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.

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[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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