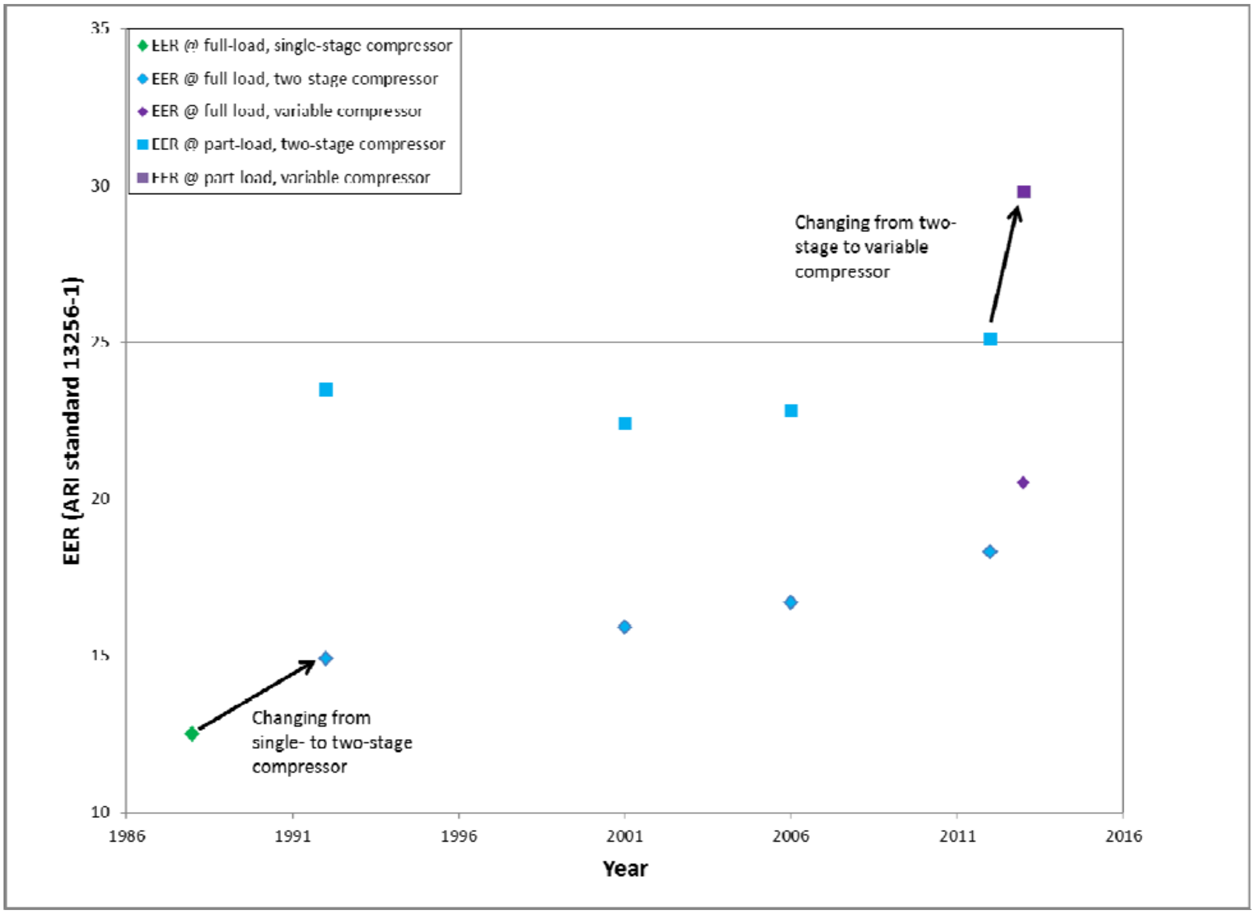

Figure 4. WaterFurnace heat pump performance in cooling over various years. Once 2-stage and variable compressors were introduced, full-load and partial-load performance numbers are provided.

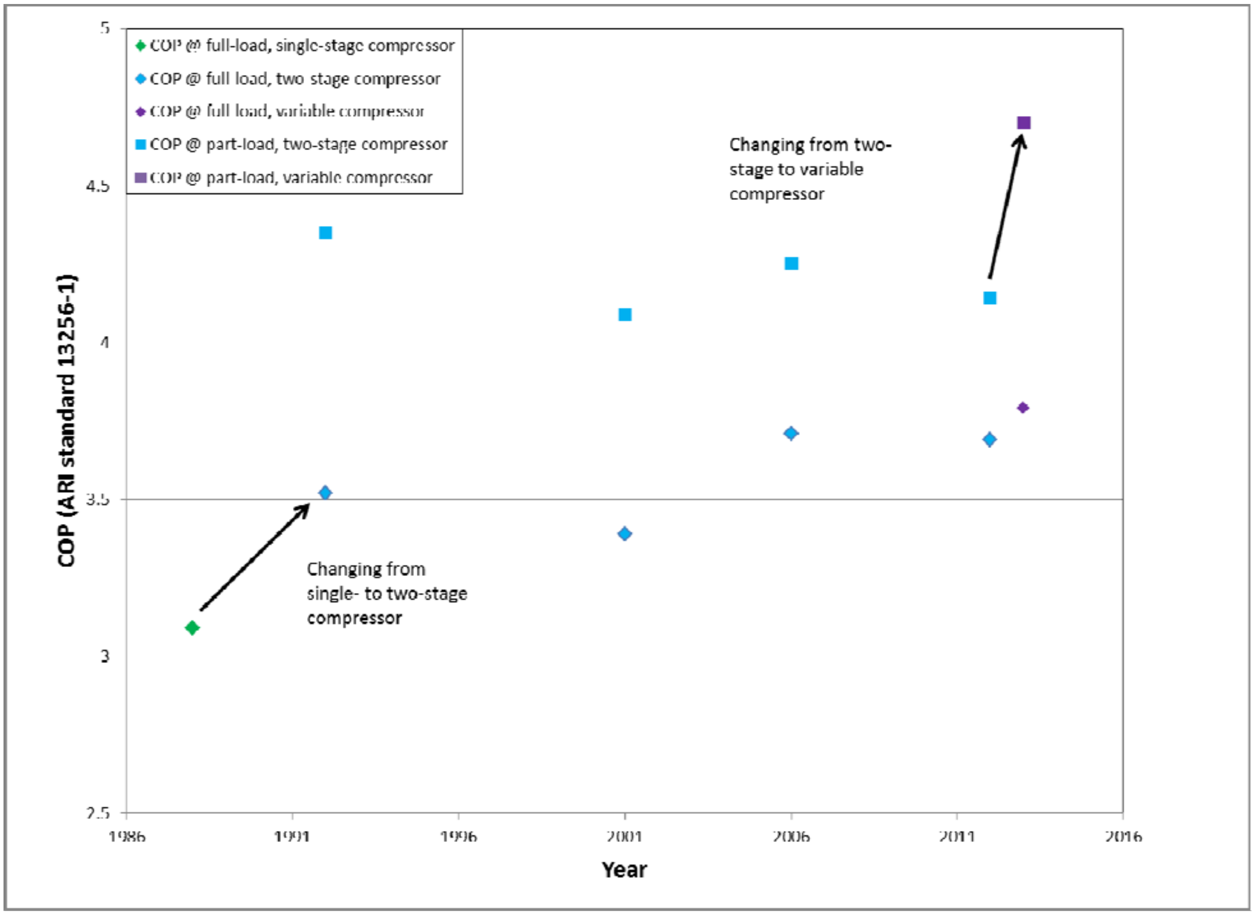

Figure 4. WaterFurnace heat pump performance in heating over various years. Once 2-stage and variable compressors were introduced, full-load and partial-load performance numbers are provided.

In Figures 4 and 5 the geothermal heat pumps show a progressive increase in performance over the years, particularly at full capacity. Significant changes in performance occurred moving from a single-stage compressor to a two-stage compressor. The two-stage compressor has been the workhorse of the geothermal heat pump industry from about 1991 to the present, is dependable, and has a good performance to cost ratio. The next generation of heat pumps, namely variable speed compressors with thermal storage and full hot water generation capability are just entering the market now, are relatively expensive, and may not justify the increased initial cost from 2-stage heat pumps at this time. However, as technology progresses, the cost of the newer technology will decrease with increased manufacturing volume and eventual retirement of older technology. Figure 4 and 5 show the transition from single-stage compressors to 2-stage compressors in around 1991. The single stage compressor units quickly fell out of favour and 2-stage units became the industry norm. The same transition is likely to occur to variable speed compressor heat pumps over the next decade. If the improvement in efficiency during the life of 2-stage heat pumps occurs for variable speed heat pumps, it is possible to see full-load COP's in range of 4 and partial load COP's in range of 5 within the next decade. Theoretical limit on heat pump efficiency in heating is approximately a COP of 10, and in cooling an EER of 60+, so there remains room for improvement. The theoretical limits are largely related to entering water temperature, which can be controlled to some extent by the amount of geothermal loop installed. Note that Figure 5 is based on an EWT of 30 ^{0}F for full-load COP's. If EWT were 40 ^{0}F, the COP's at full-load would approach those shown for partial load. Ambient ground temperature in Southern Ontario is around 50 ^{0}F. As the geothermal loop capacity is increased, EWT will approach that ambient temperature resulting in higher heat pump efficiency.

There has been a continued trade off in capacity of installed geothermal loop, efficiency of installed equipment, and initial cost of installation. Longer (or higher performing) geothermal ground loops and higher efficiency equipment will continue to decrease operating costs of geothermal systems. As can be seen in Figure 3, today's standard geothermal equipment and standard installation designs leads to comparable operating costs. Improvements in either geothermal heat pumps or geothermal loops will further decrease the operating costs of geothermal systems.

<u>Cost of Equipment vs Volume Sold</u>

The question has often been raised, why are geothermal heat pumps so expensive? They are really just an air conditioner with a reversing valve combined with the blower and thermostat. They are, in fact, not much different from gas furnaces and air conditioners, and one might argue, they are simpler. So why do geothermal heat pumps cost $10,000 versus a similar capacity furnace and air conditioner for around $6,000. The answer is volume.

For example, look at the cost of solar PV shown in Figure 6. Cost decreases linearly with increasing volume at a certain percentage depending on product. The same goes for airplanes, automobiles, and computers.

Geothermal heat pump annual sales volume has not increased significantly since the mid 1990's and so prices have remained nearly constant. And, because there are not nearly as many produced as conventional air conditioners and gas furnaces, the cost per unit for comparable product is higher. However, gas furnace sales will not increase significantly and the market is saturated. This is not the case for geothermal heat pumps. Even an increased market in Ontario will dramatically improve sales of North American manufacturers and costs for equipment will begin to decrease, just as they do for most other mass-produced products. Presently geothermal heat pumps account for about 1% of the HVAC market. Increase that market share to 10% and costs of geothermal heat pumps will likely become competitive with conventional equipment.

The PV example, below, may be instructive in projecting future costs of geothermal systems once scale increases, although given the current state of the geothermal market, it is unlikely that cost reductions for geothermal systems will be as steep as the PV curve. Reductions of 20-30%, relative to efficiency level, are quite reasonable expectations.

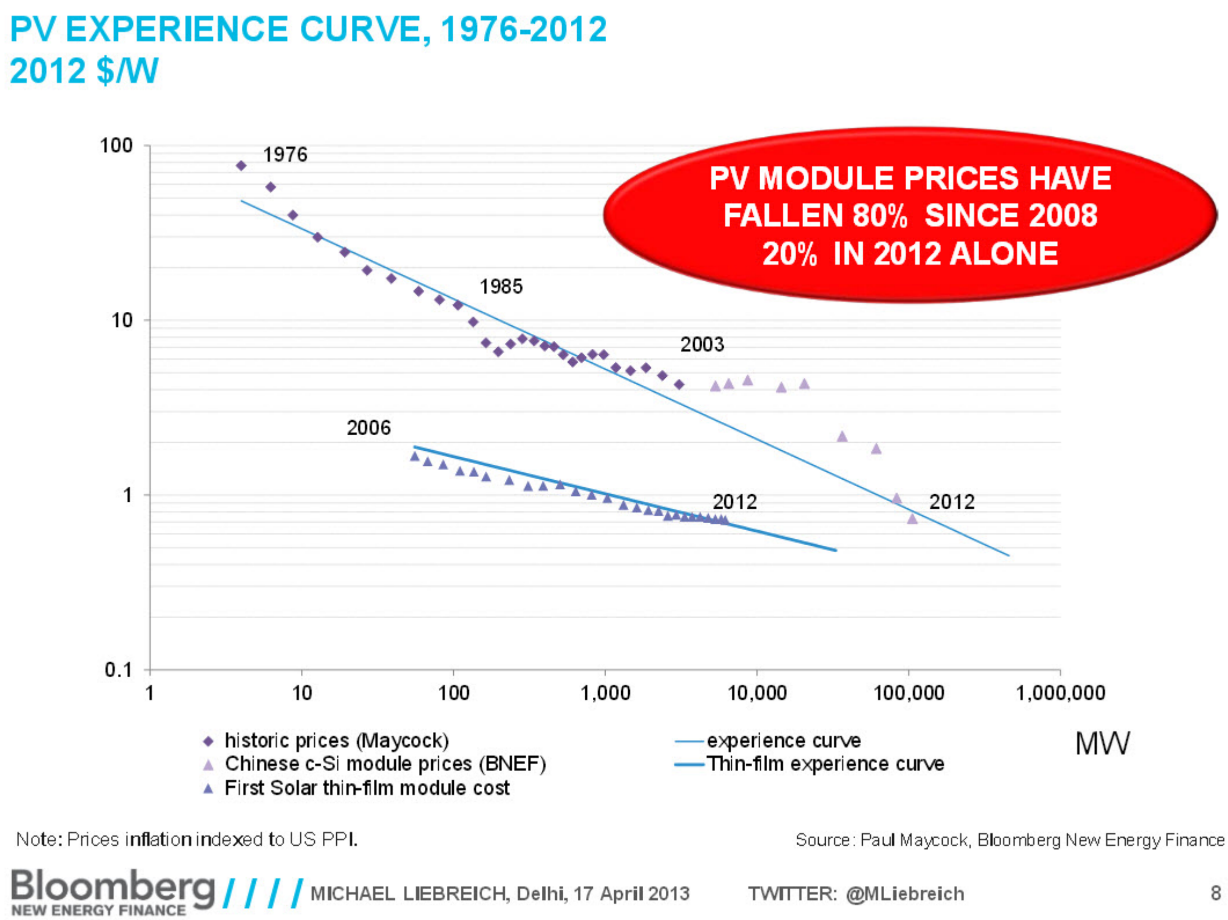

Figure 6. Cost of solar PV as $/W with annual volume sold. Source of data provided on figure.

<u>Move to Renewable Energy and the Value of Thermal Storage</u>

Power generation in the United States is moving from coal to other sources gradually over the last decade moving from 49.3% of total in 2006 to a projected 32.3% in 2017 (EIA Short-Term Energy Outlook, March 2016). Power generation using natural gas is approaching that of coal, projected to be equal in 2017. There has been very large focus on natural gas but the interesting story is the move to renewable energy. Figure 7 shows the growth in electrical power generation from both natural gas and non-hydro renewables (largely wind and solar PV) relative to 2008. Natural gas power generation increased by approximately double that of renewables. Natural gas power generation is projected to increase 53% from 2008 to 2017 (4.8% per year) whereas renewables are projected to grow 187% over the same time period (17% per year). Additional installed capacity of solar and wind are expected to double additional natural gas generation in 2016.

It should be noted that largest year-over-year increases in natural gas generation coincide with low prices (2012 and 2015) and that declines in generation occurred with increasing prices (from 2012 to 2013). On the other hand, power generation from renewables continue to grow and are expected to grow another 50% by 2020, regardless of the price of natural gas. If natural gas prices increase, it is possible to see the year-over-year increase in renewable power generation to exceed that of natural gas.

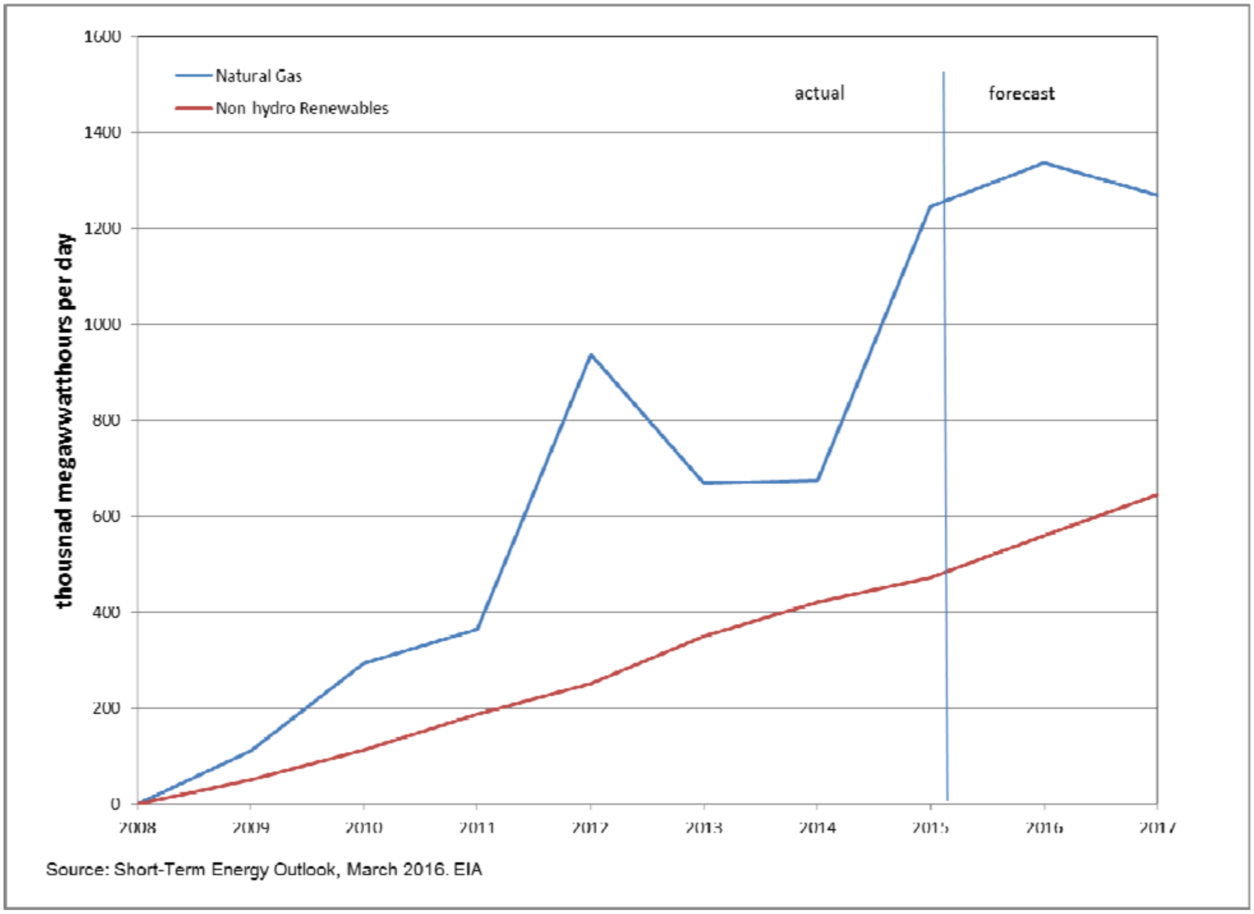

Figure 7. Increase in power generation from new natural gas and non-hydro renewables over 2008 levels forecast out to 2017. EIA

The rapid growth of renewable power generation, both wind and solar, shows the power of increased market volume and reduced cost of manufacturing. The holy grail of 'grid parity' is being approached where the cost of producing power with renewables is equal to or less than that of conventional power generation using coal, natural gas, or nuclear. At this point power generation will move even further towards renewables. The difficulty with renewable power generation is the intermittent behaviour of generation (night time and cloudy days for solar, reduce wind speeds for wind). This can, however, also present an opportunity for energy storage, including geothermal.

Thermal storage is presently the least expensive storage per kWh, and presence of phase change material (ice for storing 'cold' or either hot water tanks or Lauric Acid for storing heat). Utilizing geothermal systems with thermal storage will provide a viable option for optimizing the use of renewable power generation, where when excess electrical power is available, thermal energy is stored, and when electrical power is limited, the stored thermal energy can be utilized to either heat or cool the building.

9 APPENDIX C – WITNESS CVs

CURRICULUM VITAE
As of March, 2016

STANLEY REITSMA, P. Eng.

ADDRESS: Geosource Energy Inc.
1508 Hw 54
Caledonia, ON N3W 2G9
905 928-1407 (cell)
E-mail: sreitsma@geosourceenergy.com

EDUCATIONAL QUALIFICATIONS:

Ph.D. (1996) - Civil Engineering, Queen's University

M.A.Sc. (1992) - Earth Sciences, University of Waterloo

B.A.Sc. (1990) - Geological Engineering, University of Waterloo

EMPLOYMENT RECORD

06/04-present **Geosource Energy Inc., CEO, Owner**

- Began operating Geosource Energy Inc. with one partner and one drill rig in 2004 to start the first geothermal focused drilling company in Ontario at that time
- Built the company to its present state now with two partners, 6 state-of-the-art drill rigs, high speed and capable of drilling most conditions
- Continue research into new drilling techniques, heat exchangers, building control strategies, thermal storage, grouts, plastics etc. related to geothermal systems
- Millions of feet drilled, thousands of geothermal loops installed, hundreds of residential and commercial geothermal systems operating as designed across Ontario

01/98-06/04 **Civil and Environmental Engineering, University of Windsor, Assistant Professor**

- developed active research program in the area of groundwater contamination and remediation and ground source heating
- completing field, laboratory, and numerical modelling research
- successful in attracting research funding through Canadian Foundation of Innovation, NSERC, Canada Research Chair program, and Environment Canada

01/97-12/97 **ENSR Consulting and Engineering, Acton, Massachusetts**

- acted as a hydrogeologic specialist on several contaminated sites.
- provided project management on remediation and research projects.

01/89-08/89 **Mobil Oil Canada, Calgary, Alberta**

- completed hydrogeologic and water chemistry studies for the Swan Hills Member in Southern Alberta for oil exploration initiatives.

PROFESSIONAL ASSOCIATIONS

- Registered Professional Engineer - Ontario
- Member - Heating Refrigeration Air Conditioning Institute (HRAI)
- Board Member, Ontario Geothermal Association
- Corporate member of Building Industry and Land Development Association (BILD), Canada Green Building Council (CaGBC), and Ontario Sustainable Energy Association (OSEA)

CHAPTERS IN BOOKS

1. Bolisetti, T., and S. Reitsma, 2002. Effect of heterogeneity scale on chemical grouting in porous media, in *Developments in Water Science, Computational Methods in Water Resources*, *Vol. 1*, eds. S. M. Hassanizadeh, R. J. Schotting, W. G. Gray, and G. F. Pinder, Elsevier, Amsterdam, 891-898.
2. Dai, Q, and S. Reitsma, 2002. Kinetic Study of Permanganate Oxidation of Tetrachloroethylene at pH 10.60±0.1, in *Remediation of Chlorinated and Recalcitrant Compounds-2002, Paper 2C-09. Proceedings of the Third International Conference on Remediation of Chlorinated and Recalcitrant Compounds, Monterey, CA, May 20-23, 2002*, eds. A. R. Gavaskar and A. S. C. Chen, ISBN 1-57477-132-9, Battelle Press, Columbus, OH.
3. Dai, Q., and S. Reitsma, 2002. Two-dimensional experimental studies of permanganate flushing of pooled DNAPL, in *Remediation of Chlorinated and Recalcitrant Compounds-2002, Paper 1A-13. Proceedings of the Third International Conference on Remediation of Chlorinated and Recalcitrant Compounds, Monterey, CA, May 20-23, 2002*, eds. A. R. Gavaskar and A. S. C. Chen, ISBN 1-57477-132-9, Battelle Press, Columbus, OH.
4. Reitsma, S., W. Pramono, and W. Mpesha, 2002. Simulation of sediment dynamics in Detroit River caused by wind-generated water level changes in Lake Erie, in *Developments in Water Science, Computational Methods in Water Resources*, *Vol. 2*, eds. S. M. Hassanizadeh, R. J. Schotting, W. G. Gray, and G. F. Pinder, Elsevier, Amsterdam, 1669-1676.
5. Reitsma, S., and J. Randhawa, 2002. Porous media permeability reduction due to manganese dioxide precipitation, in *Remediation of Chlorinated and Recalcitrant Compounds-2002, Paper 2C-39. Proceedings of the Third International Conference on Remediation of Chlorinated and Recalcitrant Compounds, Monterey, CA, May 20-23, 2002*, eds. A. R. Gavaskar and A. S. C. Chen, ISBN 1-57477-132-9, Battelle Press, Columbus, OH.

6. Bolisetti, T., and S. Reitsma, 2000. Assessment of numerical transverse dispersion for the advection-dispersion equation using the finite analytical technique, in *Computational Methods in Water Resources*, *Vol. 1 Computational Methods for Subsurface Flow and Transport*, eds. L. R. Bentley, J. F. Sykes, C. A. Brebbia, W. G. Gray, and G. F. Pinder, Balkema, Rotterdam, 411-416.

7. Dai, Q., and S. Reitsma, 2000. BIEM for modelling flow over and through rockfill embankments, in *Computational Methods in Water Resources*, *Vol. 1 Computational Methods for Subsurface Flow and Transport*, eds. L. R. Bentley, J. F. Sykes, C. A. Brebbia, W. G. Gray, and G. F. Pinder, Balkema, Rotterdam, 21-28.

8. Dai, Q., and S. Reitsma, 2000. Modeling of free surface location behind a sheetpile by BIEM, in *Computational Methods in Water Resources*, *Vol. 1 Computational Methods for Subsurface Flow and Transport*, eds. L. R. Bentley, J. F. Sykes, C. A. Brebbia, W. G. Gray, and G. F. Pinder, Balkema, Rotterdam, 29-38.

9. Reitsma, S., and Q. Dai, 2000. Reaction enhanced mass transfer from pooled NAPL pools, in *Chemical Oxidation and Reactive Barriers: Remediation of Chlorinated and Recalcitrant Compounds*, eds. G. B. Wickramanayake, A.R. Gavaskar, and A.S. Chen, Battelle Press, Columbus, OH, 33-40.

10. Reitsma, S. and B.H. Kueper, 2000. The use of alcohol flooding to remediate rock fractures containing DNAPL, in *Remediation in Rock Masses*, eds. H. Inyang and C. Bruell, ASCE Press, Reston, Virginia, pp. 220-236.

11. Reitsma, S. and M. Marshall, 2000. Experimental study of oxidation of pooled NAPL, in *Chemical Oxidation and Reactive Barriers: Remediation of Chlorinated and Recalcitrant Compounds*, eds. G. B. Wickramanayake, A.R. Gavaskar, and A.S. Chen, Battelle Press, Columbus, OH, 25-32.

12. LaChance, J., S. Reitsma, R. Baker, D. McKay, and A. Hewitt, 1998. *In situ* oxidation of trichloroethylene using potassium permanganate: Part 1. Background, in *Physical, Chemical, and Thermal Technologies: Remediation of Chlorinated and Recalcitrant Compounds*, eds. G. B. Wickramanayake and R.E. Hinchee, Battelle Press, Columbus, OH, 397-402.

13. McKay, D., A. Hewitt, S. Reitsma, J. LaChance, and R. Baker, 1998. *In situ* oxidation of trichloroethylene using potassium permanganate: Part 2, Pilot study, in *Physical, Chemical, and Thermal Technologies: Remediation of Chlorinated and Recalcitrant Compounds*, eds. G. B. Wickramanayake and R.E. Hinchee, Battelle Press, Columbus, OH, 397-402.

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1. D. Gordon, T. Bolisetti, D.S-K. Ting, S. Reitsma, “Short-term fluid temperature variations in either a coaxial or U-tube borehole heat exchanger,” Geothermics, under review.

2. Dehkordi, S. E., R..A. Schincariol, S. Reitsma, 2015. “Thermal performance of a tight borehole heat exchanger”, Renewable Energy, May, pp. 698-704.

3. C.G. Cvetkovski, S. Reitsma, T. Bolisetti, D.S-K. Ting, 2015. “Heat transfer in a U-bend pipe: Dean number versus Reynolds number,” Sustainable Energy Technologies and Assessments,

11:148-158.

4. C.G. Cvetkovski, S. Reitsma, T. Bolisetti, D.S-K. Ting, 2014. “Ground source heat pumps: should we use single U-bend or coaxial ground exchanger loops?,” International Journal of Environmental Studies, 71(6): 828-839.

5. Reitsma, S. and Q. Dai, 2001. Reaction-enhanced mass transfer and transport from non-aqueous phase liquid source zones, Journal of Contaminant Hydrology, Vol. 49, Issue 1-2, pp. 49-66.

6. Reitsma, S. and B.H. Kueper, 1998. Non-equilibrium compositional alcohol flooding model for immiscible phase remediation: 1. Equation development, Advances in Water Resources, Vol. 21, No. 8, pp. 649-662.

7. Reitsma, S. and B.H. Kueper, 1998. Non-equilibrium compositional alcohol flooding model for immiscible phase remediation: 2. Model development and application, Advances in Water Resources, Vol. 21, No. 8, pp. 663-678.

8. Reitsma, S. and B.H. Kueper, 1994. Laboratory measurement of capillary pressure-saturation relationships in a rock fracture, Water Resources Research, Vol. 30, No. 4, pp. 865-878, April.

9. Kueper, B.H., D. Redman, R.C. Starr, S. Reitsma and M. Mah, 1993. A field experiment to study the behavior of tetrachloroethylene below the water table: Spatial distribution of residual and pooled DNAPL, Ground Water, Vol. 31, Num. 5, pp. 756-766, September-October.

CONFERENCE PROCEEDING PUBLICATIONS – Refereed

1. Bolisetti, T., and S. Reitsma, 2003. Numerical simulation of chemical grouting in heterogeneous porous media, *Grouting and ground treatment, Geotechnical Special Publication No. 120*, ASCE, Reston, VA, pp 1454-1465.

2. Tomczak M, KG Drouillard, I Churchill, GD Haffner, S Reitsma, R Lazar, 2001. Comparison of two techniques for organic carbon content determination in Detroit River sediments and its relevance to the distribution of organic contaminants in an AOC. Presented at the 44th Annual International Conference on Great Lakes Research, Jun 10-14, Green Bay, WI, USA.

3. Mpesha, W., M. Tomczak, S. Reitsma, and J.A. Koschik, 2001. Flow pattern analysis of the Detroit River channel using the Acoustic Doppler Current Profiler (ADCP). Presented at the 44th Annual International Conference on Great Lakes Research, Jun 10-14, Green Bay, WI, USA.

4. Reitsma, S. and B.H. Kueper, 1996. Compositional modelling study of alcohol flooding for recovery of DNAPL, In proceedings of ASCE 1996 Annual Convention and Exposition, Non-Aqueous Phase Liquids (NAPLs) in Subsurface Environment: Assessment and Remediation, Washington, D. C., November 12 B 14, pp. 526-537.

CONFERENCE PROCEEDING PUBLICATIONS - Non-refereed

1. Reitsma, S., and Q. Dai, 2002. Influence of manganese oxide precipitation on pooled NAPL removal rate. Second International Conference on Oxidation and Reduction Technologies for In-Situ Treatment of Soil and Groundwater, Toronto, November 17-21.

2. Kueper, B.H., M. Mah and S. Reitsma, 1993. Distribution of dense, non-aqueous phase liquid

residual in a naturally occurring sand aquifer, Proceedings: Eleventh Canadian Hydrotechnical Conference, Fredericton, New Brunswick, Canada, June 8-11.

LIST OF PUBLISHED ABSTRACTS

1. Reitsma, S. and B.H. Kueper, 1992. Laboratory Measurement of Capillary Pressure-Saturation Relationships in Natural Rock Fractures, EOS, Transactions, American Geophysical Union, Vol. 72, No. 44, p. 160.

CONFERENCE PRESENTATIONS

1. Bolissetti, T., and S. Reitsma, 2004. Flow and transport simulation of chemical grouts in porous media: shear effects on gelation, American Geophysical Union Fall Meeting, San Francisco, December 8-12.
2. Reitsma, S., G. D. Haffner G.D., and K.G. Drouillard, 2003. The Detroit River as a loadings source of PCBs and Hg to western Lake Erie . Presented at the 3rd Biennial Conference of the Lake Erie Millennium Network, May 6-7, University of Windsor, Windsor, ON, Canada.
3. Drouillard, K.G., S. O'Rourke, S, D.M. Whittle,., S. Reitsma, and G. D. Haffner, 2003. Trophodynamics of contaminants in western Lake Erie as influenced by the Detroit River. Presented at the 3rd Biennial Conference of the Lake Erie Millennium Network, May 6-7, University of Windsor, Windsor, ON, Canada.
4. Bolisetti, T., and S. Reitsma, 2003. Numerical simulation of chemical grouting in heterogeneous porous media, Grouting and ground treatment, ASCE, New Orleans, Feb 2003.
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6. Reitsma, S., Q. Dai, 2002. Influence of manganese oxide precipitation on pooled NAPL removal rate. Second International Conference on Oxidation and Reduction Technologies for In-Situ Treatment of Soil and Groundwater, Toronto, November 17-21.
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8. Dai, Q., and Reitsma, S., 2002. Two-dimensional experimental studies of permanganate flushing of pooled DNAPL, Third International Conference on Remediation of Chlorinated and Recalcitrant Compounds, Monterey, May 20-23.
9. Reitsma, S., W. Pramono, and W. Mpesha, 2002. Simulation of sediment dynamics in Detroit River caused by wind-generated water level changes in Lake Erie. XIV International Conference on Computation Methods in Water Resources, Delft, June 23-28.
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12. Mpesha, W., M. Tomczak, S. Reitsma, and J.A. Koschik, 2001. Flow pattern analysis of the Detroit River channel using the Acoustic Doppler Current Profiler (ADCP). Presented at the 44th Annual International Conference on Great Lakes Research, Jun 10-14, Green Bay, WI, USA.

13. Tomczak, M., G.D. Haffner, J.C. Barrette, B. Fryer, S. Reitsma, and E. Kimball, 2000. Distribution of mercury accumulation in bottom sediments of the Detroit River (1999-2000), 20th Annual Conference, Society of Environmental Toxicology and Chemistry, Nashville, Tennessee, Nov. 12-16.

14. Dai, Q., and S. Reitsma, 2000. Modeling of free surface location behind a sheetpile by BIEM, XIII International Conference on Computation Methods in Water Resources, Calgary, June 25-29.

15. Dai, Q., and S. Reitsma, 2000. BIEM for modelling flow over and through rockfill embankments, XIII International Conference on Computation Methods in Water Resources, Calgary, June 25-29.

16. Bolisetti, T., and S. Reitsma, 2000. Assessment of numerical transverse dispersion for the advection-dispersion equation using the finite analytical technique, XIII International Conference on Computation Methods in Water Resources, Calgary, June 25-29.

17. Reitsma, S., and Q. Dai, 2000. Reaction enhanced mass transfer from pooled NAPL pools, Second International Conference on Remediation of Chlorinated and Recalcitrant Compounds, Monterey, May 22-25.

18. Reitsma, S. and M. Marshall, 2000. Experimental study of oxidation of pooled NAPL, Second International Conference on Remediation of Chlorinated and Recalcitrant Compounds, Monterey, May 22-25.

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21. Reitsma, S. and B.H. Kueper, 1998. Interphase mass transfer during alcohol flooding, First International Conference, Remediation of Chlorinated and Recalcitrant Compounds, Monterey, California, May 18-21, 1998.

22. Reitsma, S. and B.H. Kueper, 1996. Compositional modelling study of alcohol flooding for recovery of DNAPL with varied injection concentration and slug size, American Society of Civil Engineers, 1996 Annual Convention and Exposition, November 12-14.

23. Reitsma, S. and B.H. Kueper, 1992. Laboratory Measurement of Capillary Pressure-Saturation Relationships in Natural Rock Fractures, American Geophysical Union Fall Meeting, San Francisco, December 7-11.

10 WORKSHOPS

1. Drouillard KG, S Reitsma, M Tomczak, GD Haffner. 2002. Biomonitors, surficial sediments, and food web datasets on the Detroit River, 1991-2001. Workshop Presentation: Evaluating Ecosystem Results of PCB Control Measures for the Detroit River - Western Lake Erie Basin, June 18, 2002, University of Windsor, Windsor, ON, Canada.
2. Reitsma S, K Drouillard, D Haffner. 2002. Simulation of sediment dynamics in the Detroit River caused by wind-generated water level changes in Lake Erie and implications to PCB contamination. Workshop Presentation: Evaluating Ecosystem Results of PCB Control Measures for the Detroit River - Western Lake Erie Basin, June 18, University of Windsor, Windsor, ON, Canada.

THESES AND REPORTS

1. Reitsma, S., W. Pramono, and W. Mpesha, 2002. Detroit River modeling and management framework modeling report and manual, submitted to Detroit River Canadian Cleanup Committee.
2. Haffner, D., S. Reitsma, K. Drouillard, and M. Tomczak, 2002. Detroit River modeling and management framework interpretive report, submitted to Detroit River Canadian Cleanup Committee.
3. Reitsma, S., 1996. Equilibrium and non-equilibrium compositional models for simulation of alcohol flooding, Ph.D. Thesis, Queen's University, October.
4. Reitsma S., S. Lunn and B.H. Kueper, 1995. The use of alcohol flooding to remediate sites contaminated by dense, non-aqueous phase liquids, Progress Report #2, (Subcontract No. 19Y-GUG26V), prepared for Martin Marietta Energy Systems, February 7.
5. Lunn, S., S. Reitsma and B.H. Kueper, 1994. The use of alcohol flooding to remediate sites contaminated by dense, non-aqueous phase liquids, Progress Report #1, (Subcontract No. 19Y-GUG26V), prepared for Martin Marietta Energy Systems, May 31.
6. Reitsma, S., 1992. Laboratory measurement of capillary pressure-saturation relationships in natural rock fractures, M.Sc. Thesis, University of Waterloo.
7. Reitsma, S., 1990. The effect of upward hydraulic gradients on the downward migration of dense, non-aqueous phase liquids in porous media, B.A.Sc. Thesis, University of Waterloo.

Profile

David L. Hatherton

Accomplishments

1980 Co-Founder of WaterFurnace in Canada with Frances Hatherton (wife)

1983 Co-Founder WaterFurnace in the USA with Dan Ellis

1987 Founding Committee member International Ground Source Heat Pump Association IGSHPA

1988 Founding President Canadian Earth Energy Association

1989 Founding member Earth Energy Association, Washington DC, Precursor to GHPC

1989 Wrote first drafts of CSA 445 standard for ground source heat pumps.

1991 Founder Earth Systems Inc. DX heat pump manufacturer, Kitchener Ontario, sold to WF USA

1992-95 VP Industry and Government Relations, WaterFurnace

1993 Founding member Geothermal Heat Pump Consortium – Washington

1993 Testified in US Congress to validate $100M request for funding, approved.

1995-96 VP Industry and Government Relations, ClimateMaster

1997-1998 Consultant to Exelon Energy/s GSHP program.

1999-2011 Co-Founder of NextEnergy Inc. with Frances Hatherton (wife)

2003 Founding Committee member Canadian GeoExchange Coalition.

2008 Invited contributor to Obama Administration’s report on geothermal by Oak Ridge National Labs which was instrumental in the Administration granting a 30% tax credit for new and retrofit residential and 10% tax credit with accelerated depreciation for commercial installations.

2010 Harper wins majority, dismantles renewable energy strategies, cancels programs, bails on Kyoto

2011 Sold NextEnergy and Retired.

2015 Paris Accord a wakeup call, Government change in Canada creates new opportunities

Founded or Co Founded Companies have over 500,000 installations, 1,500,000 tons of capacity, and over $6 billion in installed system retail value.

Curriculum Vitae

Martin Luymes

Employment

Various Positions with the *Heating Refrigeration and Air Conditioning Institute of Canada (HRAI)*, 1995-present, including Director, Programs and Relations, Vice-President, Senior Director and Manager, Contractors Division. Responsibilities have included:

- Lead responsibility for all government and industry relations work of the association;
- Oversight of HRAI's three membership divisions (manufacturers, wholesalers and contractors divisions) including the performance of member programs;
- Oversight of HRAI's training division (*SkillTech Academy*), which provides HVAC system design and installation training across Canada;
- Strategic direction and leadership for the planning and execution of the association's long term goals;
- Public relations and marketing, and specifically the work of: a) the HRAI *Marketing Committee* whose mandate is to educate end users about the HVACR industry; and b) the *Careers Promotion Committee* whose mandate is to promote the HVACR industry to young people as an attractive career destination;
- Industry communications (including a semi-annual national magazine – the *National Review* -- and monthly newsletters);
- HRAI's Conservation and Demand Management (CDM) department which administers industry-specific energy conservation programs for end users on behalf of the Ontario Power Authority;
- Oversight of Extended Producer Responsibility (EPR) programs including *Refrigerant Management Canada* (RMC) and the *Thermostat Recovery Program*;
- Oversight for the *HVAC Coalition Inc.*, a separately incorporated advocacy body involved in interventions on behalf of members before the Ontario Energy Board on electric and gas utility issues of concern to industry;
- Management of the *Emerging Technologies Committee*, an industry volunteer council set up to research and identify new technologies of note, especially renewable energy technologies.

Project Manager, the *Social Investment Organization (SIO)*, 1993-95. Co-ordinated all aspects of the development and implementation of the Community Economic Development Resource and Information Clearinghouse (*CEDric)*, an electronic network for community economic development (CED) practitioners.

Research Director, the *Independent Power Producers' Society of Ontario (IPPSO)*, 1992-93. Co-ordinated the work of 17 consultants and experts as part of IPPSO's intervention in the Environmental Assessment Board's hearings concerning Ontario Hydro's 25 year Demand/Supply Plan.

Principal Investigator on the following projects (at the University of Toronto):

Report on the State of the Nation's Housing, with Dr. John Miron, Centre for Urban and Community Studies at the Universty of Toronto, 1991.

Housing Two Million: Urban Solutions, a Charette held by the Canadian Urban Institute and sponsored by the Canadian Construction Council, 1990.

Mapping Residential Development and Tenure Patterns in Toronto, 1860-1940, with Dr. Richard Harris (McMaster University), 1987.

An Analysis of Variation in the Internal Structure of Canadian Cities, with Dr. Larry Bourne at the Centre for Urban and Community Studies (University of Toronto), 1985.

University Instructor in the following courses at the University of Toronto (1989-1995): GGR 357 *The Geography of Housing and Housing Policy*; GGR 246 *The Regional Geography of Canada;* GGR 252 *Marketing Geography;* GGR 124 *Urbanization, Contemporary Cities and Urban Development*; GGR 117 *Introduction to Physical Geography.*

Education

Bachelor of Arts (Hons.), Queen's University, 1984. Majored in Urban Economic Geography, with minors in history and philosophy. Graduated first in class. Awarded the R.R. Millar Prize, 1984.

Master of Arts, Department of Geography, University of Toronto, 1986. Awarded Connaught Graduate Scholarship, 1984-1985.

Ph.D. (completed all but dissertation), Department of Geography and Urban Planning, University of Toronto. Awarded Canada Mortgage and Housing Corporation (CMHC) Graduate Research Scholarship, 1986-1989.

Diploma in Financial and Managerial Accounting for Executives, Schulich School of Business, York University, 2007.

Selected Volunteer Activities

Chair of the *Canadian Energy Efficiency Alliance* (2015-2016, board member since 2013), Canada's leading independent advocate for the economic and environmental benefits of energy efficiency.

Director of the *CRC Extension Fund* (1998-2012), a $100 million RRSP fund that provides low-interest mortgage loans for non-profit building projects across Canada.

Coach/Trainer/Business Manager (2001-2011) for various sporting activities, including: a) minor hockey with the *Toronto Ice Dogs* and *Mississauga Hornets* (Greater Toronto Hockey League); b) minor soccer with *West End United*; and c) minor lacrosse with the *Mimico Minor Lacrosse Association*.

Executive Member of and Treasurer for the *North Toronto Co-housing Co-operative* (1995-2000), a non-profit organization set up to develop private housing around the principles of "intentional community", and homeowner participation in the design and development process.

Member and Vice-President of the Board of Directors, *Bread and Roses Credit Union* (1992-1996).