


Closing the Loop: A Survey of Owners, Operators and Suppliers of Urban Geoexchange Systems in the Greater Toronto Area

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THE SUSTAINABLE TECHNOLOGIES EVALUATION PROGRAM

The Sustainable Technologies Evaluation Program (STEP) is a multi-agency program, led by the Toronto and Region Conservation Authority (TRCA). The program helps to provide the data and analytical tools necessary to support broader implementation of sustainable technologies and practices within a Canadian context. The main program objectives are to:

- monitor and evaluate clean water, air and energy technologies;
- assess barriers and opportunities to implementing technologies;
- develop tools, guidelines and policies, and
- promote broader use of effective technologies through research, education and advocacy.

Technologies evaluated under STEP are not limited to physical products or devices; they may also include preventative measures, alternative urban site designs, and other innovative practices that help create more sustainable and liveable communities.

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EXECUTIVE SUMMARY

Background

In Canada, vast amounts of energy are used every year to maintain comfortable temperatures in the buildings where we live, work, and play. Geoexchange is an environmentally sustainable alternative to conventional heating and cooling systems that uses the earth as a heat source and sink. Geoexchange systems typically require 30 to 70 percent less energy for heating and 20 to 95 percent less energy for cooling than conventional systems.[1] The Canadian Geoexchange Coalition has predicted that a 16% penetration of Ontario's residential market by geoexchange would result in a savings of 1,485,742 tons of eCO_2, or the equivalent of removing 442,185 cars from the road.[2]

Within the last decade, Canada's geoexchange industry has rapidly expanded. Between 2005 and 2010, annual growth of the industry exceeded 40%, and there are currently over 100,000 geoexchange systems installed in Canada.[3] Despite these successes, geoexchange technology has not yet achieved mainstream status, and widespread adoption continues to be limited by the persistence of several key market barriers, including: (i) high up-front costs, (ii) high price of electricity relative to natural gas, (iii) lack of consumer awareness and confidence in geoexchange technology, (iv) lack of policymaker and regulator awareness and confidence in geoexchange technology, and (v) lack of geoexchange design and installation infrastructure (including standards and certifications, decision support tools, and a sufficient number of qualified contractors and consultants). To address these barriers, there is a clear need for improved demonstration and documentation of the performance and benefits of geoexchange systems.[4]

Study objectives

The overall goal of this study is to share the experiences of geoexchange system owners, operators, and suppliers in developing and implementing geoexchange projects in the Greater Toronto Area. More specifically, this study:

1. Documents key issues experienced by facility managers and site owners related to geoexchange project planning, design, implementation, system operation and maintenance, and other factors that affect owner and operator satisfaction.
2. Assesses the costs and payback of local geoexchange projects.
3. Advances our understanding of the major challenges and opportunities facing geoexchange service providers in the Province of Ontario.

[1] Natural Resources Canada, 2002.
[2] Canadian Geoexchange Coalition. 2010. Comparative Analysis of Greenhouse Gas Emissions of Various Residential Heating Systems in the Canadian Provinces. Online document: http://www.geo-exchange.ca/en/UserAttachments/article63_GES_Final_EN.pdf (Accessed February 11, 2013)
[3] Canadian Geoexchange Coalition, 2012.
[4] Hughes, P.J. 2008. Geothermal (Ground-Source) Heat Pumps: Market Status, Barriers to Adoption, and Actions to Overcome Barriers. Oak Ridge National Laboratory. ORNL/TM-2008/232.

4. Provides recommendations for addressing major challenges and improving the process of developing and implementing geoexchange projects in the Province of Ontario.

Study approach

Data were collected through a series of oral interviews with owners, operators, and suppliers of geoexchange systems in the Greater Toronto Area. A total of 14 interviews (approximately 45 to 90 minutes in length) were conducted between June and December, 2013. A semi-structured approach was taken in which participants were asked a common set of questions but were free to elaborate on new topics as they arose. Thirteen interviews with owners and operators of large-scale geoexchange installations were conducted with a total of 21 respondents who collectively owned 29 installed systems in the Greater Toronto Area. To complement the perspectives of system owners and operators, an interview was also conducted with two prominent suppliers of geoexchange systems (a leading driller and system designer).

Study findings

Overview of geoexchange projects

Respondents owned and operated a total of 29 installed geoexchange systems, with an additional 17 in development. Of the 29 installed systems, 18 were new builds and 11 were retrofits. The geoexchange systems were installed between 2006 and 2013 and were located in group homes, large-scale commercial, institutional, and multi-unit residential buildings.

Two different models of geoexchange system ownership were encountered. In the first model, the geoexchange system owner also owns the building and pays for utilities. All tenants in the building pay an equal portion of these costs, regardless of usage. In the second model, termed the 'utility model', the geoexchange system owner does not own the building in which the system is installed. A developer or utility company installs the system, retains ownership, and is responsible for ongoing operation and maintenance. The utility recoups their initial investment by selling the generated energy to the building owner for a fee that is comparable to the cost of conventional heating and cooling. The geoexchange system is tied to the title of the property, and system ownership options are available to the owner if desired.

Planning and feasibility

Different reasons were provided by respondents for implementing geoexchange projects. Several chose the option of geoexchange in order to: (i) meet sustainability objectives and demonstrate environmental leadership, (ii) 'green' their brand so as to gain a competitive edge in the marketplace, (iii) reduce long term energy costs, and (iv) improve the thermal comfort of their facilities. The geoexchange utility model offered sustainable, community-based investment opportunities and was believed to hold significant promise in the Ontario market. Five of nine respondents reported that the geoexchange project received some type of external funding, either through the federal ecoENERGY

Retrofit program or through incentives or loans from other levels of government. Since the up-front cost of geoexchange systems was significant, grants and loans often facilitated the decision to implement the project.

Geoexchange is a relatively new technology, and as such, the majority of respondents perceived some type of risk prior to project implementation. Five major types of risks were identified by respondents:

1. Technology risk: Will the system work? Will it perform as effectively as a conventional HVAC system?
2. Financial risk: Will unexpected costs arise? Will the predicted payback be achieved?
3. Environmental risk: What are the environmental impacts associated with deep drilling and long term operation?
4. Regulatory risk: Will the project be delayed or rejected during the permitting process?
5. Social risk: Will the project be supported by stakeholders?

Financial and technology risks were the most common concern, followed by environmental, regulatory, and social risks. Financial and regulatory risks were difficult to mitigate, but did not serve as a deterrent to implementation of the project. Technology, environmental, and social risks were usually addressed during project planning and development. It is important to note that although these risks are distinct, many are interrelated. For example, financial risk concerning whether the expected payback will be achieved is strongly related to the technology risk of whether the system will meet performance expectations. Similarly, social risk is rooted in perceived financial, technology, and environmental risks. The interconnection of different risks types is beneficial from a risk mitigation perspective, as a single strategy may be used to address multiple risk factors.

Nine of thirteen respondents stated that a feasibility study was performed, but the factors considered in these assessments varied widely. Detailed information about feasibility studies was difficult to obtain because respondents did not typically have an in-depth involvement in the process. Respondents that had extensive experience developing and implementing geoexchange projects believed that a feasibility assessment for each project was not always necessary, and chose to rely on past experience with geoexchange in similar types of buildings. Reported simple payback predictions ranged from 5 to 40 years. However, two respondents believed that simple payback analysis was not an effective tool for evaluating the feasibility of geoexchange projects. The experiences of respondents highlighted the need for standard geoexchange feasibility assessment guidelines and tools that ensure assessment outcomes provide an accurate and unbiased reflection of post-project cost and performance.

Design

An integrated design approach in which the geoexchange system is designed within the context of the whole building was believed to optimize system efficiency and obtain maximum benefits. Respondents identified several measures that can help to enhance the performance of geoexchange systems, including effective integration with the distribution and ventilation systems, backup system, and/or domestic hot water or solar thermal system. Building energy efficiency measures such as enhanced insulation and air leak prevention were also seen as important in reducing the variability of building heating and cooling demands, and preventing or reducing the need for back-up heating systems.

The design process for retrofit projects was more complex because new components needed to be integrated with existing systems. Retrofits often involved several upgrades to the building to better accommodate the geoexchange system and were most successful when an integrated design approach was used. Several characteristics of an existing building that allow it to better accommodate a geoexchange retrofit were specified. For both new builds and retrofits, proper balancing of the building's heating and cooling loads helps to maintain long term system performance. Strategies used to ensure heat storage and heat removal from the earth remained balanced included: (i) slightly oversizing the system to obtain extra storage capacity and (ii) using excess heat for water heating or snow melting applications.

The majority of geoexchange systems encountered in this study were hybrid systems. Nine of the ten respondents who discussed this topic reported owning or operating hybrid systems. However, seven respondents stated that the backup system was rarely or never used, suggesting that conventions regarding backup requirements in hybrid systems may not always be applicable. Two respondents owned or operated decentralized geoexchange systems, which provide individualized space conditioning for individual apartments or condominiums. These systems were beneficial in buildings that have variable loads due to their ability to heat and cool different units simultaneously.

Project implementation

The procurement process was often a challenge for respondents that lacked previous experience with geoexchange systems. Prequalification of consultants and contractors during procurement helped to ensure the best possible team was retained. Four respondents reported using a formal prequalification process, which could include an evaluation of a company's previous experience with geoexchange projects, technical knowledge, financial capacity, and references. It was common for respondents to evaluate submitted bids based on multiple criteria rather than on pricing alone, as geoexchange projects require specialized technical knowledge. Ten of eleven respondents stated that they were satisfied with the performance of contractors and consultants on the project team.

Contracts structured as design-builds were reported to place less responsibility on the system owner and reduce the time spent on project management, whereas the design-bid-build approach allowed the system owner to play a larger role in project management and implementation. Estimates of the time and resource commitments required of respondents during project implementation ranged between 5 minutes a day and 100% of their time. Time and resource commitments were dependent on several factors, including: (i) whether the system was a new build or a retrofit, (ii) the contract structure, (iii) the phase of the project, and (iv) whether the respondent was a building owner or a facility manager.

Monitoring and verification of installed geoexchange systems is essential for assessing technical and financial performance. Ten of thirteen respondents stated that the geoexchange system is being monitored, but the monitoring approach and intensity varied widely. In three cases, detailed performance data were being collected but analysis of these data was not a priority due to limitations of time and budget. However, several respondents recognized the value of a comprehensive monitoring program that went beyond tracking basic parameters such as ground loop temperatures. These efforts helped to detect problems early, saving time and money in the long run. Evaluation of building energy consumption was particularly valuable, as abnormalities in natural gas or electricity consumption of the building can be caused directly or indirectly by a problem with the geoexchange system. In retrofit scenarios, a lack of reliable baseline data often impeded assessments of energy and cost savings. Only one respondent possessed a reliable record of both pre- and post-retrofit building electricity and natural gas consumption.

Twelve of thirteen respondents stated that operation and maintenance required the same or less effort for geoexchange systems than for conventional HVAC systems. The time spent on routine maintenance ranged from two hours quarterly to six hours per month. Routine maintenance was reported to be relatively simple and was usually performed by building operators. Two organizations chose to procure an external maintenance contract for the geoexchange system or for all of the mechanical systems within the building. Although external service contracts were likely more expensive, they were a beneficial arrangement for organizations lacking internal staff resources. One respondent commented that the building automation system (BAS) greatly facilitated maintenance by allowing for trending on building alarms. Operation and maintenance challenges identified by respondents included: (i) education and training of maintenance personnel in the face of high staff turnover and (ii) maintaining desired building temperatures during the shoulder seasons.

Level of satisfaction

Nine of ten respondents reported that building occupants were satisfied with the performance of the geoexchange system. Geoexchange systems offered building occupants several advantages over conventional heating and cooling systems, including: (i) increased user control, (ii) expanded service within the building, (iii) reduction in cost of living, and (iv) reduced costs for winter walkway maintenance. Indirect benefits of geoexchange projects included: (i) improved thermal comfort and (ii) improved air quality. Building owners and operators demonstrated a strong willingness to implement geoexchange technologies in other buildings. Of the eleven respondents who discussed this topic, five stated they would install geoexchange in other buildings and six gave a qualified yes, depending on the circumstances. Five of eight respondents stated that the geoexchange system was able to satisfy more than 90% of heating and cooling demand in the building on an annual basis.

Costs and financing

The total cost of geoexchange projects varied widely and was reported in different ways, making comparisons between systems difficult. The number of projects that were completed on or under budget was equal to the number that went over budget. In relation to the cost of the proposed conventional alternative, the cost premium for geoexchange systems ranged from 20% to nearly 300%. More quantitative data are necessary to accurately assess project costs and enable comparisons among systems. Respondents mentioned several factors that affected project costs, including: (i) type of build, (ii) loop orientation, (iii) contractor workload, and (iv) contract structure. In all reported cases, maintenance costs for geoexchange systems were the same or lower than for conventional HVAC systems.

Geoexchange industry perspectives

In the early 1980s through the early 1990s, Ontario's geoexchange industry experienced burgeoning growth. Industry growth beginning in the 1980s can largely be attributed to the grant program implemented by Ontario Hydro. The industry entered a period of decline beginning in the early 1990s that lasted until the mid-2000s due to the termination of the Ontario Hydro grant in 1993 as well the negative publicity surrounding a series of faulty geoexchange installations. Revival of the industry began in the mid-2000s and continues today. Incentive programs such as the federal ecoENERGY Retrofit were introduced in the mid-2000s and played a key role in the rejuvenation of the industry. The respondents believed that incentives are the main drivers of the residential geoexchange industry, but that the commercial sector is driven primarily by the green building movement and certification programs such as Leadership in Energy and Environmental Design (LEED). Assessments of industry growth continue to be hampered by a lack of information about installed systems. However, the respondents estimated that the industry is now growing at a rate of between 10 and 20% per year and future outlook was positive.

Six major barriers to growth of Ontario's geoexchange industry were identified by respondents: (i) lack of geoexchange awareness and expertise in the design community, (ii) lack of mandatory certification standards for geoexchange industry professionals, (iii) negative implications of Ontario Regulation 98/12 to the province's drilling industry, (iv) short term thinking, (v) low cost of natural gas, and (vi) rising costs of electricity in Ontario.

The respondents also identified four emerging opportunities for geoexchange technologies in Ontario. Wider use of variable capacity heat pumps in geoexchange systems may be on the horizon in Canada. In some applications, variable capacity heat pumps may consume less energy than single or two stage models and achieve a higher coefficient of performance (COP). An integrated approach to building design promotes innovation and performance optimization of geoexchange systems. Geoexchange is well-suited to district heating applications, and the expanding district heating industry provides opportunities for wider uptake of geoexchange technologies. Finally, improved marketing of geoexchange to a broader audience and to the architecture community in particular has great potential to result in significant gains.

Recommendations

A number of recommendations are provided to address the challenges experienced or identified by respondents. These are directed at geoexchange system owners, operators, designers, regulators, facility managers and industry associations and academic institutions involved in geoexchange research. Key recommendations arising out of this study include the following:

Project planning and design. To reduce costs, organizations considering replacing their conventional HVAC system with a geoexchange system should undertake the retrofit when the existing system is due for replacement. Sufficient contingency should be built into the budget and schedule to account for unanticipated delays and expenses. For both new builds and retrofits, geoexchange systems should be designed within the context of the overall building to capitalize on all possible efficiencies. Factors such as a tight building envelope as well as distribution, ventilation, and backup systems that integrate well with geoexchange can help to optimize system performance. Retrofits can be more successful when upgrades to all of these building features are performed. System sizing should be based on average annual loads rather than peak loads.

***Project procurement*.** The search for qualified contractors and consultants to undertake geoexchange projects should include a thorough prequalification process. Prequalification may involve evaluation of a company's previous experience with geoexchange projects, technical knowledge, financial capacity, and references. Interviews should also be conducted with other organizations that have implemented geoexchange systems. For organizations with limited geoexchange experience, a design-build contract structure may save time on project management and promote continuity in the project.

Optimizing return on investment. A number of opportunities are available to improve returns on geoexchange investments. From the outset, prospective geoexchange system owners should ensure they are knowledgeable about the various sources of funding and incentive programs that may be available. Several respondents also found that detailed scoping and planning of the geoexchange project prior to implementation could translate into significant savings. Once completed, the system should be thoroughly tested and commissioned by qualified professionals to ensure the system is appropriately interlinked with other building systems and functioning as designed. Investments in post-project monitoring were also found to result in significant savings.

Geoexchange system monitoring. Monitoring programs should be carefully planned with well-defined goals and objectives to ensure optimal system performance and savings. Monitoring programs should be undertaken and overseen by experienced staff or external consultants. Benchmarking the system against expected performance can help detect performance changes that may otherwise go unnoticed. For retrofit projects, it is crucial to collect pre-retrofit baseline data and project timelines need to take this into account.

Operation and maintenance. System operators should inspect and maintain the geoexchange system regularly to enhance long-term performance. Although geoexchange system maintenance requirements are not more onerous than conventional HVAC systems, neglect of simple tasks such as changing filters can significantly impair the functioning of the system. A maintenance schedule should be developed based on input from system designers and installation contractors. It is important for facility managers to invest in ongoing operation and maintenance training for geoexchange system operators, especially where staff turnover is high.

Enhancing system performance. Modular or decentralized geoexchange systems provide customized space conditioning at the individual unit level and may offer greater flexibility in the delivery of heating and cooling. To maintain long term health and performance of the geoexchange system, it is important to consider the balance of the building's heating and cooling loads during the design phase and take appropriate actions to maintain balance in the long term. Excess heat may be used to provide snow melting services or domestic hot water heating. One respondent found that running the geoexchange system during the summer in 'free exchange' mode (in which heating or cooling is achieved through free circulation of the heat transfer fluid without the use of the heat pump) significantly boosted performance of the system and reduced electricity bills.

Infrastructure and capacity building within the industry. Geoexchange associations should work with academic and industry stakeholders to develop and disseminate decision-support tools for geoexchange projects. These may include a feasibility assessment template, detailed guidance for system procurement and commissioning, and monitoring protocols specific to geothermal. To foster ongoing professional development within the industry, a larger number of educational opportunities should be offered, including practical, hands on training programs, workshops, e-learning and certification programs that utilize guidelines and standards established by the industry and regulatory bodies. Training related to operation and maintenance of geoexchange systems for building operators and service contractors is especially needed.

Outreach and communication. Geoexchange industry associations should improve outreach and education to regulatory officials and promote geoexchange technology to a broader audience. Promotion efforts should be targeted to the architecture community as architects are in a unique position to drive building innovation. The geoexchange utility model should be promoted to municipal authorities and utilities. A knowledge sharing forum accessible to system owners and operators, researchers, and geoexchange industry stakeholders would be beneficial.

Improvements in regulatory regimes**.** Existing regulations should be strengthened to ensure that only suitably qualified professionals may operate in the market. Higher energy efficiency standards should be incorporated into the building code. Records concerning the type and size of geothermal systems as well as borehole logs and thermal conductivity tests should be stored in a publicly accessible ministry database. Improved record keeping would facilitate assessments of industry growth and would help to identify geographical areas that are particularly suitable for geoexchange.

Education and research**.** Geoexchange content should be expanded in university level mechanical engineering and science programs. Topics for special focus include: (i) ground exchanger design, (ii) effective use of modelling tools, (iii) integrated design, (iv) building HVAC systems, and (v) financial analysis. Apprenticeship and internship opportunities need to be provided for new graduates. Post-secondary institutions can also play a valuable role in addressing key questions facing the Canadian geoexchange industry through rigorous, independent research.

Incentive programs**.** Incentive programs that provide financial assistance or reduce development charges should be more widely available both for retrofit and new geoexchange projects. The incentive programs should be targeted at fostering growth of the industry in Ontario in a manner that creates the economies of scale that allow geoexchange to compete more effectively with conventional heating and cooling technologies.

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1.0 BACKGROUND

In Canada, vast amounts of energy are used every year to maintain comfortable temperatures in the buildings where we live, work, and play. Between 1990 and 2010, 50% of the total energy consumed in the commercial and institutional sectors was devoted to space heating and cooling.[5] In the Province of Ontario, 73% of commercial and institutional buildings are heated using natural gas and 20% using electricity.[6,7] Remaining buildings rely on other fuels such as heating oil, propane, and wood. Electricity is the predominant source of energy for space cooling, serving 83% of commercial and institutional buildings.[8]

Geoexchange is an environmentally sustainable alternative to conventional heating and cooling systems that uses the earth as a heat source and sink. It consists of three main components: (i) a ground loop, (ii) a heat pump, and (iii) a distribution system. During the heating season, heat energy is absorbed from the earth by a heat transfer fluid circulated through underground pipes, known as the ground (or groundwater) loop. The heat pump extracts this heat energy and produces a much warmer fluid that is used by the distribution system to heat the building. In the cooling season, the process is reversed and excess heat from the building is rejected to the earth. In addition to space heating and cooling, geoexchange systems may be configured to provide domestic hot water heating.

Geoexchange systems utilize natural heat from the earth and combustion is not necessary. Depending on the conventional fuel source, installation of a geoexchange system may decrease the amount of energy required for space conditioning. The use of non-renewable sources of energy in space heating and cooling applications may also be reduced. When sized appropriately, geoexchange systems perform consistently throughout the year because the temperature of the earth remains relatively constant.[9] For every unit of electricity consumed, a geoexchange system can produce 3 to 4 units of heat energy that is transferred from the earth.[10] Geoexchange systems typically require 30 to 70 percent less energy for heating and 20 to 95 percent less energy for cooling than conventional systems.[11] The Canadian Geoexchange Coalition has predicted that a 16% penetration of Ontario's residential market by

[5] Natural Resources Canada. 2013. Energy Efficiency Trends in Canada 1990 to 2010, Chapter 4. Online document: http://oee.nrcan.gc.ca/publications/statistics/trends12/trends2010chapter4.pdf (Accessed March 4, 2014)
[6] In the Province of Ontario, the principal sources of electricity are nuclear, hydroelectricity, and natural gas.
[7] Natural Resources Canada. 2008. Commercial & Institutional Consumption of Energy Survey. Summary Report. Online document: http://oee.nrcan.gc.ca/publications/statistics/cices08/pdf/cices08.pdf (Accessed April 22, 2014)
[8] Natural Resources Canada, 2008.
[9] On a seasonal basis, the coefficient of performance (COP) of a geoexchange system is higher in cooling mode than in heating mode, and COP tends to decline from the beginning to the end of a heating or cooling season.
[10] Natural Resources Canada. 2002. Commercial Earth Energy Systems: A Buyer's Guide. Online document: http://publications.gc.ca/collections/Collection/M92-251-2002E.pdf (Accessed December 12, 2013)
[11] Natural Resources Canada, 2002.

geoexchange would result in a savings of 1,485,742 tons of eCO_2, or the equivalent of removing 442,185 cars from the road.[12]

Within the last decade, Canada's geoexchange industry has rapidly expanded. Between 2005 and 2010, annual growth of the industry exceeded 40% due mainly to the federal ecoENERGY Retrofit program, financial assistance from provincial governments and utilities, as well as the development of a national training, accreditation, and certification program by the Canadian Geoexchange Coalition.[13] As of 2012, there were over 100,000 geoexchange systems installed in Canada.[14]

Despite these successes, geoexchange technology has not yet achieved mainstream status. Widespread adoption continues to be limited by the persistence of several key market barriers, including:

- High up-front costs
- High price of electricity relative to natural gas
- Lack of consumer awareness and confidence in geoexchange technology
- Lack of policymaker and regulator awareness and confidence in geoexchange technology
- Lack of geoexchange design and installation infrastructure (including standards and certifications, decision support tools, and qualified contractors and consultants)

To address these barriers, there is a clear need for improved demonstration and documentation of the performance and benefits of geoexchange systems.[15] While it is important to collect hard data on system performance and costs, firsthand information from system owners and operators concerning the benefits and challenges associated with geoexchange installations is also needed. Without clear documentation of the benefits of geoexchange it is unlikely that public awareness and confidence in the technology will improve. This information also supports the development of programs, policies, analytical tools, and market infrastructure necessary to deploy geoexchange technology on a broader scale. To help further these objectives, this study documents the benefits and challenges associated with large, urban geoexchange systems in the Greater Toronto Area through surveys of local geoexchange system owners, operators, and service providers. A companion document will provide a discussion of data and results from monitoring of installed systems.

[12] Canadian Geoexchange Coalition. 2010. Comparative Analysis of Greenhouse Gas Emissions of Various Residential Heating Systems in the Canadian Provinces. Online document: http://www.geo-exchange.ca/en/UserAttachments/article63_GES_Final_EN.pdf (Accessed February 11, 2013)

[13] Canadian Geoexchange Coalition. 2012. Canadian Geoexchange Heat Pump Industry Technology Roadmap: Final Report. Online document: http://www.geo-exchange.ca/en/UserAttachments/article84_Roadmap_FINAL_E.pdf (Accessed January 14, 2013)

[14] Canadian Geoexchange Coalition, 2012.

[15] Hughes, P.J. 2008. Geothermal (Ground-Source) Heat Pumps: Market Status, Barriers to Adoption, and Actions to Overcome Barriers. Oak Ridge National Laboratory. ORNL/TM-2008/232.

2.0 STUDY OBJECTIVES

The overall goal of this study is to share the experiences of geoexchange system owners, operators, and suppliers in developing and implementing geoexchange projects in the Greater Toronto Area. More specifically, this study:

1. Documents the key issues experienced by facility managers and site owners related to geoexchange project planning, design, implementation, system operation and maintenance, and other factors that affect owner and operator satisfaction.
2. Assesses the costs and payback of local geoexchange projects.
3. Offers insights into the major challenges and opportunities facing geoexchange service providers in the Province of Ontario.
4. Provides recommendations for addressing major challenges and improving the process of developing and implementing geoexchange projects in the Province of Ontario.

3.0 STUDY APPROACH

Data were collected through a series of oral interviews with owners, operators, and suppliers of geoexchange systems in the Greater Toronto Area. Respondents were selected based on their experience and involvement with geoexchange project management, installation and/or operation and maintenance. To obtain a broader understanding of the issues, an attempt was made to include a cross section of projects representing different:

- Scales
- Types of systems (horizontal vs. vertical loop)
- Types of build (new build vs. retrofit)
- Models of ownership

A total of 14 interviews were conducted between June and December, 2013. The interviews were approximately 45 to 90 minutes in length and were recorded to ensure perspectives and experiences were accurately transcribed. A semi-structured approach was taken in which participants were asked a common set of questions but were free to elaborate on new topics as they arose. Thirteen interviews with owners and operators of large-scale geoexchange installations were conducted with a total of 21 respondents who collectively owned 29 installed systems in the Greater Toronto Area. To complement the perspectives of system owners and operators, an interview was also conducted with two prominent suppliers of geoexchange systems (a leading driller and system designer). Interview participants and affiliated organizations are listed at the beginning of the report.

The interview guides for owners/operators and suppliers can be found in Appendix A and Appendix B, respectively. Key themes and findings from the interviews are summarized in the report. Where possible, the responses of participants are quantified.

4.0 RESEARCH FINDINGS

4.1 Overview of geoexchange projects

Respondents owned and operated a total of 29 installed geoexchange systems, with an additional 17 in development. Of the 29 installed systems, 18 were new builds and 11 were retrofits. The geoexchange systems were installed between 2006 and 2013 and were located in large-scale commercial, institutional, and multi-unit residential buildings. Projects are summarized in Table 1.

Table 4.1: Summary of geoexchange projects (installed and in development)

System owner	Number of systems	Building type/use	Build type (new/retrofit)	Installation date
Anonymous organization	4	Mid to high rise residential	3 new 1 retrofit	Unknown
City of Toronto (Toronto Police Services)	3	Police stations, police college	New	2008-2009
Earth Rangers	1	Office building/green building demonstration facility	Retrofit	2007
Greater Toronto Airports Authority	1	Fire hall	Retrofit	2011
Exhibition Place	1	Administrative building	Retrofit	2008
Kortright Centre for Conservation (TRCA)	1	Visitor's centre	Retrofit	2012
Heart Lake Conservation Area (TRCA)	1	Administrative centre/workshop	New	In development
Restoration Services (TRCA)	1	Office building with garage	New	2008
Green Life	6	Condominiums	New	Various
Downsview Park	1	Office building	Retrofit	2009
Region of Peel	4	Social housing units, office building	Retrofit	2009-2010
The Diversicare Canada Group	4	Retirement homes and long term care residences	New	Various
Oakville Hydro	17	Condominiums, town homes	New	Town homes installed in 2013, condos planned for spring 2014
Lange Transportation	1	Office building with warehouse space	Retrofit	2006

Two different models of geoexchange system ownership were encountered. In the first model, the geoexchange system owner also owns the building and pays for utilities. In cases where the building is leased or rented to tenants, it is common for utility costs to be factored into the gross rent. All tenants in the building generally pay an equal portion of these costs, regardless of usage. In the second model, termed the 'utility model', the geoexchange system owner does not own the building in which the system is installed. A developer or utility company installs the system, retains ownership, and is responsible for ongoing operation and maintenance. The utility recoups their initial investment by selling the generated energy to the building owner for a fee that is comparable to the cost of conventional heating and cooling. The geoexchange system is tied to the title of the property, and system ownership options are available to the owner if desired. In Ontario, utilities have access to low interest capital through Infrastructure Ontario loans, allowing them to finance geoexchange projects at a substantially lower cost.

4.2 Planning and feasibility

4.2.1 Rationale for geoexchange projects

Geoexchange projects helped organizations to meet sustainability objectives and demonstrate environmental leadership. The majority of organizations surveyed were striving to reduce the environmental impact of doing business. Involvement with Leadership in Energy and Environmental Design (LEED), Net Zero Energy Building Certification, or programs such as the ISO 14000 standards for environmental management was common, and geoexchange systems provided a means to achieve environmental targets. In organizations with specific mandates to advocate for sustainability, such as Conservation Authorities, geoexchange systems were seen as a way to transform their principles into action. Although geoexchange systems are widely available in Ontario today, they have not yet achieved mainstream status. By providing real world demonstrations of geoexchange systems, several respondents hoped to increase public awareness and build confidence in the technology.

> ***"It's got … to do with the optics, and the reputation, and the leadership. We espouse sustainability so we have to be prepared to put our money where our mouth is."***
> ***– Restoration Services, TRCA***

Geoexchange projects offered 'green' marketing opportunities and helped to attract an environmentally-oriented client base. As concerns about climate change and the environment mount, the demand for sustainable products and services continues to grow. Facilities ranging from conference centres to airports to condominium developments were using geoexchange to help 'green' their brand so as to gain a competitive advantage in the marketplace. Geoexchange was often regarded as a selling feature and it allowed organizations to connect with clients that have strong environmental values.

Geoexchange projects were a means to reduce long term energy costs. Although geoexchange systems have high upfront costs, operational costs may be considerably lower than those of conventional heating and cooling systems. Geoexchange systems have the potential to offer substantial cost savings in the long term[16], as the ground loop is designed to last well over 50 years. Three

[16] The Pembina Institute has estimated that payback for commercial scale geothermal systems ranges from immediate to 8 years for horizontal closed loop systems and from 2 to 10 years for vertical closed loop systems

respondents chose to install a geoexchange system in order to safeguard against future increases in the costs of non-renewable fuels. Although the price of natural gas is relatively low today, respondents generally believed that prices will increase in the future. The financial case for geoexchange becomes progressively stronger as natural gas and other fuels become more expensive.

Relative to conventional systems, geoexchange systems were believed to have superior performance and the ability to deliver improved thermal comfort. In two cases, a geoexchange retrofit was implemented because the performance of the existing conventional system was unsatisfactory. Heating and cooling were not being evenly distributed throughout the space, causing the occurrence of hot and cold spots. In an office space, this led to decreased employee productivity and satisfaction. In social housing units involving sensitive client groups, the comfort of residents was a particular concern. Respondents did their research and believed that a geoexchange system would improve thermal comfort in the building because it could easily integrate with high quality distribution systems, such radiant in-floor heating or hydronic-based forced-air multi-zoned cooling.

Geoexchange projects provided sustainable, community-based investment opportunities. The geoexchange utility model employed by Oakville Hydro was viewed as a sustainable investment opportunity and an attractive business venture because there is currently little competition in this field within Ontario. Geoexchange systems also contribute to peak load reduction, which was another major benefit identified by the utility. The utility model helps to encourage wider uptake of geoexchange technology among homeowners by removing the upfront cost barrier and reducing the perception of risk. This model has the capacity to significantly reduce fossil fuel emissions associated with housing developments.

4.2.2 The role of government incentives in promoting wider uptake of geoexchange technologies

Approximately half of the projects in this study received a government incentive of some kind, which often facilitated the decision to implement a geoexchange project. Of the nine respondents who discussed this topic, five stated that a government incentive was received. The federal government's ecoENERGY Retrofit Incentive for Buildings provided financial support for energy efficiency and renewable energy retrofit projects in commercial and institutional buildings. The program was terminated in 2012, but some post-2012 projects did receive funding from other levels of government, including:

- The City of Toronto's Better Buildings Partnership (http://bbptoronto.ca/)
- The Federation of Canadian Municipalities (FCM) (http://www.fcm.ca/home.htm)
- The Municipal Eco Challenge Fund (MECF) (http://www.mah.gov.on.ca/Page5487.aspx)

(http://www.pembina.org/reports/geoexchangefactsheet.pdf). If the geoexchange system performs consistently for the duration of its expected life (50 years), significant long term cost savings may be achieved.

Only two system owners shared the value of the incentive they received. One incentive was valued at 25% of the total project cost and the other at 10% of the hard costs of the ground loop system. Where government grants were not accessible, projects often received some type of external funding, such as:

- Infrastructure funding from the federal government
- 25 years of rent paid up front by tenant
- Increase in the net rental rate of the building
- Infrastructure Ontario loan
- Waived provincial sales tax on equipment
- Three year loan from the federal government

Incentives for commercial scale buildings offered by government and the private sector that were not mentioned by respondents include the following. Note that some of these incentives may no longer be available.

- Canada-Ontario Affordable Housing Initiative: Renewable Energy Initiative (http://www.hamilton.ca/NR/rdonlyres/6F255A94-EC7D-4C7B-B127-726322A34300/0/Communique20104Attach1.pdf)
- Building Owners & Management Association Retrofit Incentives (http://www.bomacdm.com)
- Ontario Power Authority saveONenergy Business Programs (https://saveonenergy.ca/Business.aspx)
- Electricity Retrofit Incentive Program (ERIP) (http://www.hydroone.com/MyBusiness/SaveEnergy/Pages/ERIP.aspx)
- City of Toronto Sustainable Energy Funds (http://bbptoronto.ca/financing/sustainable-energy-funds/)
- The Northern Energy Program (http://www.ec.gc.ca/financement-funding/sv-gs/search_results_e.cfm?action=details&id=355&start_row=1&all_records_details=region&region=ont)
- Enbridge Retrofit Incentives (https://www.enbridgegas.com/businesses/energy-management/commercial/retrofit-incentives.aspx#SPACE%20HEATING)

4.2.3 Perceived risks associated with geoexchange technologies

Technology risk. Respondents who had prior experience owning or operating geoexchange systems were generally quite confident in the technology. However, first time system owners and operators often had concerns prior to project implementation about how well the technology would perform and whether or not it would provide heating and cooling as effectively as a conventional heating, ventilation and air-conditioning (HVAC) system. In one case, the respondent was the first in Canada to install a geoexchange system in an office-warehouse complex and felt he lacked guidance relevant to this type of building. Although the technology risk was perceived as significant for four first time owners (Figure 1), it was not a deterrent. Strategies to mitigate this risk included: (i) installing 100% conventional backup and (ii) using a rigorous procurement process to obtain the best possible design and installation professionals. It should be noted that installing 100% conventional backup may not be a cost-effective strategy for addressing technology risk.

> *"It would be more expensive for us to reach net zero energy if we didn't have geoexchange. It's part of a system."*
> *- Green Life*

Financial risk. Given the high upfront costs of geoexchange systems, four respondents perceived substantial financial risk prior to project implementation. Respondents were uncertain whether unexpected costs would arise over the course of the project, whether operation and maintenance costs would be as low as expected, and whether the predicted payback would be achieved. To mitigate financial risk, one respondent chose to place a cap on the amount to be paid for the project, reducing the organization's exposure to financial risk. The future price of non-renewable fuels is difficult to predict, but the current consensus is that prices will rise in the long term, making geoexchange an attractive option from a risk perspective.

Environmental risk. Three respondents were concerned about the potential environmental impacts caused by deep drilling activities. Perceived risks included: (i) drilling into hazardous substances, (ii) potential rupture of the wells, and (iii) improper containment of excavated substrates. However, many of these risks were addressed during the project planning phase by conducting site assessments and developing appropriate health and safety procedures. Long term environmental risks associated with the operation of the geoexchange system, such as potential soil or groundwater contamination due to pipe leaks, were not mentioned as a major concern, in part because most systems employed nontoxic heat transfer fluids. Only one respondent reported owning direct exchange (DX) systems in which refrigerant is circulated though the ground loop. Environmental contamination risks may be mitigated when best practices for installation, operation, and decommissioning of geoexchange systems are followed. Best practices are discussed in the United States Environmental Protection Agency's *Manual on Environmental Issues Related to Geothermal Heat Pump Systems, 1997.*

Regulatory risk. Two respondents believed that understanding and acceptance of geoexchange technology was low within the regulatory sector. Geoexchange projects were perceived to be at greater risk of delay or rejection during the permitting process. In one case, the contractor had "a great deal of trouble" convincing municipal authorities that the technology would perform and that the mechanical design was sound. Building code requirements were also seen to work against geoexchange, as they have been developed based on the use of conventional heating and cooling systems. For example, it is commonly required for underground parking garages to have gas heaters. Geoexchange systems have the capability to heat parking garages without supplementary gas heat, but one respondent was not able to persuade building engineers of this fact. To provide the necessary data, the respondent undertook an in-depth temperature monitoring program to demonstrate that the temperature of the underground garage would remain within an acceptable range throughout the year.

Social risk. Social risk occurred when there was a potential lack of acceptance of geoexchange technologies by parties within or external to an organization. This risk was effectively mitigated through public education and outreach. For example, one respondent was concerned that noise due to drilling activities would disturb property owners adjacent to the site. As a preventive measure, the respondent distributed flyers and engaged in dialogue with those who had questions. This respondent also went to great lengths to build acceptance of geoexchange technology within the various internal groups and unions affected by the project. In addition to several rounds of meetings and other communications, the respondent took stakeholders on a bus tour to visit operational geoexchange systems in the local area and learn how they work.

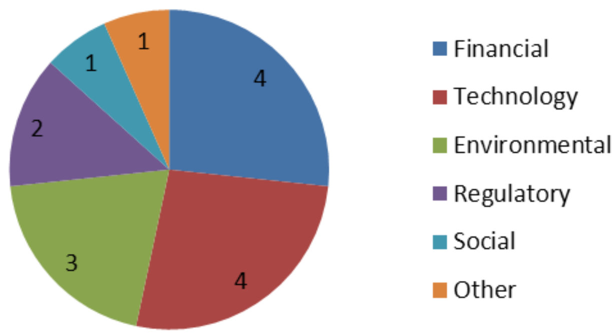

Figure 4.1: Perceived risks associated with geoexchange technology prior to project implementation (9 respondents total; in some cases multiple risks were perceived)

4.2.4 Feasibility studies

The majority of respondents considered alternatives to geoexchange during the pre-feasibility phase of the project. Of the ten respondents who discussed this topic, five stated that the choices evaluated were a geoexchange versus a conventional or high efficiency natural gas fired boiler system. In two cases, a sustainable technology project was desired, so the alternatives to geoexchange that were considered included solar PV, solar walls, wind, thermal storage, and cogeneration (sustainable energy as well as heating and cooling options were assessed). For two projects, geoexchange was the only option that was considered. Although many building owners and operators were aware of air source heat pump systems, they were not seriously considered as an alternative to geoexchange. In most instances, respondents did not have confidence that air source heat pumps would provide sufficient capacity during extreme cold events, and most were not aware of recent advances that have improved efficiencies over a wide range of outdoor temperatures,[17] or had implemented their projects prior to the advent of these improvements. In some cases, the scale of the project was perceived to be better suited to geoexchange.

In the majority of cases a feasibility study was performed, but the factors considered in these assessments varied widely. The prevalence of feasibility studies for geoexchange projects is displayed in Figure 2. Nine of thirteen respondents reported that a feasibility study was performed. However,

[17] Sustainable Technologies Evaluation Program. Performance Assessment of a Variable Capacity Air Source Heat Pump and a Horizontal Loop Coupled Geoexchange System. Online document: http://sustainabletechnologies.ca/wp/wp-content/uploads/2013/01/ASHP-GSHP-Technical-Brief.pdf (Accessed March 4, 2014)

most respondents did not have an in-depth understanding of the analysis because the feasibility study was usually conducted by an external consultant. Known factors included in feasibility assessments included:

- Business case
- Thermal conductivity testing
- Groundwater analysis
- Projected energy savings
- Balance of the building's heating and cooling loads
- Head load analysis to determine system sizing
- Ability to control heat and cooling within the building
- Economic analysis to determine the most cost effective size of the geoexchange system
    - At what point does the cost of the geoexchange system exceed the benefits it provides?
    - Is it more cost effective to size the geoexchange system to meet the entire load, or to make up a portion of the load with a conventional backup system?
- Assessment of a building's suitability to house a geoexchange system (for retrofit projects)
- Benchmarking of pre-retrofit energy consumption

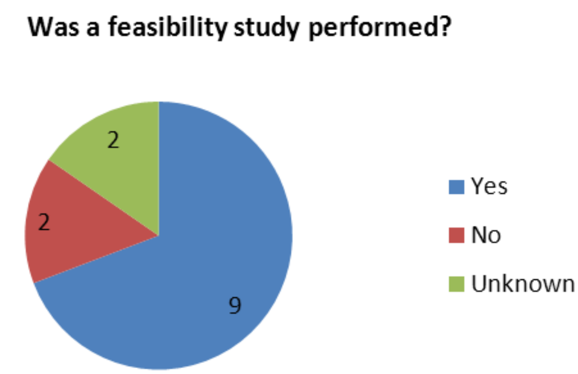

Figure 4.2: Prevalence of feasibility studies for geoexchange projects (13 respondents total)

Reported simple payback predictions ranged from 5 to 40 years. The simple payback of a project is the amount of time required for the cost savings resulting from the project to equal the initial investment. Seven respondents disclosed the simple payback of the geoexchange project. Five respondents reported paybacks between 5 and 10 years, and two reported significantly longer paybacks of 23 and 40 years (Figure 3). The expected cost savings associated with a geoexchange system depends on the cost of the conventional alternative that the system will replace. Prior to 2008, the cost of natural gas was approximately four times higher than it is today, making the payback of pre-2008 projects more favourable.

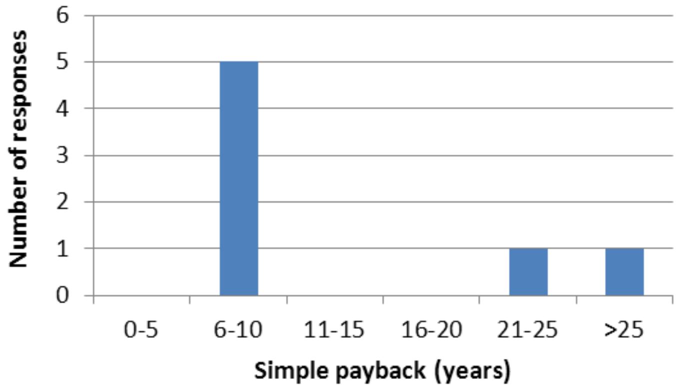

Figure 4.3: Reported simple payback of geoexchange projects in the Greater Toronto Area (7 respondents total)

Two respondents believed that simple payback analysis was not an effective tool for evaluating the feasibility of geoexchange projects. The simple payback of a project does not account for the costs associated with long term operation, maintenance, and replacement of system components. Simple payback analysis also omits the construction cost savings that may be realized in a building that contains a geoexchange system. In the experience of one respondent, buildings that use geoexchange require substantially less mechanical space than buildings that are heated and cooled using conventional HVAC systems.[18] Floor-to-ceiling heights may also be reduced. Another respondent noted that when a cooling tower is not required, the costs of installation, structural upgrades to the roof, drainage, water treatment chemicals, and sewage impulse fees are not incurred. All of these factors decrease the cost of constructing and maintaining the building and may not be apparent in system-to-system comparisons. One respondent offered the suggestion that life cycle costing be conducted to fully account for the long term benefits and cost savings associated with geoexchange systems.

Two respondents lacked confidence in the feasibility assessment process. Respondents that had extensive experience developing and implementing geoexchange projects believed that a feasibility assessment for each project was not always necessary, and chose to rely on past experience with geoexchange in similar types of buildings. For example, one respondent had overseen the installation of 4 geoexchange systems to date and since each was installed in a similar type of building, the respondent looked to past projects to determine system sizing and predict costs.

One respondent now avoids performing feasibility studies due to a negative experience on an early project. The project was completed in 2007 and in retrospect the ground loop was found to be grossly oversized. The respondent believed this occurred because the consultants working on the project lacked experience designing geoexchange systems. Since that time, the size of new systems has been reduced by nearly 50% without consequence.[19] In another case, a project partner of the respondent

[18] This claim is supported in Natural Resources Canada's Commercial Earth Energy Systems: A Buyer's Guide, 2002.
[19] Since no change in performance was observed when system size was reduced by 50%, the systems may still be oversized.

from a different organization refused to implement geoexchange in their jointly owned facility due to the negative outcome of a feasibility study. Even though the respondent had carried out several successful geoexchange projects in similar facilities and had monitoring data documenting system performance, the partner organization refused the project based on the results of the feasibility analysis conducted by an external consultant. This experience highlights the need for standard geoexchange feasibility assessment guidelines and tools that ensure assessment outcomes provide an accurate and unbiased reflection of post-project cost and performance.

4.3 Design

The majority of geoexchange systems encountered in this study were hybrid systems. In a hybrid system, geoexchange is used to meet a certain portion of a building's heating and cooling loads, with the remainder supplied by a different energy source. Beyond a certain point, the cost effectiveness of a geoexchange system may decrease disproportionately as the size of the system increases relative to the load. With hybrid systems, geoexchange system sizing has the potential to be optimized. Of the ten respondents who discussed this topic, nine reported owning or operating hybrid systems. However, seven respondents stated that the backup system was rarely or never used (refer to Section 4.5 for more details). This finding suggests that conventions regarding backup requirements in hybrid systems may not always be applicable. It is worth noting that buildings designed to high standards of energy efficiency have a much lower demand for heating and cooling, which may easily be met by a geoexchange system alone. Backup systems included:

> ***"The geothermal system is just one aspect of the operating systems within the building. Everything is connected, and I need an entire HVAC system that incorporates all of the components. … I need one design that accommodates all of the functions."***
> ***- Restoration Services, TRCA***

- Natural gas fired boilers
- Cooling tower (as a secondary option to dissipate waste heat from the heat pump)
- Generators
- Backup to the circulation pumps only
- In line element heaters
- Electric baseboard heaters

Advances in system design and drilling technology have expanded the range of sites capable of housing a geoexchange system. At one site, the existing building occupied most of the property lot, leaving little outdoor space for installation of the ground loop. The solution to this problem was to install the vertical ground loops beneath the underground parking garage in a 400 foot by 100 foot area. This drilling capability is advantageous for buildings located in dense urban areas where space constraints are a major issue. Horizontal directional drilling also provided increased flexibility for system installation, particularly in retrofit situations. This technique was used in two geoexchange retrofits where obstructions to trenching or vertical drilling existed.

It is important to consider the behavior of the building occupants when designing a geoexchange system. One respondent stated that building occupants are prone to opening windows when they are hot and turning on ovens when they are cold. Geoexchange systems can take longer than conventional HVAC systems to meet set temperatures. For instance, if the windows are kept open on a warm day and the temperature drops at night, it is more difficult for the system to recover the lost heat. Knowledge of occupant behaviour during the design phase can allow for appropriate sizing of the geoexchange system. In facilities where occupants rarely leave the building, such as long term care residences, heating and cooling must be provided around the clock. Geoexchange may be especially advantageous in these scenarios due to the potentially lower costs of heating and cooling.

Decentralized systems allowed for greater flexibility in the delivery of heating and cooling. Decentralized geoexchange systems have a heat pump in each unit, providing individualized space conditioning. Decentralized systems are especially beneficial in buildings that have variable loads due to their ability to heat and cool simultaneously. For example, in the winter a decentralized system can deliver cooling to rooms on the south side of a building while heating the rooms on the north side. One respondent commented that to have the capability to heat and cool at any time of the year using a conventional HVAC system, a four pipe fan coil system would be required. The respondent stated that the cost of this system is comparable to the cost of a two pipe decentralized geoexchange system (including the cost of the ground loop). The four pipe fan coil system is typically less efficient because a large compressor must be used to satisfy small loads. It follows that the feasibility of geoexchange systems may increase in buildings that require customized heating and cooling at the unit level. Two respondents stated that they owned or operated one or more decentralized geoexchange systems. These were located in multi-unit residential complexes.

An integrated design approach optimized the efficiency of the geoexchange system and obtained maximum benefits. Eleven respondents discussed the importance of using a holistic approach to building design. Building systems do not work in isolation and should be designed in an integrated manner in order to reduce heating and cooling demand as well as improve the efficiency of the geoexchange system. Respondents identified several aspects of a building that can help to optimize the performance of geoexchange systems, including:

- A tight building envelope (appropriate insulation, double or triple glazed windows, etc.)
- A distribution system that integrates well with geoexchange
- Heat recovery ventilation
- Demand-controlled ventilation
- Use of excess heat for snow melting or water heating
- Integration of solar thermal and geoexchange
- Earth tube technology
- Building orientation and zoning to optimize solar gains and passive cooling

- Proper integration of the geoexchange system with backup heating and/or cooling
- Use of a desuperheater for domestic hot water heating

It is important to achieve a balance between the building's heating and cooling loads. When the heating and cooling loads in buildings are balanced, approximately the same amount of heat that is extracted from the ground during the heating season is replaced during the cooling season. Proper balancing of heat storage and heat removal helps to maintain the long term performance of the geoexchange system. In Canada, most buildings are heating dominant but cooling dominance may occur in some commercial and institutional buildings. Where imbalances exist, innovative design and engineering can be used to better balance a building's heating and cooling loads. Seven respondents stated that consideration was given to the balance of the loads during the design phase, but they were usually not aware of the actual steps taken. Strategies used to ensure the loads remained balanced included: (i) slightly oversizing the system to obtain extra storage capacity and (ii) using excess heat for domestic hot water or snow melting applications.

"… What we thought initially was we would put this isolated geothermal system in, and then through maybe a heat exchanger we would just slap it together. … There was a cascading effect [which caused] modification to the existing system that we didn't anticipate."
- Greater Toronto Airports Authority

The design process for retrofit projects was more complex because new components needed to be integrated with existing systems. Geoexchange systems perform best when installed in an energy efficient building. Respondents indicated that geoexchange retrofits were commonly performed in concert with other building upgrades in order to obtain maximum benefit from the system. Several characteristics of an existing building that allow it to better accommodate a geoexchange retrofit were specified. These included:

- A radiant, closed loop distribution system
- Availability of heat pumps as part of the existing heating and cooling system
- A large thermal mass, which acts as a buffer against the effects of extreme outdoor temperatures
- Adequate space for on-site drilling that is unobstructed by pre-existing communication lines, gas lines, or other cabling
- An accessible mechanical room
- Building controls infrastructure that can be integrated effectively with the geoexchange system
- Long remaining life expectancy of the building – will it still exist in 50 years?
- Usage that will remain unchanged – for example, converting a building from office space to another commercial use can significantly alter its load profile
- An ownership model that allows for installation costs to be offset to building occupants – for example, if the owner charges an energy delivery fee to tenants

- Scheduled replacement of the conventional HVAC system – where budget is already set aside for conventional HVAC replacement, these funds can be allocated to the geoexchange installation
- Planned upgrades to other aspects of the building – one respondent performed the geoexchange retrofit in concert with a parking lot expansion
- The needs of building occupants – occupants that require specific temperature conditions will benefit from the even heating and cooling provided by geoexchange systems, which have the potential to be customized at the individual unit level
- Support of tenants and other stakeholders

4.4 Project implementation

4.4.1 Procurement of qualified contractors

Prequalification of consultants and contractors during procurement helped to ensure the best possible team was retained. The procurement process was often a challenge for respondents that lacked previous experience with geoexchange systems. Respondents who had many years of experience in the industry often commented that in the early years there were only a small number of suitably qualified companies to choose from and, therefore, it was a challenge to procure qualified professionals. In recent years, the opposite problem was encountered and first time owners were intimidated by the volume of choice that existed. Prequalification of bidders was an important step in narrowing the choice and ensuring that only companies with the desired level of expertise were invited to bid. Since a smaller number of bids were submitted, this also saved time and effort in selecting the successful bidder.

"[For] building retrofits, I'm a bit pickier. I make sure [the contractors and consultants] have done retrofits previously with significant budgets because retrofits are tricky. You need someone that's really qualified that can do these kinds of jobs. If you run into issues, you need those resolved quickly."
-Kortright Retrofit, TRCA

Four respondents reported using a formal prequalification process, which could include an evaluation of a company's previous experience with geoexchange projects, technical knowledge, financial capacity, and references. In addition, two of these respondents held a mandatory prequalification meeting where they explained the project and the responsibilities of the contractor in detail. In four cases, respondents did not use a formal prequalification process, but simply checked the references of potential companies or relied on word of mouth from geoexchange industry contacts.

It was beneficial to evaluate bids using multiple criteria. Since geoexchange projects require specialized technical knowledge, many respondents believed that evaluating bids based on pricing alone was not an effective strategy. While awarding a tender to the lowest bid was appropriate in some cases, it was common for respondents to evaluate bids based on several weighted selection criteria. In highly technical projects, pricing was weighted as low as 25% of the total score.

Spending time up front to create detailed tender documents facilitated procurement and helped to keep project costs down. One respondent stressed the importance of including as much information as possible in the request for tender and project specifications. For example, if the building will be operational during system installation, contractors may be required to accommodate daily facility operations in their schedule of work. If this is not identified up front, the organization may be charged with 'extras.' This may increase the cost of the project and potentially cause delays.

Respondents generally had a high level of satisfaction with the performance of contractors and consultants. Of the eleven respondents who discussed this topic, ten reported that they were satisfied with contractor performance. Overall, respondents were very pleased with the level of service and quality of workmanship delivered by the project team. In two cases, respondents implementing their first geoexchange project had negative experiences with unqualified contractors. In spite of initial challenges, many respondents now have a network of trusted contractors and consultants that they continue to work with on geoexchange projects. However, looking to the future, one respondent believed that the current size of Ontario's geoexchange industry may not be sufficient to meet new demand.

4.4.2 Contract structure and coordination

Two major types of contract structures were encountered in this study: the design-build and the design-bid-build. In a design-build, a single party is contracted for all design and construction services associated with the project. The contract holder is responsible for all subcontracting activities. The contract holder in a design-build scenario can be either the supply and installation contractor or a design professional such as an architect or engineer. In the design-bid-build model, design and construction services are contracted to separate parties and the project is managed and co-ordinated by the contracting organization. Subcontracting occurs through one of the major contract holders. The design-build model was slightly more prevalent (Figure 4).

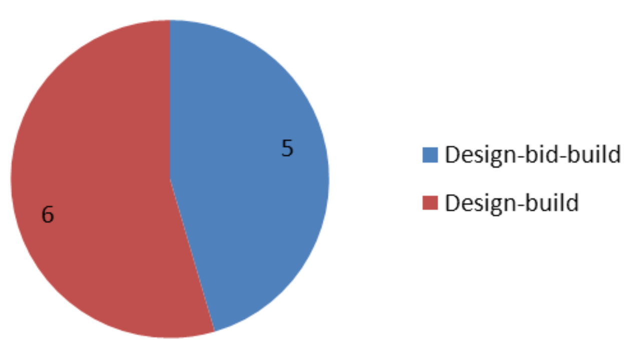

Figure 4.4: Contract structure of geoexchange projects (11 respondents total)

The design-build model placed less responsibility on the system owner and reduced the time spent on project management. One of the major advantages offered by the design-build model was that there was a single point of contact for the client organization. This facilitated communication between the owner and the project team. Another benefit of the design-build was that the primary contract holder was responsible for coordination of all subcontractors, which significantly reduced the time spent on project management by the client. In this model, decision-making was generally more efficient because there was ultimately one party that makes the final decision. The design-build was believed to be a more streamlined model with a faster project completion time than the design-bid-build approach. However, one respondent noted that since only one party holds authority, errors are more likely to go undetected. Design-build contracts can also be more expensive because more of the project management responsibilities are taken on by the contract holder. However, one respondent believed that the design-build model can be more cost effective when a pre-engineered building is used.

The design-bid-build approach allowed the system owner to play a larger role in project management and implementation. The design-bid-build model was preferable to respondents that wanted to be closely involved in the implementation of the geoexchange project. This model often required larger owner time commitments for project management and coordination. Decision-making and conflict resolution could also present a challenge because there was not a single authority on the project team. In some instances, responsibility for a problem was deflected between different contract holders. However, one respondent favoured the design-bid-build approach because it allowed for different parties to assume authority at different times, depending on the situation. Parties with different areas of expertise (for example, ground loop and building loop designers) could collaborate in a more balanced way to ensure continuity in the installed system.

4.4.3 Commissioning

Geoexchange system commissioning helped to identify and resolve issues that may otherwise have been overlooked. The commissioning process verifies that the geoexchange system has been properly and safely installed. This helps to ensure optimal system performance in the long term. Eleven of thirteen respondents stated that commissioning was performed following system installation. The parties responsible for commissioning included: (i) the supply and installation contractor, (ii) the system designer, (iii) the heat pump manufacturer, (iv) a building automation professional, (v) a third party commissioning agent, or (vi) some combination of these. System owners and operators did not typically have an in-depth involvement in the commissioning process. The following issues were detected during system commissioning:

- Improper interfacing of the geoexchange system with the BAS
- BAS malfunctions (programming, software glitches, hardware, wiring)
- Incorrect installation of temperature sensors
- Insufficient metering to obtain desired data
- Insufficient purging of air in the system which caused the pumps to cavitate and burn out
- Frequently clogged filters due to construction on a neighbouring lot

- Excessive heat loss through the building's roof, indicating the need for a new insulated roof

4.4.4 Time commitments over the course of project implementation

Estimates of the time and resource commitments required of respondents during project implementation varied widely. Respondents reported spending between 5 minutes a day and 100% of their time on the geoexchange project. Time and resource commitments were dependent on several factors, including:

- **The type of build.** Unexpected delays often arose during geoexchange retrofits due to the difficulties associated with integrating a geoexchange system into an existing building. Retrofit projects also involved increased project coordination efforts if the building remained operational during system installation.
- **The contract structure.** In design-build projects, the majority of project management responsibilities are typically offloaded to the primary contract holder, reducing the time commitments required of the client. Estimates of internal time spent on project management ranged from less than 5 minutes per day to 20% of the respondent's time for design-builds and from 50% to 100% for design-bid-build projects.
- **The phase of the project.** The planning phase often required less involvement from respondents, while the procurement and construction phases were more time and resource intensive.
- **The role of the respondent.** Site owners and facility managers typically have different roles in project implementation. For example, owners likely had greater involvement in the project during the feasibility phase, while building operators played a larger role during construction and ongoing monitoring and maintenance.

"… We had meetings, we had designs done, we had the feasibility study done, the energy loads analysis, we showed pictures, we educated, we did a bus tour. It sounds like a big deal, but at the end of the day what was on trial here wasn't just that we wanted to have geoexchange on three group homes, it was, does geoexchange really work and so forth. So those were the challenges around stakeholder buy-in and capacity building and training."
- Region of Peel

4.4.5 Monitoring

Monitoring approach and intensity were variable. Monitoring and verification of installed geoexchange systems is essential for assessing technical and financial performance. Real world performance data inform research and development and help to increase public confidence in geoexchange technologies. For geoexchange suppliers, monitoring data can improve sales by showcasing system performance and greenhouse gas emissions reductions potential. Ten of thirteen respondents stated that the geoexchange system is being monitored (Figure 5), but approaches to monitoring were varied. Parameters being tracked included:

- Ambient outdoor and/or indoor temperature
- Supply from air handling unit
- Distribution and/or ground loop side supply and return fluid temperatures
- Fluid flow rate on the distribution and/or ground-loop side of the heat pump
- Building electricity and/or gas consumption (in one case energy consumption was normalized for weather and compared to a reference building)
- Building water consumption
- Heat pump compressor unit and circulator pump power consumption

Monitoring data were evaluated to determine:

- Cost savings
- Coefficient of performance (COP) / energy efficiency ratio (EER)
- Greenhouse gas emissions reductions

In two cases, a post-commissioning monitoring program was implemented to evaluate the balance of the building's heating and cooling loads. However, in-depth monitoring efforts lasted just one year, which may not be sufficient to assess the long term balance of the geoexchange system.

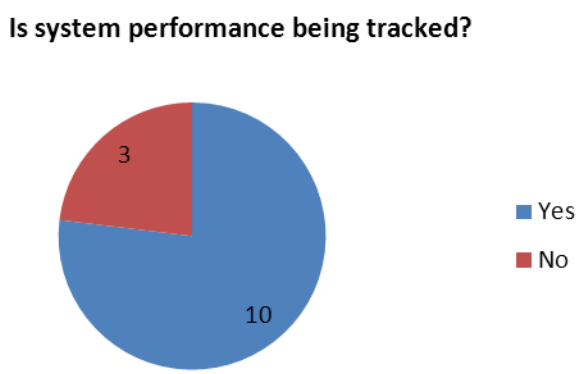

Figure 4.5: Monitoring of geoexchange systems (13 respondents total)

Where time and budget were limited, monitoring of the geoexchange system was typically overlooked. In-depth performance tracking of geoexchange systems can require a substantial effort. Three respondents simply did not have extra time to devote to system monitoring or the financial resources to contract these services externally. Performance of the geoexchange system was evaluated based only on the thermal comfort of the building. In three cases, detailed performance data were being collected but analysis of these data was not a priority. In-depth performance data can be useful for both performance assessment and as a troubleshooting tool. If the geoexchange system appeared to be functioning well from a thermal comfort perspective, perhaps respondents did not believe it was necessary to evaluate the collected data.

In-depth monitoring programs helped to detect problems early, saving time and money in the long run. Several respondents recognized the value of a comprehensive monitoring program that went beyond tracking basic parameters such as ground loop temperatures. Two respondents chose to hire external consultants to remotely monitor the system and provide regular reporting on system performance. These programs were crucial for identifying and resolving issues efficiently. For example, when a heat pump malfunctioned in an office-warehouse complex, the system owner received a phone call from the monitoring firm notifying them of the issue and the expected drop in building temperatures. The monitoring firm also offered to dispatch a service technician immediately.

Evaluation of building energy consumption was a valuable supplement to the monitoring regime. Abnormalities in natural gas or electricity consumption of the building can be caused directly or indirectly by a problem with the geoexchange system. One respondent found that natural gas consumption in one of their buildings was unusually high relative to other buildings of similar size and use (all had geoexchange systems). Upon investigation, the cause of the issue was linked to Heat Recovery Ventilators (HRVs) operating below their optimal efficiency, combined with a discharge air temperature that was too high. When the problem is resolved the organization expects to save nearly $30,000 per year in natural gas costs. This finding underscores the need to benchmark collected data against expected performance to facilitate identification of anomalies and/or gradual changes in performance over time.

> *"One of the problems we had was… the 40 year old roof…as fast as the heat was being generated, it went through the roof just as fast… the first good chance in the spring I had, I put on a new insulated roof. But it was way overdue, and that made all the difference in the world. The second year, [the geoexchange system]worked marvelously in the winter time."*
> *- Lange Transportation*

A lack of reliable baseline data often impeded assessments of energy and cost savings associated with geoexchange retrofits. In most cases, monitoring data characterizing the pre-retrofit period were insufficient to provide an accurate benchmark of building energy use. Only one respondent possessed a reliable record of both pre- and post-retrofit building electricity and natural gas consumption. Where a base case does exist, it may be difficult to isolate the energy or cost savings resulting from the geoexchange retrofit. This is because retrofits are usually accompanied by other upgrades to the building, such as improvements to building insulation, windows, and lighting.

4.4.6 Operation and maintenance

In nearly all cases, operation and maintenance required the same or less effort for geoexchange systems than for conventional HVAC systems. Since geoexchange systems are located primarily indoors and underground, they are not exposed to the elements and are at less risk of vandalism. This reduces maintenance requirements. One respondent commented that the heat pumps were installed in accessible locations, facilitating maintenance. Only one of thirteen respondents stated that maintenance requirements were higher for the geoexchange system than for a conventional HVAC system. This was due to a design issue that was causing ongoing problems when the system was in heating mode. The respondent estimated that had the system been functioning properly, maintenance would have been equivalent to a conventional heating and cooling system.

The time spent on routine maintenance ranged from two hours quarterly to six hours per month. Routine maintenance tasks performed by respondents included:

- Changing filters
- Inspection of circulating pumps (for leaks, cavitation, bearing issues, proper operation of BFDs)
- Water quality inspection
- Maintaining an adequate concentration of antifreeze and corrosion inhibitors
- Inspection of drains
- Inspection for fluid leaks

Routine maintenance was usually performed internally. It was common for building operators to perform routine maintenance of the geoexchange system because this task is relatively simple. Only two organizations chose to procure an external maintenance contract for the geoexchange system or for all of the mechanical systems within the building. Although external service contracts were likely more expensive, they were a beneficial arrangement for organizations lacking internal staff resources. One respondent entered into a maintenance contract with a company that installed the building mechanical systems. The installer developed a maintenance schedule and subcontracted out the maintenance of the ground loop when necessary.

Maintenance programs were improved with the use of a well-designed building automation system. One respondent commented that the building automation system (BAS) greatly facilitated maintenance by allowing for trending on building alarms. Analysis of the building alarms on a daily or weekly basis helped to indicate problems and resolve them in a timely manner. To prevent 'nuisance alarms', it is important to ensure the BAS is programmed to suit the needs of the facility. In one isolated case, improper programing of the BAS impaired the functioning of the geoexchange system. Faulty code in the BAS software caused the geoexchange system to shut down on several occasions during the first 3 years of operation. Ongoing troubleshooting by the manufacturer of the BAS has largely resolved this problem.

Education and training of maintenance personnel was a challenge in the face of high staff turnover. Geoexchange technology was often unfamiliar to building maintenance personnel. Although staff typically received operation and maintenance training when the geoexchange system was installed, three respondents stated that this knowledge was not being retained because turnover was high and regular training sessions were not being held. One respondent made it a priority to increase confidence in geoexchange technologies among building operators by engaging them in the maintenance process. Every six months, this respondent brings together facility managers, engineers, heat pump manufacturers, and service contractors to discuss operation and maintenance of geoexchange systems and address any ongoing problems.

In some cases, it was difficult to maintain desired building temperatures during the shoulder seasons. During the shoulder seasons (spring and fall), outdoor air temperatures can fluctuate more widely than during the summer or winter. It is not uncommon to experience a cold day after a week of high temperatures, and vice versa. Three respondents experienced problems maintaining building temperatures during the shoulder seasons because the geoexchange system was not able to adapt quickly to outdoor temperature variation or switch seamlessly between heating and cooling modes. In systems that use a buffer tank, the entire tank volume must be heated or cooled prior to switching between heating and cooling modes. This may explain the slow transitions experienced by some respondents. In any case, this problem was generally perceived to be a minor inconvenience and did not significantly impact the satisfaction of respondents with overall system performance. Buildings with large thermal mass were better able to cope with temperature fluctuations during the shoulder seasons. One respondent expected that the shoulder seasons will become less of a challenge with the advent of the next generation of building controls, which will be both adaptive and predictive (i.e. able to make decisions based on both past and forecasted temperatures).

Geoexchange systems were reported to have a longer life cycle than conventional HVAC systems. The ground loop was generally believed to have a life cycle of approximately 50 years. Heat pumps and circulation pumps were reported to last up to 25 and 30 years, respectively. These figures coincide roughly with the United States Department of Energy's estimates for the average life expectancy of geoexchange systems, which were 20+ years for the ground source heat pump and 25 to 50 years for the ground loop.[20]

4.4.7 Strategies for optimizing system performance

Operating the geoexchange system in free exchange mode substantially increased system efficiency during the summer. During free-exchange, the fluid circulating through the ground loop of a geoexchange system is directly circulated through the building load (or interfaced with the building via a heat exchanger) and the heat pump is not used. One respondent achieved considerable increases in system efficiency by using free exchange during the cooling season, reporting coefficients of performance (COPs) in excess of 200. This is much higher than typical COPs for closed loop geoexchange systems, which range between 3.1 and 5.9 in cooling mode.[21] It is reasonable to expect drastic increases in COP with the use of free exchange. When using free exchange during the cooling season, the heat pump is only turned on to dehumidify the building, or to boost cooling performance during very hot days. This mode of operation can transfer large amounts of heat energy while consuming only the small amount of power that is required to run the circulator pumps, resulting in very large COPs. Since dehumidification requires that the heat pump be turned on, the humidity level in the building is kept at close to 70%, which is higher than in most office buildings. To compensate for the

[20] United States Department of Energy. 2011. Guide to Geothermal Heat Pumps. Online document: http://energy.gov/sites/prod/files/guide_to_geothermal_heat_pumps.pdf (Accessed April 22, 2014)
[21] In Natural Resources Canada's Commercial Earth Energy Systems: A Buyer's Guide, 2002, the energy efficiency ratio (EER) of closed loop geoexchange systems is rated between 10.5 and 20. These values were converted to COP using the following conversion factor: EER = 3.41 BTU/hr/watt x COP.

elevated humidity, and achieve the desired level of thermal comfort, the building is maintained at a lower temperature. This strategy is effective because the building has a large thermal mass, making it easier to maintain constant indoor temperatures. In this case, the building uses a radiant distribution system for both heating and cooling in which water is circulated through concrete slabs.

Subsurface irrigation of the borefield may result in improved heat transfer. As the water content of a soil increases, so does its thermal conductivity. As water replaces air in the void spaces between soil particles, the heat transfer properties of the soil increase because the thermal conductivity of water is approximately 20 times greater than air. One respondent operating a horizontal loop system irrigated the borefield with non-potable water for 30 minutes a day each fall in an attempt to enhance system performance over the heating season. This procedure may also increase heat rejection to the borefield during the cooling season. The respondent claimed that heat transfer was improved by implementing this practice, but supporting evidence has not been provided. It is not clear whether any gains in heat transfer would compensate for the environmental and financial impacts associated with using large quantities of water in this way.

4.5 Level of satisfaction

Building occupants were highly satisfied with the performance of geoexchange systems. The satisfaction of building occupants is presented in Figure 6. Only one respondent received complaints that the space was too cold during the heating season, and this was at a building where the system was not functioning properly in heating mode due to a design issue. Geoexchange systems offered building occupants several advantages over conventional heating and cooling systems, including:

"…, the reason we jumped in feet first with [geoexchange] is that …we are the kind of operation that is 24 hours a day, 7 days a week, 365 days of the year. So you can't just ratchet back all of the utilities or bring them up when people are in or out. Our residents are in there all day, every single day. So we have to be careful of how we're using our gas and electricity. And geoexchange just seems to be a no brainer for us because we're getting the benefit of it, all day every day." – The Diversicare Canada Group

- **Increased user control.** Decentralized geoexchange systems allowed for control of temperature and humidity at the individual unit level. In a zoned system, the respondent permitted employees to set the thermostat in each zone in accordance with their preferences because the geoexchange system was claimed to be relatively inexpensive to operate.[22]
- **Expanded service within the building.** In an office-warehouse complex, the warehouse portion of the building had not been air conditioned due to the expense of doing so using a conventional HVAC system. When the geoexchange system was installed, the warehouse received air conditioning at a relatively low cost, greatly increasing the satisfaction of employees working in the space.

[22] An independent financial analysis is beyond the scope of this study. This is a respondent claim.

- **Reduction in cost of living.** One respondent claimed that in condominiums served by geoexchange and certified as Net Zero Energy Buildings, energy consumption was reduced by up to 75% relative to conventional buildings. This respondent also claimed that electricity bills[23] and condominium fees were substantially lower than in comparable facilities and that the gas bill was eliminated altogether, indicating that geoexchange was used to provide both space heating and domestic hot water.
- **Reduced costs for winter walkway maintenance.** In cooling dominant buildings, surplus heat must be utilized in order to maintain a balance between heat extraction from and rejection to the ground. In one building, the front walkway was heated to reduce snow removal and salting. The respondent identified reduced corrosion of building infrastructure from winter road salts and decreased winter maintenance costs as significant additional advantages of this approach.

Indirect benefits of geoexchange projects included:

- **Improved thermal comfort.** Geoexchange systems were reported to provide evenly distributed heating and cooling, eliminating the existence of hot and cold spots. In two retrofit scenarios the need for supplementary space conditioning with baseboard heaters or portable air conditioners was eliminated. However, it should be noted that thermal comfort in a building is primarily determined by the distribution system. Upgrades to a building's distribution system were often performed concurrently with geoexchange retrofits, and so improvements in thermal comfort are likely a result of these upgrades. Zoned distribution systems (such as zoned forced-air or radiant in-floor systems) are associated with improved thermal comfort and can work effectively with geoexchange as well as certain conventional systems.
- **Improved air quality.** One respondent stated that upgrades to the building's ventilation system that occurred with the geoexchange retrofit increased the comfort of occupants and eliminated complaints of dustiness. In another case, a tenant suffering frequently from allergic reactions noticed a significant improvement in symptoms following the retrofit project, which included distribution system upgrades and installation of an HRV.

"… One tenant had allergic reactions before the [geoexchange] retrofit and was always sneezing. After – no sneezing. No hot spots or cold spots. … It wasn't just the implementation of the technology, it was the fact that we're reaching out to make a better place for people who use the services of Peel."
- Region of Peel

[23] Relative to buildings served by natural gas, the use of geoexchange would increase the electricity bill because an electric heating source has replaced natural gas. However, overall energy consumption for heating and cooling may decrease. The decreased electricity consumption that was observed in the Net Zero Energy condominiums was likely a result of the energy efficiency measures implemented and cannot be directly attributed to the geoexchange system.

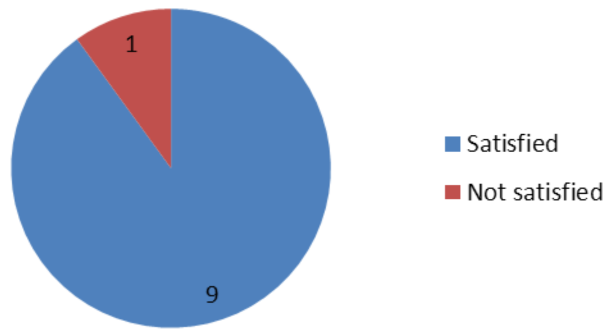

Figure 4.6: Satisfaction of building occupants with the performance of the geoexchange system (10 respondents total)

Building owners and operators demonstrated a strong willingness to implement geoexchange technologies in other buildings. Respondents were generally very satisfied with both the financial and technical performance of geoexchange systems. Of the eleven respondents who discussed this topic, five stated they would install geoexchange in other buildings and six gave a qualified yes, depending on the circumstances (Figure 7). Factors that affected a respondent's willingness to implement future geoexchange projects included:

- The type of build (two respondents that had completed geoexchange retrofits were only willing to install geoexchange again in new buildings)
- The cost of natural gas and electricity
- The projected business case
- Budget availability
- Availability of incentives
- Internal programs and policies relating to organizational sustainability
- Involvement in certification programs such as Net Zero Energy Building
- The balance of the facility's heating and cooling loads
- Land availability

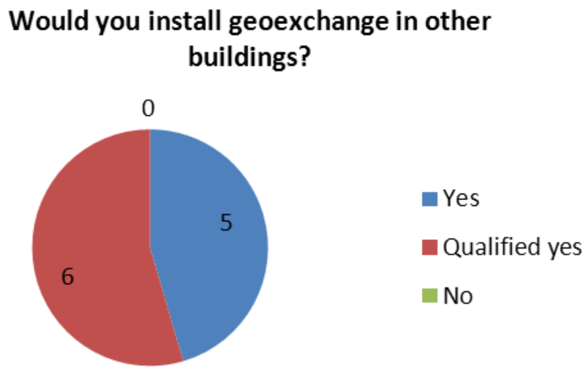

Figure 4.7: Willingness of respondents to install geoexchange in other buildings (11 respondents total)

In most cases, the geoexchange system was able to satisfy more than 90% of heating and cooling demand. As discussed in Section 4.3, the majority of the geoexchange installations in this study were hybrid systems, containing both geoexchange and a conventional backup system. The use of backup systems is presented in Figure 8. Of the eight respondents who answered this question, four reported that the geoexchange system was able to meet 100% of the building's heating and cooling loads. One respondent stated that 90% of the loads were satisfied by the geoexchange system. Two respondents stated that 100% of the load was met by the geoexchange system for a certain portion of the year, but that backup was required during the peak heating or cooling season.

"[Geoexchange] is clean, it's easy to maintain, and it gives a better quality of heating and cooling than traditional duct systems or hot water systems."
- Toronto Police Services

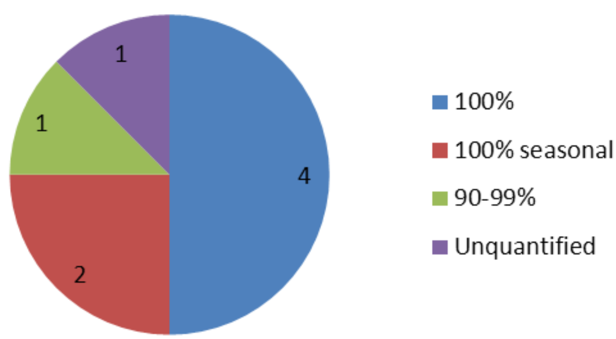

Figure 4.8: Proportion of annual heating and cooling load met by geoexchange systems (8 respondents total)

4.6 Costs and financing

The total cost of geoexchange projects varied widely. Ten of thirteen respondents shared information about the cost of the geoexchange system. Costs were reported in different ways, making comparisons between systems difficult. Figure 9 presents the cost of geoexchange projects in relation to expectations. The number of projects that were completed on or under budget was equal to the number that went over budget. Two respondents reported the cost of the project in relation to the cost of the proposed conventional alternative. The cost premium for geoexchange systems ranged from 20% to nearly 300%. More quantitative data are necessary to accurately assess project costs and enable comparisons among systems. Respondents mentioned several factors that affected project costs, including:

- **Type of build.** Geoexchange retrofit projects typically involved unanticipated costs, as modifications to the existing building were often more extensive than initially expected.
- **Loop orientation.** Moving from a horizontal to a vertical loop geoexchange system increased costs considerably (however, increases in system performance may have offset some of the added expense).
- **Contractor workload.** If contractor workload was heavy in a given year, they tended to bid higher on new projects because they did not need the work.
- **Contract structure.** Design build contracts could cost more up front, but offered efficiencies and savings in internal staff time and resources over the course of project implementation.

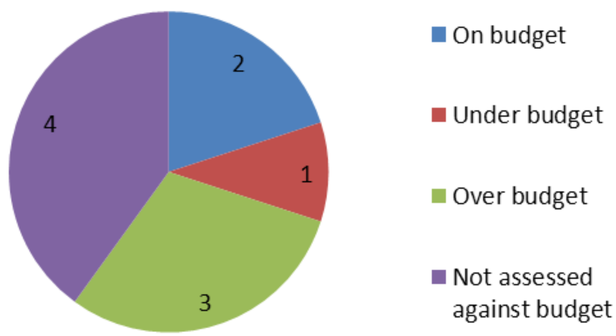

Figure 4.9: Costs of geoexchange installations relative to expectations (10 respondents total)

Maintenance costs for geoexchange systems were consistently the same or lower than for conventional HVAC systems. The operation and maintenance costs of geoexchange systems relative to conventional HVAC systems are presented in Figure 10. Of the eight respondents who discussed this topic, none reported that geoexchange maintenance costs exceeded maintenance costs for a conventional system. The majority of maintenance costs were related to the labour required to change filters and perform other routine maintenance duties. In some cases, it was difficult for respondents to evaluate geoexchange maintenance costs because they were included within the general operating costs of the building.

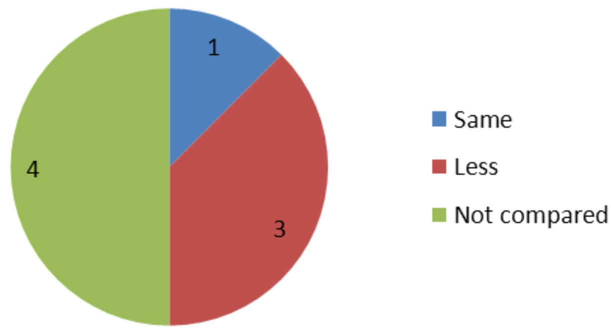

Figure 4.10: Operation and maintenance costs of geoexchange systems compared to conventional HVAC systems (8 respondents total)

Knowledge sharing initiatives attracted funding. One organization was repeatedly awarded grants and low interest loans for renewable energy projects because of its commitment to knowledge sharing. The organization has implemented several trial projects involving different green technologies. Performance monitoring and communication of research outcomes are essential to each project. This model was attractive to grant programs and investors.

In one instance, the geoexchange project was financed through donations of equipment and capital. One respondent continues to receive nearly all of the green technologies installed in the building by donation. This arrangement has proven to be mutually beneficial to both the recipient organization and its various donors. The recipient gains access to cutting edge sustainable technologies that may not otherwise have been affordable, and donors often receive tax deductions for charitable donations. Donations also have marketing value, helping to improve the corporate image of the donor and demonstrate a commitment to sustainability. Large companies often have sustainability or corporate outreach divisions with a budget for donations.

4.7 Geoexchange industry perspectives

4.7.1 Development and current status of Ontario's geoexchange industry

In the early 1980s through the early 1990s, Ontario's geoexchange industry experienced burgeoning growth. The growth of Ontario's geoexchange industry beginning in the 1980s can largely be attributed to the grant program implemented by Ontario Hydro. The grant was initially valued at $250 per ton[24] of installed equipment. The respondents estimated this was equivalent to approximately one third of the cost of the heat pump equipment or one tenth of total project costs. During this era, uptake of geoexchange technologies was quite large within the education sector. Geoexchange systems were appealing to school boards because they could be configured to provide a heat pump in each classroom, allowing for customized temperature and humidity based on the preferences of students and the conditions in each room.

[24] A ton is a unit of heating power equivalent to 12,000 British thermal units (Btu) per hour.

By the end of 1992, the Ontario Hydro grant had increased to $600 per ton. According to the two respondents, this was a mixed blessing. Although the grant caused a large spike in activity, the industry was still young and was not equipped with the design and installation infrastructure to cope with the increased demand. Geoexchange was seen as an attractive business opportunity, and several new companies entered the market. However, the respondents believed that the knowledge and competency of several of these new entrants were questionable. It was estimated that at this point, Ontario's geoexchange industry was growing at rate of approximately 30% a year, but in a rather disorganized manner.

> *"The reality in this industry is [that] it's had all kinds of ups and downs. There's a nice spurt of energy, new guys on the scene, new buildings, and then all of a sudden you see a drop. And it drops because there's a number of people that entered at the peak and [mistakes were made] and then all of a sudden word spread. Bad news travels at the speed of light. Good news, you never hear. Systems that work well, you never hear."*
> *- Robert Mancini*

Ontario's geoexchange industry entered a period of decline beginning in the early 1990s that lasted until the mid-2000s. A major cause of the industry decline identified by the respondents was the termination of the Ontario Hydro grant in 1993. Without the incentive program, demand slowed, and several suppliers exited the industry. The respondents chose to remain in the geoexchange business, but the low demand in Ontario caused them to seek work in the United States.

The decline of the industry during this period can also be attributed to the negative publicity surrounding a series of faulty geoexchange installations. For example, a number of projects were supplied with defective piping from a certain manufacturer. The pipe was not certified to any standard and after it had been installed it cracked and began leaking. The general public and the media failed to recognize that the problem stemmed from the defective piping and not the geoexchange system itself. Good news stories about geoexchange were not being told, and the negative press dealt a near-crippling blow to the industry.

Revival of Ontario's geoexchange industry began in the mid-2000s and continues today. Incentive programs such as the federal ecoENERGY Retrofit were introduced in the mid-2000s, which rejuvenated the industry. The respondents believed that incentives are the main drivers of the residential geoexchange industry, but that the commercial sector is driven primarily by the green building movement and certification programs such as LEED. Natural gas prices were rising quite sharply until 2008, which also provided impetus for the wider adoption of geoexchange technologies. The respondents estimated that the industry is now growing at a rate of between 10 and 20% per year. However, periods of low growth continue to occur, straining the entire industry. This unsteady growth pattern is an indicator that the geoexchange industry is still in the early phases of development. Future outlook of the respondents was positive.

Assessments of industry growth are hampered by a lack of information about installed systems. Records concerning the type and size of geoexchange installations in Ontario are not readily accessible. There are currently no requirements for installers or system owners to provide documentation on installed systems to the provincial government or other central agency. Information on heat pump sales is also difficult to obtain because this information is guarded by heat pump manufacturers to maintain their competitive edge.

With regard to drilling, some data are now being collected. Under the recently enacted *Ontario Regulation 98/12 (Ground Source Heat Pumps)*, anyone constructing or altering a vertical closed loop geoexchange system that is more than 5 metres deep is required to obtain an Environmental Compliance Approval (ECA) from the Ministry of the Environment. In applying for an ECA, drilling companies must submit information concerning the location and depth of the boreholes but not information about the type or size of the installed geoexchange system. When system installation is complete, detailed records are filed with the owner, not with the government. To this day, the industry lacks an effective mechanism for collecting and sharing information about geoexchange installations.

The overall cost of geoexchange systems has remained relatively stable despite reductions in drilling costs. The respondents estimated that drilling costs have decreased from $22 a foot to $15 a foot in recent years. However, savings in drilling costs are balanced by rising costs of equipment, which the respondents claimed have increased significantly. One respondent believed that it is competition between contractors and not economies of scale that is driving drilling costs down in Ontario. Although consumers benefit from lower prices, it becomes difficult to sustain the industry in the long term if drillers are not profiting sufficiently from their work. One respondent also commented that when government incentives were introduced, it was common for contractors to build the value of the incentive into their prices, benefitting the supply side instead of system owners. Overall, the respondents estimated that materials and installation costs have decreased slightly but not enough to suggest that the industry has fully matured.

4.7.2 Major barriers to the growth of Ontario's geoexchange industry

Lack of geoexchange awareness and expertise in the design community. One respondent noted that firms that are specialized in building HVAC design are not typically familiar with geoexchange systems and so naturally do not promote them as a viable option. Where time and budget are limited, design innovation is not typically a priority. It is easier and more efficient for building designers to use a trusted conventional design than to spend time and money creating a new one.

When designers possess awareness of geoexchange, they often lack expertise. This lack of knowledge and experience can lead to the design of overly large or complex systems that are not well suited to the needs of the building. Some designers continue to design geoexchange systems based on peak loads, which is the rule of thumb for conventional HVAC systems but is not an effective strategy for geoexchange. There is also an incentive to design large and expensive systems because designers often are paid a percentage of the total project cost.

When these complex systems are assessed against conventional alternatives during the feasibility phase, geoexchange consistently appears to be unfavourable. Even if clients strongly support geoexchange, they will not generally challenge the results of a feasibility assessment performed by a qualified professional. The respondents commented that feasibility studies are not usually presented in a format that is understandable to a non-technical audience. Consequently, building owners are not able to determine the quality or accuracy of the feasibility analysis.

Lack of mandatory certification standards for geoexchange industry professionals. Although certification and accreditation programs exist for geoexchange professionals in Ontario, they are not mandatory. This allows underqualified individuals and companies to operate in the industry. When the quality of their work is poor, it reflects poorly on the entire industry and promotes the misconception that geoexchange technologies are unreliable. The respondents commented that this is a particular problem for the residential geoexchange industry.

Negative implications of Ontario Regulation 98/12 to the province's drilling industry. *Ontario Regulation 98/12 (Ground Source Heat Pumps)* was enacted in May 2012. This regulation was intended to help reduce the risk that explosive or flammable gases will be encountered during deep drilling for vertical closed loop geothermal systems.[25] One respondent believed that this regulation was too stringent, precluding the existence of small drilling operations due to the expense of licensing. This is a particular concern in remote and underserved regions of the province. The respondent estimated that there are approximately 20 licensed drilling contractors currently operating in Ontario and all of these are located south of Muskoka-Haliburton. Geoexchange is currently not accessible or is prohibitively expensive in northern communities that stand to benefit significantly from the technology. The respondent stated that *Ontario Regulation 98/12* needs to be modified in order to better serve northern Ontario, where, due to its geology, the risk of encountering hazardous gas during drilling is considerably lower.

Short term thinking. The respondents believed that a culture of shortsightedness exists in Canada. In Europe, projects with paybacks of up to 20 years often move forward, whereas in Canada, a payback of no longer than 5 years is usually the standard. In large cities, it is not uncommon for 50 million dollars to be spent on a commercial or institutional building. Clients may have no qualms spending tens of millions of dollars on top quality materials and elaborate architecture, but they may refuse to spend a million dollars on a geoexchange system unless a short term payback exists. The respondents believed that since geoexchange projects are a long term investment, they should not be expected to achieve a 5 year payback. One respondent noted that when a life cycle cost analysis is performed, the value of the geoexchange system increases with time in relation to the cost of the conventional fuel source.

[25] Environmental Registry. Registry Exception Notice: Revocation and Replacement of the Ground Source Heat Pumps Regulation (O. Reg. 177/98) under the Environmental Protection Act with a New Regulation and Consequential Amendments to O. Reg. 524/98 and O. Reg. 245/11. http://www.ebr.gov.on.ca/ERS-WEB-External/displaynoticecontent.do?noticeId=MTE2NTY1&statusId=MTc0NTE0&language=en. (Accessed January 23, 2014)

Low cost of natural gas. The business case for geoexchange technologies is based on the cost of the conventional fuel source. The cost of natural gas declined sharply between 2008 and 2009 and has remained relatively low since then. From a solely financial perspective, this may make geoexchange less attractive relative to natural gas based HVAC systems. However, the respondents believed that as public concern about fracking increases and regulations are introduced, natural gas prices will eventually rise. The respondents did not believe that fracking was a long term solution and were confident that the business case for geoexchange would improve with time.

Rising costs of electricity in Ontario. The Ontario government plans to raise electricity prices by 33% over the next 3 years.[26] The respondents perceived this to be a barrier to industry growth because geoexchange systems require electricity and if electricity prices rise, operating costs will increase in tandem. However, since electricity is a major source of energy for space heating and cooling in Ontario, the operating costs of conventional electric heating and cooling systems will also increase. This may provide an impetus for building owners to switch to geoexchange, since geoexchange systems use less electricity than conventional electric heating and cooling systems.

"We don't have any gas or oil in Ontario. We have to import it all. But nobody seems to care about that. This is right under your feet! It's solar energy."
-Robert Mancini

4.7.3 Emerging opportunities for geoexchange technologies in Ontario

Technological innovation: variable capacity heat pumps. Variable capacity heat pumps contain a variable speed compressor that allows the heat pump to operate in accordance with building demand. Depending on the application, variable capacity heat pumps may provide substantial efficiency gains relative to the single or two stage models commonly used in Canada, which must frequently cycle on and off to maintain constant temperatures. One respondent believed that wider use of variable capacity heat pumps in geoexchange systems is imminent in Canada.

Variable capacity heat pumps are currently more expensive than single or two stage units. In some applications, the benefits of variable capacity heat pumps relative to two stage models may not justify the cost. In a comparative analysis, a variable capacity ground source heat pump was observed to perform better on an annual basis than an on/off controlled ground source heat pump provided the heat pump was sized to meet no greater than approximately half of peak heating demand.[27]

[26] Leslie, Keith. Ontario electricity rates to rise 33% in three years under Liberals' long-term energy plan. Financial Post. December 2, 2013. http://business.financialpost.com/2013/12/02/ontario-electricity-rates-to-keep-rising-as-long-term-energy-plan-released/?__lsa=a849-0716 (Accessed February 20, 2014)

[27] Madani, H., Claesson, J., and Lundqvist, P. 2011. Capacity control in ground source heat pump systems part II: Comparative analysis between on/off controlled and variable capacity systems. 2011. International Journal of Refrigeration. Vol.34, Iss.8. pp. 1934–1942.

Design innovation: district heating. District heating refers to the use of a centralized system to provide heating and cooling for a group of buildings. District heating systems capitalize on the diversity of the heating and cooling needs of different types of buildings. Industrial, commercial, institutional, and residential buildings each have different heating and cooling load profiles due to factors such as the timing and type of facility use, lighting, and ventilation requirements.[28]

Geoexchange systems are well suited for district heating applications. Different types of buildings within a district heating system extract and replace heat to the ground at different times. This may help to keep the ground temperature relatively constant. It also has the potential to make the ground source heat pumps in each building operate more efficiently.[29] The respondents believed that there are extensive opportunities to implement geoexchange-based district heating systems in Ontario.

The respondents also described a variation of a district heating system that is ideal for residential housing developments. Instead of using a large centralized system, which can be impractical for subdivisions, each home has a dedicated geoexchange system. The boreholes are installed by a utility or developer during the construction phase, allowing the driller to service a large number of properties at one time and take advantage of economies of scale. Using this model, one respondent was able to drill boreholes for a cost of $5,000 per unit. The utility owns the geoexchange system and recoups its investment by charging the user for the energy consumed, which is measured using metering on the home. Although examples of the utility model exist, it has not been marketed on a broad scale.

Design innovation: integration of building systems. In an integrated approach to building design, the building is conceptualized as a holistic system rather than as an assembly of distinct components. Integrated design helps to ensure that building systems work in harmony, improving energy efficiency. This approach requires the involvement of knowledgeable, creative design professionals that are willing to make innovation a priority. Geoexchange systems afford several opportunities for integration with other building systems, including domestic hot water, solar thermal, and snow melting applications. Dual exchange systems also hold promise, allowing for simultaneous extraction and rejection of heat.

Marketing innovation: promotion of geoexchange technologies to a broader audience. The respondents believed that improved marketing and information sharing is necessary for further growth and development of Ontario's geoexchange industry. Green building conferences are an ideal forum, as they typically attract a wide range of professions including design, construction, and real estate. The respondents believed that it is especially important to promote geoexchange technologies to the architecture community, which could be targeted through the Ontario Association of Architects (OAA). Architects have the potential to play a key role in the uptake of geoexchange technologies, as they usually lead the project team and have authority to develop and promote innovative building designs.

[28] Lohrenz, E. 2012. Smart Communities in Cold Climates. Quality Urban Energy Systems of Tomorrow (QUEST) Presentation.
[29] Lohrenz, E. 2012. Smart Communities in Cold Climates. Quality Urban Energy Systems of Tomorrow (QUEST) Presentation.

Architects also have an interface with the client and are in a position to educate skeptical building owners about the benefits of geoexchange systems.

5.0 CONCLUSIONS

This study has documented the experiences of owners, operators, and suppliers of geoexchange systems in developing and implementing geoexchange projects in the Greater Toronto Area. A total of 20 owners and operators of large-scale urban geoexchange systems were interviewed. Collectively, they own a total of 29 installed geoexchange systems. To provide perspectives from the industry, a leading driller and system designer were also interviewed. The interviews explored key issues relating to project development, implementation, and ongoing monitoring and maintenance of geoexchange systems, as well as the barriers and opportunities that currently exist in Ontario's geoexchange industry.

The rationale of respondents for implementing geoexchange projects was varied. Geoexchange projects were seen to offer opportunities for organizations to demonstrate environmental leadership, provide corporate image and marketing benefits, deliver substantial savings on long term operating costs, and provide improved thermal comfort relative to conventional HVAC systems. The geoexchange utility model offered sustainable, community-based investment opportunities and was believed to hold significant promise in the Ontario market. Five of nine respondents stated that the geoexchange project received some type of external funding, either through the federal ecoENERGY Retrofit program or through incentives or loans from other levels of government. Since the up-front cost of geoexchange systems was significant, grants and loans often facilitated the decision to implement the project.

"The best way of convincing people [of the effectiveness of geoexchange] is science. You have to believe that building codes are founded on practical science, which is what engineering is, a school of practical science. Therefore if you're going to change science, you probably need science to do so."
- Green Life

Geoexchange is a relatively new technology, and as such, the majority of respondents perceived some type of risk prior to project implementation. Financial and technology risks were the most common concern, followed by environmental, regulatory, and social risks. Financial and regulatory risks were difficult to mitigate, but did not serve as a deterrent to implementation of the project. Technology, environmental, and social risks were usually addressed during project planning and development. It is important to note that although these risks are distinct, many are interrelated. For example, financial risk concerning whether the expected payback will be achieved is strongly related to the technology risk of whether the system will meet performance expectations. Similarly, social risk is rooted in perceived financial, technology, and environmental risks. The interconnection of different risks types is beneficial from a risk mitigation perspective, as a single strategy may be used to address multiple risk factors.

Detailed information about feasibility studies was difficult to obtain because system owners and operators did not typically have an in-depth involvement in the process. It is clear that a wide range of factors were considered in feasibility studies and that a common method of assessment did not exist. Since feasibility studies were commonly performed by an external consultant, system owners and operators did not typically have a thorough understanding of the analysis and had no way of determining its quality or accuracy. In two cases, the respondent lacked confidence in feasibility assessments and chose to implement geoexchange projects based on the success of past projects. Expected simple payback was 10 years or less in five of seven cases. However, two respondents believed that simple payback analysis does not adequately account for long term cost savings.

A key finding concerning the design of geoexchange systems was that the system must be properly integrated in the context of the whole building. This is especially important for geoexchange retrofits, which must be in installed buildings designed to house a conventional HVAC system. For both new and retrofit projects, effective integration with the backup system, the distribution system, and with building features such as domestic hot water and heat recovery ventilation were seen as crucial for achieving optimum performance of the geoexchange system. Energy efficiency measures such as improvements to insulation, windows, and lighting were also seen as important. Retrofits often involved several upgrades to the building to better accommodate the geoexchange system and were most successful when an integrated design approach was used. Where the building's heating and cooling loads were imbalanced, different strategies were employed to prevent heating or cooling of ground temperatures over time. These included: (i) slightly oversizing the system to obtain extra storage capacity and (ii) using excess heat for domestic hot water or snow melting applications.

Challenges in project implementation often occurred during the procurement phase, which was intimidating to many first time owners. Respondents that used a rigorous procurement process that included a prequalification step and the use of ranking matrixes based on multiple selection criteria were most successful. Despite initial challenges, the majority of respondents had gained a network of trusted professionals who they continue to work with on geoexchange projects. Satisfaction with contractor performance was generally very high.

The time and resource commitments required over the course of project implementation varied widely, and depended on several factors including: (i) whether the project was new or a retrofit, (ii) the phase of the project, (iii) the role of the respondent, and (iv) the contract structure. Design-build contracts allowed respondents to offload the majority of project management responsibilities to the primary contract holder, saving internal time and resources. The design-bid-build model allowed respondents to play a more hands-on role in project implementation, which was preferable to those with past experience managing geothermal projects.

Monitoring of geoexchange systems (i) is crucial for identifying and resolving problems proactively, (ii) contributes to ongoing research and development, and (iii) enables the good news stories to be documented and shared. Ten of thirteen respondents were monitoring the geoexchange system, but the approach to monitoring varied widely and it was not a priority in most cases. The most successful monitoring programs were the most comprehensive, tracking parameters such as building electricity, gas, and water consumption in addition to parameters directly related to the geoexchange system. Two respondents chose to hire external consultants to remotely monitor the system on an ongoing basis and provide regular reporting on system performance. In three cases, detailed performance data were being collected but analysis of these data was not a priority due to time or budgetary constraints. This finding highlights the importance of not only tracking the appropriate parameters but also having a strategy in place for analysis and effective use of the data.

In all but one case, respondents claimed that operation and maintenance of geoexchange systems involved the same or less effort than for conventional HVAC systems. The time spent on routine maintenance ranged from two hours quarterly to six hours per month. Although external service contracts were occasionally procured, in many cases routine maintenance was performed by building operators. In three instances, it was a challenge to provide sufficient training to building operators in the face of high staff turnover. Three respondents found it challenging to maintain building temperatures during the shoulder seasons when the geoexchange system had to alternate frequently between heating and cooling modes. Decentralized geothermal systems were believed to be more adaptable in these conditions.

An encouraging finding that emerged from this study was the overwhelming satisfaction of system owners, operators, and building occupants with the performance of geoexchange systems. The major benefits offered by geoexchange systems included: (i) increased user control, (ii) expanded service within the building, (iii) reduced utility costs, and (iv) decreased costs for winter walkway maintenance. Indirect benefits of geoexchange projects included improved thermal comfort and improved air quality, which resulted from upgrades to building distribution and ventilation systems that occurred concurrently with the geoexchange retrofit. Respondents were nearly unanimous in their willingness to implement future geoexchange projects.

Assessment of geoexchange project costs was impeded by the fact that several respondents did not share absolute costs and instead reported costs relative to budget or to the conventional alternative. A total of two projects were completed on budget, one project came in under budget, and three projects exceeded the budget. The cost premium of geoexchange over a conventional HVAC system was claimed to range from 20% to nearly 300%. The cost of large-scale geoexchange installations was dependent on several factors such as: (i) whether the project was a new build or a retrofit, (ii) the orientation of the loop, (iii) the workload of contractors at a given time, and (iv) the contract structure (design-build contracts were believed to be more expensive). A more meaningful cost comparison could have been achieved if reported costs were standardized based on system size, capacity, or other useful metric.

A reoccurring theme in the dialogue with geoexchange suppliers was the fact that although much progress has been made, Ontario's geoexchange industry continues to show symptoms of an industry in the early phases of development. Unsteady patterns of growth, reliance on incentive programs, and high capital costs relative to other heating and cooling options are all symptoms of an industry that has not yet matured. The suppliers also observed that in certain sectors of the industry, qualified contractors are in short supply and underqualified professionals continue to operate. However, the suppliers believed that the industry has recovered from the effects of the negative publicity it received in the 1990s and that good news stories are now in abundance. Despite several key market barriers, the industry continues to expand and the future outlook of suppliers was very positive.

Several emerging opportunities for advancement of Ontario's geoexchange industry were identified. Wider use of variable capacity heat pumps in geoexchange systems may be on the horizon in Canada. In some applications, variable capacity heat pumps may consume less energy than single or two stage models and achieve a higher COP. An integrated approach to building design promotes innovation and performance optimization of geoexchange systems. The expanding district heating industry provides opportunities for wider uptake of geoexchange technologies. Finally, improved marketing of geoexchange to a broader audience and to the architecture community in particular has great potential to result in significant gains.

Geoexchange technology is widely available today and its effectiveness has been demonstrated in a variety of contexts. The owners and operators of geoexchange systems surveyed in this study were highly satisfied with system performance and have gained confidence in the technology. By understanding the successes and challenges experienced on the ground, it is possible to build on what works and begin to devise solutions for what doesn't, ultimately increasing public acceptance and market penetration of geoexchange technologies.

6.0 RECOMMENDATIONS

The following recommendations are offered based on feedback provided through the surveys conducted as part of this study. The recommendations are organized relative to the group to which they most apply, although some may have relevance to multiple groups.

6.1 Potential and current system owners

6.1.1 Planning and design

- Some respondents felt that geoexchange systems carried a stigma of being new or innovative, and that the technology was not well understood. **Education and outreach is an important step in building acceptance and support for geothermal technology** among building occupants and other stakeholders in the organization.
- Whenever possible, **geoexchange retrofits should be performed when the existing HVAC system is due for replacement**. This reduces the cost of the project by the amount that would have been spent on the replacement of the conventional system.
- Unexpected delays and expenses often arise during geoexchange retrofits. Organizations considering a retrofit should **ensure that a suitable contingency is built into the budget**.
- Financial incentives and loan programs are available from different levels of government for the implementation of geoexchange systems. **Prospective owners should ensure that they are knowledgeable about the various sources of funding that may be available**.[30]
- A willingness to implement trial projects and a strong commitment to knowledge sharing can attract funding for geoexchange projects. **Prospective owners should demonstrate research or knowledge sharing intentions clearly to potential investors and agencies.**
- **Today's low interest rates provide an ideal opportunity to implement projects with long paybacks, such as geoexchange,** because the cost of the up-front investment is reduced.
- **If customized space conditioning at the individual unit level is desired, prospective owners should consider installing a decentralized geoexchange system.** Decentralized systems also have a faster response time, eliminating the problems experienced with many centralized systems when transitioning between heating and cooling mode during the shoulder seasons.

6.1.2 Project implementation

- Investments in detailed planning prior to project implementation can result in significant savings. **Ensure the scope of work is laid out in detail before entering the procurement phase.**
- Several respondents expressed different levels of satisfaction with the geoexchange service providers hired to work on their projects. The search for qualified providers should **include**

[30] The Canadian Geoexchange Coalition maintains an online database of provincial and federal incentives. The online database can be accessed at: http://www.geo-exchange.ca/en/geoexchange_financial_support_grants_rsc70.php

interviews with others who have implemented geoexchange systems. Prospective owners can also **consult the Canadian Geoexchange Coalition's public registry of certified geoexchange companies**. The registry includes designers, installers, and drillers, and is a resource for potential system owners during the procurement process.

- **Prequalification of contractors and consultants can facilitate procurement and help to ensure that all parties have the knowledge and experience required to perform the work.** Effective prequalification processes included evaluation of a company's previous experience with geoexchange projects, technical knowledge, financial capacity, and references.
- For organizations with limited experience with geoexchange projects, **a design-build contract structure may save time on project management and promote continuity in the project**. This model can increase accountability and streamline decision making, as there is one party that holds clear authority. Procurement is also facilitated, as the design-builder selects the project team and can ensure that contractors and consultants possess geoexchange expertise.
- The commissioning process verifies that the geoexchange system is optimized to function as efficiently as possible. System owners should **ensure that the system is commissioned by qualified professionals.** Although it costs money up front, commissioning saves money in the long term by reducing operation and maintenance costs.

6.2 Facility managers and system operators

6.2.1 Monitoring

- If used effectively, monitoring programs can be an important tool for troubleshooting as well as technical and financial performance assessments of geoexchange systems. The monitoring program should be tailored to the size of the installation and the resources of the system owner. **It is useful to clearly identify monitoring goals upfront so that the monitoring program can be appropriately designed to meet defined goals.** The monitoring goals and program design should be formally recorded in a document so that there is clear communication between all stakeholders involved in the monitoring process.
- **To compare technical and financial performance before and after a retrofit, it is crucial to collect pre-retrofit baseline data** and project timelines need to take this into account. Monitoring protocols should be based on recognized standards, such as the International Performance Measurement and Verification Protocol (IPMVP).[31]
- **To evaluate the quantity of heat delivered or removed and the geoexchange system COP, the following points must be monitored** using calibrated instruments:
    - Heat pump power consumption
    - Distribution and ground loop circulator pump power consumption

[31] The IPMVP is an internationally recognized standard which outlines procedures and best practices for verifying results of energy efficiency, water efficiency, and renewable energy projects in commercial and industrial facilities. It may also be used to assess and improve facility performance.

  - Supply and return fluid temperatures on either the distribution or ground loop side using matched pair sensors
  - Fluid flow rate corresponding to the fluid temperature measurements (ie. if fluid temperature measurements are on the distribution side then the flow measurement must also be on the distribution side)
- **Qualified staff or experienced external consultants should be responsible for checking system performance data on a routine basis and diagnosing problems as they arise.** If no one is looking at the data, measurement errors or performance issues can persist for months or even years undetected, resulting in higher operating costs. Benchmarking the system against expected performance can help detect performance changes that may otherwise go unnoticed.
- **Expensive monitoring equipment cannot make up for a lack of monitoring program design or a lack of routine data checking.** Without the latter elements money may be spent with little gain.

6.2.2 Operation and maintenance

- **Inspect and maintain the geoexchange system regularly to enhance long-term performance.** Although maintenance requirements are relatively minimal, neglect of simple tasks such as changing filters can significantly impair the functioning of the system.
- **Invest in ongoing operation and maintenance training for geoexchange system operators,** especially where staff turnover is high. Develop a knowledge transfer plan so that new staff may learn from experienced system operators.
- **When developing the maintenance schedule, seek input from system designers and installation contractors.** These parties understand the idiosyncrasies of the installed system and can provide recommendations for enhancing operation and maintenance. Periodic meetings or teleconferences to re-evaluate the maintenance program and discuss any recurring challenges may be valuable.
- **One respondent with a radiant floor heating and cooling distribution system found that running the geoexchange system in 'free exchange' mode during the summer can significantly boost the performance of the system and reduce electricity bills.** In free exchange the fluid circulating through the ground loop of a geoexchange system directly cools the building without the use of the heat pump.

6.3 Designers

- **Geoexchange retrofits are most successful when upgrades to the entire building are performed.** It is especially important to ensure that the building envelope is appropriately insulated. It is most efficient to perform all building upgrades prior to sizing the geoexchange system. This allows the building's new heating and cooling load profile to be accurately characterized and the geoexchange system to be sized appropriately.
- **Size the geoexchange system based on annual loads rather than peak loads.** Sizing based on peak loads typically results in an oversized system.

- **Design the geoexchange system within the context of the whole building to capitalize on all possible efficiencies.** The following building features may help to optimize system performance:
    - A tight building envelope (appropriate insulation, double or triple glazed windows, etc.)
    - A distribution system that integrates well with geoexchange
    - Heat recovery ventilation
    - Demand-controlled ventilation
    - Use of excess heat for snow melting or water heating
    - Integration of solar thermal and geoexchange
    - Earth tube technology
    - Building orientation and zoning to optimize solar gains and passive cooling
    - Proper integration of the geoexchange system with backup heating and/or cooling
    - Use of a desuperheater for domestic hot water heating
- **Consider the balance of the building's heating and cooling loads during the design phase and take appropriate actions to maintain balance in the long term.** Waste heat may be used to provide snow melting services or domestic hot water heating. Alternatively, the system may be slightly oversized to obtain extra storage capacity.
- **Building loop and ground loop designers should collaborate during the design process** in order to promote continuity and efficiency in the geoexchange system.
- **Use of variable capacity ground source heat pumps may decrease electrical consumption of the heat pump, increase COP, and prolong the life of the heat pump** by reducing on/off cycling. Assess the suitability of this technology for each application as marginal increases in performance may not justify the expense.
- **Demand-controlled ventilation (using motion sensors to detect occupancy or carbon dioxide sensors to measure air quality) can significantly reduce fresh air intake requirements and reduce heating and cooling demand.** Ensure that all spaces within a ventilation zone have a similar usage profile. For example, it is not effective to include a cafeteria in the same zone as office space because they are used at different times of day and so have different ventilation requirements.
- In central geoexchange systems, dehumidification can be quite costly because a large heat pump must be operated to dehumidify the building. One respondent claimed that **modular or**

In order to overcome [an imbalance in the facility's heating and cooling loads], we had to find places to reject [excess] heat. So we put in an extra couple of water-to-water heat pumps and we are rejecting heat through the snowmelt. Now the system is working beautifully and it's rejecting all the heat we need. ....we actually have snowmelt all the way down the entrance, right to the municipal sidewalk. .. .It saves a pile of money, it saves all the time and the effort of snow clearing, and it also saves all the costs of using some kind of snow melting agent on top."

– The Diversicare Canda Group

decentralized systems may be more efficient for dehumidification, especially when multi-stage heat pumps are used. This reduces loads and allows dehumidification to be targeted to areas where it is needed.

- **Explore partnerships with other industries for the delivery of integrated energy solutions**, so that building owners would not be required to procure solar, geoexchange, and other services separately. This would streamline project implementation and improve the cost effectiveness of energy efficiency and renewable energy initiatives.

6.4 Provincial and/or national geoexchange associations

6.4.1 Decision support tools

- **Based on input from experienced system designers and installers, develop a standard, stand-alone feasibility assessment template for geoexchange projects.** This would help to increase transparency and accountability within the feasibility assessment process. Separate feasibility templates should be developed for different building types. Templates should include:
    - Modelling tools to evaluate alternative scenarios for heating and cooling the building using both geoexchange and conventional HVAC systems. The tools should allow for building-to-building, as well as system-to-system comparisons. In building-to-building comparisons, cost savings due to reduced requirements for mechanical space and decreased floor-to-ceiling heights can be quantified.
    - Assessment of heating and cooling load profiles.
    - Life cycle cost analysis to account for long term costs including operation, maintenance, and replacement of system components. Life cycle costing evaluates the full benefits and cost savings associated with a geoexchange system, including the fact that the value of the geoexchange system often increases with time in relation to the cost of the conventional fuel source.
    - Guidance on other key factors that should be considered in the feasibility assessment and standard methods to evaluate these factors.
- **Develop standardized monitoring protocols specific to geoexchange systems** which would allow for performance comparisons of different systems and of pre- and post-retrofit scenarios. An effective monitoring program is critical in determining the technical and financial performance of geoexchange systems. Monitoring protocols may need to encompass other building mechanical systems, as problems with these systems can reflect underlying problems with the geoexchange system. For retrofits, monitoring should include the collection of baseline data so that actual performance of the system may be assessed against a benchmark. This recommendation may apply mainly to large-scale geoexchange systems. Depending on the application, in-depth monitoring for small-scale systems may be cost prohibitive.
- **Create guidance on a procurement process specific to geoexchange projects** to assist first time system owners in selecting a qualified, experienced project team.

- **Create a standard checklist for commissioning geoexchange systems** to verify that the system has been properly and safely installed and effectively integrated within the building.
- Performance monitoring of small-scale geoexchange systems is often cost-prohibitive because it requires the installation of expensive monitoring equipment and qualified specialists to perform data analysis. **An instrumentation-free performance assessment web tool similar to those that have been developed for the residential-scale solar photovoltaic (PV) market[32] may increase the financial feasibility of monitoring small-scale geoexchange systems.** A tool could be developed that would allow owners to compare their monthly electricity bill with an expected value determined through real-time atmospheric data, baseline electricity and natural gas consumption data as well as key geoexchange system parameters. If the system owner sees that the cost of electricity is significantly greater than expected, they could have a professional in to perform system diagnostics. In this way, it may be possible to determine rough performance metrics with minimal investment of time or money, and many of the pitfalls and costs associated with traditional monitoring could be avoided.

6.4.2 Industry growth and development

- **Create a provincial or national forum for knowledge sharing about installed geoexchange systems.** Independent monitoring data, cost savings information, and lessoned learned could be collected and shared among system owners, operators, researchers, and industry professionals. This forum would help to close the feedback loop between system owners and designers, identifying operational challenges and design strategies that can help to overcome these problems. By sharing success stories, the forum would serve to build public confidence in geoexchange technologies and help geoexchange to reach the mainstream.
- **Promote geoexchange technologies within the architecture community in order to increase uptake.** Architects are in a unique position to drive building innovation because they create the vision for the building and can make energy efficiency a priority, rather than an afterthought. Architects hire the consultants working on a project and are able to assemble teams of engineers who have geoexchange expertise. Since architects interface with clients, they are able to promote the benefits of geoexchange systems to potential owners. Workshops and seminars could be held at professional conferences (such as through the Ontario Association of Architects) or hosted by third parties such as Conservation Authorities. As an incentive to participate, credits for professional training could be offered.
- Building owners that pass on occupancy costs to their tenants have little incentive to install geoexchange systems. A misaligned or split incentive exists because the benefits of the geoexchange system are not realized by the party who paid for it. **Tools such as green leases may provide a means to address split incentive problems associated with geoexchange in commercial buildings.** Where green leases are not feasible, geoexchange promotion efforts should target building owners that pay their own utility costs.

[32] See sunmetrix.com for example.

- **Strong local geoexchange associations should be established in each province.** The associations should represent designers and drillers, and address issues relevant to both residential and commercial scale geoexchange systems.
- **Promote the utility model to municipal authorities and utilities.**
- **Improve outreach to permitting and regulatory officials** to increase awareness and acceptance of geoexchange technologies.

6.4.3 Education and training

- **Create more hands-on training and workshop opportunities for contractors currently employed in the industry.** Training specific to design and installation of commercial-scale geoexchange systems is especially important, as these systems are more complex than in residential applications.
- Training is currently focused primarily on system design and installation. **Increase training related to operation and maintenance of geoexchange systems for building operators and service contractors.** Equipment manuals can be complex and do not typically contain information about troubleshooting. A practical guide that contains simple decision trees to address common problems would be valuable to building operators and would reduce the need to procure outside maintenance services. This could be an online resource in order to reach a broader audience. Online discussion forums would allow operators to ask questions and share knowledge.

6.5 Post-secondary institutions

6.5.1 Education and training

- **Increase geoexchange content in university level mechanical engineering programs.** Topics for special focus include: (i) ground exchanger design, (ii) effective use of modelling tools, (iii) integrated design, (iv) building HVAC systems, and (v) financial analysis. Theoretical learning should be balanced with practical knowledge transfer from experienced professionals.
- **Expand E-learning opportunities related to geoexchange** to reach a broader audience.
- **Create apprenticeship opportunities for new graduates**, similar to Alberta's Journeyperson Certificate program.

6.5.2 Research

- **Address key questions facing the Canadian geoexchange industry through rigorous, independent research.** Potential areas of research interest include:
    - Assessment and comparison of geoexchange system performance
    - Evaluation of design approaches (ex: understanding the merits of centralized and decentralized geoexchange systems, integrated design strategies, etc.)

  - Development and testing of strategies for optimizing system performance (ex: free exchange)
  - Examination of issues related to project management and implementation (ex: benefits of design-build and design-bid-build contract structures)

6.6 Political and regulatory bodies

- **Strengthen existing regulations to ensure that quality systems are installed and develop a regulatory framework that prevents unqualified professionals from operating in the market.**
- **Create financial incentives for developers to build sustainable buildings**, such as reduced development charges for developers that build to defined environmental performance standards. Under the City of Toronto's Green Standard, developments that meet both Tier 1 and Tier 2 criteria are eligible for a partial refund of municipal development charges. The Tier 2 standard is distinct from the LEED standard but contains several elements that contribute toward LEED certification. A Green Heat Tariff that provides incentives for geoexchange and solar thermal systems would also be valuable.
- Currently, commercial scale geoexchange retrofit projects qualify for saveONenergy retrofit incentives if they displace electric heat and/or cooling but not if they displace natural gas. When projects do qualify, the value of the incentive is usually not high enough to significantly improve the business case for the retrofit. **To address these issues, an incentive program targeted specifically to large scale geoexchange retrofit projects should be created that increases the financial feasibility of these initiatives and recognizes potential long term value. Incorporate higher energy efficiency standards into the Ontario Building Code.**
- **Use regulatory leadership to drive awareness and promote the wider use of geoexchange technologies.** A carbon trading system for green heating could be a valuable initiative.
- **Records concerning the type and size of installed geoexchange systems as well as borehole logs should be stored in a ministry database which is publicly accessible.** This would facilitate assessments of market trends and industry growth. It would also be valuable to create a public database of thermal conductivity readings obtained from geoexchange borehole testing. This may help to identify areas that are especially suitable for geoexchange.

APPENDIX A: OWNER/OPERATOR INTERVIEW GUIDE

Overview of projects

1. Please provide an overview of your organization's geoexchange projects, including the number of systems installed, the system size/capacity, the type/use of the buildings, and who owns these systems.

Project planning and system design

2. What was the rationale for choosing geoexchange for this (these) building(s)? Did government incentives help facilitate the decision? Were other alternatives considered, and if so, how were the various alternatives evaluated?

3. Prior to project development, did you perceive any risks associated with geoexchange energy systems? If so, please discuss. Did these perceptions change over the course of the project?

4. Was a feasibility assessment conducted prior to installations? If so, what were some of the factors that were considered and how was the study undertaken (e.g. was a model used, did it entail additional monitoring of the building if it was a retrofit, etc.)?

5. Were there aspects of geoexchange energy that were particularly well suited to integration into this (these) building(s)? Or alternatively, were there features of the building that made geoexchange technologies more suitable for heating and cooling than other conventional options?

6. Were there any features of the building that made the installation or operation of geoexchange technologies more difficult?

7. (Ask if the geoexchange system was installed in a new building) Were the building and mechanical systems designed to ensure the performance of the geoexchange system was optimized? If so, what modifications were made to improve overall energy performance?

8. If the geoexchange system was installed in an old building, were any retrofits necessary? If so, please describe.

Project implementation and monitoring

9. What were the major challenges faced in the implementation of the project? (e.g. challenges associated with project approval, coordination, procurement of qualified contractors, commissioning, etc.) How were these overcome?

10. Who was responsible for system design, installation, and commissioning? How did you select these companies? What were your main selection criteria? Did you feel that the companies

responsible for design, installation and commissioning were adequately qualified? Were you satisfied with their performance?

11. (For owners) Can you provide an estimate of the time and resource commitments that were required over the course of project implementation? Will any ongoing commitments be required into the future?

12. Is the system being monitored? How is the performance of the system being tracked? Who is responsible for performance tracking/monitoring? Do you know if the cooling and heating loads are balanced? Have you noticed any change in performance since the system was installed?

13. Have any problems with system operation and maintenance occurred? How were these addressed?

Costs

14. What was the total project cost? Were the costs of the project (material, installation, consultant fees) similar to expectations? Did you assess how these costs compare to a conventional energy heating/cooling system? If the building is a retrofit, how do operation costs compare before and after the retrofit?

15. How was the project financed?

16. What have the operation and maintenance costs been to date? Can you provide an estimate of the long term operation and maintenance costs?

Level of satisfaction

17. Have you received any feedback from building occupants with regards to their thermal comfort since the installation of the system? Have the residents/tenants/building occupants been satisfied with the system in terms of overall thermal comfort (if the building is rented/leased)?

18. Would you consider installing geoexchange energy in other buildings? If so, how would you select which buildings would be best suited to this source of energy?

Recommendations

19. What were the major lessons learned in the implementation of the project?

20. Do you have any recommendations for improving the process of developing and implementing geoexchange projects in Ontario?

APPENDIX B: SUPPLIER INTERVIEW GUIDE

The geoexchange industry in Ontario and Canada

1. Based on your long history working in the geoexchange sector in Ontario and Canada, could you comment generally on its current status and how the industry has grown over time?

2. What has been the trend in prices for design, installation and equipment needed for geoexchange systems?

3. What would you regard as the primary barriers to further growth of the industry?

4. What are the key actions needed to overcome these barriers and in each case, who should be the primary lead responsible for undertaking the actions?

5. Do you see emerging opportunities on the horizon that may help promote broader interest and uptake of geoexchange technologies? (Technological innovation, efficiency gains leading to lower installation costs, capacity building, improved government incentives, carbon pricing…).

Feedback from survey results

6. Interviewer summarizes survey results and requests feedback and perspectives on overall results.