Consumers Council of Canada

<u>Interrogatory 1</u>

Reference: General

Please specify whether any of the submitted material is intended to be accepted as expert evidence; if so, please specify precisely which assertions within the submitted material are intended to be expert opinions and identify the relevant expert.

<u>Response:</u>

The material is not offered as expert evidence. While the witnesses have expertise in their industry, they are presenting factual evidence based on their own experience.

Enbridge Gas Distribution

Interrogatory 1

Reference: Evidence of the OGA, Section 3

Preamble: Beginning at Section 3.2 the OGA provides a history of the geothermal industry. Enbridge wishes to better understand the structure of the industry and its participants.

Request:

a) Is the OGA aware of the Canadian GeoExchange Coalition? If so, what does the OGA understand to be the membership represented by the Coalition?
b) Has the OGA consulted with the Canadian GeoExchange Coalition about the OGA's intervention in this proceeding and does the OGA's intervention have the support of the GeoExchange Coalition?
c) If the OGA has not consulted with the Coalition about the intervention in this proceeding, why has it not done so?
d) If the OGA has consulted with the Coalition about the OGA's intervention, please describe the discussions between the two organizations in this regard?

Response:

a) The OGA is aware of the Canadian GeoExchange Coalition. The CGC is a national organization with members across the country, including 36 members in Ontario (according to the CGC website).

According to the CGC website, the organization is "guided by a vision to transform the heating, ventilation and air conditioning (HVAC) market in Canada by:

1. Expanding the market in Canada for geoexchange products and services;
2. Facilitating business development in a way that complements the participants' core business;
3. Promoting the CGC's contribution to the Canadian economy through increased sales revenues, jobs creation, and enhanced export opportunities; and,
4. Improving environmental performance, including the reduction of greenhouse gas emissions."

b) No, the OGA has not consulted with the Canadian GeoExchange Coalition about this intervention and therefore the OGA cannot make any comment about whether the CGC is supportive of the intervention.

c) The OGA Board of Directors made a decision that participation in this proceeding is important to the future of its members' and the geothermal industry in Ontario. There was no apparent reason to consult with the CGC, so they did not do so..

d) See above.

Enbridge Gas Distribution

Interrogatory 2

Reference: Evidence of the OGA, page 4

Preamble: Enbridge wishes to better understand the process for setting standards for the Ontario geothermal industry and the certification of personnel involved in the installation and servicing of geothermal space heating and water heating systems as well as how the actual performance of installed geothermal heating and water heating systems is certified.

Request:

a) Is a geological study of the site conducted before installation to estimate technical and financial feasibility of geothermal projects?
b) Is an Engineering certification of the actual geology at the site required to confirm conditions?
c) Is a thermal capacity field test of the bore holes, or horizontal loop geo exchange, provided upon completion of a geothermal heating and water heating installation?
d) Is there a performance test of the entire geothermal system provided at the site for approval or certification purposes?

Response:

a) For individual homes, this has not been required by regulation, although in many instances engineers and contractors are involved in the process. In larger projects with multiple homes or for commercial projects such as condos and multi-residential projects, technical and financial feasibility is completed.

For vertical systems, Ontario Regulation 98/12 requires sign off by a professional engineer or professional geologist to ensure safety related to natural gas during drilling operations.

CSA C448 is a design and installation s standard that has been in place for many years and continues to evolve to provide the best available industry standards to the geothermal industry. The standard was recently reviewed and adopted by the United States and re-issued as ANSI/CSA C448-2016, a bi-national standard.

b) O.Reg. 98/12 requires an engineer or professional geologist to provide a drilling plan for each site based on well records from both the MOECC's water well records and oil and gas wells. Variation from expected conditions are to be documented.

c) ANSI/CSA C448-2016 is very specific on the number of thermal conductivity tests based on expected geothermal field capacity. Thermal conductivity tests are designed to measure the capacity of individual boreholes, and in some instances, horizontal field installations. Capacity of the entire bore field is difficult to measure. However, the heat transfer dynamics of a geothermal field are reasonably well understood and engineering calculations based on one or several thermal conductivity tests can be made to determine the capacity of a geothermal field.

d) As with any mechanical heating and cooling system, there are building code requirements to ensure geothermal systems are sized properly to meet the heat loss and heat gain requirements of a building or home. For homes, the relevant standard is CSA F280. Most municipalities require that heat loss/heat gain calculations are completed by a certified HVAC designer for systems in new homes.

Enbridge Gas Distribution

Interrogatory 3

Reference: Evidence of the OGA, page 4

Preamble: In its evidence the OGA has identified a geothermal system heating efficiency (or COP) of 4 (or 400%), no reference was provided to support this value and all of the OGA's evaluations provided in their evidence rely on this value.

Request:

a) Please provide references to support or COP value 4 (or 400%).
b) Please indicate if this value is the maximum, minimum, or average performance?
c) Is this the efficiency that geothermal system installers state their system will operate at, and do they guarantee this value to the end customer?
d) The OGA have stated that several thousand residential geothermal retrofits and new construction have been installed in Ontario. Please provide documentation confirming an average seasonal COP of 4 based on the results of these actual installations.
e) Is the electricity consumed by the Geo-exchange glycol pump included in the calculation of the system COP? If not, what would the average COP be if this addition energy consumption was included?
f) Are certificates, or proof of COP performance or thermal capacity provided for installed geothermal system for municipality records, electric utility records, and for the customer? If so, what authority issues and stands behind such certificates?
g) What assurances are provided to the homeowner that the geothermal system will run at the capacity and performance as outlined in this evidence? Is there a performance guarantee, and if so who pays for and tests the system and the correction of system performance deficiencies?
h) When were these certification processes put in place and how are they enforced?

Response:

a) See S11.OGA.UGL.1. COPs of 4 are achievable during heating mode.

b) COP of 4 for heating is an average performance.

c) It is uncommon that any HVAC contractor would guarantee the performance of a heating/cooling system, including geothermal, natural gas furnaces (or water heaters), or electric air conditioners. It is well known that the rated performance of any heating and/or cooling system in the field may deviate from the original rated performance of the appliance as tested and certified. Because guarantees of field performance are not generally offered, however, does not mean that geothermal systems do not operate at the stated COPs.

d) This information is not available, to the best of our knowledge. Field tests could certainly be conducted if there was sufficient interest and funding. It is worth noting that the same can be said for other types of heating and cooling systems – i.e., there is no system in place to confirm that all gas furnaces and air conditioning systems actually perform at their factory-rated efficiency levels.

e) Yes the electricity consumed by the geo-exchange glycol pump is included in the calculation of the system COP. AHRI/ISO/ASHRAE 13256-1 standards are used to assess heat pump performance and these numbers are used as a basis for COP numbers. Circulation pump and air circulation fans are also considered in the performance numbers.

f) Performance of a properly designed and constructed system will meet performance expectations. There are no such certificates being issued for as-built performance, just as there are not for other systems, including furnaces, boilers, cooling towers, dry-coolers, etc. in applications of similar size. Properly designed and installed geothermal systems will normally meet design expectations.

g) HVAC contractors do not typically provide performance guarantees regarding energy performance of the systems they install, whether these systems are comprised of geothermal heat pumps, electrically powered air conditioning systems or natural gas fuelled furnaces or boilers. Like any other type of heating and cooling system, geothermal systems work if properly designed and installed. On this point, there is little difference between a gas furnace and a geothermal system. In dealing with their customers, HVAC contractors will determine the heating and cooling needs of the home/building, size and specify a system, propose a set of equipment to meet the building's needs and install it. With any of these solutions (as with any commercial product offering in the marketplace) problems may arise and consumers may demand that the contractor rectify the problem. Heat pumps are not particularly different. Contractors have a strong vested interest in getting the design, sizing and installation of system right the first time.

h) In addition to product performance standards and certifications, there are training and certification programs that apply to geothermal installers and technicians, including trade licenses that are overseen and enforced by the Ontario College of Trades, and system design standards that are enforced by municipalities (permits which typically require heat loss/gain calculations, sizing of equipment and loop, as well as the layout of the ductwork or hydronic system inside the home). As with all certifications relating to the HVAC industry (and the building trades in general), however, enforcement in the Province of Ontario has been spotty in the past. Prior to the creation of the Ontario College of Trades, trade certification enforcement was inconsistent, and municipal permitting and approvals processes remain uneven across the province.

Notwithstanding the above comments, it must be added that installations in newly constructed buildings -- both residential and commercial -- are normally inspected by building inspectors, and in the commercial sphere, designs are done by certified engineers.

OGA recognizes the importance of appropriate certification processes and is working with the Ontario College of Trades to ensure appropriate application and enforcement of trade licenses.

OGA is also pursuing a broad range of system design training that references the new updated ANSI/CSA C448-2016 standard, drawing in part on training developed by the International Ground Source and Heat Pump Association (IGSHPA).

Enbridge Gas Distribution

Interrogatory 4

Reference: Evidence of the OGA, "Head to Head Comparisons" (page 5)

Preamble: Enbridge seeks to better understand the data, data sources, assumptions, qualifications and sensitivity of the analyses that support the conclusions of this part of the OGA's evidence. The evidence of the OGA states that the thermal energy from the ground is "endlessly renewable".

Request:

a) Please provide the limit to the heating capacity of a defined geo-exchange vertical hole of a standard defined depth, or if the capacity is limitless for a standard defined depth?
b) Please identify any subsoil conditions that alter the capacity of heat extraction from a standard defined depth?
c) For a standard Canadian home where the geo-exchange system would provide space heating and domestic hot water year round and have no need for air conditioning would the geothermal exchange system be able to provide heat if heat was being extracted year round? To what extent would the COP be impacted on a seasonal basis in this scenario? Would additional geoexchange depth have to be considered, and how would this impact the installation cost?

Response:

a) The heating (or cooling) capacity of a borehole is dependent on a number of factors including soil or rock type, pipe size, heat exchanger configuration, grout properties, ambient soil/rock temperature, and borehole size. All these factors can be considered in the design length of a bore field for a given heating and cooling load profile. There has been significant research into the development of equations and design tools to provide proper bore field design to ensure that field can perform as expected.

There are also some rule-of-thumb borehole depths based on soil/rock properties, pipe size, soil/rock ambient temperature, and grout thermal conductivity that have been published by ASHRAE (*ASHRAE Chapter 32 HVAC 2003* – attached as Appendix A). Factors related to borehole spacing and heating to cooling imbalance are also presented.

Based on ASHRAE, a borehole to 185 m depth in shale at 10 ^{o}C rock (average temperature in Southern Ontario) and a thermal conductivity of rock of 1.4 btu/ft.hr.F, with 1.25" loop (industry standard) and grout conductivity of 1.1 btu/ft.hr.F, will have a capacity of 4.5 tons (54,300 btu/hr). If grout conductivity is 0.4 btu/ft.hr.F, and the soil is clay with a thermal conductivity of 1 btu/ft.hr,F, the capacity for the same hole is 3.0 tons.

Also based on ASHRAE, a building where borehole separation is 15 feet and the heating to cooling load is 1,000/500 (i.e. twice as many heating hours as cooling), there is no penalty in increased temperature due to borehole interference. This would be the scenario with most houses, i.e. heating dominant and boreholes spread out more than 15 feet.

What is suggested here is that there is a very good understanding of heat transfer in ground loop heat exchangers and that design criteria are available given geology, grout, and heat exchanger properties, along with building heating/cooling information, to design a functional geothermal loop.

There are well-developed design computer models such as Ground Loop Design (GLD), that provide sophisticated tools to design geothermal loops based on building loads, geology, and borehole grid configuration.

b) As noted above, there are several factors that alter the capacity of a borehole of a defined length. These include soil or rock type. Order of capacity from low to high include dry sands, moist sands and clays, shales, limestones, dolomites, and finally granites. Grout, injected around the heat exchanger and the soil/rock, increases capacity with increasing grout thermal conductivity. Pipe configuration, either size, shape, or location, can change the capacity of a geothermal heat exchanger with depth.

c) There is no “standard Canadian home.” Southern Ontario is significantly different from Northern Ontario and that has a huge range of climate. Attawapiskat is not the same as North Bay or Timmins. For Southern Ontario, where the ambient ground temperature is about 10 ^{o}C, geothermal can readily provide year-over-year heating to a home that needs (or choses to do so) no air conditioning. The ground loop will continue to recover close to ambient ground temperature from one year to the next. Ground loop sizing can readily be calculated based on an imbalance between heating and cooling. COP in Southern Ontario will not be impacted to any great extent.

In areas where the ambient ground temperature is significantly less than 10 ^{o}C, more geothermal loop will be required to achieve similar COP numbers. This can be calculated and is well-understood. For example, geothermal is being used in Manitoba in areas where the average ground temperature is around 5 ^{o}C, and the geothermal systems operate as designed.

The length of the ground loop will increase as the ambient ground temperature decreases (for heating) and the imbalance between heating and cooling increases (becomes more heating dominant). There will be very little difference for areas from Kingston to Windsor but communities to the north will each need to be assessed based on weather and ground temperature. Costs will move up proportionally with increased heating demand and increased loop size.

Enbridge Gas Distribution

Interrogatory 5

Reference: Evidence of the OGA, Section 8 Appendix B (page 33)

Preamble: The OGA evidence states that geothermal heat pump systems can be installed for all residential customers and have identified a cost to install ranging from $2000 to $3000 per Refrigerant Tonne (RT). Enbridge seeks to better understand the data, data sources, assumptions, qualifications and sensitivity of the analyses that support the conclusions of this part of the OGA's evidence. The evidence of the OGA states that the thermal energy from the ground is "endlessly renewable".

Request:

a) Does the installed cost of a geothermal heat pump system quoted of $2,000 to $3,000 per RT include all costs associated with drilling and installing the required thermal loop?
b) Please identify geological conditions in Ontario that would increase the noted estimated installation costs, impact the overall system performance, or potential negative environmental issues? To what extent are these conditions prevalent in the community expansion areas identified in the evidence of Enbridge Gas Distribution?
c) Please identify any costs or environmental implications that can arise due to different geological conditions, such as Aquifer drinking water strata, methane in Shale layers, dry porous or fractured stone layers?
d) Please confirm it is standard practice to install a peaking or redundant heating source for an electric geothermal heat pump heated home in Ontario? If not why not?
e) If auxiliary electric heat is installed as part of the geothermal heating system how much additional cost is involved?
f) What would be the impact on the OGA's quoted geothermal heat pump system COP of 4, and the lifecycle cost of a geothermal heat pump system be if it assumed that the auxiliary electric heating system is engaged for twenty days per year, including the incremental CO_2 allowance costs associated with the incremental emissions from the natural gas fired peaking plants required to meet this additional electricity demand?
g) In Appendix B of the OGA's evidence a conversion comparison was provided between a natural gas heating system and an electric geothermal heat pump system. The analysis reviews a 1500 sq ft house and assumes that a 36,000 btu/hr geothermal heat pump system would be adequate for peak space heating and water heating. Please identify the characteristics of the house used in this analysis and identify the data that supports that this represents 80% of the residential opportunities in potential community expansion projects, in terms of age of home, insulation level, and glassing characteristics.
h) Please restate the OGA's cost comparison assuming that a 60,000 btu/hr geothermal heat pump system is required.
i) Please restate the OGA's cost comparison assuming that a 80,000 btu/hr geothermal heat pump system is required.
j) Please provide a reference to support the OGA's assumption that the average design peak winter heating load for all the homes in the community expansion projects is 21,325 Btu/hr.

k) Please explain the rational so support the assumption that a thermal profile of 21,325 Btu/hr is representative of the average of all housing stock in the identified community expansion projects?
l) Please restate the OGA analysis assuming efficient geothermal system COP of and a 60,000 btu/hr heating capacity requirement. Please provide the capital cost, operating costs, and electricity demand associated with this scenario?
m) Please provide an explanation of the basis of the eQuest energy calculation result as shown in Figure #1 by providing details, of the assumed average home and weather data used for the analysis?

Response:

a) The costs are inclusive from drilling to bringing pipe into mechanical room.

b) Where space and soil conditions exist to install horizontal geothermal systems, cost of the geothermal field is relatively low compared to vertical systems.

Where space is limited, vertical geothermal heat exchangers are required. The factors that affect cost are related to location relative to the drilling contractor for mobilization and accommodation, overburden thickness, rock type, job size, and geologic hazards. While drilling technology has advanced significantly over the last decade to provide more consistent and dependable drilling despite geology, costs still do vary.

There will be some areas that are high risk to drill and each area needs to be assessed to understand the risks. The most significant risks include artesian (or flowing) conditions and high natural gas production (shale gas). Based on experience, these represent less than 3% of all drilling locations in Ontario. The majority of locations can be drilled given proper assessment and controls during drilling.

Aside from higher risk geology, thickness of overburden and type of rock drive cost. If drilling into rock is required to achieve total depth on holes, deeper overburden is more expensive. Overburden depth of approximately 100 m and 185 m holes in shale results in a per ton cost of approximately $3,000 as might be representative in Scarborough. Shallow overburden depths such as in Oakville results in per ton cost of approximately $2,100. Granite drilling in Brockville results in cost per ton around $3,300.

Each community identified by Enbridge has not individually been assessed.

c) Drilling technology has advanced significantly in the last decade to allow drilling of many conditions that were considered difficult in the recent past. Expectation is that advances will continue making problems of today simply aggravations of tomorrow.

Challenges include artesian (or flowing) conditions, natural gas from shales, rubbly rock, and high water production. Artesian conditions can generally be identified early in the drill planning or first borehole of a project. Reg 98/12 worked to establish safe drilling practices for control of natural gas during drilling of geothermal holes. Weathered and difficult rock can be addressed by drilling with various techniques that serve to stabilized the borehole. Finally, high water production during drilling can be relieved by drilling with fluids other than air.

Reg 98/12 also requires that each drill job have a drill plan designed by an engineer or professional geologist. Preparation of the plan requires review of oil, gas, and water well records. Additional information such as previous drilling in the area, discussion with local drillers, elevation maps, and geology information are also used. All geothermal drilling contractors must have a multisite Environmental Compliance Approval (ECA) from MOECC under Reg 98/12. The ECA includes requirement for development of a drilling work plan by an engineer or professional geologist. The work plan is very specific on natural gas safety during drilling, drilling techniques used, grouting procedures, and notification process in event of natural gas occurrence.

d) Geothermal should never be installed with a peaking heating source. An emergency backup heating source can be used in event of failure or malfunction of heat pump equipment, to be turned off again when equipment is serviced. Properly sized ground loops and heat pump will ensure no supplementary heat is required. See also S11.OGA.UGL.3(o).

e) Emergency backup resistive duct heating can be installed at a cost of approximately $500/system.

f) It would be different and worse. If gas generation was required to meet the auxiliary electric heat, CO_2 emissions still be better than gas heat, but not as low as calculated. No attempt is made to quantify this assumption since geothermal has no reason to be running on auxiliary for 20 days a year if properly sized to meet full load. Just as an undersized gas furnace may need auxiliary electric heat, so too would an undersized geothermal system. In our view it is not reasonable to assume that any system will be undersized.

g) We cannot provide evidence that 30,000 btu/hr (not 36,000 btu/hr) represents 80% of the residential opportunities in the community expansion projects. This estimate was based on Union Gas estimate of 2,200 m^3/yr of natural gas for a typical customer which closely reflects 30,000 btu/hr peak heating capacity. It was not the intent to justify expected heating loads in the OGA analysis.

h) **Table 3. 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). Annual gas consumption of 4568 m^3/yr – 60,000 btu/hr space heating. Cost of variable speed heat pump, domestic hot water, and loop is included.**

	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 with carbon	$3,413.66	$ 3,055.90	$3,082.47	$ 2,649.95	$ 3,609.87
top 4 PI without carbon	$2,830.96	$ 2,577.16	$3,082.47	$ 2,649.95	$ 3,339.73
Kincardine with carbon	$3,609.34	$ 3,055.90	$3,082.47	$ 2,649.95	$ 3,805.55
Kincardine no carbon	$3,026.65	$ 2,577.16	$3,082.47	$ 2,649.95	$ 3,535.42

Assumptions
60,000 btu/hr peak heating load
Variable speed geothermal system with hot water generator
$3000/ton for 5-ton geothermal loop - $15,000 total
$22,000 for geothermal mechanical system
$13,000 for natural gas furnace, air conditioner, and hot water heater
$8,801.80 for gas connection in top 4 PI
$15,588.24 for gas connection in Kincardine
Electricity and gas increase with inflation rate
Equipment replacement after 20 years
Projection out to 2050
Carbon cost at $30/ton in 2017 and increase by $3.57/ton/year until 2050
Final option is switching gas to geo in 2037 (20 years).
95% efficiency gas furnace with ECM blower
Natural gas hot water heater
21 SEER air conditioner

Discussion
For the top 4 PI projects identified by Union Gas, if cost of carbon is not included, gas is about $252/yr less expensive than geo. If carbon costs are included, gas is about $331/yr more expensive than geo. For Kincardine, gas is $56/yr less than geo without carbon and $527/yr more expensive than geo with carbon. In all cases, switching to geo after 20 years is the most expensive option.

If carbon costs are assigned and ramp up in future, geothermal is the lower cost solution over an extended period for these projects.

i) **Table 4. 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). Annual gas consumption of 6037 m^3/yr – 80,000 btu/hr space heating. Cost of variable speed heat pump, domestic hot water, and loop is included.**

	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 with carbon	$4,396.95	$ 4,143.15	$4,116.69	$ 3,539.99	$ 4,711.35
top 4 PI without carbon	$3,626.87	$ 3,373.07	$4,116.69	$ 3,539.99	$ 4,354.35
Kincardine with carbon	$4,592.64	$ 4,143.15	$4,116.69	$ 3,539.99	$ 4,907.04
Kincardine no carbon	$3,822.56	$ 3,373.07	$4,116.69	$ 3,539.99	$ 4,550.03

Assumptions
80,000 btu/hr peak heating load
Two variable speed geothermal systems, where one has hot water generator
$3000/ton for 6.6-ton geothermal loop - $20,000 total
$30,000 for geothermal mechanical system
$14,000 for natural gas furnace, air conditioner, and hot water heater
$8,801.80 for gas connection in top 4 PI
$15,588.24 for gas connection in Kincardine
Electricity and gas increase with inflation rate
Equipment replacement after 20 years
Projection out to 2050
Carbon cost at $30/ton in 2017 and increase by $3.57/ton/year until 2050
Final option is switching gas to geo in 2037 (20 years).
95% efficiency gas furnace with ECM blower
Natural gas hot water heater
21 SEER air conditioner

Discussion
For the top 4 PI projects identified by Union Gas, if cost of carbon is not included, gas is about $490/yr less expensive than geo. If carbon costs are included, gas is about $280/yr more expensive than geo. For Kincardine, gas is $294/yr less than geo without carbon and $476/yr more expensive than geo with carbon. In all cases, switching to geo after 20 years is the most expensive option.

If carbon costs are assigned and ramp up in future, geothermal is the lower cost solution over an extended period for these projects.

j) Based on 2,200 m^3/yr from Union Gas for a representative customer, the peak winter load is approximately your stated number. OGA is not suggesting this is representative of houses in Enbridge service area.

k) OGA is not assuming this profile is representative of the average housing stock in the identified community expansion projects. The numbers were provided by Union Gas and are used to provide comparison for a value that Union Gas presents as representative of their community expansion projects.

l) **60,000 btu/hr House – 2500 to 3000 sq ft house**
A GeoDesigner analysis for 60,000 btu/hr is attached as Appendix B. Minimum COP of the geothermal system on the coldest days will be 3.3 with an entering water temperature of 0 ^{o}C. The maximum peak power consumption of the geothermal system will be 5.3 kW in winter and 0.75 kW in summer. Existing systems with electric water heaters will likely exceed 5 kW peak in winter due to the hot water heater and summer exceed 9 kW (5 kW for 4 for air conditioning). The peak cooling is calculated to be approximately 48,000 btu/hr and peak EER equal to 12 for the 21 SEER air conditioner, which yields a peak air conditioning load of 4 kW.

If natural gas and air conditioning are used to replace existing systems, peak load for air conditioning will remain around 4 kW. There is not a significant difference in HVAC load for geo versus gas and air conditioning except the peak for geo is in winter and for gas and air conditioning, it is summer.

Capital cost of the geothermal system will be approximately $37,000 at today's price for the variable speed heat pumps and hot water system.

Operating cost for geothermal including hot water will be $1,408/yr and for gas with hot water $1,864/yr (without carbon) and approximately $2,075/yr with carbon at $30/ton. At year 2030 with carbon at $80/ton, cost for gas will be about $2,427/yr in 2017 dollars.

80,000 btu/hr House – 3300 to 4000 sq ft house
A GeoDesigner analysis for 80,000 btu/hr is attached as Appendix C. Minimum COP of the geothermal system on the coldest days will be 3.3 with an entering water temperature of 0 ^{o}C. The maximum peak power consumption of the geothermal system will be 7.0 kW in winter and 1.0 kW in summer. Existing systems with electric water heaters will likely exceed 6 kW peak in winter due to the hot water heater and summer exceed 11.4 kW (6 kW for 5.4 for air conditioning). The peak cooling is calculated to be approximately 65,000 btu/hr and peak EER equal to 12 for the 21 SEER air conditioner, which yields a peak air conditioning load of 5.4 kW.

If natural gas and air conditioning are used to replace existing systems, peak load for air conditioning will remain around 5.4 kW.

Capital cost of the geothermal system will be approximately $50,000 at today's price for the variable speed heat pumps and hot water system.

Operating cost for geothermal including hot water will be $1,845/yr and for gas with hot water $2,617/yr (without carbon) and approximately $2,957/yr with carbon at $30/ton. At year 2030 with carbon at $80/ton, cost for gas will be about $3,522/yr in 2017 dollars.

m) The eQuest energy calculation is for a 1400 sq ft house in Toronto area built to minimum code.

Enbridge Gas Distribution

Interrogatory 6

Reference: Evidence of the OGA, Section 5.2 (page 24)

Preamble: The OGA evidence concludes that the lifecycle cost of geothermal systems are competitive with natural gas in the proposed communities, particularly when carbon costs are considered. Enbridge seeks to better understand the data, data sources, assumptions, qualifications and sensitivity of the analyses that support the conclusions of this part of the OGA's evidence.

Request:

a) Please confirm that the OGA has used the average Carbon emissions for the entire Ontario electric generation portfolio to estimate the carbon emissions for the electric technologies?
b) Please restate the OGA's lifecycle cost analysis assuming that the analysis is based on natural gas being the only marginal fuel used for new electric generation load (including assumed CO_2 emissions costing).
c) Please confirm that all the electricity consumed for the assumed geothermal heat pump systems will represent incremental electrical load on the Province's electricity generating transmission and distribution systems. If not, why not?
d) How does the OGA assume that the additional cost associated with the incremental CO_2 created by the additional use of natural gas power plants required to satisfy the incremental electric loads imposed by additional geothermal heat pump systems be recovered? And, recovered from whom?
e) In its evidence the OGA have stated that the natural gas community expansion proposed programs proposed by Union Gas and Enbridge would produce 4 MT of carbon production by 2050 and that these same communities all converted to geothermal heat pump systems would yield only 0.2 MT. Assuming that all new marginal electricity was to be generated by natural gas fired power plants (assumed to be 45% efficient) please provide an estimate of the CO_2 produced by these power plants to support the new electric load from the OGA's proposed geothermal heat pumps assumed in the OGA's analysis.
f) The OGA states that the aggregate average peak electricity load for HVAC in winter is 2.2 kW based on the fuel usage distribution information stated in table #2. Please confirm that; -1) homes presently heated with fossil fuels would not require substantial upgrades to their electrical services, and -2) the electric LDCs serving these homes would not require significant upgrades to their distribution systems. If this is not the case, who would bear the cost of upgrading these systems?
g) Please provide the average cost of site restoration associated with the drilling of the required bore holes and installation of the thermal loops and confirm whether or not this cost was included in the OGA's "Head to Head Comparisons".

Response:

a) That is correct.

b) Upon further consideration, it is understood that geothermal systems need to address DHW requirements and replace or augment electric water heaters with geothermal heating. With this, geothermal will not add to total grid demand or peak demand and therefore should not result in additional natural gas generation.

Geothermal can also be coupled with thermal storage to provide further peak reductions. If it is determined that thermal storage is required to control peak demand, solutions to do so are readily available. Smart controls are readily available to implement additional heating when the electrical grid has excess power to charge thermal storage and utilize stored thermal energy when the electrical grid is over taxed.

c) Again, if DHW is switched from electric heat to geothermal heat, there will be no additional load.

d) Same point as in c). In this question, there is an assumption that geothermal will result in increased load.

e) No new power generation will be required if DHW is also included in the retrofits.

In event gas generation were required at a an efficiency of 45% and a seasonal average heat pump COP of 4 during heating, CO_2 emissions would be reduced by approximately 45%. With line losses, this might be 40%. This means that generating power with natural gas and heating with geothermal still reduces CO_2 emissions rather than simply burning the natural gas in the furnace.

Also, switching houses to geothermal does not lock them into continued CO_2 emissions like introducing gas infrastructure does. It may be that additional gas fired electricity is required today but that can be replaced as other sources of electricity become available. A house heated with natural gas cannot be switched quite as easily to another heating source. Further, the gas distribution infrastructure serving that community runs the risk of becoming a costly stranded asset.

f) Homes that presently use propane hot water heaters may be required to have increased electrical service. Any homes with electrical water heaters of 4-7 kW that are switched to geo should not require upgrading if the DHW is switched to geothermal.

Geothermal heating does not present a larger load increase than a hot water heater.

g) Cost of site restoration will depend on the home arrangement. Cost is included for situations where the connection to the house is readily completed. The drilling operation, when done with modern equipment, will not pose significant property disruption since all cuttings etc would be collected and removed or solidified as part of the cost of drilling. Tie-in to the house would be done in a similar manner to running gas pipe to the house and so expectation of costs for that would be similar as for gas connections. There will be instances where costs are higher for site restoration. The cost of this was not assessed.

Enbridge Gas Distribution

Interrogatory 7

Reference: Evidence of the OGA, Section 5.2 (page 24)

Preamble: Geothermal natural gas heat pump technology is available in Ontario.

Request:

a) Has the OGA examined and evaluated the use of natural gas heat pumps in geothermal systems for Ontario applications?
b) Is the OGA aware of the distributor of this technology in Ontario?
c) Is OGA aware of the gas fired heat pump applications presently operating in Ontario?

Response:

The OGA is aware of the emergence of natural gas heat pumps but has done no research regarding the initial penetration of this technology into the Ontario marketplace, nor the merits of these systems in relation to geothermal systems for Ontario applications.

Environmental Defence

Interrogatory 1

Reference: Page 29

Does the OGA agree that existing gas consumers should be required to subsidize expansions of Ontario's natural gas distribution system only if all of the following criteria are met:

a) The expansion will lead to a net reduction in Ontario's greenhouse gas emissions [e.g., this could occur if the new customers' previous energy source (e.g., heating oil) had higher greenhouse gas emissions];
b) Expanding the gas system is the most cost-effective, feasible option to achieve the greenhouse gas emission reductions [i.e., do not expand the gas distribution system using existing customer subsidies if the emission reductions could be achieved at a lower cost by energy efficiency or renewable energy investments (e.g., home energy retrofits, heat pumps)]; and
c) The subsidy is necessary to make the project happen [e.g., do not require existing customers to subsidize an expansion of the gas system if the cost could be recovered from the new customers via a surcharge on their gas rates]?

If "no", please fully justify your response. Please specifically address each of the three criteria in your response. Note that the above three criteria would not be to the exclusion of other criteria required for community expansion.

Response:

There are many costs and benefits to the expansion of natural gas infrastructure into new communities. The OGA does not agree that all such expansions should be tested solely on the basis of whether they are optimal GHG reduction programs. All costs and benefits should be considered, including environmental, economic, and others.

The OGA does not express a position on whether subsidies for new energy capabilities – whether natural gas community expansion, geothermal, or anything else - should come from existing customers, new customers, governments, or some other source. That policy decision should be made in the context of the specific proposal under consideration, and it is not clear to the OGA that all situations will favour one form of extra funding over the others.

School Energy Coalition

<u>Interrogatory 1</u>

Reference: Northeast MidStream, Gulick Evidence

Does OGA agree with the evidence of Mr. Gulick on behalf of Northeast Midstream, regarding what incremental costs should be included when evaluating options for system expansion?

<u>Response:</u>

The OGA believes that all incremental costs for any option to provide energy functionality should be considered. The OGA's witnesses have not formed an opinion on Mr. Gulick's list.

Ontario Energy Board Staff

Interrogatory 1

Reference: Evidence of Ontario Geothermal Association, Page 12

The Ontario Geothermal Association (OGA) has provided estimated conversion costs to change homes using other sources of energy to geothermal.

a) Please provide the applications that can use geothermal energy as an input.
b) Can geothermal energy be used as a source for a variety of equipment as natural gas or is it limited to space heating and hot water tank?

Response:

a) Geothermal energy is normally used for space heating and cooling which may be hydronic or forced air. Maximum temperature of geothermal is normally in range of 50 ^{o}C and minimum several degrees below freezing can be achieved. Geothermal can also be used for domestic hot water, snow melt in ramps and sidewalks, pool heating, and dehumidification. Geothermal may also be used for low temperature drying applications and in-floor heated greenhouse operations.

Geothermal can be used in applications as small as 6000 btu/hr (250 sq ft space) up to several thousand tonnes (million sq ft buildings).

Geothermal excels in cooling applications or applications where heat is required in one place and cooling in another and where heat recovery can be used.

b) Note that geothermal is very effective for cooling, something natural gas is not as well suited for.

Heat pumps are limited to output temperature around 60 C. Therefore applications where higher temperatures are required may not be suitable, although geothermal may be able to provide a significant amount of the energy by providing preheat.

Geothermal likely cannot be used for cooking, not for fireplaces, and normally not used for dryers. For household use, there are readily available solutions for these applications using electricity.

There is a variety of geothermal energy equipment that normally include a refrigeration cycle. This includes heat pumps, variable refrigerant flow (VRF) units, and centrifugal chillers.

Ontario Energy Board Staff

<u>Interrogatory 2</u>

Reference: Evidence of Ontario Geothermal Association, Page 12

OGA has noted that the aggregate average electrical consumption per household for HVAC would increase from 3,400 kWh/year to 4,450 kWh/year by switching all homes to geothermal.

a) Is geothermal an appropriate alternative to communities that do not have reliable electric supply or limited electric supply?
b) Is the OGA aware of any of the communities listed by Union Gas Limited or Enbridge Gas Distribution in their evidence that would require reinforcement of the electric grid if they were to pursue geothermal energy as an alternative in place of natural gas?

<u>Response:</u>

a) The answer is possibly. Analysis of the heating and cooling system alone suggests that peak power consumption and total power consumption will increase when switching all homes to geothermal. However, when domestic hot water is included, and where many of the water heaters are presently electric, switching those heaters to geothermal heating results in peak power usage in winter that is similar or lower than the present mix, and drastically reduces the peak in summer. Total power consumption is also decreased when hot water is provided by geothermal equipment. Thus, for a community with limited electric supply, converting both space and water heating to geothermal could reduce the demands on their electricity distribution infrastructure.

b) The comments in a) apply here. If peak and total consumption are not increased, there will be no need to improve the grid.

Ontario Energy Board Staff

<u>Interrogatory 3</u>

Reference: Evidence of Ontario Geothermal Association, Page 24

The OGA has provided the lifecycle cost comparison for the top 4 Profitability Index (PI) projects and the Kincardine project from Union Gas' evidence in EB-2015-0179.

a) Please provide the names of the communities referred to in the top 4 PI projects.
b) Assuming that the 4 communities and Kincardine are converted to geothermal and the conversion rate is the same as that assumed by Union Gas, what would be the increase in electricity consumption as a result of conversion to geothermal?
c) Can OGA confirm whether the electricity grid in Ontario would be able to provide the required electric load in these communities?

<u>Response:</u>

a) The four projects are shown in Table 8 from Union Gas submittal – included below.

Table 8
Proposed Community Expansion Projects

Community	Maximum Potential Customers	Forecast Customers	Capital Cost		Contributions (NPV)		TES/ITE Period (Months)	PI*
			Preferred Design	Minimum Design	TES	ITE		
Milverton	818	526	$4.93	$4.77	$1.01	$0.15	48	0.5
Prince Township	375	242	$2.72	$2.72	$0.22	$0.09	48	0.5
Lambton Shores / Kettle Point FN	496	281	$2.42	$1.79	$0.51	$0.01	82/48	0.73
Moraviantown FN	70	61	$0.54	$0.49	$0.10	$0.02	48	0.5
TOTAL	**1,759**	**1,110**	**$10.61**	**$9.77**	**$1.84**	**$0.27**		

All dollars are in millions

b) The original analysis provided by OGA looked specifically at the space heating and cooling requirements only.

Switching to geothermal without addressing electric water heaters will lead to an increase in power demand of approximately 3650 MWh/yr and increase in peak demand in winter of approximately 7 MW.

If electric domestic hot water heaters are switched to or augmented by geothermal along with space conditioning, peak power consumption and total power consumption is not expected to increase.
c) If electric domestic hot waters are either replaced by geothermal systems or augmented with preheat, OGA does not expect there to be an impact on the grid.

Ontario Energy Board Staff

Interrogatory 4

Reference: Evidence of Ontario Geothermal Association, Page 25-27

OGA in its evidence has noted that based on its lifecycle cost analysis, geothermal systems are competitive with natural gas in the proposed communities, particularly when carbon costs are considered. In Union's application (EB-2015-0179), a number of municipalities that do not have access to natural gas supported Union's initiative of expanding into communities that do not have access to natural gas.

Please confirm whether any of the communities listed in Union's evidence (EB-2015-0179, Exhibit A, Tab 1, Appendix D) considered pursuing geothermal energy as an alternative to natural gas. Did any of the municipalities contact the OGA directly or members of the OGA to discuss such an initiative?

Response:

The OGA was not approached by any of the municipalities listed in Union's evidence. OGA is not aware of any formal discussions between these municipalities and members of the OGA, nor can the OGA ascertain whether any of these municipalities considered pursuing geothermal as an alternative to natural gas. The OGA can, however, offer the observation that the general level of awareness about geothermal as an alternative to natural gas is quite low.

Ontario Energy Board Staff

Interrogatory 5

Reference: Evidence of Ontario Geothermal Association, Page 28-29

The OGA has suggested that the Ontario Energy Board (OEB) should reach certain specific conclusions in the proceeding with respect to cost effectiveness and carbon emissions. The OGA has urged that the regulator must be concerned with whether the expansion is in the public interest and this requires reviewing whether there are other alternatives to natural gas expansion that would serve the public interest better.

a) Should the OEB determine that natural gas is not the best alternative to expand into communities that do not have access to natural gas, what powers under the Act does the OEB have to facilitate the adoption of geothermal energy in communities that are not currently served by natural gas?
b) If a municipality determines that it would consider geothermal energy as an alternative to other forms of energy, does it require any approval or permission from the OEB to pursue such an alternative?

Response:

It is the understanding of the OGA that the OEB does not have specific powers under the Act to facilitate the adoption of geothermal energy in communities that are not currently served by natural gas. To the extent that geothermal depends on the electrical grid and the availability of electricity, however, the OEB's regulatory oversight of local delivery companies may have some impact.

If a municipality determines that it would consider geothermal energy as an alternative to other forms of energy, the OGA does not believe that such a decision would require any approval or permission from the OEB.

Union Gas Limited

Interrogatory 1

Reference: EB-2016-0004 – Natural Gas Expansion Generic Proceeding

Preamble: In the Executive Summary of the evidence (p.3), it states that geo systems can provide all of the space heating, space cooling, and water heating needs of Ontario buildings at a typical efficiency of "*about 400% for heating and 800% for cooling*".

Question:

a) Please confirm that this refers to the Coefficient of Performance (COP) for both heating (ie. COP=4.0) and cooling (ie. COP=8.0).
b) Please provide a reference for commercially available equipment that can achieve the stated COPs.
c) Please provide the comparable seasonal average COP that could be achieved based on the referenced equipment.

Response:

a) Yes, that is correct.

b)

- Two-stage heat pumps with variable ECM fan and variable speed circulation pump – Details attached as Appendix D for Tranquility Series 30 Model. All COP numbers include the power consumption for the circulation pump for the ground loop and the fan blower.
- At entering water temperature of 4.4C, Full load COP is around 4.5 in heating and at -1.1C temperature, around 4.1.
- At entering water temperature of 15.5C, full load EER is around 27 (COP of 7.9) and at partial load ERR is around 31 (COP of 8.5). Peak cooling loads for houses are normally much smaller than peak heating loads which means that during cooling, geothermal heat pumps are normally running at partial load. A COP of 8 is readily achieved.
- COP of the heat pump depends on entering water temperature (from ground loop), entering dry bulb air temperature, and air and water flow rate, and of course equipment selection. COP may be lower or higher than 4 and so a representative value of 4 was used to provide estimates of power consumption.
- Enbridge also provided some concerns on using a peak COP of 4 during heating. We provide a power consumption profile for a heat pump with a peak COP of 3.5 to demonstrate the difference that will occur with lower COP. This curve is shown in Figure 1.

c) Attached as Appendix E is a simulation using GeoDesigner for the Tranquility Series 30 Model installed in a house with one 500 ft deep borehole, representative of a house using equivalent of approximately 2200 m^3/year of natural gas. Seasonal average COP is 3.9 for heating and for cooling (SEER=28) COP of 8.2.

Union Gas Limited

Interrogatory 2

Reference: EB-2016-0004 – Natural Gas Expansion Generic Proceeding

Preamble: At p.10 of the evidence, OGA references "…EER of 27 versus an air conditioner with an EER of 9 …"

Question:

a) Please provide the relevant seasonal energy efficiency ratio ("SEER") number in this example for the air conditioner with energy efficiency ratio ("EER") of 9.
b) In this example, is the SEER comparable with the highest efficiency air conditioners currently available?
c) If not, what is the SEER rating for the highest efficiency air conditioners that are currently commercially available?
d) Please reconcile the SEER number provided with the existing National Energy Code of Canada for Buildings 2011 (division B, Table 5.2.12.1) requiring a minimum SEER of 14. Please explain how the example cited is a relevant efficiency comparison.

Response:

a) Definitions:

EER – energy efficiency ratio given at specific conditions at time of operation including indoor dry and wet bulb temperature, outdoor air temperature, air flow rates, air handler, etc. EER is the ratio of the amount of cooling in btu's versus the power required to deliver the cooling in Watts.

SEER – seasonal energy efficiency ratio which is an integrated average of EER based on varying conditions during the cooling season.

SEER can be used to determine costs of operating a cooling system for the year but should not be used to determine peak electrical loads of the equipment. SEER is generally a

The performance numbers were used from Carrier's Comfort™ 13 Series air conditioners. SEER rating for that air conditioner is 13. Performance numbers vary significantly depending on a number of factors including entering web bulb temperature on evaporator and entering air temperature on condenser. The Carrier Comfort™ 13 has a EER around 9.5 when outdoor temperature is 38 C. This was discounted slightly to represent performance of air conditioners with age.

b) No. Higher SEER units are available.

c) Variable speed and 2-stage compressor units with SEER ratings of up to 21 are available from Carrier. It should be noted that even with SEER rating of 21, when outdoor temperature is at 38 C, and the unit is operating at full capacity, EER is in range of 11.5 to 12.5 based on published data for Carrier model Infinity® 21 2-stage air conditioner.

d) A higher value of EER at 12 is used in calculations to provide a range of scenarios reflecting the possible range of air conditioners that could be selected. Peak load for HVAC for a home with air conditioning and gas heat is reduced from 1.4 kW to 1.05 kW using EER of 12 rather than 9. Figure 1 (modified) shows the daily expected power consumption for a geothermal HVAC system versus a natural gas and conventional air conditioner system. Decreasing heat pump COP from 4 to 3.5 increases peak consumption for the heat pump from 2.9 kW to 3.3 kW.

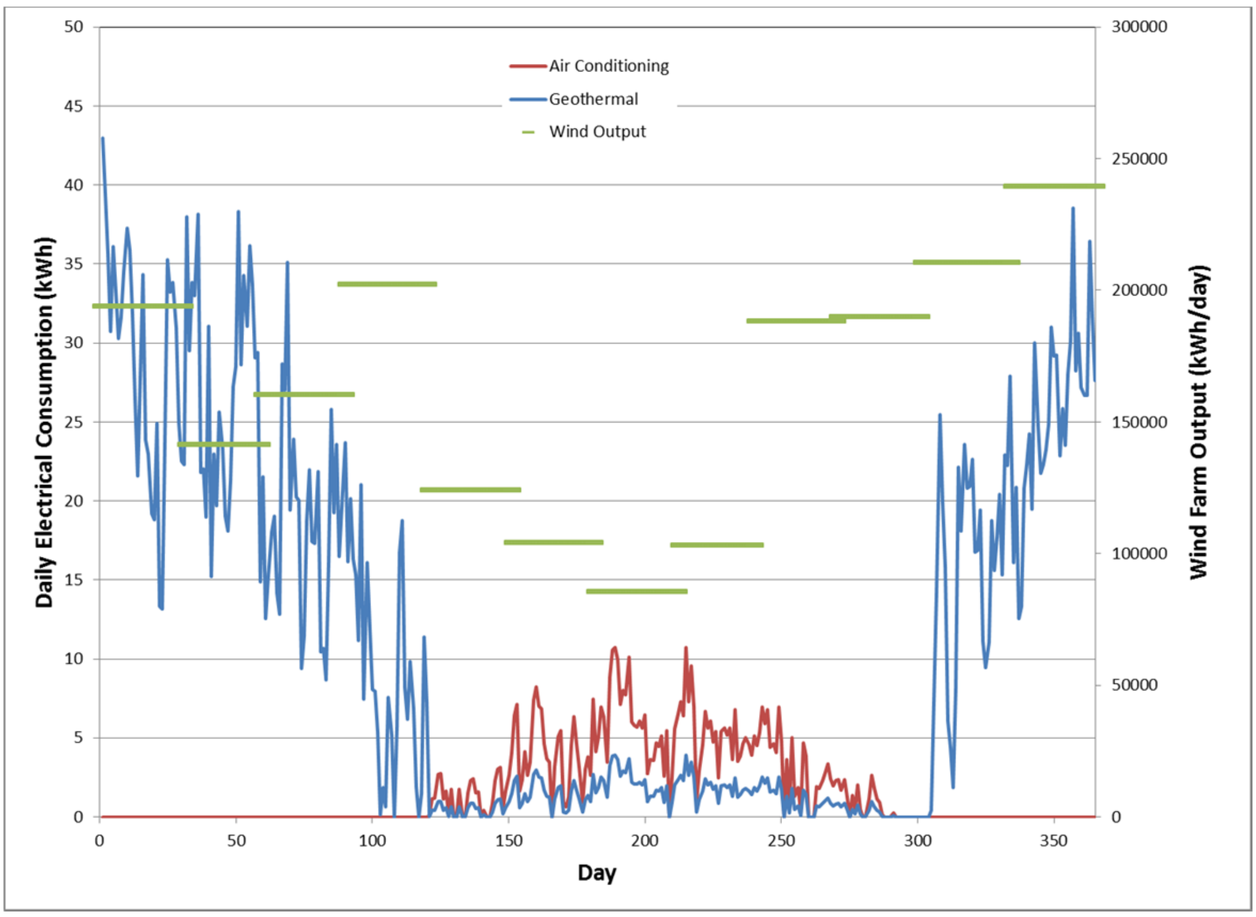


Figure 1 (modified). Comparison of daily electrical consumption for a geothermal system (both heating and cooling) versus an air conditioner (cooling only) for a 1500 sq ft typical house (LHS axis). Consumption is based on simulated hourly loads from EQuest. Also shown is the power production (averaged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

Second last paragraph on Page 10 of OGA evidence is modified to read:

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 (3.3 kW) than for the air conditioning (1.05 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 611 kWh for air to 3992 kWh for geothermal[1]. Note that power consumption does not reflect costs of running the fan for gas heating or electric hot water.

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,. 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 3.5 times that of a geothermal system or 10.2 kW per system. During summer peak load is assumed to be 1.05 kW per system(high SEER air conditioners) 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 3.3 kW (peak COP of 3.5) and 0.37 kW, respectively.

With existing systems, the calculated aggregate average peak electrical load for HVAC in winter is approximately 2.0 kW per household and in summer 1.05 kW. For 100% geothermal the aggregate average peak electrical consumption for HVAC in winter would be 3.3 kW per household and in summer 0.4 kW. By switching all systems to geothermal, the aggregate electrical peak is then expected to increase 1.3 kW/household in winter and decrease 0.65 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 611 kWh/yr. Electric heat pumps systems are assumed to be geothermal with an existing consumption of 3992 kWh/yr. Electrical systems are expected to consume 3.5 times the amount of geothermal for heating, giving a total for air conditioning and heating of 14,000 kWh/yr. Following conversion to geothermal, all systems would use 3,992

[1] 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).

kWh/yr.

The aggregate average electrical consumption per household for HVAC would increase from 3311 kWh/yr to 3,992 kWh/yr by switching all homes to geothermal.

The effect of utilizing higher efficiency air conditioners from 13 SEER to 21 SEER serves to reduce calculated peak for conventional air conditioning by approximately 0.35 kW/house and reduce total load by 200 kWh.

Switching Domestic Hot Water (DHW) from Electric to Geothermal

Domestic hot water is often heated with electrical heat where natural gas is not present or propane is not being used. Geothermal can be used to provide all the hot water requirements at a COP similar to that for space heating. A typical electrical water heater has 4 kW heaters or greater and a typical house with 3 or 4 residents will use in range of 4,000 to 7,000 kWh/yr for water heating. If DHW is provided by geothermal with a seasonal average COP of 3.5, the peak demand will be reduced by 2.85 kW and total consumption reduced by 2850 to 5000 kWh.

If we assume all homes that are not on propane have electric water heaters and these were replaced with geothermal along with the geothermal heating system, and the total electrical usage for domestic hot water for the average house is 4,000 kWh, we can look at what happens if houses are switched from existing systems to geothermal.

The picture changes drastically. Peak load for the existing fuel and electrical heaters would be in range of 4.4 kW in summer and 5.6 kW in winter on average per home and total annual load would be about 6700 kWh. For geothermal with geothermal hot water, peak load is in range of 1.5 kW in summer and 4.5 kW in winter and total annual load would be 5100 kWh.

To conclude, converting both the heating and electric water tank to geothermal heating will result in reduced summer peak by about 2.9 kW and will likely reduce winter peak 1.1 kW. Total power consumption may also be reduced by approximately 1600 kWh/yr.

Alternatively, geothermal can be used to preheat water before it goes into the electric water tank using a preheat water tank and a super deheater heat exchanger on the heat pump. This is presently a very common way to install a geothermal system.

Union Gas Limited

Interrogatory 3

Reference: EB-2016-0004 – Natural Gas Expansion Generic Proceeding

Preamble: In Section 5.2 – Costs (p.23) and Section 8 – Appendix B – Geothermal vs. Natural Gas Conversion (p.32), Union seeks to understand the analysis presented.

Question:

a) On what basis does OGA assume that the average size of a home is 1,200 to 1,500 square feet? Please provide a reference for this assumption and confirm that it applies to single family detached residential dwellings in Ontario
b) Please provide all assumptions and calculations used to determine the values in Table 1 (p.24).
c) Please explain how life cycle costs have been converted to annual cost equivalents in Table 1.
d) Please provide the breakdown (number and length) of horizontal and vertical ground loops which underlie the estimated "with loop" geothermal costs in Table 1.
e) Please confirm that OGA's Life Cycle Costs in Table 1 and Total Capital Costs shown in Table 2 (p.34) are based only on homes being converted from oil to natural gas, and do not reflect average costs for conversions from other energy forms to natural gas. Please explain why this approach was taken.
f) Please provide references that validate the estimated costs for each item in the oil to gas conversion estimates provided in Appendix B.
g) Please confirm that cost estimates for conversion from oil to gas assume that 100% of homes will install central air conditioning, and provide any references that validate that assumption.
h) Please provide reasons why in cases where a home has a pre-existing central air conditioning system OGA has assumed that the central air conditioning components would never be re-used when a furnace is converted.
i) Please indicate whether OGA has double counted any costs for converting to natural gas in the analysis presented in Table 1 by including both the gross capital costs per customer as well as the annual ongoing natural gas costs (which are in part a means to recover the gross capital costs over the economic life of each project).
j) Please provide data and references supporting the assumption that the heating load for a home consuming 2,200 m^3 of natural gas per year is equivalent to a peak heating load of 30,000 btu per hour, which in turn is equivalent to a 2.5 ton heating/cooling load.
k) Please confirm that geothermal ground loop costs assumed in Table 2 (p.34) include a single horizontal or vertical loop, and that their lengths are estimated at 225 metres (horizontal) or 125 metres (vertical) based on 2.5 tons times the length as specified in Section 2.3 (p.7).
l) Please confirm that the loop costs of $3,750 (horizontal) and $6,250 (vertical) provided include all installation costs, including labour and commissioning to meet relevant code requirements for a typical single residential geothermal customer in an urban setting. If not, please provide these costs. Please provide references for the figures provided.
m) Please provide a reference for the carbon price estimates specified, and provide a comparison to expected carbon prices announced by the Ontario Government.
n) On what basis does OGA assume that 25% of geothermal systems can be installed using horizontal loop systems?

o) Please explain the extent to which supplemental heating (ie. resistance heating) or cooling equipment or components are installed with geothermal systems in Ontario, the approximate percentage of geothermal systems they are installed with in Ontario, their incremental cost if installed at the time a geothermal system is installed, and how they have been factored into both the installation costs and annual operating costs in OGA's analysis.
p) Please indicate whether the statement; "*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.*" (p.25) is accurate for the Province of Ontario given the electricity price increases forecasted in the provincial Long Term Energy Plan.

Response:

a) Union Gas provides an estimate of 2,200 m^3/year per customer as a representative value for their Union South and Union North customers as indicated on Page 4 and 9 of Union Gas Exhibit A Tab 1. This was used as a basis to calculate equivalent load for a geothermal system to provide comparison. The intention was to provide a reasonable comparison between house size and cost to operate either natural gas or geothermal rather than compare very different sized homes. When analysis was done on the different equipment solutions, the gas heat home was selected such that it consumed 2,200 m^3 of gas annually.

b) Assumptions for NPV calculation:

- Time Period: 2017 to 2050, inclusive
- Gas price and electrical price increase at inflation rate of 2%/annum
- For price of carbon, $30/ton or $0.056/$m^3$ in 2017 and increasing by $3.57/year to 2050 so that by end of 2030, price is $80/ton and at 2050, $140.71/ton, in 2017 dollars
- Carbon emission is based on 2,200 m^3/yr of natural gas[2]
- Cost of gas equipment retrofit $10,975 (including air conditioner)
- Cost of gas connection for first 4 projects included in Union Gas list (projects 1, 2, 3, and 5) as $8,801.80/house and Kincardine, Tiverton, Paisley, Chesley project (project 29) as $15,588.24 based on cost of estimated capital cost and forecast customers
- Cost of geothermal equipment retrofit $15,050/house
- Cost of geothermal loop and connection $6,500/house
- Replacement of mechanical equipment after 20 yrs at cost of the $10,975 for gas and $15,050 for geothermal, in 2017 dollars. Geothermal equipment is replaced at this time with variable speed compressor equipment to reflect progress in equipment performance. In the case where gas is replaced with geothermal after 20 yrs, cost of geothermal equipment and the geothermal loop are included equivalent to $21,550, in 2017 dollars.
- Cost of electricity is $0.18/kWh until end of 2019 and then goes to $0.135/kWh starting in 2020, in 2017 dollars. This reflects the changes to Hydro One billing where variable distribution cost is

[2] Original evidence from OGA assumed in this comparison that gas consumption was equal to the estimated gas consumption provided by Union Gas for the 29 projects divided by the total number of forecast customers giving an average house consumption of 2,834 m^3/yr. The correction to 2,200 m^3/yr of gas is intented to provide a more reasonable comparison.

replaced with fixed distribution cost. The increased electrical cost of operating the geothermal system is the incremental increase in the electrical bill since the distribution cost is already being paid.

- Gas cost is assumed to be $0.36/m^3$ reflecting the annual cost of gas in Figure 1 of Union Gas Exhibit A Tab 1 (page 9) of $800/yr and 2,200 m^3/yr.
- Annual operating costs of each system were calculated using GeoDesigner.
- Inflation was assumed to be 2% on all costs.

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). Corrected to reflect annual gas consumption of 2,200 m^3/yr. Cost of 2-stage heat pumps are used.

	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	$2,333.12	$ 2,079.32	$1,820.58	$ 1,633.15	$ 2,266.22
top 4 PI without carbon	$2,052.60	$ 1,798.62	$1,820.58	$ 1,633.15	$ 2,136.27
Kincardine with carbon	$2,528.81	$ 2,079.32	$1,820.58	$ 1,633.15	$ 2,461.90

Correction to Table 1 provides similar conclusion to the original calculations provided on page 24 of the OGA evidence.

A second table is included to assess the lifecycle cost of switching to the latest generation of geothermal equipment that has seasonal COP of 4.3, generates all the domestic hot water, and reduces electrical demand of the geothermal system to a point where no additional power generation is required. An additional ton of loop is also considered. The cost of the heat pump system with hot water system is approximately $5000 more and the loop is assumed to $2500 more for a total increase in initial cost of $7500.

Table 2. 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). Corrected to reflect annual gas consumption of 2,200 m^3/yr. Cost of variable speed heat pump, domestic hot water, and additional loop is included.

	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	$2,333.12	$ 2,079.32	$2,052.19	$ 1,792.67	$ 2,486.21
top 4 PI without carbon	$2,052.60	$ 1,798.62	$2,052.19	$ 1,792.67	$ 2,356.09
Kincardine with carbon	$2,528.81	$ 2,079.32	$2,052.19	$ 1,792.67	$ 2,681.90

The cost of geothermal goes up somewhat with the variable speed equipment and hot water generation (approximately $230/yr if loop is included and $160/yr if loop is not included). Geothermal remains competitive with the higher efficiency equipment and at the same time will not affect power consumption and peak power demand if hot water is handled by the geothermal system.

c) Annual net present value is calculated as the total net present value of all the costs, discounted using assumed inflation rate, from 2017 to 2030, and dividing by number of years, which is 34 years.

d) Table 1 assumes that 100% of the loops are vertical and uses a cost of $6500/loop installed. Each loop configuration would be 2.5 tons in capacity (30,000 btu/hr). For a 2.5 ton system, the vertical loops would normally be 1 borehole to about 125 m or two holes to 62.5 m depending on drilling conditions, costs, and space.

While horizontal loops were not considered in Table 1, if they were used the horizontal systems could be 2 trenches 115 m in length with supply and return piping approximately 60-90 cm apart at a depth of 1.5-1.8 m.

e) Force-air oil to natural gas conversion were considered to demonstrate that geothermal can be competitive with natural gas in that scenario. Other conversions were not fully assessed. We do point out in our evidence that our estimated costs of retrofitting does not represent the 9% of forced air propane furnaces that can be readily converted to natural gas. The cost of converting the 3% of forced air propane furnaces that cannot be converted to gas is only slightly less costly than converting oil force air and therefore our analysis is representative of those systems. Electric forced air will be similar to forced air oil. Oil and propane boiler systems may be replaced with water-water heat pumps in some instances, with similar costs to the forced air oil furnace retrofit. Electric base board and wood (wood stoves) could be replaced with geothermal variable refrigerant flow (VRF) units, without the need for significant duct work, much like natural gas fire place.

f) Based on actual quotes for a forced air oil furnace to natural gas complete with new natural gas water tank and 15 SEER air conditioner from an HVAC dealer.

g) It is the assumption that all homes will eventually include air-conditioning. The reason to make the assumption is the functionality of geothermal provides air conditioning so to provide comparable costs, air conditioning was included.

h) There may be instances where air conditioners could be reused but it is not clear how many could be. To provide an even comparison of new equipment to new equipment, new air conditioners were assumed to be included.

i) There was no double counting. The gross capital cost for gas hook up was included at the beginning of the time frame considered. Price of gas included no extra surcharges or other costs.

j) This is based on gas consumption calculated by GeoDesigner.

k) That is correct.

l) These prices are based on quotes from dealers. The costs include all elements including labour, flush, fill, and tie-in to building. A range of pricing is provided for vertical systems on page 34 from $2000-$3000/ton due to varying geologic conditions.

m) The Western Climate Initiative Ontario carbon price forecasts came from an expert presentation to the OEB on January 20, 2016, which was attended by Union Gas and Enbridge. The same forecasts were later presented publicly at an Ontario Energy Association event in February, 2016, by the consulting firm that developed them, ICF International. The forecasts show that the cost of gas for a typical Ontario home will increase by $450 per year by 2030 due to the cost of carbon. Because the details of the Ontario participation in the Western Climate Initiative are still being developed, and because market-based carbon pricing is inherently unpredictable at this early point in its history, OGA does not assert that these forecasts are reliable or accurate. If the gas utilities have better forecasts, those would also be useful to consider. Other forecasts show much higher carbon costs. Any calculation of the costs and benefits of natural gas community expansion should include an explicit set of carbon cost assumptions, with appropriate justifications.

n) Table 1 was calculated based on assuming all loops were vertical systems. Table 2 provides a comparison of the various costs if all horizontal, all vertical, or a 75%/25% mix of vertical to horizontal. There is no assumption at this point what the mix would be. Table 1, with all vertical loops, is meant to represent the most expensive geothermal scenario.

o) Supplemental heating systems are not installed in geo systems today, rather if installed they are referred to as emergency backup heat in event there is a failure in the some component of the heat pump or ground loop. Geothermal systems can be designed to provide 100% of the geothermal load of a building and that is assumed in the calculations. It would be the expectation that retrofits in these communities would be 100% geothermal systems with no supplemental electrical resistance heating.

Unlike air-source heat pumps, geothermal heat pump systems, when designed and installed properly, do not require supplemental heat.

p) No attempt is made to predict the price of electricity or gas and calculations of operating cost and net present value do not include any projections on price. There are certainly projections for electricity and gas in various jurisdictions that do not all agree. Ontario's 2013 LTEP projects an annual real increase in residential price of electricity of 1.36% from 2016 to 2032 . EIA's 2015 Annual Energy Outlook projects an increase in residential gas prices of 1.75% per year above inflation rate on residential prices. While electrical prices vary significantly

between jurisdictions, natural gas prices are more closely tied to North American gas prices. It would suggest that while electrical prices are set to increase well above inflation rates, natural gas prices will increase even more rapidly.

To put the small yearly difference in perspective (electricity increasing at 1.36%/yr to 2032 and natural gas increasing at 1.75%/yr to 2032), and factoring in the price of carbon, the Union Gas typical house (2200 m^3/year of natural gas), the house using geothermal will cost $1402/yr to operate while the same house with natural gas will cost $2455/yr. If this continues out to 2050, the geothermal house costs $1,921/yr and the natural gas house costs $4855/yr.

Union Gas Limited

Interrogatory 4

Reference: EB-2016-0004 – Natural Gas Expansion Generic Proceeding

Preamble: In Section 5.2 – Carbon Emissions (p.25), Union seeks to understand the analysis presented.

Question:

a) Please provide assumptions and references for the estimated 48,000 tonnes/year of burner tip CO_2 emissions.

Response:

a) From Union Gas proposal for the projects up to number 29, the total amount of gas consumed is estimated to be 25.81 Million m^3/yr (Exhibit A, Tab 1 Appendix D pg 1). For the following calculation, from https://www.eia.gov/environment/emissions/co2_vol_mass.cfm, complete combustion of 1000 cubic feet of natural gas produces 53.12 kg of CO_2.

Burner tip emissions (tonnes/yr) = 25,810,000 m^3/yr * 53.12 kg/1000 cubic ft * 1 cubic ft/$(0.3048)^3$ m^3 * 1 tonne/1000 kg = 48,417 tonnes/yr

This does not include the CO_2 emissions from production or transmission, nor does it include the effects of fugitive methane emissions during drilling, fracking, production, transportation, storage, and combustion.

Vulnerable Energy Consumers Coalition

Interrogatory 1

Reference: page 5

Please provide OGA understands of "contributions in aid of construction". Do new customers provide contributions in aid of construction? Why does OGA believe that these are subsidies? Please provide OGA's definition of the word "subsidy".

Response:

Contributions in aid of construction are a recognition by the customer and the utility that the new connection is uneconomic. Customers agree to pay what is, in effect, a premium price for their service (through an up-front cost) to make the new service economic. In a technical sense, this is not a subsidy, because the customer is paying for what it is getting. It is more of a premium price.

CIACs are subsidies only in the narrower, colloquial sense in which someone, in this case the customer, has to make an extra payment to the utility, over and above normal rates, to allow it to proceed with the project. Whether that payment comes from the government, or from existing customers, or from the new customers, it has the same effect. It tilts an uneconomic project to economic. It is only in this more limited sense that CIACs are subsidies, and that is how the word is being used in this context.

Vulnerable Energy Consumers Coalition

Interrogatory 2

Reference: page 28

Please explain the term “cost /benefit ratio” as OGA understands it. Is it the same as the EBO188 Profitability Index? If not, please explain the differences and provide a mathematical formula that shows how OGA’s cost/benefit ratio is calculated.

Response:

The term “cost/benefit ratio” on page 28 refers to the Profitability Index.

OGA INTERROGATORY RESPONSES

APPENDIX A

S11.OGA.EGD.4

Attached as a separate document.

OGA INTERROGATORY RESPONSES

APPENDIX B

S11.OGA.EGD.5(l)

60,000 BTU
GEODESIGNER® SYSTEM ANALYSIS

Prepared For:

6000 btu natural gas vs geothermal

South Western Ontario
generic, CAN n/a

Sample Heating and Cooling
555 W. Demo Road
Anywhere, USA 25487

Joe Sample
2/3/2016

Project Information

Prepared For:		Prepared By:	
	6000 btu natural gas vs geothermal		Sample Heating and Cooling
	South Western Ontario		555 W. Demo Road
	generic, CAN n/a		Anywhere, USA 25487
Home	n/a	Main	555-1212
Work	n/a	Fax	555-1212
Cell	n/a		
	n/a	Contact	Joe Sample
			555-1212
			jsample@sample.com

Notes: Notes:

Design Data

Heating Load:	60.0	kBtuh	Heating Setpoint:	72.0	Deg F
Htg Load Temp Diff:	74.0	Deg F	Cooling Setpoint:	75.0	Deg F
Cooling Load:	30.0	kBtuh	Begin Cooling At:	65.0	Deg F
Clg Load Temp Diff:	9.0	Deg F	Hot Water Setpoint:	130.0	Deg F
Sensible Cooling:	23.1	kBtuh	Hot Water Users:	3	
			Continuous Fan:	No	
Reference City:	Waterloo-Wellington, CAN-ON				
Winter Design:	-2.0	Deg F	Annual Heating Load:	126	MMBtu
Summer Design:	84.0	Deg F	Annual Cooling Load:	23	MMBtu
Bldg Balance Temp:	61.2	Deg F	Ann. Hot Water Load:	17	MMBtu
Avg Internal Gains:	8.7	kBtuh	Daily Hot Water Use:	208	Litres

Estimated Operating Cost Summary

System	Heating CDN$	Cooling CDN$	Hot Water CDN$	Cont. Fan CDN$	Total CDN$	Monthly CDN$
5 ton variable heat pump	1,218	35	155	0	1,408	117
5 ton 2-stage heat pump	1,279	116	405	0	1,800	150
95% Efficiency Natural Gas	1,383	236	245	0	1,864	155

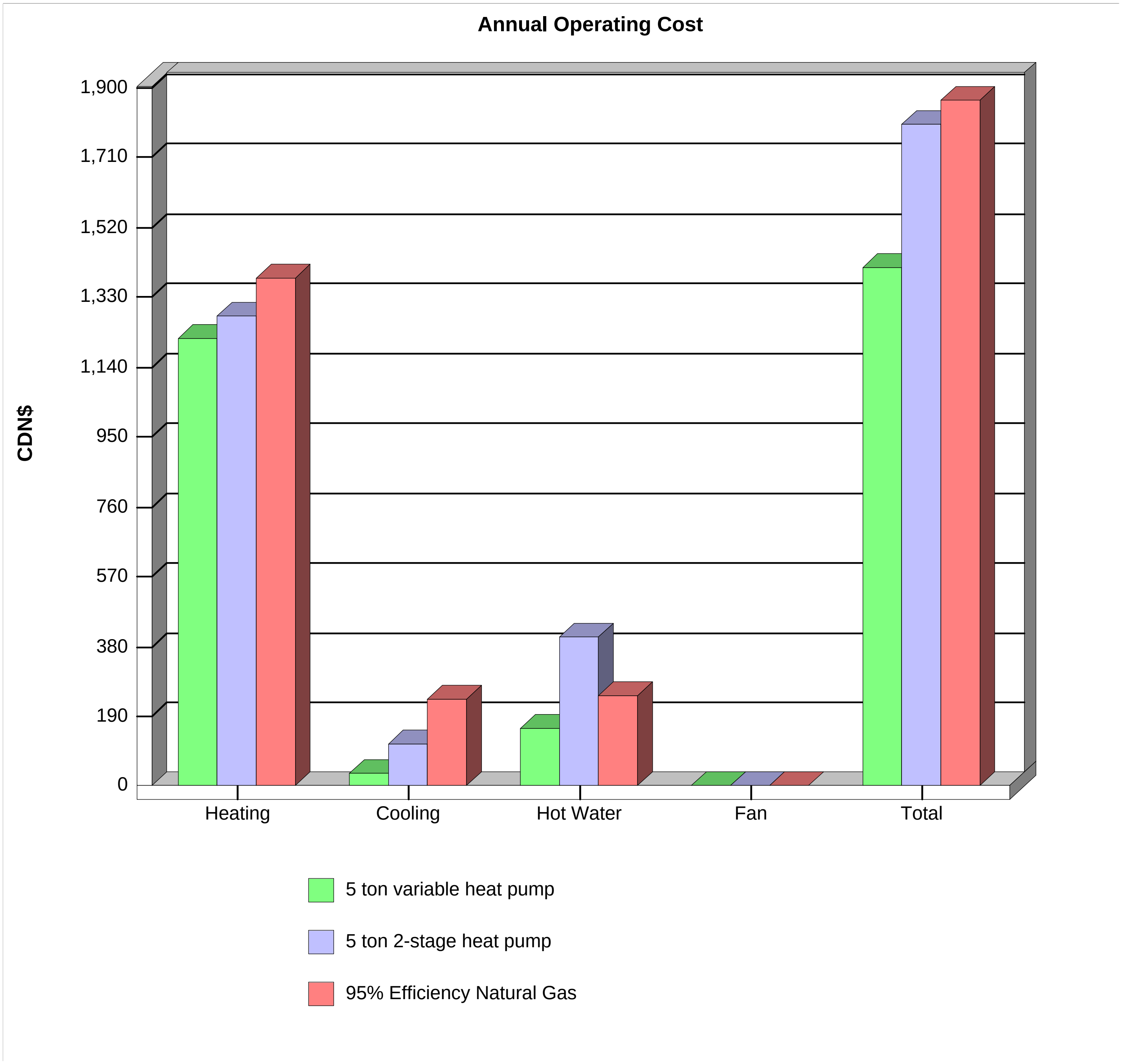
Comments:
$0.30/m3 Natural Gas $0.135/kWh electricity with constant distribution cost within 4 years, variable speed equipment

Utility Cost	CDN$	Summer	Winter
Electric - Geothermal	per kWh	.135	.135
Electric - Heat Pump	per kWh	.135	.135
Electric - Furnace	per kWh	.135	.135
Natural Gas	per m3	0.30	0.30
Propane	per Litre	0.58	0.58
Fuel Oil	per Litre	0.93	0.93

60000 btu case.ged

Due to the variability of weather, system installation, and living habits this analysis is to be considered an estimate.

System Comparison Graph



ClimateMaster, Inc. GeoDesigner®	2/3/2016	60,000 btu

System Summary

5 ton variable heat pump

ClimateMaster Unit

Series:	Trilogy	
Model:	1860	
Style:	Variable Capacity	
Water Heating:	Q-Mode	
	Run Hours	Avg Speed
Heating:	4,578	37%
Cooling:	937	19%
Hot Water:	585	35%

Geothermal Source

Source Type:	Vertical Closed Loop
Soil Type:	Average Rock
Pipe Type:	1-1/4" IPS HDPE SCH 40
Pipe Configuration:	1 U-Tube in Bore
Avg Pipe Depth:	250 Feet
Bore Length:	875 Feet
Min Freeze Protect:	12 Deg F
Max Source-Cooling:	74 Deg F
Avg Source-Cooling:	55 Deg F
Avg Source-Heating:	42 Deg F
Min Source-Heating:	32 Deg F
Deep Earth Temp:	50.1 Deg F
Surface Swing:	22.6 Deg F
Swing Time Lag:	39 Days
Soil Conductivity:	1.40 Btu/h-ft-F
Soil Diffusivity:	0.96 ft2/day
Loop Conductivity:	2.11 Btu/h-ft-F

Auxiliary Heat

Type:	Electric Resistance
Style:	Duct Heater
Auxiliary Required:	0 Kw
Optional Emergency:	16 Kw
Efficiency:	100 %
Aux Balance Point:	N/A Deg F

Water Heater

Type:	iGate Smart Tank
Style:	Communicating - Electric
Efficiency:	94.0 %

Heating

Trilogy

Electrical Use:	9,020 kWh
Average Efficiency:	4.08 COP (W/W)
Annual Contribution:	100 %
Annual Cost:	$1,218

Electric Resistance

Electrical Use:	1 kWh
Average Efficiency:	100 %
Annual Contribution:	0 %
Annual Cost:	$0

Annual Heating Cost: $1,218

Cooling

Trilogy

Electrical Use:	259 kWh
Average Efficiency:	89.2 EER (Btu/W)

Annual Cooling Cost: $35

Water Heating

Trilogy Q-Mode

Electrical Use:	1,133 kWh
Average Efficiency:	4.31 COP (W/W)
Annual Contribution:	100 %
Annual Cost:	$153

iGate Smart Tank

Electrical Use:	14 kWh
Average Efficiency:	94 %
Annual Contribution:	0 %
Annual Cost:	$2

Annual Water Heating Cost: $155

Continuous Fan

Electrical Use: 0 kWh

Annual Continuous Fan Cost: $0

Total Annual Operating Cost: $1,408

Due to the variability of weather, system installation, and living habits this analysis is to be considered an estimate.

4/16/16

System Summary

5 ton 2-stage heat pump

ClimateMaster Unit

Series:	Tranquility 30 - Digital	
Model:	64	
Style:	Two Stage - Var Spd Fan	
Hot Water Generator:	Yes	
Heating Run Time:	3,135	Hours
Cooling Run Time:	419	Hours
Heating Stage 1:	92	% of Htg
Cooling Stage 1:	100	% of Clg

Geothermal Source

Source Type:	Vertical Closed Loop	
Soil Type:	Average Rock	
Pipe Type:	1-1/4" IPS HDPE SCH 40	
Pipe Configuration:	1 U-Tube in Bore	
Avg Pipe Depth:	250.0	ft
Bore Length:	885.0	ft
Min Freeze Protect:	12.0	Deg F
Max Source-Cooling:	74.5	Deg F
Avg Source-Cooling:	55.2	Deg F
Avg Source-Heating:	41.0	Deg F
Min Source-Heating:	32.0	Deg F
Deep Earth Temp:	50.1	Deg F
Surface Swing:	22.6	Deg F
Swing Time Lag:	39	Days
Soil Conductivity:	1.40	Btu/h-ft-F
Soil Diffusivity:	0.960	ft2/day
Loop Conductivity:	2.11	Btu/h-ft-F

Auxiliary Heat

Type:	Electric Resistance	
Style:	Forced Air	
Auxiliary Required:	1	kW
Optional Emergency:	16	kW
Efficiency:	100	%
Aux Balance Point:	-1.6	Deg F

Water Heater

Type:	Electric Storage Water Heater	
Style:	Standard Efficiency	
Efficiency:	88	%

Heating

Tranquility 30 - Digital

Electrical Use:	9,422	kWh
Average Efficiency:	3.90	COP (W/W)
Annual Contribution:	100	%
Annual Cost:	1,272	CDN$

Electric Resistance

Electrical Use:	53	kWh
Average Efficiency:	100	%
Annual Contribution:	0	%
Annual Cost:	7	CDN$

Annual Heating Cost: 1,279 CDN$

Cooling

Tranquility 30 - Digital

Electrical Use:	856	kWh
Average Efficiency:	27.00	EER (Btu/W)

Annual Cooling Cost: 116 CDN$

Water Heating

Geothermal Hot Water Generator

Electrical Use:	661	kWh
Average Efficiency:	4.29	COP (W/W)
Annual Contribution:	58	%
Annual Cost:	89	CDN$

Electric Storage Water Heater

Electrical Use:	2,340	kWh
Average Efficiency:	88	%
Annual Contribution:	42	%
Annual Cost:	316	CDN$

Annual Water Heating Cost: 405 CDN$

Continuous Fan

Electrical Use:	0	kWh

Annual Continuous Fan Cost: 0 CDN$

Total Annual Operating Cost: 1,800 CDN$

Due to the variability of weather, system installation, and living habits this analysis is to be considered an estimate.

System Summary

95% Efficiency Natural Gas

Air Conditioner

Type:	Air Conditioner - Split
Style:	21 SEER - 2stg - R410a
35 C Cool Capacity:	46.1 kBtuh
35 C Cool Efficiency:	12.10 EER (Btu/W)
Indoor Coil Match:	Hi-Eff Furn
Outdoor Coil Rating:	Average
35 C Low Cool Cap:	33.0 kBtuh
35 C Low Cool Eff:	13.05 EER (Btu/W)
Run Time:	761 Hours

Heating System

Type:	Gas Furnace
Style:	Ignitor-Cond-Mod-Vspd
Input Capacity:	70.0 kBtuh
Output Capacity:	68.6 kBtuh
Efficiency:	98.0 AFUE
Low Input Cap:	28.0 kBtuh
Low Output Cap:	27.4 kBtuh
Run Time:	4121 Hours

Water Heater

Type:	Gas Storage Water Heater
Style:	Standard Efficiency
Efficiency:	58.0 %

Heating

Gas Furnace

Fuel Use:	3,753 m3
Electrical Use:	1,903 kWh
Average Efficiency:	95 %

Annual Heating Cost: 1,383 CDN$

Cooling

Air Conditioner - Split

Electrical Use:	1,750 kWh
Average Efficiency:	13.21 EER (Btu/W)

Annual Cooling Cost: 236 CDN$

Water Heating

Gas Storage Water Heater

Fuel Use:	815 m3
Average Efficiency:	58 %

Annual Water Heating Cost: 245 CDN$

Continuous Fan

Electrical Use:	0 kWh

Annual Continuous Fan Cost: 0 CDN$

Total Annual Operating Cost: 1,864 CDN$

Due to the variability of weather, system installation, and living habits this analysis is to be considered an estimate.

OGA INTERROGATORY RESPONSES

APPENDIX C

S11.OGA.EGD.5(l)

80,000 BTU
GEODESIGNER® SYSTEM ANALYSIS

Prepared For:

80000 btu natural gas vs geothermal

South Western Ontario
generic, CAN n/a

Sample Heating and Cooling
555 W. Demo Road
Anywhere, USA 25487

Joe Sample
2/3/2016

Project Information

Prepared For:

80000 btu natural gas vs geothermal
South Western Ontario
generic, CAN n/a
Home n/a
Work n/a
Cell n/a
n/a

Notes:

Prepared By:

Sample Heating and Cooling
555 W. Demo Road
Anywhere, USA 25487
Main 555-1212
Fax 555-1212

Contact Joe Sample
555-1212
jsample@sample.com

Notes:

Design Data

Heating Load:	80.0	kBtuh
Htg Load Temp Diff:	74.0	Deg F
Cooling Load:	40.0	kBtuh
Clg Load Temp Diff:	9.0	Deg F
Sensible Cooling:	30.8	kBtuh
Reference City:	Waterloo-Wellington, CAN-ON	
Winter Design:	-2.0	Deg F
Summer Design:	84.0	Deg F
Bldg Balance Temp:	61.2	Deg F
Avg Internal Gains:	11.7	kBtuh

Heating Setpoint:	72.0	Deg F
Cooling Setpoint:	75.0	Deg F
Begin Cooling At:	65.0	Deg F
Hot Water Setpoint:	130.0	Deg F
Hot Water Users:	4	
Continuous Fan:	No	
Annual Heating Load:	168	MMBtu
Annual Cooling Load:	31	MMBtu
Ann. Hot Water Load:	21	MMBtu
Daily Hot Water Use:	265	Litres

Estimated Operating Cost Summary

System	Heating CDN$	Cooling CDN$	Hot Water CDN$	Cont. Fan CDN$	Total CDN$	Monthly CDN$
5 ton variable heat pump	1,606	43	195	0	1,845	154
No Option Selected	0	0	0	0	0	0
95% Efficiency Natural Gas	1,975	331	311	0	2,617	218

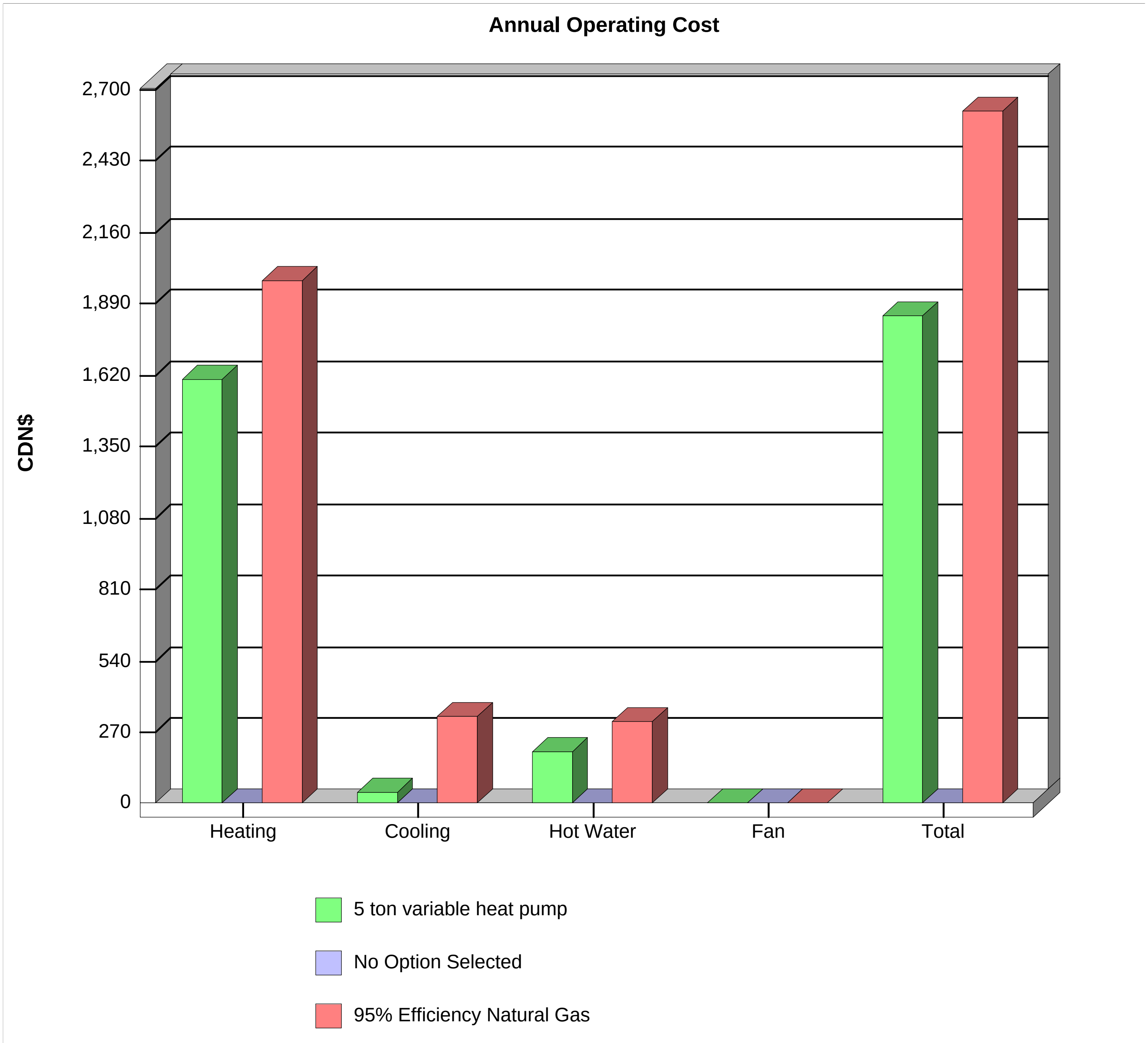
Comments:
$0.30/m3 Natural Gas $0.135/kWh electricity with constant distribution cost within 4 years, variable speed equipment

80000 btu case.ged

Utility Cost	CDN$	Summer	Winter
Electric - Geothermal	per kWh	.135	.135
Electric - Heat Pump	per kWh	.135	.135
Electric - Furnace	per kWh	.135	.135
Natural Gas	per m3	0.30	0.30
Propane	per Litre	0.58	0.58
Fuel Oil	per Litre	0.93	0.93

Due to the variability of weather, system installation, and living habits this analysis is to be considered an estimate.

System Comparison Graph



ClimateMaster, Inc. **80,000 btu**
GeoDesigner® **2/3/2016**

System Summary

5 ton variable heat pump

ClimateMaster Unit

Series:	Trilogy	
Total Capacity:	6.6	Tons
Style:	Variable Capacity	
Water Heating:	Q-Mode	

	Run Hours	Avg Speed
Heating:	4,325	32%
Cooling:	819	18%
Hot Water:	459	35%

Geothermal Source

Source Type:	Vertical Closed Loop	
Soil Type:	Average Rock	
Pipe Type:	1-1/4" IPS HDPE SCH 40	
Pipe Configuration:	1 U-Tube in Bore	
Avg Pipe Depth:	250	Feet
Bore Length:	1,165	Feet
Min Freeze Protect:	11	Deg F
Max Source-Cooling:	74	Deg F
Avg Source-Cooling:	55	Deg F
Avg Source-Heating:	41	Deg F
Min Source-Heating:	31	Deg F
Deep Earth Temp:	50.1	Deg F
Surface Swing:	22.6	Deg F
Swing Time Lag:	39	Days
Soil Conductivity:	1.40	Btu/h-ft-F
Soil Diffusivity:	0.96	ft2/day
Loop Conductivity:	2.11	Btu/h-ft-F

Auxiliary Heat

Type:	Electric Resistance	
Style:	Duct Heater	
Auxiliary Required:	0	Kw
Optional Emergency:	22	Kw
Efficiency:	100	%
Aux Balance Point:	N/A	Deg F

Water Heater

Type:	iGate Smart Tank	
Style:	Communicating - Electric	
Efficiency:	94.0	%

Heating

Trilogy

Electrical Use:	11,898	kWh
Average Efficiency:	4.13	COP (W/W)
Annual Contribution:	100	%
Annual Cost:	$1,606	

Electric Resistance

Electrical Use:	0	kWh
Average Efficiency:	100	%
Annual Contribution:	0	%
Annual Cost:	$0	

Annual Heating Cost: $1,606

Cooling

Trilogy

Electrical Use:	320	kWh
Average Efficiency:	96.3	EER (Btu/W)

Annual Cooling Cost: $43

Water Heating

Trilogy Q-Mode

Electrical Use:	1,445	kWh
Average Efficiency:	4.31	COP (W/W)
Annual Contribution:	100	%
Annual Cost:	$195	

iGate Smart Tank

Electrical Use:	0	kWh
Average Efficiency:	94	%
Annual Contribution:	0	%
Annual Cost:	$0	

Annual Water Heating Cost: $195

Continuous Fan

Electrical Use: 0 kWh

Annual Continuous Fan Cost: $0

Total Annual Operating Cost: $1,845

Due to the variability of weather, system installation, and living habits this analysis is to be considered an estimate.

4/16/16

System Summary

95% Efficiency Natural Gas

Air Conditioner

Type:	Air Conditioner - Split
Style:	21 SEER - 2stg - R410a
35 C Cool Capacity:	105.6 kBtuh
35 C Cool Efficiency:	12.10 EER (Btu/W)
Indoor Coil Match:	Hi-Eff Furn
Outdoor Coil Rating:	Average
35 C Low Cool Cap:	75.7 kBtuh
35 C Low Cool Eff:	13.05 EER (Btu/W)
Run Time:	474 Hours

Heating System

Type:	Gas Furnace
Style:	Ignitor-Cond-Mod-Vspd
Input Capacity:	85.1 kBtuh
Output Capacity:	83.4 kBtuh
Efficiency:	98.0 AFUE
Low Input Cap:	34.1 kBtuh
Low Output Cap:	33.4 kBtuh
Run Time:	4318 Hours

Water Heater

Type:	Gas Storage Water Heater
Style:	Standard Efficiency
Efficiency:	58.0 %

Heating

Gas Furnace

Fuel Use:	4,999 m3
Electrical Use:	3,519 kWh
Average Efficiency:	95 %
Annual Heating Cost:	1,975 CDN$

Cooling

Air Conditioner - Split

Electrical Use:	2,452 kWh
Average Efficiency:	12.57 EER (Btu/W)
Annual Cooling Cost:	331 CDN$

Water Heating

Gas Storage Water Heater

Fuel Use:	1,038 m3
Average Efficiency:	58 %
Annual Water Heating Cost:	311 CDN$

Continuous Fan

Electrical Use:	0 kWh
Annual Continuous Fan Cost:	0 CDN$

Total Annual Operating Cost: 2,617 CDN$

Due to the variability of weather, system installation, and living habits this analysis is to be considered an estimate.

OGA INTERROGATORY RESPONSES

APPENDIX D

S11.OGA.UGL.1(b)

Performance Data — Tranquility® 30 Model 038 - Part Load

Performance capacities shown in thousands of Btuh

Antifreeze use recommended in this range. Also Clip JW3 on DXM2 board.

EWT °F	Cooling - EAT 80/67°F											Heating - EAT 70°F										
	GPM	WPD PSI	WPD FT	CFM	TC	SC	kW	EER	HR	LWT	HWC	GPM	WPD PSI	WPD FT	CFM	HC	kW	COP	HE	LAT	LWT	HWC
20	1.4	0.7	1.7	860	32.0	21.1	0.99	32.4	35.4	70.0	1.2	6.0	4.9	11.2	860	17.2	1.56	3.2	11.8	88.5	16.1	1.7
	1.4	0.7	1.7	1000	32.7	22.6	1.01	32.5	36.1	70.0	1.2	6.0	4.9	11.2	1000	17.4	1.49	3.4	12.3	86.1	15.9	1.7
30	1.8	0.7	1.7	860	32.0	21.1	0.99	32.4	35.4	70.0	1.2	3.0	1.5	3.4	860	18.8	1.57	3.5	13.5	90.3	21.0	1.9
	1.8	0.7	1.7	1000	32.7	22.6	1.01	32.5	36.1	70.0	1.2	3.0	1.5	3.4	1000	19.1	1.50	3.7	14.0	87.7	20.7	1.8
	1.8	0.7	1.7	860	32.0	21.1	0.99	32.4	35.4	70.0	1.2	4.5	2.6	6.0	860	19.8	1.57	3.7	14.4	91.3	23.6	2.0
	1.8	0.7	1.7	1000	32.7	22.6	1.01	32.5	36.1	70.0	1.2	4.5	2.6	6.0	1000	20.1	1.51	3.9	14.9	88.6	23.4	1.9
	1.8	0.7	1.7	860	32.0	21.1	0.99	32.4	35.4	70.0	1.2	6.0	3.8	8.9	860	20.3	1.57	3.8	14.9	91.9	25.0	2.0
	1.8	0.7	1.7	1000	32.7	22.6	1.01	32.5	36.1	70.0	1.2	6.0	3.8	8.9	1000	20.6	1.51	4.0	15.4	89.1	24.9	2.0
40	2.4	0.7	1.7	860	32.0	21.1	0.99	32.4	35.4	70.0	1.2	3.0	1.1	2.5	860	21.7	1.58	4.0	16.3	93.4	29.1	2.2
	2.4	0.7	1.7	1000	32.7	22.6	1.01	32.5	36.1	70.0	1.2	3.0	1.1	2.5	1000	22.0	1.52	4.3	16.8	90.4	28.8	2.1
	2.4	0.7	1.7	860	32.0	21.1	0.99	32.4	35.4	70.0	1.2	4.5	2.0	4.7	860	22.9	1.59	4.2	17.4	94.6	32.2	2.3
	2.4	0.7	1.7	1000	32.7	22.6	1.01	32.5	36.1	70.0	1.2	4.5	2.0	4.7	1000	23.2	1.52	4.5	18.0	91.5	32.0	2.2
	2.4	0.7	1.7	860	32.0	21.1	0.99	32.4	35.4	70.0	1.2	6.0	3.1	7.2	860	23.5	1.59	4.3	18.1	95.3	34.0	2.4
	2.4	0.7	1.7	1000	32.7	22.6	1.01	32.5	36.1	70.0	1.2	6.0	3.1	7.2	1000	23.8	1.53	4.6	18.6	92.1	33.8	2.3
50	3.0	0.9	2.0	860	31.6	21.0	1.05	30.2	35.2	73.5	1.4	3.0	0.9	2.0	860	24.6	1.60	4.5	19.1	96.5	37.2	2.5
	3.0	0.9	2.0	1000	32.3	22.5	1.07	30.3	35.9	73.9	1.4	3.0	0.9	2.0	1000	24.9	1.53	4.8	19.7	93.1	36.9	2.4
	3.6	1.2	2.7	860	32.0	21.1	0.99	32.4	35.4	70.0	1.2	4.5	1.7	3.9	860	26.0	1.61	4.7	20.5	98.0	40.9	2.6
	3.6	1.2	2.7	1000	32.7	22.6	1.01	32.5	36.1	70.0	1.2	4.5	1.7	3.9	1000	26.3	1.54	5.0	21.1	94.4	40.6	2.5
	3.6	1.2	2.7	860	32.0	21.1	0.99	32.4	35.4	70.0	1.2	6.0	2.7	6.2	860	26.7	1.61	4.9	21.2	98.8	42.9	2.7
	3.6	1.2	2.7	1000	32.7	22.6	1.01	32.5	36.1	70.0	1.2	6.0	2.7	6.2	1000	27.1	1.55	5.1	21.8	95.1	42.7	2.6
60	3.0	0.8	1.8	860	30.3	20.7	1.21	25.0	34.4	82.9	1.9	3.0	0.8	1.8	860	27.5	1.62	5.0	22.0	99.6	45.3	2.7
	3.0	0.8	1.8	1000	30.9	22.1	1.23	25.0	35.1	83.4	2.0	3.0	0.8	1.8	1000	27.9	1.55	5.3	22.6	95.9	44.9	2.7
	4.5	1.5	3.5	860	31.4	21.0	1.08	29.1	35.1	75.6	1.5	4.5	1.5	3.5	860	29.1	1.63	5.2	23.6	101.4	49.5	2.9
	4.5	1.5	3.5	1000	32.0	22.4	1.10	29.2	35.8	75.9	1.5	4.5	1.5	3.5	1000	29.5	1.56	5.5	24.2	97.4	49.2	2.8
	6.0	2.4	5.5	860	31.8	21.1	1.02	31.3	35.3	71.8	1.3	6.0	2.4	5.5	860	30.0	1.63	5.4	24.4	102.3	51.9	2.9
	6.0	2.4	5.5	1000	32.5	22.6	1.04	31.4	36.0	72.0	1.3	6.0	2.4	5.5	1000	30.4	1.57	5.7	25.1	98.2	51.6	2.9
70	3.0	0.8	1.9	860	28.6	20.1	1.40	20.4	33.4	92.3	2.7	3.0	0.8	1.9	860	30.5	1.64	5.5	24.9	102.8	53.4	3.0
	3.0	0.8	1.9	1000	29.2	21.5	1.43	20.5	34.1	92.7	2.7	3.0	0.8	1.9	1000	30.9	1.57	5.8	25.6	98.6	53.0	2.9
	4.5	1.5	3.4	860	29.9	20.6	1.25	23.9	34.2	85.2	2.1	4.5	1.5	3.4	860	32.3	1.65	5.7	26.7	104.8	58.1	3.1
	4.5	1.5	3.4	1000	30.5	22.0	1.28	24.0	34.9	85.5	2.1	4.5	1.5	3.4	1000	32.8	1.58	6.1	27.4	100.4	57.8	3.0
	6.0	2.3	5.3	860	30.5	20.7	1.18	25.9	34.6	81.5	1.8	6.0	2.3	5.3	860	33.3	1.66	5.9	27.7	105.9	60.8	3.2
	6.0	2.3	5.3	1000	31.2	22.2	1.20	25.9	35.3	81.8	1.8	6.0	2.3	5.3	1000	33.8	1.59	6.2	28.4	101.3	60.5	3.1
80	3.0	0.9	2.0	860	26.7	19.4	1.61	16.6	32.2	101.5	3.6	3.0	0.9	2.0	860	33.5	1.66	5.9	27.8	106.1	61.4	3.2
	3.0	0.9	2.0	1000	27.3	20.8	1.64	16.6	32.9	101.9	3.7	3.0	0.9	2.0	1000	34.0	1.59	6.3	28.5	101.5	61.0	3.1
	4.5	1.5	3.4	860	28.1	20.0	1.45	19.4	33.1	94.7	2.9	4.0	1.3	2.9	860	35.0	1.67	6.1	29.3	107.7	65.0	3.3
	4.5	1.5	3.4	1000	28.7	21.4	1.48	19.4	33.8	95.0	3.0	4.0	1.3	2.9	1000	35.5	1.60	6.5	30.1	102.9	65.0	3.2
	6.0	2.2	5.2	860	28.9	20.2	1.37	21.0	33.5	91.2	2.6	4.0	1.3	2.9	860	35.0	1.67	6.1	29.3	107.7	65.0	3.3
	6.0	2.2	5.2	1000	29.4	21.6	1.40	21.1	34.2	91.4	2.6	4.0	1.3	2.9	1000	35.5	1.60	6.5	30.1	102.9	65.0	3.2
90	3.0	0.9	2.1	860	24.7	18.6	1.84	13.5	31.0	110.7	4.7	2.4	0.7	1.7	860	35.0	1.67	6.1	29.3	107.7	65.0	3.3
	3.0	0.9	2.1	1000	26.7	20.6	1.70	15.7	32.5	111.1	4.0	2.4	0.7	1.7	1000	35.5	1.60	6.5	30.1	102.9	65.0	3.2
	4.5	1.5	3.5	860	26.2	19.2	1.67	15.7	31.9	104.2	3.9	2.4	0.7	1.7	860	35.0	1.67	6.1	29.3	107.7	65.0	3.3
	4.5	1.5	3.5	1000	26.7	20.6	1.70	15.7	32.5	104.4	4.0	2.4	0.7	1.7	1000	35.5	1.60	6.5	30.1	102.9	65.0	3.2
	6.0	2.2	5.2	860	26.9	19.5	1.59	16.9	32.3	100.8	3.5	2.4	0.7	1.7	860	35.0	1.67	6.1	29.3	107.7	65.0	3.3
	6.0	2.2	5.2	1000	27.5	20.9	1.62	17.0	33.0	101.0	3.6	2.4	0.7	1.7	1000	35.5	1.60	6.5	30.1	102.9	65.0	3.2
100	3.0	0.9	2.1	860	22.7	17.7	2.07	11.0	29.8	119.9	6.1	1.7	0.5	1.2	860	35.0	1.67	6.1	29.3	107.7	65.0	3.3
	3.0	0.9	2.1	1000	23.2	19.0	2.11	11.0	30.4	120.3	6.2	1.7	0.5	1.2	1000	35.5	1.60	6.5	30.1	102.9	65.0	3.2
	4.5	1.5	3.5	860	24.1	18.3	1.91	12.6	30.6	113.6	5.1	1.7	0.5	1.2	860	35.0	1.67	6.1	29.3	107.7	65.0	3.3
	4.5	1.5	3.5	1000	24.6	19.6	1.94	12.7	31.2	113.9	5.2	1.7	0.5	1.2	1000	35.5	1.60	6.5	30.1	102.9	65.0	3.2
	6.0	2.2	5.1	860	24.8	18.7	1.82	13.6	31.0	110.3	4.7	1.7	0.5	1.2	860	35.0	1.67	6.1	29.3	107.7	65.0	3.3
	6.0	2.2	5.1	1000	25.3	20.0	1.86	13.6	31.7	110.6	4.8	1.7	0.5	1.2	1000	35.5	1.60	6.5	30.1	102.9	65.0	3.2
110	3.0	0.8	1.8	860	20.8	16.9	2.32	9.0	28.8	129.2	7.6	1.3	0.3	0.6	860	35.0	1.67	6.1	29.3	107.7	65.0	3.3
	3.0	0.8	1.8	1000	21.3	18.0	2.36	9.0	29.3	129.6	7.7	1.3	0.3	0.6	1000	35.5	1.60	6.5	30.1	102.9	65.0	3.2
	4.5	1.4	3.2	860	22.1	17.4	2.15	10.2	29.4	123.1	6.5	1.3	0.3	0.6	860	35.0	1.67	6.1	29.3	107.7	65.0	3.3
	4.5	1.4	3.2	1000	22.5	18.7	2.19	10.3	30.0	123.3	6.7	1.3	0.3	0.6	1000	35.5	1.60	6.5	30.1	102.9	65.0	3.2
	6.0	2.1	4.9	860	22.8	17.7	2.07	11.0	29.8	119.9	6.0	1.3	0.3	0.6	860	35.0	1.67	6.1	29.3	107.7	65.0	3.3
	6.0	2.1	4.9	1000	23.2	19.0	2.11	11.0	30.4	120.1	6.2	1.3	0.3	0.6	1000	35.5	1.60	6.5	30.1	102.9	65.0	3.2
120	3.0	0.5	1.1	860	19.2	16.1	2.57	7.5	28.0	138.7	9.4	1.1	0.1	0.2	860	35.0	1.67	6.1	29.3	107.7	65.0	3.3
	3.0	0.5	1.1	1000	19.6	17.2	2.62	7.5	28.5	139.0	9.5	1.1	0.1	0.2	1000	35.5	1.60	6.5	30.1	102.9	65.0	3.2
	4.5	1.1	2.6	860	20.2	16.6	2.41	8.4	28.5	132.6	8.2	1.1	0.1	0.2	860	35.0	1.67	6.1	29.3	107.7	65.0	3.3
	4.5	1.1	2.6	1000	20.6	17.7	2.45	8.4	29.0	132.9	8.4	1.1	0.1	0.2	1000	35.5	1.60	6.5	30.1	102.9	65.0	3.2
	6.0	1.9	4.4	860	20.8	16.8	2.33	8.9	28.7	129.6	7.6	1.1	0.1	0.2	860	35.0	1.67	6.1	29.3	107.7	65.0	3.3
	6.0	1.9	4.4	1000	21.2	18.0	2.37	9.0	29.3	129.8	7.8	1.1	0.1	0.2	1000	35.5	1.60	6.5	30.1	102.9	65.0	3.2

Interpolation is permissible; extrapolation is not.
Flow is controlled to maintain minimum LWT 70° F in cooling and maximum LWT 65° F in heating.
Table does not reflect fan or pump power corrections for AHRI/ISO conditions.
For operation in the shaded areas, please see the Performance Data Selection Notes.

All performance is based upon the lower voltage of dual voltage rated units.
Operation at or below 40° F EWT is based on 15% methanol antifreeze solution.
See Performance correction tables for operating conditions other than those listed above.

Performance Data — Tranquility® 30 Model 038 - Full Load

Performance capacities shown in thousands of Btuh

Antifreeze use recommended in this range. Also Clip JW3 on DXM2 board.

EWT °F	Cooling - EAT 80/67°F											Heating - EAT 70°F										
	GPM	WPD		CFM	TC	SC	kW	EER	HR	LWT	HWC	GPM	WPD		CFM	HC	kW	COP	HE	LAT	LWT	HWC
		PSI	FT										PSI	FT								
20	2.0	1.2	2.7	1080	44.0	27.4	1.65	26.7	49.6	70.0	1.9	9.0	8.3	19.1	1080	25.6	2.09	3.6	18.5	91.9	15.9	2.1
	2.0	1.2	2.7	1250	44.8	29.4	1.71	26.3	50.6	70.0	1.9	9.0	8.3	19.1	1250	26.0	2.02	3.8	19.1	89.2	15.8	2.1
30	2.5	1.2	2.7	1080	44.0	27.4	1.65	26.7	49.6	70.0	1.9	4.5	2.6	6.0	1080	27.9	2.12	3.9	20.7	93.9	20.8	2.4
	2.5	1.2	2.7	1250	44.8	29.4	1.71	26.3	50.6	70.0	1.9	4.5	2.6	6.0	1250	28.3	2.05	4.0	21.3	91.0	20.5	2.4
	2.5	1.2	2.7	1080	44.0	27.4	1.65	26.7	49.6	70.0	1.9	6.8	4.5	10.5	1080	29.2	2.14	4.0	21.9	95.1	23.5	2.6
	2.5	1.2	2.7	1250	44.8	29.4	1.71	26.3	50.6	70.0	1.9	6.8	4.5	10.5	1250	29.7	2.07	4.2	22.6	92.0	23.3	2.5
	2.5	1.2	2.7	1080	44.0	27.4	1.65	26.7	49.6	70.0	1.9	9.0	6.9	16.0	1080	30.0	2.15	4.1	22.6	95.7	25.0	2.7
	2.5	1.2	2.7	1250	44.8	29.4	1.71	26.3	50.6	70.0	1.9	9.0	6.9	16.0	1250	30.4	2.08	4.3	23.3	92.5	24.8	2.6
40	3.4	1.3	3.0	1080	44.0	27.4	1.65	26.7	49.6	70.0	1.9	4.5	2.0	4.7	1080	31.9	2.18	4.3	24.4	97.3	29.1	2.9
	3.4	1.3	3.0	1250	44.8	29.4	1.71	26.3	50.6	70.0	1.9	4.5	2.0	4.7	1250	32.4	2.12	4.5	25.2	94.0	28.8	2.9
	3.4	1.3	3.0	1080	44.0	27.4	1.65	26.7	49.6	70.0	1.9	6.8	3.8	8.7	1080	33.5	2.22	4.4	25.9	98.7	32.3	3.1
	3.4	1.3	3.0	1250	44.8	29.4	1.71	26.3	50.6	70.0	1.9	6.8	3.8	8.7	1250	34.0	2.15	4.6	26.7	95.2	32.1	3.0
	3.4	1.3	3.0	1080	44.0	27.4	1.65	26.7	49.6	70.0	1.9	9.0	5.9	13.6	1080	34.4	2.23	4.5	26.7	99.5	34.1	3.2
	3.4	1.3	3.0	1250	44.8	29.4	1.71	26.3	50.6	70.0	1.9	9.0	5.9	13.6	1250	34.9	2.16	4.7	27.5	95.8	33.9	3.2
50	4.5	1.7	3.9	1080	43.7	27.3	1.68	26.0	49.5	72.0	1.9	4.5	1.7	3.9	1080	35.9	2.27	4.6	28.2	100.8	37.5	3.4
	4.5	1.7	3.9	1250	44.5	29.3	1.75	25.5	50.4	72.4	2.0	4.5	1.7	3.9	1250	36.5	2.20	4.9	29.0	97.0	37.1	3.3
	5.1	2.0	4.7	1080	44.0	27.4	1.65	26.7	49.6	70.0	1.9	6.8	3.2	7.5	1080	37.8	2.31	4.8	29.9	102.4	41.1	3.7
	5.1	2.0	4.7	1250	44.8	29.4	1.71	26.3	50.6	70.0	1.9	6.8	3.2	7.5	1250	38.4	2.24	5.0	30.7	98.4	40.9	3.6
	5.1	2.0	4.7	1080	44.0	27.4	1.65	26.7	49.6	70.0	1.9	9.0	5.2	11.9	1080	38.8	2.33	4.9	30.8	103.3	43.1	3.8
	5.1	2.0	4.7	1250	44.8	29.4	1.71	26.3	50.6	70.0	1.9	9.0	5.2	11.9	1250	39.4	2.26	5.1	31.7	99.2	43.0	3.7
60	4.5	1.5	3.5	1080	42.2	26.8	1.86	22.7	48.5	81.6	2.6	4.5	1.5	3.5	1080	40.0	2.36	5.0	31.9	104.3	45.8	3.9
	4.5	1.5	3.5	1250	42.9	28.8	1.93	22.3	49.5	82.0	2.7	4.5	1.5	3.5	1250	40.6	2.29	5.2	32.8	100.1	45.4	3.8
	6.8	2.9	6.7	1080	43.4	27.2	1.73	25.1	49.3	74.6	2.1	6.8	2.9	6.7	1080	42.1	2.42	5.1	33.9	106.1	50.0	4.2
	6.8	2.9	6.7	1250	44.1	29.2	1.79	24.7	50.2	74.9	2.1	6.8	2.9	6.7	1250	42.8	2.34	5.4	34.8	101.7	49.7	4.1
	9.0	4.7	10.8	1080	43.9	27.3	1.67	26.3	49.6	71.0	1.9	9.0	4.7	10.8	1080	43.3	2.44	5.2	34.9	106.8	52.2	4.3
	9.0	4.7	10.8	1250	44.6	29.4	1.73	25.9	50.5	71.2	1.9	9.0	4.7	10.8	1250	43.9	2.37	5.4	35.8	102.5	52.0	4.2
70	4.5	1.5	3.4	1080	40.2	26.0	2.06	19.5	47.3	91.0	3.4	4.5	1.5	3.4	1080	44.1	2.47	5.2	35.7	107.8	54.1	4.4
	4.5	1.5	3.4	1250	40.9	28.0	2.14	19.2	48.2	91.4	3.5	4.5	1.5	3.4	1250	44.8	2.39	5.5	36.6	103.2	53.7	4.3
	6.8	2.7	6.3	1080	41.7	26.6	1.91	21.8	48.2	84.3	2.8	6.8	2.7	6.3	1080	46.5	2.53	5.4	37.8	109.8	58.8	4.7
	6.8	2.7	6.3	1250	42.4	28.6	1.98	21.4	49.2	84.6	2.9	6.8	2.7	6.3	1250	47.2	2.45	5.6	38.8	104.9	58.5	4.5
	9.0	4.4	10.1	1080	42.4	26.8	1.84	23.0	48.6	80.8	2.5	9.0	4.4	10.1	1080	47.8	2.56	5.5	39.0	111.0	61.3	4.8
	9.0	4.4	10.1	1250	43.1	28.8	1.91	22.6	49.6	81.0	2.6	9.0	4.4	10.1	1250	48.5	2.48	5.7	40.0	105.9	61.1	4.7
80	4.5	1.5	3.4	1080	38.0	25.2	2.29	16.6	45.8	100.4	4.3	4.5	1.5	3.4	1080	48.2	2.58	5.5	39.4	111.3	62.5	4.9
	4.5	1.5	3.4	1250	38.6	27.1	2.37	16.3	46.7	100.8	4.4	4.5	1.5	3.4	1250	49.0	2.50	5.7	40.4	106.3	62.0	4.7
	6.8	2.7	6.2	1080	39.6	25.8	2.13	18.6	46.8	93.9	3.6	5.6	2.0	4.6	1080	49.7	2.62	5.6	40.8	112.6	65.0	5.0
	6.8	2.7	6.2	1250	40.3	27.7	2.20	18.3	47.8	94.2	3.7	5.6	2.0	4.6	1250	50.5	2.54	5.8	41.8	107.4	65.0	4.9
	9.0	4.2	9.7	1080	40.4	26.1	2.05	19.7	47.4	90.5	3.3	5.6	2.0	4.6	1080	49.7	2.62	5.6	40.8	112.6	65.0	5.0
	9.0	4.2	9.7	1250	41.1	28.1	2.12	19.4	48.3	90.7	3.4	5.6	2.0	4.6	1250	50.5	2.54	5.8	41.8	107.4	65.0	4.9
90	4.5	1.5	3.5	1080	35.6	24.1	2.54	14.0	44.3	109.7	5.3	3.3	1.0	2.4	1080	49.7	2.62	5.6	40.8	112.6	65.0	5.0
	4.5	1.5	3.5	1250	37.9	26.7	2.45	15.4	46.2	110.1	4.7	3.3	1.0	2.4	1250	50.5	2.54	5.8	41.8	107.4	65.0	4.9
	6.8	2.6	6.1	1080	37.2	24.9	2.37	15.7	45.3	103.4	4.6	3.3	1.0	2.4	1080	49.7	2.62	5.6	40.8	112.6	65.0	5.0
	6.8	2.6	6.1	1250	37.9	26.7	2.45	15.4	46.2	103.7	4.7	3.3	1.0	2.4	1250	50.5	2.54	5.8	41.8	107.4	65.0	4.9
	9.0	4.1	9.5	1080	38.1	25.2	2.28	16.7	45.9	100.2	4.3	3.3	1.0	2.4	1080	49.7	2.62	5.6	40.8	112.6	65.0	5.0
	9.0	4.1	9.5	1250	38.7	27.1	2.36	16.4	46.8	100.4	4.3	3.3	1.0	2.4	1250	50.5	2.54	5.8	41.8	107.4	65.0	4.9
100	4.5	1.5	3.5	1080	33.2	23.0	2.82	11.8	42.8	119.0	6.5	2.4	0.7	1.7	1080	49.7	2.62	5.6	40.8	112.6	65.0	5.0
	4.5	1.5	3.5	1250	33.7	24.8	2.92	11.6	43.7	119.4	6.7	2.4	0.7	1.7	1250	50.5	2.54	5.8	41.8	107.4	65.0	4.9
	6.8	2.6	6.1	1080	34.8	23.8	2.63	13.2	43.7	113.0	5.7	2.4	0.7	1.7	1080	49.7	2.62	5.6	40.8	112.6	65.0	5.0
	6.8	2.6	6.1	1250	35.4	25.6	2.73	13.0	44.7	113.2	5.8	2.4	0.7	1.7	1250	50.5	2.54	5.8	41.8	107.4	65.0	4.9
	9.0	4.1	9.4	1080	35.6	24.1	2.54	14.0	44.3	109.8	5.3	2.4	0.7	1.7	1080	49.7	2.62	5.6	40.8	112.6	65.0	5.0
	9.0	4.1	9.4	1250	36.2	26.0	2.63	13.7	45.2	110.0	5.4	2.4	0.7	1.7	1250	50.5	2.54	5.8	41.8	107.4	65.0	4.9
110	4.5	1.4	3.2	1080	30.8	21.9	3.11	9.9	41.5	128.4	7.9	1.9	0.4	1.0	1080	49.7	2.62	5.6	40.8	112.6	65.0	5.0
	4.5	1.4	3.2	1250	31.4	23.5	3.23	9.7	42.4	128.8	8.0	1.9	0.4	1.0	1250	50.5	2.54	5.8	41.8	107.4	65.0	4.9
	6.8	2.5	5.9	1080	32.3	22.6	2.92	11.1	42.3	122.5	7.0	1.9	0.4	1.0	1080	49.7	2.62	5.6	40.8	112.6	65.0	5.0
	6.8	2.5	5.9	1250	32.9	24.3	3.03	10.9	43.2	122.8	7.1	1.9	0.4	1.0	1250	50.5	2.54	5.8	41.8	107.4	65.0	4.9
	9.0	4.0	9.2	1080	33.1	23.0	2.83	11.7	42.7	119.5	6.6	1.9	0.4	1.0	1080	49.7	2.62	5.6	40.8	112.6	65.0	5.0
	9.0	4.0	9.2	1250	33.7	24.7	2.93	11.5	43.6	119.7	6.7	1.9	0.4	1.0	1250	50.5	2.54	5.8	41.8	107.4	65.0	4.9
120	4.5	1.1	2.6	1080	28.7	20.8	3.43	8.4	40.4	138.0	9.4	1.5	0.1	0.2	1080	49.7	2.62	5.6	40.8	112.6	65.0	5.0
	4.5	1.1	2.6	1250	29.2	22.3	3.55	8.2	41.4	138.4	9.6	1.5	0.1	0.2	1250	50.5	2.54	5.8	41.8	107.4	65.0	4.9
	6.8	2.4	5.4	1080	30.0	21.4	3.23	9.3	41.0	132.2	8.4	1.5	0.1	0.2	1080	49.7	2.62	5.6	40.8	112.6	65.0	5.0
	6.8	2.4	5.4	1250	30.5	23.1	3.35	9.1	41.9	132.4	8.6	1.5	0.1	0.2	1250	50.5	2.54	5.8	41.8	107.4	65.0	4.9
	9.0	3.9	8.9	1080	30.7	21.8	3.13	9.8	41.4	129.2	7.9	1.5	0.1	0.2	1080	49.7	2.62	5.6	40.8	112.6	65.0	5.0
	9.0	3.9	8.9	1250	31.2	23.4	3.25	9.6	42.3	129.4	8.1	1.5	0.1	0.2	1250	50.5	2.54	5.8	41.8	107.4	65.0	4.9

Interpolation is permissible; extrapolation is not.
Flow is controlled to maintain minimum LWT 70° F in cooling and maximum LWT 65° F in heating.
Table does not reflect fan or pump power corrections for AHRI/ISO conditions.
For operation in the shaded areas, please see the Performance Data Selection Notes.

All performance is based upon the lower voltage of dual voltage rated units.
Operation at or below 40° F EWT is based on 15% methanol antifreeze solution.
See Performance correction tables for operating conditions other than those listed above.

OGA INTERROGATORY RESPONSES

APPENDIX E

S11.OGA.UGL.3(j)

TODAY'S PRICES

GEODESIGNER® SYSTEM ANALYSIS

Prepared For:

30000 btu natural gas vs geothermal

South Western Ontario
generic, CAN n/a

Sample Heating and Cooling
555 W. Demo Road
Anywhere, USA 25487

Joe Sample
2/3/2016

System Summary

95% Efficiency Natural Gas

Air Conditioner

Type:	Air Conditioner - Split	
Style:	15 SEER - R410a	
35 C Cool Capacity:	23.3	kBtuh
35 C Cool Efficiency:	11.72	EER (Btu/W)
Indoor Coil Match:	Hi-Eff Furn	
Outdoor Coil Rating:	Average	
Run Time:	565	Hours

Heating System

Type:	Gas Furnace	
Style:	Ignitor-Cond-Mod-Vspd	
Input Capacity:	40.0	kBtuh
Output Capacity:	39.2	kBtuh
Efficiency:	98.0	AFUE
Low Input Cap:	16.0	kBtuh
Low Output Cap:	15.7	kBtuh
Run Time:	3810	Hours

Water Heater

Type:	Gas Storage Water Heater	
Style:	Standard Efficiency	
Efficiency:	58.0	%

Heating

Gas Furnace

Fuel Use:	1,879	m3
Electrical Use:	1,239	kWh
Average Efficiency:	95	%
Annual Heating Cost:	749	CDN$

Cooling

Air Conditioner - Split

Electrical Use:	1,017	kWh
Average Efficiency:	11.37	EER (Btu/W)
Annual Cooling Cost:	183	CDN$

Water Heating

Gas Storage Water Heater

Fuel Use:	297	m3
Average Efficiency:	58	%
Annual Water Heating Cost:	83	CDN$

Continuous Fan

Electrical Use:	0	kWh
Annual Continuous Fan Cost:	0	CDN$

Total Annual Operating Cost: 1,015 CDN$

Due to the variability of weather, system installation, and living habits this analysis is to be considered an estimate.

System Summary

3 ton 2-stage heat pump

ClimateMaster Unit

Series:	Tranquility 30 - Digital	
Model:	49	
Style:	Two Stage - Var Spd Fan	
Hot Water Generator:	Yes	
Heating Run Time:	2,020	Hours
Cooling Run Time:	269	Hours
Heating Stage 1:	100	% of Htg
Cooling Stage 1:	100	% of Clg

Geothermal Source

Source Type:	Horizontal Closed Loop	
Soil Type:	Damp Silt/Clay	
Pipe Type:	3/4" IPS HDPE SDR 11	
Pipe Configuration:	2 Pipes in Trench	
Avg Pipe Depth:	6.0	ft
Trench Length:	900.0	ft
Min Freeze Protect:	11.1	Deg F
Max Source-Cooling:	72.3	Deg F
Avg Source-Cooling:	55.4	Deg F
Avg Source-Heating:	41.2	Deg F
Min Source-Heating:	31.1	Deg F
Deep Earth Temp:	50.1	Deg F
Surface Swing:	22.6	Deg F
Swing Time Lag:	39	Days
Soil Conductivity:	0.75	Btu/h-ft-F
Soil Diffusivity:	0.600	ft2/day
Loop Conductivity:	1.82	Btu/h-ft-F

Auxiliary Heat

Type:	Electric Resistance	
Style:	Forced Air	
Auxiliary Required:	0	kW
Optional Emergency:	8	kW
Efficiency:	100	%
Aux Balance Point:	N/A	Deg F

Water Heater

Type:	Electric Storage Water Heater	
Style:	Standard Efficiency	
Efficiency:	88	%

Heating

Tranquility 30 - Digital

Electrical Use:	4,777	kWh
Average Efficiency:	3.85	COP (W/W)
Annual Contribution:	100	%
Annual Cost:	860	CDN$

Electric Resistance

Electrical Use:	0	kWh
Average Efficiency:	0	%
Annual Contribution:	0	%
Annual Cost:	0	CDN$

Annual Heating Cost: 860 CDN$

Cooling

Tranquility 30 - Digital

Electrical Use:	424	kWh
Average Efficiency:	27.28	EER (Btu/W)

Annual Cooling Cost: 76 CDN$

Water Heating

Geothermal Hot Water Generator

Electrical Use:	267	kWh
Average Efficiency:	4.39	COP (W/W)
Annual Contribution:	66	%
Annual Cost:	48	CDN$

Electric Storage Water Heater

Electrical Use:	693	kWh
Average Efficiency:	88	%
Annual Contribution:	34	%
Annual Cost:	125	CDN$

Annual Water Heating Cost: 173 CDN$

Continuous Fan

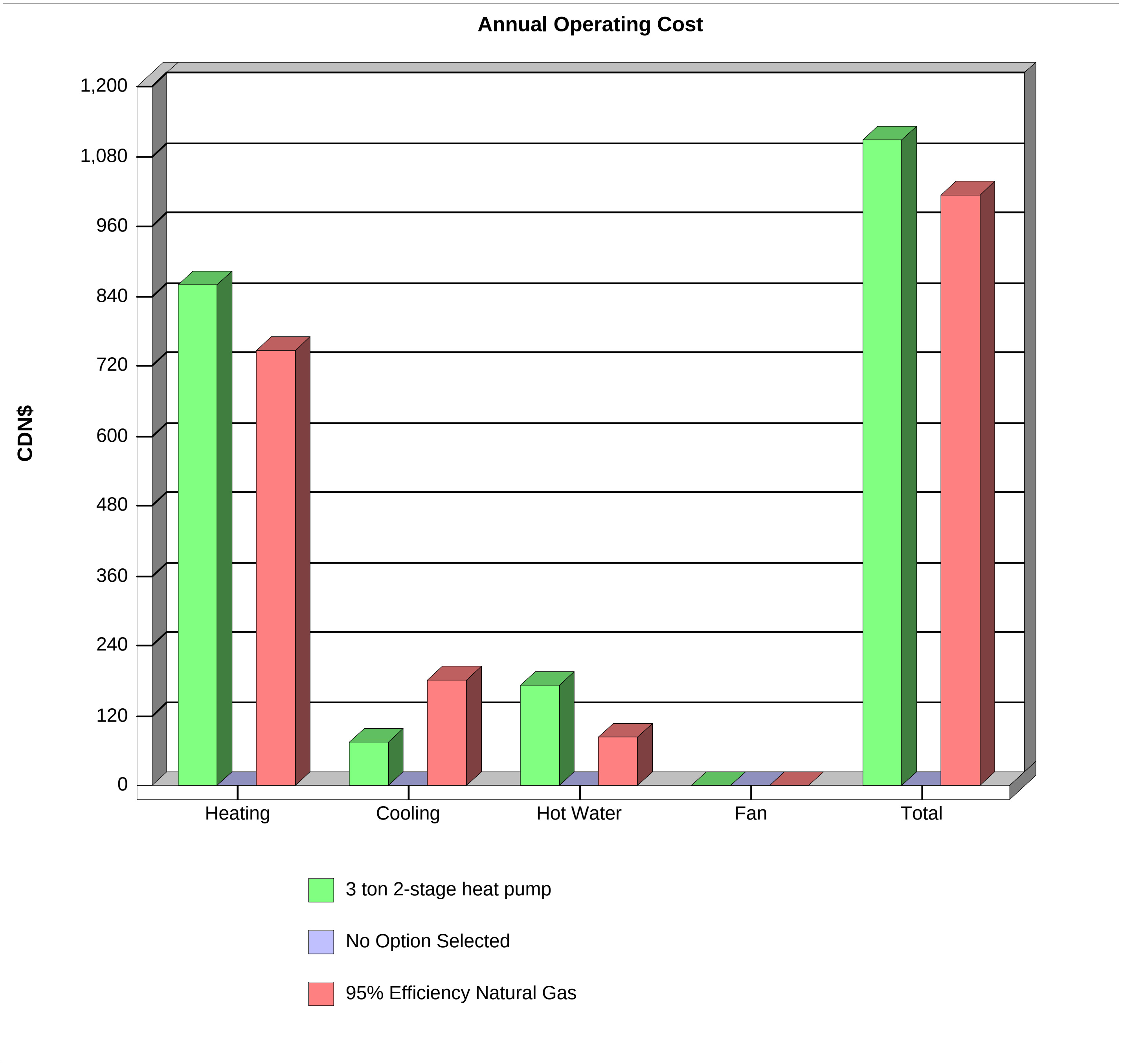
Electrical Use: 0 kWh

Annual Continuous Fan Cost: 0 CDN$

Total Annual Operating Cost: 1,109 CDN$

Due to the variability of weather, system installation, and living habits this analysis is to be considered an estimate.

System Comparison Graph



Project Information

Prepared For:

30000 btu natural gas vs geothermal
South Western Ontario
generic, CAN n/a
Home n/a
Work n/a
Cell n/a
n/a

Notes:

Prepared By:

Sample Heating and Cooling
555 W. Demo Road
Anywhere, USA 25487
Main 555-1212
Fax 555-1212

Contact Joe Sample
555-1212
jsample@sample.com

Notes:

Design Data

Heating Load:	30.0	kBtuh
Htg Load Temp Diff:	74.0	Deg F
Cooling Load:	15.0	kBtuh
Clg Load Temp Diff:	9.0	Deg F
Sensible Cooling:	11.6	kBtuh
Reference City:	Waterloo-Wellington, CAN-ON	
Winter Design:	-2.0	Deg F
Summer Design:	84.0	Deg F
Bldg Balance Temp:	61.2	Deg F
Avg Internal Gains:	4.4	kBtuh

Heating Setpoint:	72.0	Deg F
Cooling Setpoint:	75.0	Deg F
Begin Cooling At:	65.0	Deg F
Hot Water Setpoint:	130.0	Deg F
Hot Water Users:	1	
Continuous Fan:	No	
Annual Heating Load:	63	MMBtu
Annual Cooling Load:	12	MMBtu
Ann. Hot Water Load:	6	MMBtu
Daily Hot Water Use:	76	Litres

Estimated Operating Cost Summary

System	Heating CDN$	Cooling CDN$	Hot Water CDN$	Cont. Fan CDN$	Total CDN$	Monthly CDN$
3 ton 2-stage heat pump	860	76	173	0	1,109	92
No Option Selected	0	0	0	0	0	0
95% Efficiency Natural Gas	749	183	83	0	1,015	85

Comments:
$0.28/m3 Natural Gas, $0.18/kWh electricity, today's equipment

natural gas vs geo today's prices today's equipment.ged

Utility Cost	CDN$	Summer	Winter
Electric - Geothermal	per kWh	.180	.180
Electric - Heat Pump	per kWh	.180	.180
Electric - Furnace	per kWh	.180	.180
Natural Gas	per m3	0.28	0.28
Propane	per Litre	0.58	0.58
Fuel Oil	per Litre	0.93	0.93

Due to the variability of weather, system installation, and living habits this analysis is to be considered an estimate.