GEOTHERMAL FOR MULTI-UNIT RESIDENTIAL BUILDINGS

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Sustainable Buildings Canada
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URBAN EQUATION

FOREWORD

This study was undertaken by Urban Equation for Sustainable Buildings Canada to increase awareness of geothermal and the role it can play in reducing carbon emissions for multi-unit residential buildings in Ontario.

ACKNOWLEDGEMENTS

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EXECUTIVE SUMMARY

In an effort to reduce carbon emissions, innovative building design has seen a shift to exploring more diverse options for energy supply, such as on-site renewable energy. For multi-unit residential buildings (MURBs) in Canada, natural gas use for space heating represents the highest energy end use[1], which presents an opportunity for emission reductions.

A geo-exchange system uses the earth's constant temperatures to provide space heating and cooling for a building. When a building uses a geo-exchange system, it can reduce or replace natural gas use.

Many in the industry use the terms 'geo-exchange' and 'geothermal energy' interchangeably. Geothermal energy, by definition, refers to the extraction of thermal energy from the earth. On the other hand, geo-exchange involves the transferring of heat with the ground. For simplicity, this paper will refer to geo-exchange systems as "geothermal".

The energy and carbon benefits of geothermal have been understood for some time, yet there has been slow uptake in the MURB sector. This white paper aims to demonstrate not only these benefits, but also the lesser understood business benefits of geothermal and address the perceived barriers of implementation.

Analysis of Energy, Emissions, and Cost Savings of Using Geothermal

Using an energy model of an archetype MURB building[2], the potential energy and emissions savings of switching from a traditional 2-pipe fan coil unit HVAC system to a geothermal heat pump system were determined. The results showed a 33% decrease in annual energy use and a 47% decrease in greenhouse gas (GHG) emissions. This also resulted in an annual operating energy cost savings of 10%, when normalized by suite. The greatest savings in energy and emissions were found in space heating energy and the related decrease in natural gas usage.

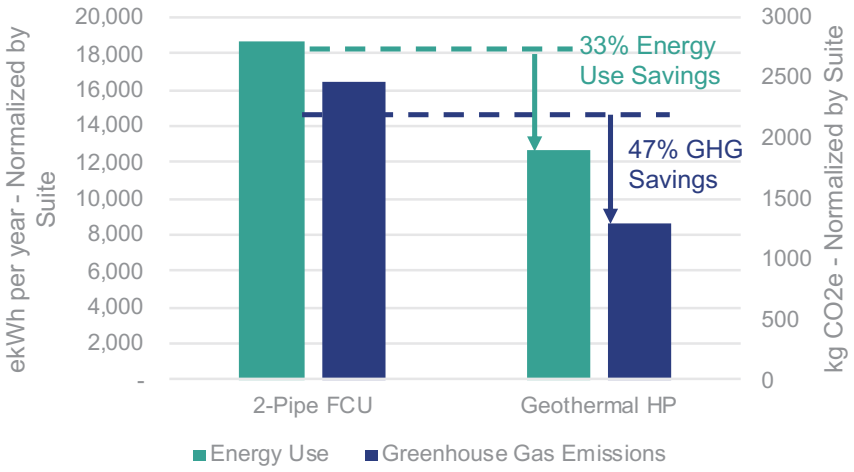

Figure A-1: Energy and GHG Emissions Reductions from Geothermal

[1] Appendix A of Making the Case for Building for Zero Carbon, Canada Green Building Council (2019)
[2] Described in Section 1.2

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One of the major barriers to entry to the geothermal industry is the increase in capital costs between a business-as-usual HVAC system and geothermal. However, geothermal actually has the potential to reduce capital costs, when a third-party provider is engaged to be the owner/operator. In the case where a developer elects to own the system, there have been demonstrated paybacks of between 5 – 7 years.

A simplified cost analysis[3] was completed on an archetype MURB building in Ontario, in order to determine the expected capital cost savings of engaging a third-party provider for geothermal. The areas explored for cost savings are:

- Removing costs of heating/cooling equipment (such as boilers and chiller), and transferring the capital costs for geothermal to the third-party provider;
- Reducing the system to 2-pipes rather than four, and;
- Construction cost savings from reduced mechanical room space.

The results are an expected capital cost savings of $1.60/ft^2 for the developer. However, specific cost savings will differ on a per building basis.

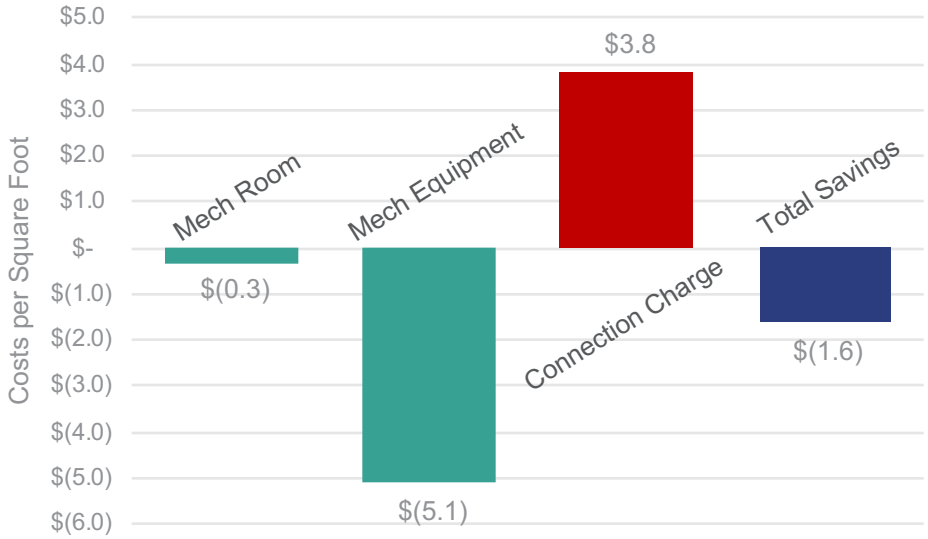


Figure A-2: Analysis of Potential Cost Savings to Developer

Geothermal can also provides a number of other benefits for a developer, including:

- Meeting and exceeding city or building energy code requirements;
- Contributing to sustainability certification standards;
- Reducing/simplifying mechanical systems and related maintenance;
    - Providing flexibility for the program of rooftop space. In some cases, removing mechanical equipment from the roof can allow for additional building height.
    - Reducing the physical size of the mechanical room.

[3] Described in Section 4.2

Barriers to Entry for Geothermal – Perceptions and Reality

Based on experience, as well as interviews with developers, geothermal providers, and industry peers, the following real or perceived barriers for implementing geothermal on multi-unit residential buildings were discovered, with the realities of these barriers described below.

- **Geothermal costs more than a traditional heating and cooling system**

Geothermal costs more per square foot than a boiler + chiller. Given the energy savings, the systems will pay back over time. Also, there are geothermal providers in the market who offer alternative financing models to help developers bridge the cost and savings gap.

- **Back-up boilers are needed for most of the winter to supply space heating**

Back-up boilers may be needed depending on the building characteristics and geothermal capacity, but in many cases they can be omitted from the project.

- **Some soil types and ground conditions won't allow for geothermal**

Soil types can drive the economic viability, but there are limited cases where a system could not be applied in some way.

- **Cheap natural gas energy costs make geothermal unviable**

Because of the savings in energy consumption realized with geothermal, total annual operating energy costs for a building can also be reduced. In the analysis completed for this report, switching from a 2-pipe FCU system to a geothermal HP system resulted in a 10% total annual energy cost savings[4].

- **Geothermal is complicated and requires specialized equipment**

Geothermal consists of underground pipes and heat exchangers. They are compatible with various existing HVAC systems in the market today, including those traditional in MURBs.

- **Geothermal does not heat up a space as fast as traditional systems**

Geothermal is paired with various HVAC systems, all of which operate the same as they would if they were connected to a more traditional boiler system.

- **There may be soft cost premiums from mechanical engineers**

The design of the in-building HVAC systems are generally the same or less as a traditional system.

- **Geothermal may compromise relationship with condo board**

Several condo developers have incorporated energy agreements into their condo purchase agreements, where the heating/cooling system and energy rates are clearly communicated. In addition, there are precedents that demonstrate no resistance when energy rates included are on par with market energy rates.

- **Geothermal will cause a delay in construction schedule**

While it is true that no other work can be done on site while drilling boreholes, this can be built into the construction schedule from the project start. Some methods will install boreholes from ground level before excavation of the site to maintain the project schedule.

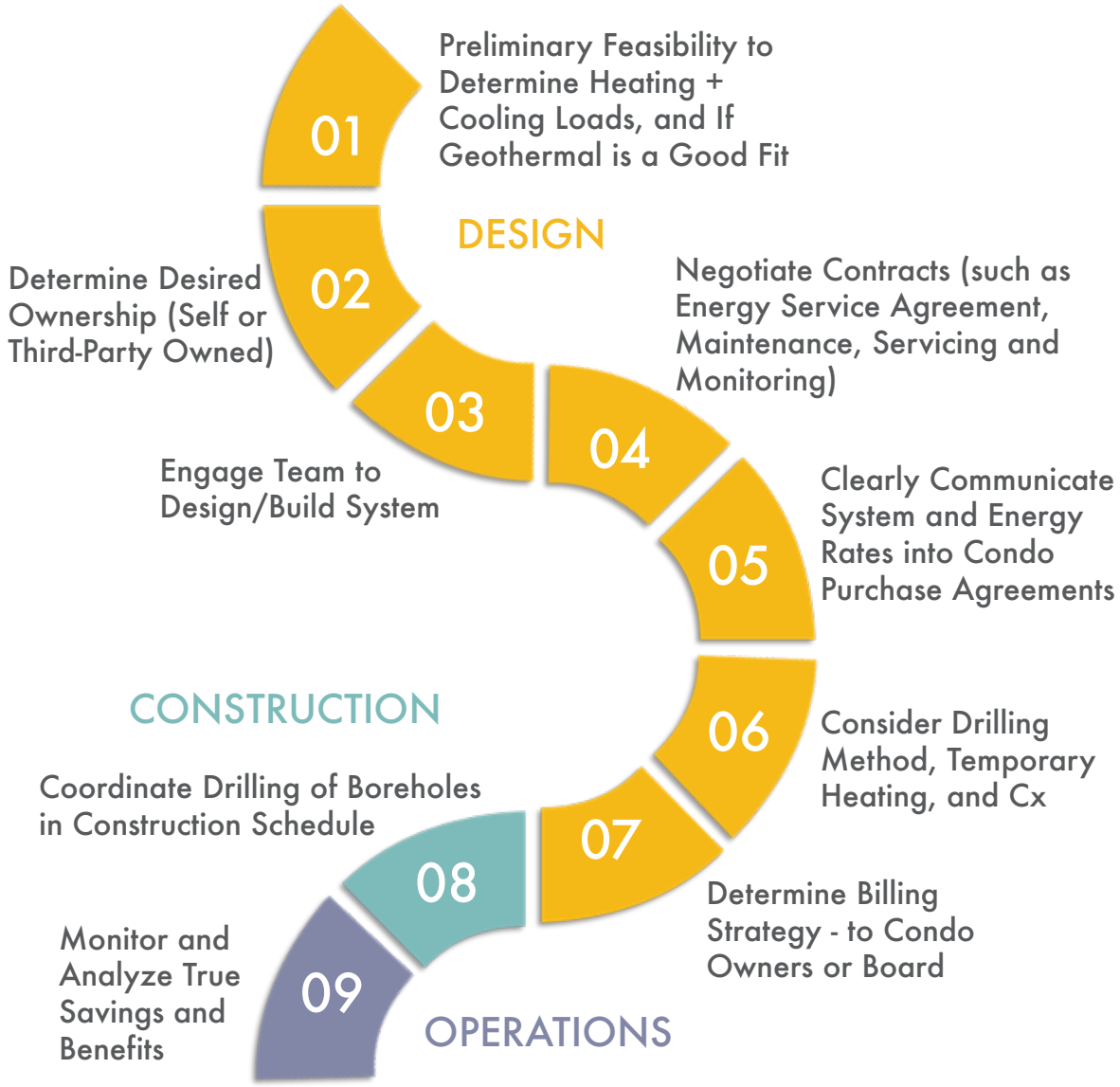
- **Geothermal does not provide a benefit on life expectancy of HVAC**

According to NRCAN, geothermal heat pump systems typically have an average life expectancy of 20–25. The bore-field will provide effective heating and cooling for 100+ years.

[4] See Section 1.2

Roadmap to Implementing Geothermal on a Development Project

This white paper highlights several case studies from developers and engineers who have successfully implemented geothermal on projects. Using this information, along with our experience, we have developed the following high level road map to assist developers interested in implementing geothermal.



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1 Geothermal - An Opportunity to Reduce Emissions

1.1 A Shift Away from Natural Gas

A building's carbon emissions are not only impacted by the design or type of building built, but also to a great degree on the energy sources used. In an effort to reduce carbon emissions, innovative building design has seen a shift to exploring more diverse options for energy supply, such as on-site renewable energy.

In Canada, we generally rely on fossil fuels (namely natural gas) to heat our buildings, and the electricity grid to supply our electrical needs - Figure 1.

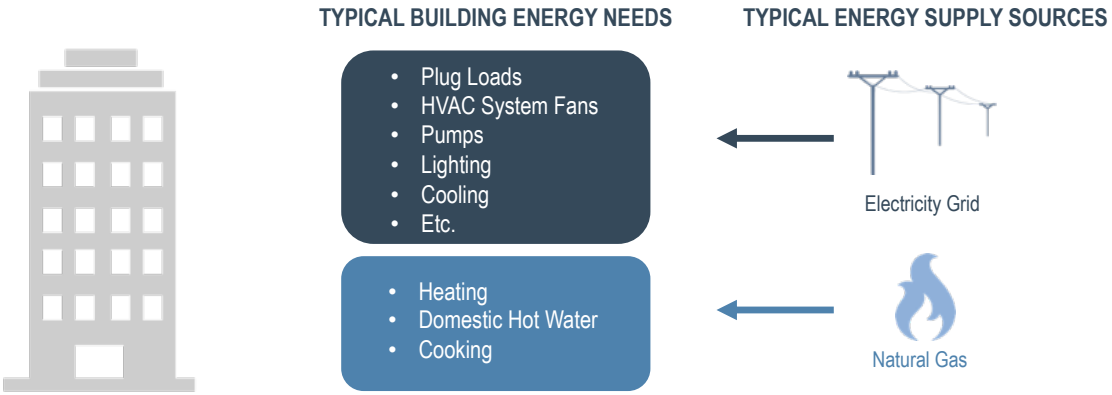

Figure 1: Typical Building Energy Needs

Building sector greenhouse gas (GHG) emissions vary province to province, where some province emissions are dominated by electricity use and others by natural gas combustion - Figure 2. This is because provinces such as Quebec, Ontario, and BC use low-carbon sources to generate electricity, resulting in a higher relative impact from natural gas on GHG emissions.

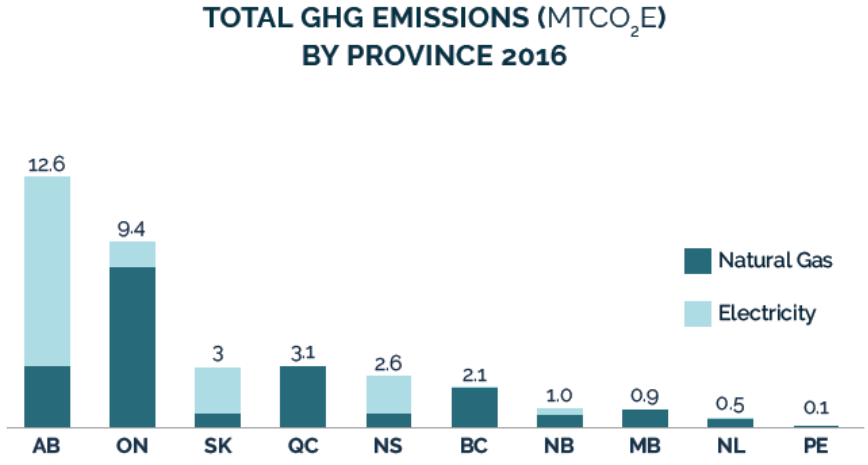

Figure 2: Building Sector Greenhouse Gas Emissions by Province[12]

For multi-unit residential buildings (MURBs) in Canada, natural gas use for space heating represents the highest energy end use[6]. This presents an opportunity for GHG emissions reductions, particularly in provinces where electricity generation is low-carbon.

A geo-exchange system – commonly referred to as 'geothermal' or 'ground source heat pump' – uses the earth's constant temperatures to provide heating and cooling to a building. When a building uses a geo-exchange system, it can replace natural gas use for heating entirely, using only a small amount of electricity to convert the earth energy. This energy can also be used to satisfy any number of diverse loads throughout the building, including domestic water heating and snow melt.

The energy and carbon benefits of geothermal have been understood for some time, yet there has been slow uptake in the MURB sector. This white paper aims to demonstrate not only carbon benefits, but also the lesser understood business benefits of these systems, and address the perceived barriers of implementing them.

Terminology in the Industry

Many in the industry use the terms 'geo-exchange' and 'geothermal energy' interchangeably. Geothermal energy, by definition, refers to the extraction of thermal energy from the earth. On the other hand, geo-exchange involves the transferring of heat with the ground. Geo-exchange systems are also often called 'ground source heat pumps', and refer to the same type of system.

For simplicity, this paper will refer to geo-exchange systems as "geothermal".

[6] Making the Case for Building for Zero Carbon, Canada Green Building Council (February 2019) – Appendix A

1.2 Energy and Carbon Efficiency

In addition to replacing natural gas as an energy source and reducing related greenhouse gas emissions, geothermal can also reduce total energy consumption of a development. Geothermal can provide space heating and cooling of an Ontario building at a typical efficiency of 400% for heating, and 800% for cooling, according to a report by the Ontario Geothermal Association[7]. In other words, for every unit of energy used by the system, 4 units of heat are added to the space or 8 units of heat are removed from the space.

Predicted Energy and Carbon Savings

Energy models allow developers to predict a building's energy use based on various design options. Developers use energy models during the design phase to help inform decisions about energy reduction investments. Energy predictions depend on several different variables, such as a building's size, location, envelope, and its mechanical systems. Depending on the jurisdiction, energy models can be required by building codes to compare energy performance of the designed building to a reference building or absolute targets.

Specific energy savings differ on a per building basis, however, geothermal heat pumps can be used to meet code requirements for energy use and greenhouse gas emissions reductions. An analysis of an energy model was completed to determine the impacts of geothermal on energy and greenhouse gas (GHG) emissions for a MURB located in Ontario. This energy model was provided by EQ Building Performance.

In this analysis, the space heating and cooling systems of a building were isolated, keeping all other characteristics of the building constant, to analyze the potential energy savings between a typical boiler-fed 2-pipe fan coil unit (FCU) and a geothermal heat pump (HP) HVAC system[9]. The study showed a 33% total energy savings when using a geothermal heat pump system vs. the traditional 2-pipe FCU, and a 47% decrease in GHG emissions. This also resulted in an annual operating energy cost savings of 10% when normalized by suite. A detailed breakdown of the energy savings by end use can be seen in Figure 3, and a breakdown of emissions savings by energy source can be seen in Figure 4.

The largest decrease in energy use between the two systems is found in space heating energy (reduced by 93%), resulting in a significant decrease in related GHG emissions due to the reduction in natural gas consumption. Electricity use in the geothermal case increases slightly due to the use of heat pumps to provide the in-suite heating and cooling at the desired temperature.

[7] Ontario's Low Carbon Future: Geothermal Heat Pumps (March 2016), Ontario Geothermal Association
[9] This analysis used monitored historical data to estimate the energy savings between the two systems.

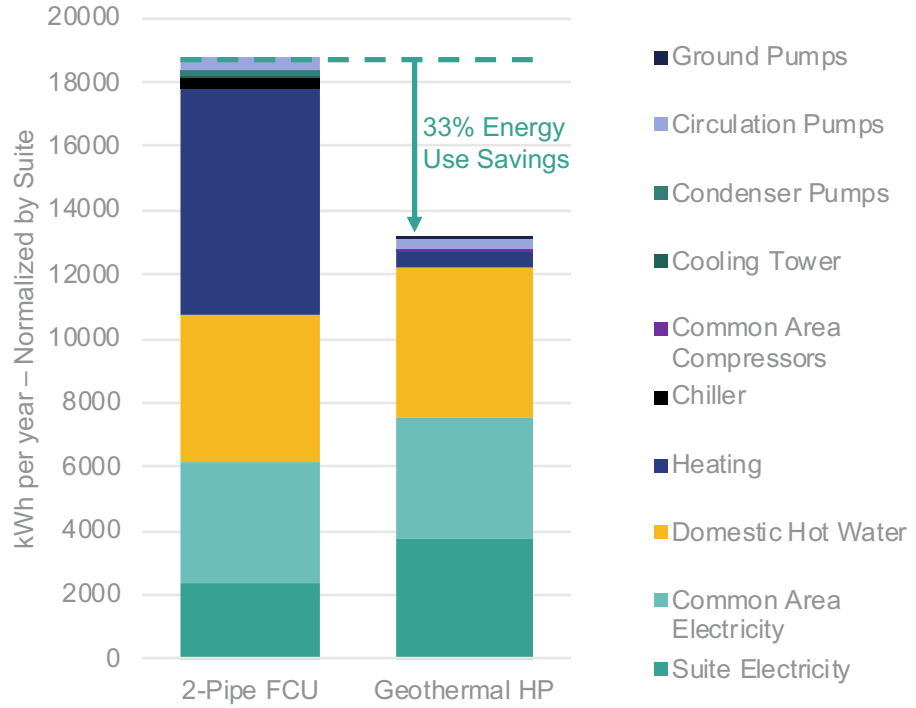

Figure 3: 2-Pipe Fan Coil Unit vs. Geothermal Energy Savings - Modelled

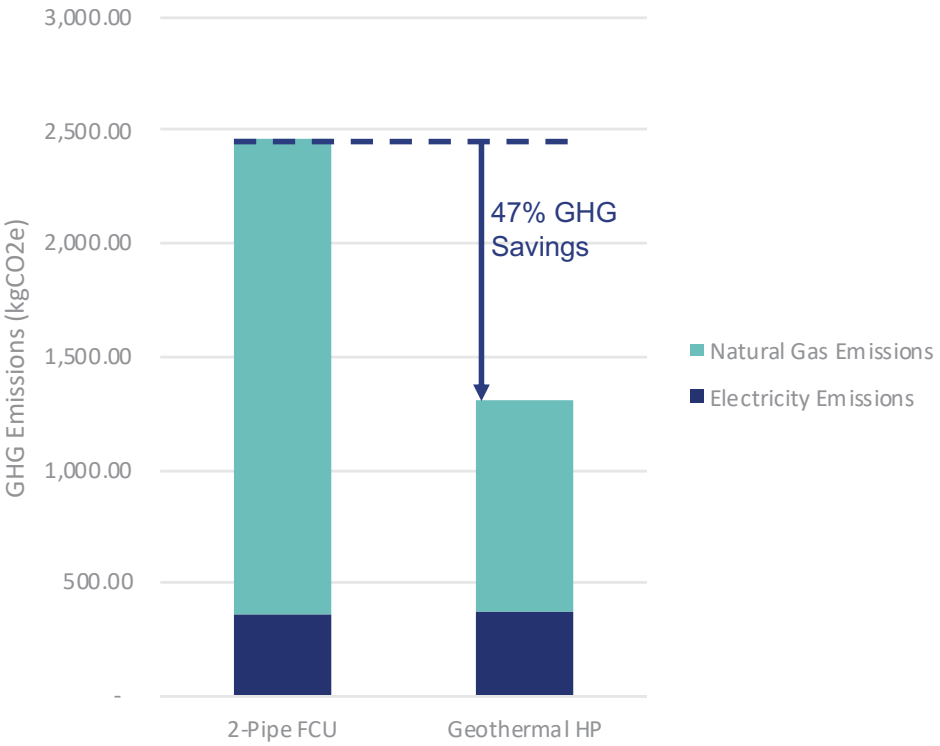

Figure 4: 2 Pipe Fan Coil Unit vs. Geothermal Emissions Savings - Modelled

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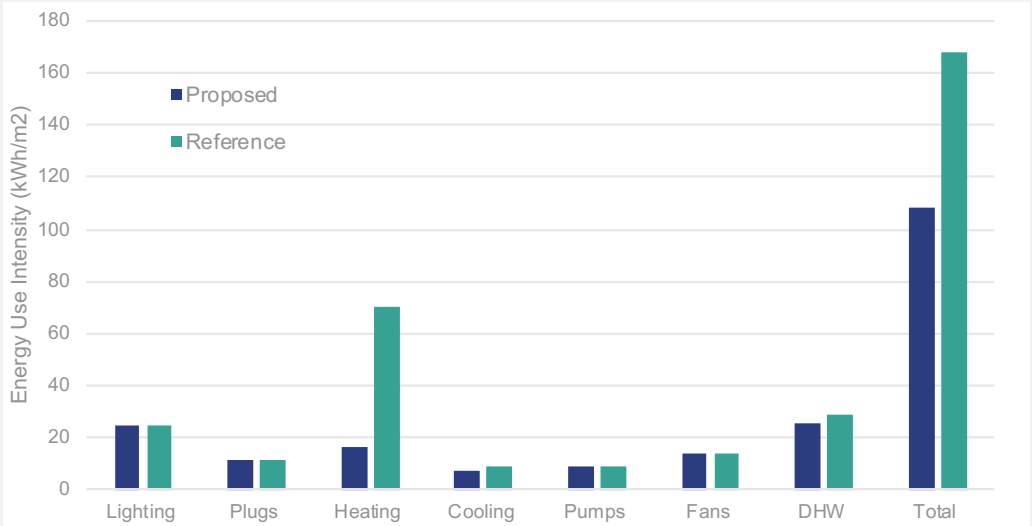
Case Study – Geothermal Modelled Energy Savings to Meet Code Requirements

In Ontario, energy models are used to determine compliance with the building code. In order to reduce energy use and related emissions, a multi-unit residential building in the City of Toronto installed a geothermal heat pump system to supply heating and cooling energy for the building. The mid-rise building includes ground floor retail and podium commercial space.

The energy model showed a total energy savings for the building of 35% when compared to an ASHRAE 90.1-2010 reference building, exceeding the requirements of the building code and meeting Tier 2 of the Toronto Green Standard at the time. There was a 77% reduction in heating, and 19% reduction in cooling energy for the building. The related CO_2e savings were 49% compared to the reference building. This resulted in a development charge rebate from the City of Toronto of approximately $250,000.



kWh/m2	Lighting	Plugs	Heating	Cooling	Pumps	Fans	DHW	Total
Proposed	24.8	11.7	16.2	7.2	9.2	13.9	25.3	108.4
Reference	24.8	11.7	70.1	8.9	9.2	14.2	29.1	167.9
Savings	**0%**	**0%**	**77%**	**19%**	**-1%**	**2%**	**13%**	**35.5%**

Figure 5: Energy Model Results for MURB in Toronto with Geothermal

Note that this building's energy model does not isolate for effect of geothermal. For example, the R-values of roof and walls and the U value of windows differ from the reference building, and the proposed design includes energy recovery ventilators (ERVs), all of which would impact the energy use. Specific energy savings differ on a per building basis, however geothermal heat pumps can be used to meet code requirements for energy use and greenhouse gas emissions reductions.

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2 Geothermal Described

2.1 'Free' Energy from the Earth – How it Works

Now that the energy and carbon benefits of these systems are understood, this section describes how they work. Below the frost line (about 3 meters), the earth maintains a constant temperature of around 10 – 15 degrees Celsius all year round. This temperature is warmer than the outside air during the winter, and cooler than the air in the summer.

A geothermal heat pump takes advantage of this temperature difference by exchanging heat with the earth through a ground source heat exchanger. Pipes are installed in the ground to leverage this mass of earth as a form of energy battery, rejecting heating in cooling mode and drawing out energy in heating mode.

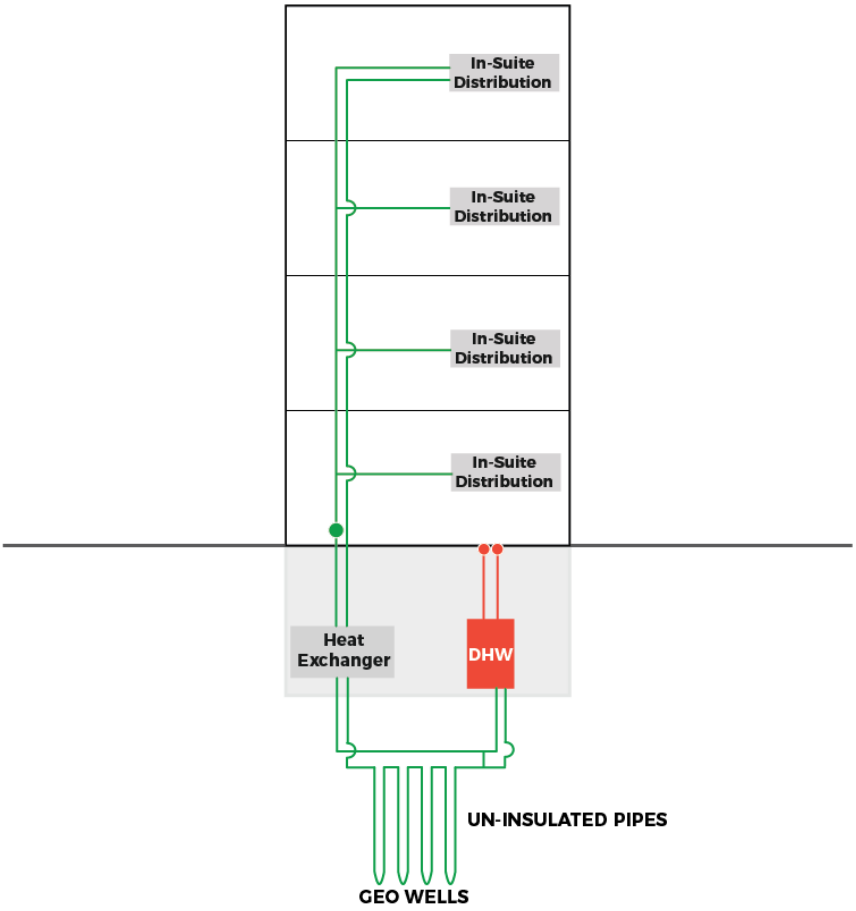

Figure 6: Simple Diagram of a Geothermal Heat Pump System

The heat is transferred via fluid to in-suite HVAC units, such as heat pumps, fan-coil units, or similar compressor-based systems such as variable refrigerant flow systems, to provide heating and cooling to the space - Figure 6. This fluid is supplied to these systems at an ambient temperature, reducing the work that the base building HVAC equipment must output to maintain a comfortable environment indoors.

Systems are available that use geothermal heat pumps to supply energy for various other end uses such as domestic hot water, but the fluid must be tempered to meet the higher temperature needs. Depending on project design and goals, geothermal can also be used to heat sidewalks and parking ramps for snow melting.

Generally, geothermal is feasible in all Canadian climate zones, with limited situations where a system would not work. However, systems will vary in efficiency and cost savings depending on specific site conditions.

Site conditions that can add complexity to installation of geothermal include sites with:

- Little space at-grade;
- Existing underground infrastructure;
- Unconsolidated overburden sitting on top of bedrock/shale that is prone to cave-in.
    - Bedrock/shale provides ideal drilling conditions for boreholes. Where there is unconsolidated overburden, the boreholes need to be cased during drilling to prevent collapse.
- Artesian aquifers underground (aquifers between two layers of impervious strata that hold water under pressure).

Types of Systems

There are two main types of geothermal loops, which are categorized as either closed- or open-loop:

- Open-loop - These systems use an aquifer or surface body of water as the heat exchange fluid that circulates directly through the geothermal pipes. These systems are only practical when the development is located on or near a water source.
- Closed-loop – These systems can be horizontal or vertical, which refers to the direction of the piping. Water (and sometimes with an added refrigerant solution) circulates through a loop of pipes underground to reject heat into in the summer and extract heat from in the winter. The fluid is “closed off” to the surrounding environment.

The system type chosen for a specific development will depend on the physical characteristics of the site. Closed-loop systems provide a scalable energy system. Open-loop systems are location specific, in that they can only be deployed in areas with prevalent aquifers or surface water.

In areas where there are significant ground water resources, open-loop can prove to be more capital cost effective. From an operational perspective, open-loop systems are also slightly more energy efficient; however, are inherently more complicated and maintenance intensive due to the direct use of ground water in a mechanical process. Open-loop systems may also require a permit to utilize water from and discharge water back into an aquifer, and other environmental regulations which can prolong a project.

2.2 Multi-Unit Residential Building Design Implications

Many of the effects of geothermal on the design of MURBs can also be deemed as benefits to a project. The main effects on building design are:

- Mechanical Room
    - Sizing – Depending on the specific building and site conditions, geothermal can reduce or even eliminate the need for boilers and chillers.
    - Location – A mechanical room would ideally be located close to grade or underground in order to connect to the ground loop.
    - Equipment - The energy transfer station, which connects the ground loop to the HVAC system in the building, is located in the mechanical room and will need to have metering equipment to maintain long-term performance of the system.
- Building Height
    - Geothermal may reduce the amount of mechanical equipment needed on the roof. This can allow for additional height of a building or rooftop amenity space.
- HVAC Distribution Systems
    - As mentioned, geothermal can work with many typical in-building distribution systems such as heat pumps, fan-coil units, or variable refrigerant flow systems.
- Domestic Hot Water Boilers
    - Rather than installing additional boilers to provide back-up or top-up for geothermal, some building projects will upsize the domestic hot water boiler to provide this back-up, when needed. This can be done at a marginal cost, and can eliminate the need for an entirely separate boiler for back-up.

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3 Geothermal in the Development Industry Today

3.1 Uptake in the Market – Current Trends

According to a study which reviewed energy models of 95 MURBs in the Toronto market to identify design trends, the most popular HVAC systems in the last 5 years are gas-fired FCU systems[16]. None of these 95 buildings used geothermal. However, at a global scale, one study identified the growth rate of geothermal to be 52% between 2010-2015, in terms of total installed capacity[17].

In conversation with geothermal providers in the Canadian market, there is a growing interest from MURB developers, where most are now at least exploring the potential. In addition, as the system and opportunities are better understood, there is a growing interest in the ownership of this energy asset.

There are built examples of multi-unit residential buildings in Ontario using geothermal - a list of selected precedents can be found in Appendix A.

3.2 Barriers to Implementation – Perceptions and Reality

Based on experience, as well as interviews with developers, geothermal providers, and industry peers, the following real or perceived barriers for implementing geothermal on multi-unit residential buildings were discovered, with the realities of these barriers described below.

High up-front costs make installing geothermal inviable

- Geothermal costs more per square foot than a boiler + chiller. Given the energy savings, the systems will pay back over time. Third-party system providers in the market today, described in Section 4, offer alternative financing models that help condo developers bridge the cost and savings gap. In some cases, the upfront costs of certain mechanical equipment for developers can be reduced or avoided altogether.

Back-up boilers are needed for most of the winter to supply space heating

- Back-up boilers may be needed depending on the building characteristics and geothermal capacity, but in many cases they can be omitted from the project. When omitted, the payback period for the system can be reduced.

Some soil types and ground conditions won't allow for geothermal

- Ground temperatures are relatively constant throughout Canada, so geothermal heat pumps can be used almost anywhere. However, soil types can drive the economic viability, as some conditions can impact thermal performance and therefore the size of geothermal field needed.

[16] Sidewalk Labs Toronto Multi-Unit Residential Buildings Study, EQ Building Performance and Urban Equation (January 2019)
[17] Spitler, Jeffrey. Latest Developments and Trends in Ground-Source Heat Pump Technology. European Geothermal Congress 2016

Cheap natural gas energy costs make geothermal unviable

- Because of the savings in energy consumption realized with geothermal, total annual operating energy costs for a MURB can actually be reduced. In the analysis completed for this report, switching from a 2-pipe FCU system to a geothermal HP system resulted in a 10% total annual energy cost savings per suite.

Geothermal does not heat up a space as fast as traditional systems

- There is a perception that geothermal may not be able to heat up a space as quickly as gas-fired HVAC systems. Geothermal are paired with various HVAC distribution systems – heat pumps, fan coils, VRF – all of which operate the same as they would if they were connected to a boiler system. Much like conventional HVAC systems, properly designed geothermal has no effect on space heating and occupant comfort.

Geothermal may result in tough relationship with condo board

- There is a concern from the industry that a condo board may choose to reject geothermal once the building is completed, resulting in complicated court cases. Several condo developers have successfully incorporated energy service agreements into purchases, where the heating and cooling system and energy rates are clearly communicated. In addition, there is often no resistance when energy rates included are on par with market energy rates. This may differ depending on the real estate market conditions, and the type of buyers that are attracted to the development.

Geothermal will cause a delay in construction schedule

- While it is true that no other work can be done on site while boreholes are being drilled, this can be built into the construction schedule from the onset of the project. Some methods will see boreholes being installed from ground level before excavation of the site to maintain the project schedule and avoid coordination issues with other trades.

Geothermal does not provide a benefit on life expectancy of HVAC systems

- According to ASHRAE, geothermal heat pump systems typically have an average life expectancy of 25 – 30 years, where conventional equipment may have a service life of 15 – 20 years. However, the bore-field, if designed and operated to be balanced, will provide effective heating and cooling for 100+ years.

Geothermal is complicated and require specialized equipment

- Geothermal consists of underground pipes and heat exchangers. They are compatible with various existing HVAC systems in the market today, including those traditional in MURBs.

There may be soft cost premiums from base building mechanical engineers

- The design of the building HVAC systems are generally the same or less, as well designed geothermal will eliminate some equipment (i.e. cooling towers and/or boilers). If an experienced geothermal design engineer is part of the team, the mechanical engineer can rely on that external expertise to easily execute their scope of work.

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4 Lesser Known Benefits of Geothermal

4.1 Financial Value to Developer as Owner/Operator

Depending on the type of project, the developer may decide to be the owner/operator of the system. While geothermal does have a higher upfront capital cost (~$7 per sf)[6] relative to a business-as-usual mechanical system (~$5 per sf)[20], there have been demonstrated paybacks of between 5 – 7 years despite the higher upfront capital costs. At it's most simple form, the business case for geothermal consists of the initial capital expenditures and on-going operating expenses offset over time by revenue from the energy supply.

In order to determine what monthly charges (i.e. revenue) can reasonably be achieved by the system, a comparison to a typical energy bill is completed. For example, the baseline heating energy bill would include costs for electricity, natural gas, make-up water, maintenance, and capital reserves. The monthly charges for geothermal heating would then be calculated to either be equal to or less than the expected typical energy bill per suite. Other considerations would include an annual escalation percentage for fees, and the replacement costs for equipment such as the heat exchanger.

There are a number of other cost savings that can be achieved with geothermal, that are more difficult to evaluate, and vary more widely on a case-by-case basis, such as:

- Freeing up roof area for amenity space;
- Financial incentives from government or other agencies;
- Reduced rooftop structural capacity if eliminating HVAC equipment could result in smaller structural reinforcement.

Enabling Tools

In some cases, developers can apply for rebates or specialized financing from the government or government agencies to enable geothermal on their projects. In Toronto, for example, the Toronto Green Standard Development Charge Rebate is available to projects that achieve higher levels of energy and carbon performance. As demonstrated in Section 1, Geothermal can help provide the energy use and GHG savings needed to meet the rebate requirements.

For developer's who elect to own and finance the system, the Government of Canada provides business income tax incentives under Classes 43.1 and 43.2 in Schedule II of the Income Tax Regulations, of which more information can be found here.

[20] Per analysis completed for development site in Southern Ontario – does not account for any in-building distribution systems (such in-suite equipment, distribution piping or ductwork).

Case Study – Discovering the Benefits of Geothermal in Senior's MURBs

One team we interviewed, Fram Building Group and Verve, develop and manage seniors living buildings. Because they manage the buildings, they have a long-term interest in the assets. To date, three of their buildings have completed and are operating with geothermal.

The key benefits that draw this group to geothermal are the simplicity, adaptability, sustainable performance, and the proven technology. To determine how their systems were performing, Verve analyzed their first two systems over 3 years of operation. They found that these systems offered a 6 – 7 year payback due to avoided capital costs and operational energy savings. These first two systems included a back-up boiler system, but the owners projected the payback period could be reduced to 5 years if this was removed and the system was tied into the domestic hot water loop for back-up instead. An additional benefit that was found in the earlier building is that excess heat was available from the system in the winter, which they used to heat sidewalks and parking ramps.

4.2 The Role of Geothermal Providers in a Development Project

In many projects, a developer will engage a third-party provider of geothermal to design, build, finance, own, and operate the system. However, for projects where the developer will be the lifecycle owner/operator of the asset, they may choose to finance, own and operate the system.

Beyond having experience with these systems, engaging a geothermal provider can provide benefits to a development project, including financial benefits, and technical performance.

From a financial perspective, geothermal providers prefer engaging with larger sites, as economies of scale assist in offsetting costs, and provide greater revenue potential. In two interviews with geothermal professionals, they indicated the ideal size of a development to enter a partnership with is greater than 100,000 square feet (9,300 square metres).

Geothermal can be assumed to run at maximum efficiency when the geothermal provider is responsible for operations, as it is in their best interest to maximize profits by running the system as efficiently as possible.

Energy Service Agreements - How They Work

Upon entering a partnership with a geothermal provider, an agreement is generally signed by the developer (on the behalf of the condo board, if a condominium building), and the geothermal provider, to purchase the thermal energy provided by the system – often referred to as an Energy Service Agreement (ESA).

Things for a developer to consider in an ESA include:

- The service guarantee, which outlines the committed operating parameters of the system to meet the heating and cooling needs of the building. The service guarantee shifts the financial, technical, and legal responsibility of the system's performance to the provider, and holds them accountable for the system.
- The annual energy price escalation rate and payment terms, and the contract lifetime/expiry.
    - Geothermal providers set a specific date for the start date of their revenue, and will begin to charge the monthly rate regardless on if they building is complete. A delay in construction could likely result in a developer paying for the geothermal energy regardless on if it is being used.
    - The developer may contribute up-front capital to the provider, which will result in lower rates to the residents and further improve marketability. This contribution can be equal to the avoided capital cost for mechanical equipment gained by joining an agreement with a geothermal provider.
- Ownership parameters of physical equipment;
- The operations and maintenance, servicing, and monitoring provided;
- Example contract language for inclusion in sales documentation;
- Include a buy-out clause for the system.

Typically, a geothermal provider will determine the rates to be charged for the geothermal energy based on a number of factors, including avoided operations and maintenance for traditional equipment, and avoided reserve fund costs to replace traditional equipment. From the provider's prospective, some of the biggest factors impacting the actual cost of the system include:

- Depth to bedrock – one of the main drivers that affect the costs of drilling;
- Number of boreholes required and cost per borehole;
- Energy balance of geothermal – this affects the system sizing, in that systems that are unbalanced conventionally result in being oversized, and;
- Other factors such as artesian aquifers, soil conditions, and climate.

Cost Benefits of Engaging a Geothermal Provider

The terms of each partnership will differ depending on the specific project. In the table below, we have outlined a typical arrangement of ownership between provider and developer.

Geothermal Provider	Developer/Building Owner
• Geothermal Loops • Boreholes • Circulating pump & controls for ground side	• Building HVAC System including heat pumps, makeup air units, etc.

Because the third-party provider will be owning and operating the system, capital cost savings can be found through:

- Removing costs of heating/cooling equipment (boilers and chiller), and transferring capital costs for geothermal to the third-party provider;
- Reducing the system to 2-pipes rather than four, and;
- Construction cost savings from reduced mechanical room space.

In order to analyse the expected capital cost savings of switching from a traditional boiler-fed, 4-pipe fan coil HVAC system to a geothermal heat pump system, we completed a simple cost analysis on an archetype MURB building in Ontario. Specific cost savings will differ on a per building basis.

The following assumptions were made:

- The baseline building has a 4-pipe fan coil unit system in place
- The new design would not be using boilers for domestic hot water. Additional equipment, not priced here, would be needed to provide higher temperature needs.
- A third-party provider will be brought on to finance, design, own, and operate the system.
- A Connection Charge would be paid by the developer to the provider (assumes 70% of avoided mechanical cost). In some cases, a connection charge is used by an energy provider to offset initial capital costs of the system.

Using values from a range of sources, including a professional cost consultant and the Toronto Green Standard, we calculated the expected capital cost savings from the developer's perspective. The results are an expected capital cost savings of $1.60/ft^2. However, specific cost savings will differ on a per building basis.

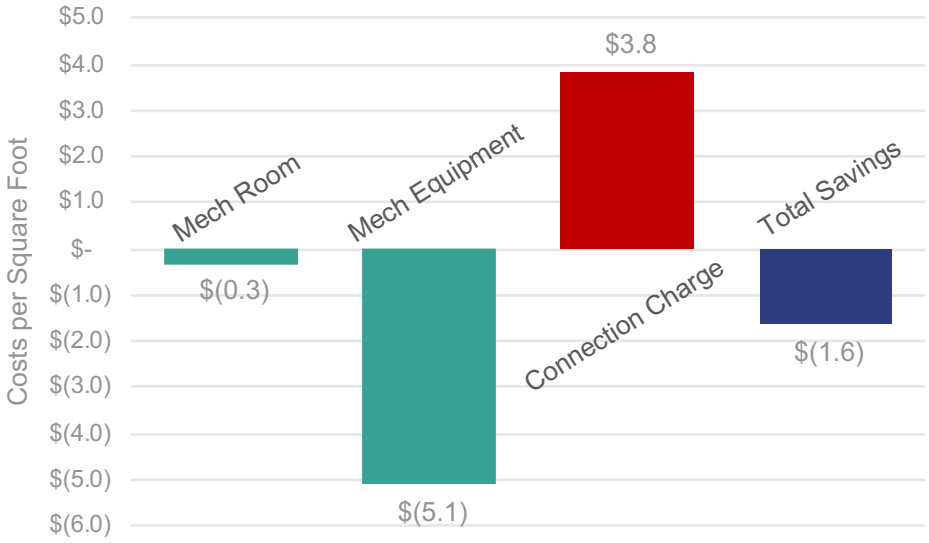


Figure 7: Analysis of Potential Cost Savings to Developer

5 How to Deliver Geothermal on a Development Project

This white paper has demonstrated the many benefits geothermal can have on a development project. To further assist developers understand changes, this section outlines key considerations by project stage.

5.1 Design Phase

Including geothermal will affect the project budget, the mechanical design, construction scheduling, and potentially the marketing of the project, so it is important to consider early on in the design process. If geothermal is considered before the Site Plan Approval phase (or other similar phase, depending on jurisdiction), the system will have minor spatial impacts but can inform planning approvals (such as building heights).

When considering options for geothermal, developers generally have two ownership options:

1. Third-party owned. Procure a geothermal provider to design, build, finance, own, and operate the system
2. Developer owned. In some cases, the geothermal provider will design, build, and/or maintain the system.

Some factors that can affect the decision between these two options include:

Option 1 – Third-Party Owned	Option 2 – Developer Owned
• Good for developers of condominium projects, who do not have a long-term interest in the property (will hand it over to condo board or other). • Good for developers who are not interesting in holding and managing an energy asset.	• Good for developers of purpose-built rental apartments • Good for developers who are looking to expand investments into energy assets.

Option 1 – Third-Party Owned

If geothermal is in line with developer or project specific goals/aspirations, it is recommended that a developer explore relationships with a provider during the early design stage of a project. Geothermal providers will analyze the specific characteristics of your site to optimize the system, both in terms of cost and energy supply potential.

We have outlined typical steps to procuring a third-party geothermal provider:

1. Hire an energy consultant to create an early stage energy model of your development
    a. This will assist in defining the heating and cooling needs for the project, the level of energy and carbon performance being targeted, as well as evaluating the proposed energy savings by the geothermal providers.
2. Scan the market for prospective partners
    a. Issue an expression of interest to determine potential partners.

3. Determine which partner best aligns with project
    a. Depending on size and complexity of the project, a formal request for proposals can be considered to select the best provider/business terms.
    b. Ensure their philosophies align with your team and they can quickly establish a good working relationship.

Option 2 – Developer Owned

If geothermal is in line with the developer or project specific goals/aspirations, and the owner wishes to retain the asset upon construction completion, the suggested steps would vary slightly from those listed above. The design of the system can either occur through a design-bid-build or a design-build/design-assist procurement strategy.

In a design-bid-build scenario, the owner would retain an engineer at an early design phase to design the system, working in conjunction with the rest of the design team for the rest of the building systems. The design engineer could be, but doesn't have to be, the same engineer designing the building HVAC systems. Once the system is fully designed, it would be tendered for construction.

Design-assist strategies utilize a project delivery method where the construction team (in this case, the geothermal provider) is engaged by the owner to collaborate with the architect or engineer during the design phase. When in this model, the developer can sign a guaranteed maximum price (GMP) contract in the design phase, increasing cost certainty.

In any case, it is still advised to hire an energy consultant to create an early stage energy model.

5.2 Construction Phase

When a geothermal provider is engaged, they will typically retain their own construction team, including sub-trades. In this case, the developer is responsible for ensuring the construction manager and geothermal provider are connected at the onset of the project, and the construction manager will coordinate the schedule based on input by the provider.

If the developer elects to own the system, the construction process would follow a more traditional design-bid-build structure, where the construction manager would procure a team to provide and build the system once it is designed. In the design-assist model, the geothermal provider will have already been brought on to the construction team in the design phase.

Drilling

A key consideration for developers during construction is the drilling of the boreholes. While it is true that no other work can be done on site while boreholes are being drilled, this can be built into the construction schedule from the onset of the project.

In conversations with developers and providers, the following general time estimates for borehole drilling were outlined, which will differ on a project to project basis depending on site conditions:

- “About 0.75 – 1 boreholes per day per drill rig” for a MURB project in Toronto during winter conditions;
- “1 – 1.5 [boreholes] drilled and grouted per rig per day” in Toronto during summer conditions, with consistent bedrock/shale;
- “If the soil conditions change part way through the drilling (ex. Change from sand to shale and back to sand), production can be cut in half (i.e 0.5-1 boreholes per day)” in Ottawa with varying conditions.

Some providers will include 1 – 2 weeks in the schedule for mobilization/demobilization.

In many cases, modern geothermal boreholes are installed below the building footprint. This allows for great flexibility in the installation, but can impact the schedule when coordinating with other trades. To minimize this impact, some providers drill the boreholes from grade level prior to bulk excavation, terminating the pipes below the lowest level of the building. Drilling from grade is not only more efficient, but completing the boreholes before the rest of the trades are mobilized generally has less impact on the timeline.

Case Study – Damages to Boreholes during Excavation Works

In one interview with a development team, the team mentioned that their project used the drilling from grade method, where the boreholes were drilled before excavation work had begun. Due to the ground conditions on this site, a rock blasting method was used to excavate the site after the geothermal bore-field was complete.

As excavation work was underway, about 20% of the geothermal bore-field was destroyed. Although unfortunate, the development team came up with two strategies to provide additional capacity to the system:

- The design teamed increased the domestic hot water boiler from a 5000 BTU to 6000 BTU capacity for a marginal cost increase to supply back-up hot water, and;
- Ran the risers in the building up to the roof, in the case they needed to add a cooling tower to the system in the future.

Six years into operation, there has been no need to install a cooling tower, as the system has provided the heating and cooling needs for the building despite losing 20% of it’s capacity during construction.

Other considerations for the construction phase include:

- Provide the geothermal provider with adequate time allotted for the drilling of the boreholes when the construction schedule is being created, so as not to face unexpected delays and associated increased costs for the project.
- If the construction manager and trades are aware/knowledgeable of the geothermal boreholes, there is less opportunities for damage while other site works are being complete;
- Drillers should test each geothermal well to ensure they are installed correctly before grouting them shut;

- Water must be available for drilling, along with a staging area to hold the water and spoils on site;
- Depending on timing and duration of construction, it is likely that temporary heating may be required during construction. Consideration should be given to whether or not the base-building HVAC system will supply the temporary heating. If using the house system, give consideration to geothermal, mainly when it starts operation and how it may affect the long term energy agreement;
- Suggest commissioning or documenting the condition of the geothermal well field once it is constructed, prior to continuing remaining building construction work. If there are issues during final commissioning, this will provide a record of when these issues arose.
- Although geothermal and the base-building HVAC system are commissioned separately, there are benefits in hiring the same commissioning agent, as the systems must operate in tandem after project completion;
- In the case that a geothermal provider is owner/operator of the system, a specific start date for the monthly energy charges is generally included in the ESA. If construction of the total project is delayed for any reason, this date does not change, and could result in the developer paying these charges until the building is complete.

5.3 Operations

The developer of a multi-unit residential condominium is responsible for creating the condo's operating budget and retains responsibility for operating costs in the first year of operations. There is a potential for reputational harm to the developer if condo fees of past projects rise above industry norms. As such, operations and maintenance of the system is an important consideration.

The majority of the operating cost savings are realized through reduction in capital reserve. When less heating and cooling equipment is installed, the need to save funds for replacing and maintaining the displaced equipment is elminated. Utility costs, such as natural gas, electricity and water, are also reduced.

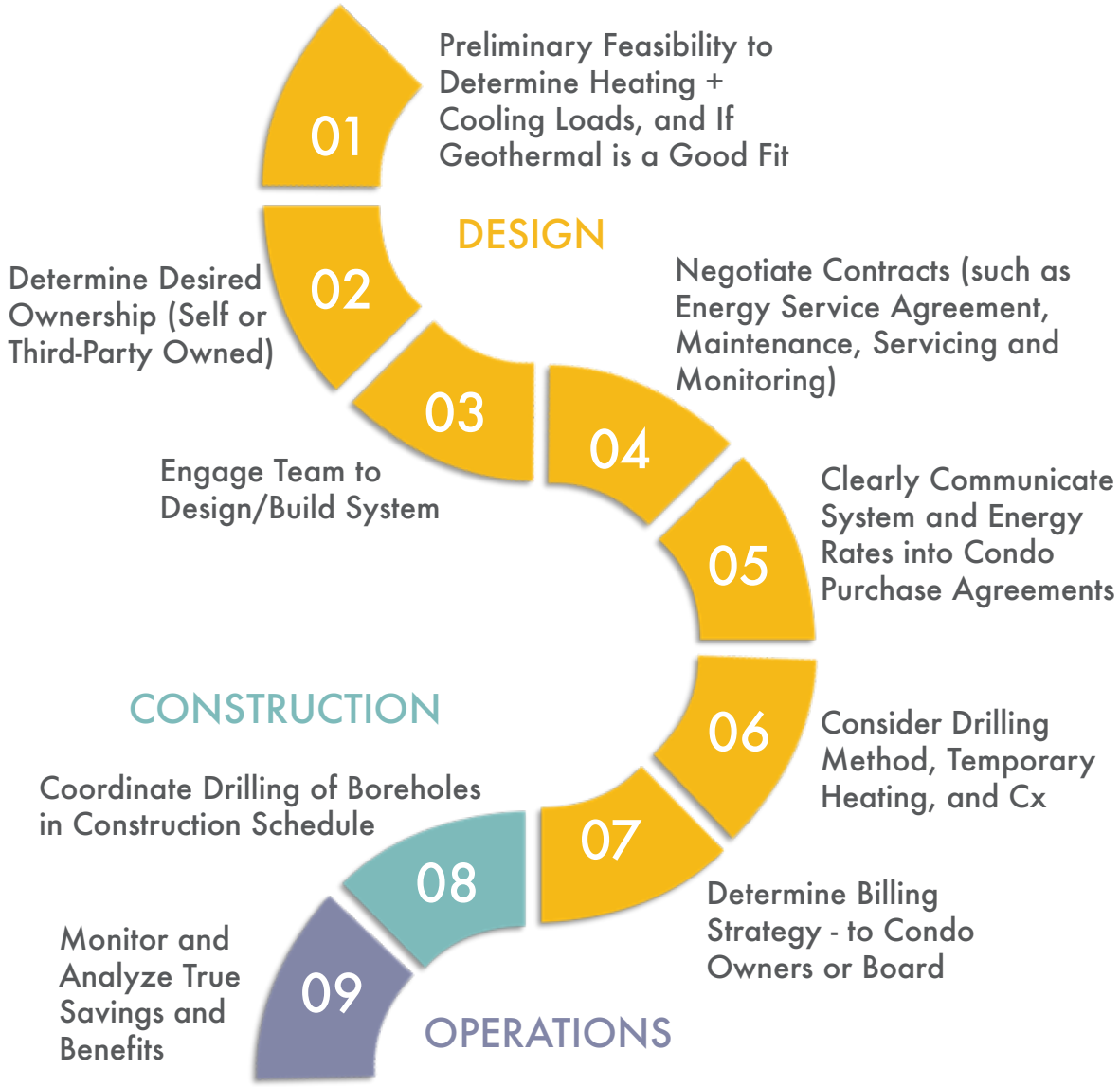
The details on operations and maintenance are typically specified in the agreement between the Geothermal Provider and the Condo Board/Building Owner Operator. The scope of service that a provider typically offers is on the ground-loop component of the system, with the demarcation being the heat exchanger (separating building systems from ground-loop systems). Other items likely included in the operations and maintenance plan include:

- Regularly scheduled maintenance on mechanical equipment and 24/7 on-call services to address acute problems. Access is typically restricted to the geothermal energy transfer room and fees are baked into monthly rates.
- Some geothermal providers will incorporate remote monitoring abilities, in order to make updates to the system without physically entering the space.

In the case where a developer elects to own the system, a service provider would likely be hired to maintain the system on their behalf to provide the same level of maintenance as would be expected with a geothermal provider.

5.4 Roadmap - What to Consider and When

This white paper highlights several case studies from developers and engineers who have successfully implemented geothermal on projects. Using this information, along with our experience, we have developed the following high level road map to assist developers interested in implementing geothermal.



6 Conclusion

The use of geothermal has the potential to reduce natural gas use and related carbon emissions. Particularly natural gas usage for space heating, which represents the highest energy end use for MURBs in Canadian climate.

This white paper demonstrated the many benefits of these systems, both technical and financial, addresses the barriers to implementation from the developer's perspective. Not only is geothermal energy efficient, but it can provide a number of different benefits to a project.

Beyond these benefits, geothermal is simple in nature and can be used to meet Canada's emissions reductions goals.

URBAN EQUATION

Appendices

Appendix A – Sample List of Building Precedents in Ontario

Developer	Project	Building Type
Windmill Development Group	The Plant, Toronto, Ontario	9 storey condominium with ground floor mixed use
	The Eddy, Ottawa, Ontario	6 storey condominium with ground floor mixed use
	Arch Lofts, Toronto, Ontario	3 storey condominium
LCH Developments	Merge Condos, Scarborough, Ontario	11 storey condominium
COLLECDEV	Tretti Condos, Toronto, Ontario	13 storey condominium with ground floor mixed use
New Horizon Development Group	Mint Condos, Oakville, Ontario	8 storey residential building
Fram Building Group	The Roxborough Retirement Residence, Newmarket, Ontario	6 storey seniors living building
	Four Elms Retirement Residence, Thornhill, Ontario	6 storey seniors living building
Castleridge Homes	Clairington Condos, Brampton, Ontario	11 storey condominium building