Sustainable Technologies
EVALUATION PROGRAM

Heating and Cooling

Geothermal Feasibility Assessments:

Guidance for Prospective System Owners

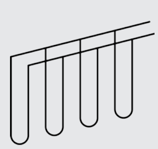
INTRODUCTION AND SCOPE

Geothermal is a high-efficiency space heating and cooling technology. The design of geothermal systems for *large* buildings is more involved than that for conventional systems, often resulting in higher up-front planning costs and variability in cost estimates. This document provides considerations for building managers/owners interested in evaluating the feasibility of geothermal. While the focus is primarily retrofits, many considerations are applicable to new-builds. Considerations are based on a review of actual feasibility studies and consultation with industry experts/stakeholders.

WHY CHOOSE GEOTHERMAL?

There are many reasons why organizations choose geothermal. It offers significant carbon reductions, helping to achieve sustainability mandates while also bolstering organizational reputation. It is the most efficient heating/cooling technology and may help reduce operating costs. It may also help to achieve building certifications like LEED or Net-Zero. The primary system components are durable and long-lasting, and are often cheaper to maintain and operate. The ground heat exchanger (GHX), which is the largest cost component of an installation, is extremely long-lasting.

This is a technology with many names. "Geothermal", "geoexchange", "ground-source heat pump systems" and "ground-coupled heat pump systems" are all terms used to describe the same thing: a technology that utilizes the ground (or surface/ground water) as a source or sink for heat energy in building heating and cooling applications. This document uses "geothermal" because it seems to be the most commonly used term.



Geothermal technology uses the ground for seasonal heat energy storage. In the summer, a building is cooled by rejecting excess heat energy to the ground, typically with the help of an electric heat pump. This is reversed in the winter when that heat energy is provided back to the building. The most common geothermal system type in urban areas incorporates a closed-loop vertical ground heat exchanger (GHX). The GHX consists of piping that extends deep into the ground, acting as the interface for heat exchange between the ground and the building.

HOW DOES GEOTHERMAL SAVE MONEY?

It is often the case that feasibility studies only evaluate financial performance based on utility cost savings. However, geothermal systems offer many other potential sources of savings:

- saved person-hours for operation and maintenance,
- saved person-hours and materials for other building operations (e.g. geothermal can melt snow from walkways and this reduces salting, snow plowing/shoveling, cleaning from salt tracking, corrosion from salt, risk to occupants),
- saved water and chemical treatment for cooling towers,
- saved infrastructure cost (new-builds), and
- capital reserve savings due to longer component lifetimes.

There are substantial utility savings when retrofitting geothermal in buildings outside of the natural gas network. However, when compared against natural gas, the *heating-mode* utility savings of a geothermal system powered by an electric heat pump varies with the costs of electricity and natural gas. Historical natural gas prices have been much higher and this has promoted the cost-effectiveness of geothermal installations but, at *current* utility prices in Ontario (April 2017), minimal *heating-mode* utility savings are expected versus conventional high-efficiency natural gas heating equipment. Other sources of savings, such as cooling mode savings and those mentioned above, need to be carefully considered. It should be noted that many commercial buildings are actually cooling dominant.

UNIQUE DESIGN CONSIDERATIONS

Conventional heating and cooling equipment is sized to maintain indoor temperatures on the hottest and coldest days of the year. The energy source to power that equipment is essentially unlimited in supply from the utility. In a geothermal system, both the equipment *and the energy source* need to be sized. The energy source is the GHX, and the size of the GHX places a limit on the amount of energy that can be supplied. However, the GHX is the largest cost component of an installation and an oversized GHX adds unnecessary cost.

It is often the case that conventional heating equipment is sized without fully considering internal heat gains (from occupancy, equipment, solar gain, etc.), resulting in a system with more capacity then will be actually needed. However, internal heat gains may actually represent a significant portion of the power required to heat a building, as much as 50-60%. In a geothermal system, there is a significant cost penalty incurred by neglecting internal heat gains. Cost-effective geothermal system design requires a detailed assessment of building loads, and heat gains, using building energy modelling.

A cost-optimized GHX is "balanced," meaning that on an annual basis, the heat taken from the ground during the heating season is replaced in the cooling season. Balancing is crucial because it ensures that the GHX is used to its maximum potential and that the system is viable over the long-term. Most building loads are not balanced naturally. A geothermal system designer should achieve a balanced system through an iterative design process. Different heating or cooling loads within the building are analyzed, alongside other potential building changes, within the context of an hourly room-to-room building energy model. This determines which loads should be incorporated, and which building changes should be made, to support a cost-optimized geothermal system.

> "If someone wants a geo system, the quick response by the design firm is to use a couple of quick "rules of thumb" to put together a budget cost. I would estimate that probably 80% of potential geo systems are [unfairly] lost to conventional HVAC systems at this point. On three projects I've done with [a certain] utility, two would not have ended up with a geo system. On all three of them, compared to the "rule of thumb" feasibility assessment, the size and cost of the GHX was reduced by 40-60% [by using proper GHX sizing]."
>
> -Ed Lohrenz, GEOptimize and the GreyEdge Group

These unique design considerations are discussed in the Certified GeoExchange Designer (CGD) course offered by the International Ground Source Heat Pump Association (IGSHPA) and the Association for Energy Engineers (AEE). CGD-certification can help potential system owners verify that designers understand the concepts necessary for cost-effective GHX design.

FEASIBILITY ASSESSMENT BARRIERS

Large geothermal systems are normally preceded by a feasibility study that calculates financial metrics (payback, ROI, NPV, etc.). However, *an **accurate** analysis requires cost-optimized GHX sizing*. There are two key barriers: GHX sizing demands specialized expertise that is not available at every engineering consultancy, making consultant selection crucial, and geothermal feasibility studies are more expensive than those for conventional systems due to the need for building energy modelling. This document is intended to help prospective geothermal system owners navigate these barriers.

STAGE 1: SCREENING

A prospective geothermal system owner may need to select retrofit candidate buildings from within their portfolio. Experts suggest that geothermal is possible to some extent in most types of buildings but a key consideration is the space available for the GHX. Within the GHX, piping is run through a number of boreholes that are drilled deep into the ground. The boreholes are collectively referred to as a borefield, and this requires land area. In a new-build, the borefield can normally be installed underneath a building with minimal added cost. However, in most retrofits, installing the borefield underneath a building either adds cost or may not be feasible. Geothermal *retrofits* are typically most cost-effective when there is space adjacent to the building, like a park, parking lot or field. When there is a very large area available, a *horizontal* GHX may be possible and this can notably reduce system costs. Once installed, the GHX is hidden underground. Other considerations relevant to cost-effectiveness include:

- **Fuel type and building loads:** Geothermal is often a cost-effective alternative in a building heated by electricity, propane or oil, but *current* low natural gas prices and comparatively high electricity prices reduce potential *heating* cost savings in some facilities with high heating requirements and a natural gas connection. Detailed energy load analysis, however, may show opportunities for significant cooling mode savings and also, for simultaneous heating and cooling. Many larger commercial buildings are actually cooling dominant, making heating loads a smaller component of overall energy costs.
- **Simultaneous heating and cooling:** Geothermal can be used as part of a system that pumps heat energy from one part of a building to another, or between buildings. This can greatly reduce overall system costs and ongoing utility costs. A good example of this is a community centre that has both a heated pool and an ice rink.
- **Existing mechanical equipment:** It is most cost-effective to replace equipment approaching end-of-life.
- **Other opportunities for savings:** Geothermal can eliminate costs associated with a cooling tower and other building operations (e.g. snow melting).

Further to these considerations, it is helpful to have:

- existing drawings of the building(s) (so as to not have to incur the additional expense of creating them), and/or
- a detailed energy audit of the building(s) that identified opportunities for energy savings.

STAGE 2: PREFEASIBILITY

For conventional systems, it is often the case that building owners move right to a feasibility assessment and skip a prefeasibility assessment. However, feasibility assessments for geothermal systems are more costly due to building energy modelling. It therefore makes sense to first conduct a lower-cost prefeasibility assessment to determine whether or not to proceed to a full feasibility assessment. It should be noted that *an **accurate** financial analysis can only come from the full feasibility analysis*. Different approaches to prefeasibility are possible and a consultant is required. It may take a few days of a consultant's time.

During a prefeasibility study, a consultant may be able to conduct a preliminary GHX sizing based on an already-existing building model that is similar to the candidate building. It is also possible for a consultant to develop a qualitative decision-making matrix where different heating and cooling systems are compared against a number of weighted criteria that are relevant to the prospective system owner. Criteria might include utility and operating costs, carbon savings, disruption to residents, reliability, and similar. Regardless of the approach, this stage requires the experience of a consultant that has a portfolio of experience focusing on *geothermal* projects. Consultants should therefore be prequalified and their experience should be strongly considered.

STAGE 3: FEASIBILITY

The technical requirements listed below are suggested when procuring a full geothermal feasibility assessment in an RFP/RFQ. These requirements are generalized and need to be adjusted for specific applications. It is reasonable to expect that a feasibility study may take roughly two weeks of a consultant's time (depending on the building size). Requirements are similar for both retrofits and new-builds. For new-builds, it is important that a geothermal system designer is involved at the *beginning* of the building design process. The experience of consultants should be a key consideration. CGD-certification can help ensure consultant experience but it should be noted that no single certification is currently and widely used by *all* experienced system designers.

1. Building and site assessment

- Via a site visit, consultant shall review drawings, building mechanical room, BAS capabilities, existing HVAC systems and proposed borefield location, to verify that geothermal is appropriate for the site.
- Consultant shall work with a local driller and review geological survey data to estimate the ground thermal conductivity. A test borehole is not required at the feasibility stage but is typically used during detailed design.
- Consultant shall identify any potential issues with drilling at the proposed location.
- Consultant shall describe the proposed system, including the system size, location and sizing of vertical/horizontal GHX, building connection point, heat pump configuration, and sequence of controls.

2. Building energy model

- Based on drawings, utility data and information provided by the client, consultant shall create an 8760 hour room-by-room building energy model, which incorporates all relevant source of internal heat gains.
- Consultant shall use the building energy model and GHX

model to consider opportunities that promote system balancing. This may include incorporating DHW load, loads from adjacent buildings, ventilation loads, swimming pools, snow melting, other building exterior or interior changes, hybrid system, etc. The report shall indicate which options were considered and the corresponding results.

- Consultant shall indicate a preferred system configuration and demonstrate that it is balanced.

3. GHX model/design/sizing

- GHX sizing shall *not* be based on rules of thumb. Industry-standard sizing software (e.g. GLD, EED or Looplink) should be used. Sizing software should allow 8760 hourly load input and model long-term ground temperature changes.
- Consultant shall include a plot illustrating 20-year ground temperature changes and state annual energy flows.
- Consultants shall provide a layout of the proposed borefield.

4. Energy/financial/GHG analysis

- Consultant shall evaluate the energy, cost and GHG savings against a reasonable conventional system including air-source heat pump options if desired by the client.
- Financial analysis shall include net present value (NPV) over 25 and 50 year evaluation periods using a discount rate provided by the client, return on investment (ROI), and simple payback calculations over the conventional system.
- Consultant shall identify applicable utility incentives.
- In the financial analysis, consultant shall use utility rates provided by the client but also evaluate the sensitivity of the results to changes in utility rates.
- As separate line items, consultant shall consider savings from (if applicable): cooling energy costs, heating energy costs, saved person-hours for operation and maintenance of mechanicals, saved person-hours and materials for other building operations (snow-melting), saved water usage and chemical treatment (cooling towers), saved infrastructure cost (new-builds), and capital reserve savings due to longer component lifetimes (based on ASHRAE life expectancies).
- Consultant shall refer to AHRI-rated specifications of proposed equipment to estimate equipment efficiencies. Efficiency values shall be adjusted to represent expected operating conditions where necessary.
- Components costs should be traceable and included as separate line items; acceptable sources include either RS means mechanical data and actual equipment quotes for this project or from recent previous projects.
- Consultant shall estimate GHG reductions based on emission factors provided by the client. Otherwise, consultant shall use emission factors in the National Inventory Report.

5. Environmental impact

- Consultant shall identify impacts of the GHX on local water source and the environment (if any).

6. Other

- Consultant shall provide a detailed report which clearly describes methodologies, parameter assumptions, data sources and findings, as well as potential sources of error, such that the client can verify all requirements have been met. Model files and data used to support the analysis should also be provided .
- Consultant shall outline any connections the existing BAS.

CONCLUSION

Geothermal is the most efficient heating and cooling technology and it has a variety of benefits. It also has a number of unique requirements in regards to the feasibility assessment process. This document was created to help prospective system owners navigate the process of short-listing candidate buildings and then performing prefeasibility and feasibility studies. While clear RFP/RFQ requirements for feasibility assessments can help bolster the quality of the work done by consultants, geothermal system design requires specialized expertise. Prospective system owners should seek to prequalify consultants based on their *geothermal* experience, or use geothermal experience as an important criterion when evaluating proposals and quotes.

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