Geothermal Energy and the Academic Environment

University of British Columbia Okanagan

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This research project was developed with the aim of gathering evidence and statistics on individual geothermal systems employed by academic institutions across Canada and the United States. Information about these systems will be compared to the geothermal system now being installed at UBC Okanagan in order to determine how the UBCO system rates in terms of size, energy savings, and other design features.

In addition to providing statistics on individual geothermal systems, this paper will also explore geothermal technology itself and the benefits and negative impacts associated with it. The contribution of geothermal energy use to sustainable development and its role within educational facilities will be outlined and examples will be provided of how communities are taking advantage of the technology's benefits. Some examples of other campus sustainability initiatives will also be included, many of which have been undertaken in conjunction with geothermal systems.

Many academic institutions are now assuming a leadership role in the practice of sustainable development and are working towards fostering environmentally responsible campus communities. Reduction of reliance on fossil fuels, reduction of emissions and pollution, and improvement of existing environments are common goals at educational facilities across Canada and the United States and around the world. Because of the environmental, economic, and social advantages involved with geothermal energy, it has rapidly become the technology of choice for schools when seeking to decrease environmental impacts. Schools employing the use of geothermal energy to heat and cool spaces are combining different innovative technologies and principles with the goal of sustainability in mind.

Geothermal Technology

Geothermal power (from the Greek words *geo*, meaning earth, and *therme*, meaning heat) is energy generated by heat stored beneath the Earth's surface. In a geothermal power plant, geothermal production wells drilled into geothermal reservoirs bring hot water to the surface. Water travels up the wells and is converted from liquid water to steam which powers a turbine and electricity is produced (Geothermal Education Office 2000).

A geothermal heat pump system is a heating, ventilation, and air conditioning (HVAC) system that uses the Earth's ability to store heat in ground and water thermal masses. This system takes advantage of a land mass as a heat exchanger to either heat or cool a building structure. The ground, below the frost line, stays at approximately 50 °F (10 °C) year round and a water-source heat pump uses that available heat in the winter and puts heat back into the ground in the summer. Geothermal heat pump systems are also referred to as earth energy systems and geoexchange systems (Canadian Geothermal Coalition 2007).

A geothermal heat pump system consists of working fluid, a loop field, and a heat exchanger. The working fluid flows through the loop field and the heat exchanger. Energy is alternately extracted from the fluid (during the winter) or added to it (during the summer). A Geoexchange system may be open or closed. This refers to the way the loop field is arranged. A closed loop system circulates fluid through the loop fields' pipes. In a closed loop system there is no direct interaction between the fluid and the earth; only heat transfer across the pipe. A vertical closed loop field is composed of pipes that run vertically in the ground, typically 150 to 250 feet deep (45–75 m). Vertical loop fields are typically used when there is a limited amount of land available. A horizontal closed loop field is composed of pipes that run horizontally in the ground in a long, shallow, horizontal trench deeper than the frost line. Horizontal loop fields are common and economical if there is adequate land available. An open loop system pulls water directly from a well, lake, or pond. Water is pumped from one of these sources into the heat pump, where heat is either extracted or added. The water is then reinjected at another location where it will be returned to the Earth (Geothermal Heat Pump Consortium 2003). The water may or may not be returned to the original, underground water source.

Currently, Iceland and United States are the largest users, as nations, of geothermal energy out of some 20 countries taking advantage of this resource. Canada is ranked sixth in the world in the installed capacity for earth energy heat pumps, with 435 MW of thermal capacity.

There are more than half a million installations in North America of geoexchange systems to date. Commercial enterprises and public institutions, including factories, retail stores, office buildings and schools are the biggest users of this technology (Canadian GeoExchange Coalition 2006).

Geothermal Innovations at Educational Institutions

Canadian Schools of all types consume 95 petajoules (PJ) of energy and emit 5.3 megatonnes (MT) of greenhouse gasses a year. Schools in Canada rely on natural gas for more than half of their energy, while electricity and oil make up the rest. Annual greenhouse gas emissions place schools in fourth place for commercial and institutional buildings, behind offices, retail and health care (Association of Canadian Community Colleges 2005). Changes to energy systems in Canadian schools will have an enormous impact on our national greenhouse gas emissions and will be an important step forward in the sustainability movement.

U.S. schools spend more than $6 billion a year on energy and a large part of that energy is spent on the heating and cooling of buildings. Geoexchange technology can save schools 25 to 40 percent in annual energy costs over traditional heating and cooling systems. A 25 percent reduction of costs could save U.S. schools about $1.5 billion a year. That translates into 40 million new textbooks or 30,000 new teachers not too mention the reduction in greenhouse gas emissions that would be associated with such savings (Canadian GeoExchange Coalition 2006).

A few U.S. schools pioneered the use of geothermal heat-pump technology in the early 1980's and slow growth of use continued through the decade. In 1993, the U.S. Environmental Protection Agency published a report, "Space Conditioning: The Next Frontier" encouraging schools to consider the use of geothermal technology (Abnee 1999). The report concluded that geothermal proved to be the most-environmentally friendly and energy-efficient technology available. Two years later, about 200 schools had chosen to use earth energy in new construction and retrofit projects. The advance of technologies and installation methods and increased demand for energy-smart alternatives has led to continued growth in use. According to the Geothermal Heat Pump Consortium, nearly 600 schools in 39 states in the United States have installed geothermal systems to date. More than 60 schools across Ontario have installed earth-coupled heat pumps to provide full heating, cooling, and hot water requirements (Natural Resources Canada 2005). Table 1 outlines a sample of schools across the Canada and the United States that currently employ geothermal energy systems. Energy efficiency, environmental benefits, indoor air quality, economic operation, minimal maintenance, and effectiveness in heating and cooling are among the reasons for the popularity of these systems.

Table 1. Comparison of Geothermal Use at North American Schools

Name of School	Total Size (sq.ft)	Year of completion	Number of students	Cost of GeoExchange Installation	Energy Consumption (kWh/ft.^{2})	Annual Energy Saving (kWh)	Net Annual Savings	CO_2 /year (tons)	New Construction or Retrofit	Heating or Cooling Capacity (tons)
UBC Okanagan, Kelowna, BC	1,200,000	2010	7,500				$105,563	1,047	& Retrofit	
Father M. McGivney Secondary, Markham, ON	181,000						$9,440			
Bob McMath Secondary School, Richmond, BC	150,695						$11,000			
University of Nevada, Redfield Campus, Reno, NV	84,000									
Lipscomb University, Nasville, TN	77,000			$1,200,000			$70,000			
Great Bridge Middle School South, Chesapeake, VA	112,000	1994	1,689	$240,000			$41,500		Retrofit	
Lake City High School, Coeur d'Alene, ID	185,000	1994	1,100	$1,440,000					New	503
Pease Elementary, Austin, TX	39,162	1994	298		8.3		25%		Retrofit	90
Brooke Elementary, Austin, TX	51,605	1993	346		9.6		25%		Retrofit	150
Govalle Elementary, Austin, TX	89,319	1994	626		8.5		20%		Retrofit	230
Bailey Middle School, Austin, TX	200,000	1992	1,614						New	512
The Dalles Middle School, Dalles, OR	96,000	2002	600						New	20
John W. North High School, Riverside, CA	4,800	2003							Retrofit	253
Truckee Middle School, Truckee, CA	87,000	2004					$55,000		New	59
Blue Oak School, Napa, CA	18,900	2002							Retrofit	440
Colleges at LaRue, Davis, CA	218,000	2001							New	490
Natomas High School, Sacramento, CA	235,000	2004							New	40
Squaw Valley Children's World, Squaw Valley, CA	15,000	1992							New	90
Weaverville Elementary School, Weaverville, CA	68,000	2003							Retrofit	75
Weaverville High School, Weaverville, CA	41,400	2002							Retrofit	135
Feather River College, Quincy, CA	52,000	1997					$50,000		Retrofit	
Schuyler Elementary School, Queen City, MO	55,000	1992	550	$90,000			$30,000		Retrofit	350
Neff Elementary School, Lancaster, PA	148,530									120
Paint Lick Elementary School, Paint Lick, KY	39,564						$16,250			
Onamia Elementary School, Onamia, MN										193

Name of School	Total Size (sq.ft)	Year of completion	Number of students	Cost of GeoExchange Installation	Energy Consumption (KWh/ft.^{2})	Annual Energy Saving (kWh)	Net Annual Savings	CO_2 /year (tons)	New Construction or Retrofit	Heating or Cooling Capacity (tons)
Fuqua School, Farmville, VA	18,000		700				$10,000			410
Fr. Michael McGivney Senior, Markham, ON	180,000									220
Whitman College, Walla Walla, WA	118,000	1988							New & Retrofit	157
Choptank Elementary School, Cambridge, MD	45,900									
Taylor elementary School, Arlington, VA	67,350		620				$20,800			
Sullivan County Community College, Loch Sheldrake, NY	170,000	2001				420,000	$74,000			500
Matapeake Middle School, Kent Island, MD	116,181	2007	800							
Eleanor Roosevelt Midddle School, Dubuque, IN	204,100	2005	1,215							
Plainville Public School, Northumberland, ON	23,000	1990								
St. Paul Catholic High School, Montreal, QC	6,600	1991								113
McGill University, Montreal, QC				$112,000			$5,000		Retrofit	
Rutland Elementary School, Kelowna, BC	33,500								Retrofit	60
College, Carney's Point, NJ	63,000					765,000	$72,000			
Ottoville School, Ottoville, OH		2003	850							
Brentwood College, Mill Bay, BC			425			130,000	$4,800			70
Hominy Middle School, Hominy, OK										250
Berry Hill, Berry Hill, OK										85
Murray State College, Tishomingo, OK										227
Wayne State University, Detroit, MI										105
Comanche Elementary, Comanche, OK										105
Bennington Public Schools, Benningto, OK										94
Cedar Rapids Community Schools, Cedar Rapids, IA			1,800			177,481	$399,799			
Fond du Lac High School, Fond du Lac, WI	400,000	2001	2,400				$290,000			720
Luther College Center for the Arts, Decorah, IA	60,000	2003					$102,161			248
Luther College Baker Village, Decorah, IA	33,000	1999								72

Motivations for Adopting Geothermal Technologies

The number one reason that academic communities are turning to geothermal systems is to minimize environmental impacts by reducing carbon emissions associated with traditional combustion heating systems. By adopting this technology, U.S. schools have already helped reduce annual emissions by 120 million pounds of carbon dioxide, more than 900,000 pounds of sulfur dioxide, and more than 425,000 pounds of nitric oxide (Geothermal Heat Pump Consortium 2003). In doing so, these institutions are also sending an important message of environmental stewardship to students and community.

Concern for student and staff health and safety are also factors that have led to the increased popularity of geothermal use. Geoexchange uses no combustion, requires no fuel storage and delivery, and produces no indoor pollutants such as carbon monoxide. This minimizes the health risks associated with combustion-based systems. Indoor air quality is a concern for many teachers. In many school buildings constructed during and after the energy crisis of the 1980s, outside air ventilation to the buildings was reduced to a minimum in order to conserve energy. Although this energy conservation technique is effective, it led to some serious indoor air quality problems inevitably hindering the educational experience of students. Because geoexchange systems use several relatively small heat pumps, individual classroom thermostats can be adjusted for specific conditions and outside ventilation can be incorporated.

The citizens of Coeur d'Alene, Idaho chose a new geoexchange system for a community high school as for them it was the most environmentally friendly heating and cooling system choice. School officials were also concerned about student and teacher health issues due to minimal air ventilation. According to administrators, with the new system, ventilation rates help keep students and teachers awake and attentive (Geothermal Heat Pump Consortium 1997).

Operating and maintenance costs are substantially lower with a geothermal system. Maintenance costs are reduced due of the simplicity and reliability of geothermal. Routine maintenance involves primarily the replacement of air filters and because these tasks can be done by the school custodial staff, a geothermal system requires no in-school HVAC technician.

In addition to long term economic savings and environmental benefits, geoexchange can help reduce the construction costs of buildings. Individual geothermal heat pumps can be placed in small spaces throughout the building and the amount of space dedicated to mechanical equipment can be reduced significantly. Geoexchange systems require no rooftop equipment. Structural costs can be reduced as the roof does not have to support heavy HVAC equipment. Flat roofs are not a design criterion and architects can design a more interesting and aesthetically pleasing building (Abnee 1999).

The use of this geothermal technology has even been incorporated into academic buildings in order to preserve architecture that is considered to be valuable culturally. Lady Meredith House, an architectural landmark at McGill University, was restored after suffering heavy damage from an arsonist's fire. Architects and engineers agreed that the three-story building would have to be restored to its previous Victorian magnificence, but it was less obvious how the integrity of the structure could be maintained when a conventional energy system would need large air ducts or outdoor condensing units. They decided on a ground-coupled heat pump system to avoid these conditions and annual heating and cooling costs were cut by almost 40% (Natural Resources Canada 2002). The Administration Building at Whitman

College in Walla Walla, Washington is another historical building, originally constructed in 1899 which has been renovated and now includes a geoexchange system (Geothermal Heat Pump Consortium 1997).

The UBC Okanagan Geothermal and Sustainability Initiative

Sustainable development initiatives have been incorporated into the planning process for University of British Columbia's Okanagan campus. After extensive testing and environmental assessment, it was concluded that the campus will employ geothermal energy for all heating and air conditioning to accommodate 7,500 students by 2010. The campus sits above the Okanagan aquifer, a resource of saturated sand and gravel over 50 metres thick containing all necessary properties to support an open loop system for ground water exchange. It was determined that an open loop geoexchange system would be less costly, by over 5 million dollars, than a closed loop system and would not impose the environmental risk associated with possible antifreeze contamination of the ground water that a closed loop system would (Kiernan 2006).

The first building to link up to the new geoexchange system at UBC O will be the new Fipke Centre in 2008. All newly constructed classroom, research, and administration buildings to follow will be heated and cooled by the new system and by 2010 the total campus area will encompass 1,200,000 square feet of building space. UBC O residences will not be included in the geoexchange loop. All existing buildings on campus, totaling 500,00 square feet, which currently rely on natural gas fired heating boilers and air cooled chillers with reciprocating compressors, will undergo a complete retrofit and be tied into the new geoexchange loop. The campus will be emissions free by 2010. By converting to the new geoexchange system the campus is expected to reduce carbon dioxide emissions by more than 2,700 tonnes each year (UBC Okanagan 2007).

A number of other sustainable initiatives that are suited to the campus have been or will be implemented. Buildings are designed to be energy efficient and take advantage of natural light and passive solar heating. The design of campus landscape will include native plants suited to the Okanagan climate and, with the exception of the small core at the centre of campus, will not require irrigating. An existing wetland will be enhanced and become part of the stormwater management system. Transit access, bicycle access and storage, pedestrian and cycling trails will be improved in an aim to reduce reliance on the cars as a means of transport to and from the campus (Phillips 2005).

Sustainability Initiatives Employed at Other Educational Institutions

While geothermal energy is seen as one of the most efficient and low emitting energy systems available, academic institutions are developing and implementing a variety of other innovative technologies and practices with the goal of sustainability in mind. Colleges, schools, and Universities across Canada have been at the forefront of adopting a wide range of green power and green heat options. The use of wind turbines or solar panels to generate power, and the use of biomass and earth energy to heat colleges and institutes is occurring at campuses across the country. Schools have also incorporated other energy saving design characteristics into buildings, such as efficient lighting, and energy conserving architectural design and construction.

The Princess Street Campus of Red River College in downtown Winnipeg incorporates the use of solar modules as part of the building envelope. This highly visible project, installed in

2003, has the largest building-integrated photovoltaic system in Canada. The project was supported by the Manitoba Government, City of Winnipeg, Manitoba Hydro, Red River College, and the Princess Street Consortium project team (Association of Canadian Community Colleges). A project supported and dependant on the partnership of public and private sectors. Red River College placed fifth in the World Environment Building Competition in Oslo, Norway. The British Columbia Institute of Technology in Vancouver has also installed photovoltaic modules as part of the building façade. The Institute is another example of a highly visible sustainability initiative where an academic institution is exhibiting a leadership role and sending an important message to the community.

A system employing active passive solar technology coupled with PV panels to power the fans has been successfully installed in the Toronto District School Board and at several schools in Canada, including one in Yellowknife, Northwest Territories. It is effective for both heating and cooling purposes and can be applied to any building that uses ventilation air (Natural Resources Canada 2005). Yukon College has installed a hybrid renewable energy system consisting of a wind generator and solar PV panels. This system is used as an educational demonstration facility and also supplies part of the energy needed for the College building (Association of Canadian Community Colleges 2005).

The new environmental technology wing at the School of Environmental & Natural Resource Sciences at the Sir Sandford Fleming College Frost Campus in Lindsay, Ontario has been rated as one of the most environmentally-sound buildings in Canada. The 4,000 square metre wing relies on heat from the earth provided by a closed loop geothermal system and requires 66 percent less energy compared to buildings built to current standards. Other sustainable technologies and features employed at the campus include a wind turbine, a green roof and wastewater treatment through a series of constructed wetlands (Association of Canadian Community Colleges 2005).

The Eleanor Roosevelt Middle School in Dubuque, Indiana was designed with environmental sustainability as a goal. Included in the design of the school are a storm water retention pond that doubles as a wetland that provides outdoor classroom opportunities, several acres of reintroduced natural prairie, use of local materials and locally-manufactured equipment, construction waste recycling which diverted more than fifty percent of the waste generated during construction away from the landfill, a geothermal vertical closed-loop heating and cooling system, use of significant day lighting, installation of high-efficiency equipment, and an integrated recycling system. The environmentally-conscious design of the Eleanor Roosevelt Middle School reflects the stewardship philosophy of the Dubuque Community School District, and the Dubuque community (Peter Li Education Group 2006). A public-based planning effort facilitated a group of 65 community members representing many viewpoints. This involvement of stakeholders, discussing and planning over several months, was a vital part of the process and led to the development of a successful facility and program (Peter Li Education Group 2006).

Key Partnerships in Developing Geothermal Innovations

Due to the magnitude of cost and years of planning involved, partnerships between governments, communities, private corporations, and school boards are a key ingredient in implementing large scale geothermal projects and creating long lasting sustainability programs. One example of this type of partnership which makes a large scale project possible is the University of Nevada in Reno. The new Redfield Campus is using geothermal technology to provide a new source of clean, affordable heat and power. The Nell J. Redfield Foundation donated 60 acres of land and 5 million dollars for initial construction costs to establish the new campus. The Nevada Assembly added another 5 million dollars of funding contributing to the project, while a private corporation will build and operate the geothermal power plant (University of Nevada 2003).

UBC Okanagan created a partnership with Direct Energy Business Services in order to implement the new geoexchange project on campus. Direct Energy Buisiness Services is a private energy management corporation who will install and maintain the geoexchange infrastructure on campus for a period of 25 years, at which time UBC Okanagan may opt to take over the management of the system.

The Canadian federal government is providing support to homeowners, businesses, public institutions and industrial facilities to help them reduce energy-related greenhouse gases emissions and air pollution. Natural Resources Canada's ecoENERGY Retrofit program provides financial support for the implementation of energy saving projects that will contribute to a cleaner environment for Canadians (Natural Resources Canada 2007). The ecoENERGY program offers grants available to homeowners from $300.00 to $1500.00 for the upgrading of homes with new energy efficient appliances and/or systems. The highest grant available to homeowners, $3500.00, is for the installation of a geothermal heat pump. This demonstrates the value that the federal government places on geothermal energy systems in the reduction of energy related emissions. The program also provides incentives for commercial, institutional, and industrial sectors in order to improve energy efficiency in their operations. Up to 25 percent of eligible project costs may be received through this program.

This common arrangement involves government, private and public sectors sharing the initial cost of implementing a new system. Once the public is informed and becomes involved in sustainability initiatives, communities are willing to absorb additional costs to implement programs in the interest of the health of community members, the protection of the environment, and the creation of long lasting academic institutions. One example of how a community was kept informed during the construction process is from The Fond du Lac School in Wisconsin. Video walk-throughs shown on the community cable station ensured the local community was kept abreast of the school's progress (Hall 2002).

Geoexchange Technology Enhancing Educational Opportunities

One of the most important factors or outcomes of any sustainability practice should be public education in an effort to encourage knowledge, understanding, and stewardship.

Middletown Township School District, in New Jersey, renovated two high schools and three middle schools including the complete redesign of the mechanical systems using geoexchange technology. The project is expected to save the school district $8.8 million in energy costs over 10 years and the closed-loop system is among the largest geoexchange projects in the Northeast. What is most exciting about the project is the technology being used in the classroom. Combining geoexchange technology with state-of-the-art computer systems allows Middletown students to study the performance of the geoexchange system in the classroom. Teachers can demonstrate how geoexchange uses the earth's natural stored energy and illustrate principles such as heat exchange and thermodynamics. An emphasis is placed on teaching children about energy conservation and respect for the environment. This use of technology offers a chance to bring these important lessons into the classroom (Abnee 1999).

At Choptank School in Cambridge, Maryland data on the schools energy consumption will be made available to high-school physics students who will then be able to analyze the energy and environmental benefits of geoexchange technology to complete and publish honors projects (Kemp Mill Communications). When an elementary school in Arlington, Virginia renovated and added a geoexchange system, the school also took advantage of the education benefits of the new technology. Fifth-grade students at the school became interested in the system. They gathered data, wrote reports and gave presentations on geoexchange technology (Geothermal Heat Pump Consortium 1997).

Environmental Concerns

Although the economic, environmental and educational benefits of using geothermal systems to tap into the earth's energy is quickly making this technology a popular choice for heating of academic buildings, there are concerns regarding the effect that these systems might have on our environment. Water resource availability and water contamination are two areas of concern.

Geothermal power plants require large amounts of water for cooling or other purposes and in places where water is in short supply, this need could raise conflicts over water resources. There is the chance that geothermal systems can pollute groundwater through leaks of fluids, antifreeze, in closed loop systems or the introduction of foreign microorganisms from the source to the re-injection site of an open loop system. Concern over the effects of thermal fluctuations within aquifers and how such changes will affect microorganisms has also been voiced. Subterraneous extraction of heat and fluid can cause land subsidence (Union of Concerned Scientists 2005). Destruction of geyser activity has occurred as a result of the alteration of water levels associated with geothermal power plants. Electricity generation from geothermal resources in Nevada has ended the eruptions from the second- and third-largest geyser fields in the United States (Mark Gielecki 1996). The depletion of such geysers may hinder ecosystems that depend on their unique characteristics for survival.

Geothermal power plants can generate large amounts of solid wastes as well as noxious fumes that can be hazardous or objectionable. Metals, minerals, and gases leach out into the geothermal steam or hot water as it passes through the rocks. Steam vented at the surface may contain hydrogen sulfide, ammonia, methane, and carbon dioxide. Scrubbers reduce air emissions but produce a watery sludge waste product. Sludge is also generated when hydrothermal steam is condensed. This sludge is generally high in silica compounds, chlorides, arsenic, mercury, nickel, and other toxic heavy metals may require shipping to a hazardous waste site or the liquid wastes may be injected back into a porous stratum of a geothermal well. Wastes must be injected well below fresh water aquifers to make certain that there is no transfer between the usable water and waste-water strata (Union of Concerned Scientists 2005).

Many systems are being monitored and data collected currently. Concerns over the geoexchange system at UBC Okanagan and the possible thermal effects to the underlying groundwater have led to extensive testing and computer modeling. Scientists have concluded that the temperature effects on the underlying groundwater may be negligible and confined to the UBC O campus, with temperature increases dissipating to +1 degree Celsius at campus boundaries. Thermal monitoring to ensure water quality will be undertaken and two of the wells on campus have monitors included in their installation (UBC Okanagan 2007).

The Natural Sciences and Engineering Research Council of Canada, along with Manitoba Hydro, has awarded $187,000.00 in research grants to St Francis Xavier's Earth Science professor Dr. Grant Ferguson to determine the potential for using groundwater to heat homes in a Manitoba subdivision. The grant money provided will be used for monitoring the effects of extracting groundwater from a regional aquifer for heating and cooling applications, and the hydrological impact of climate and land-use on subsurface temperatures. The readings will be used to design sustainable, low temperature geothermal energy systems (News @ StFX, 2006).

A large closed-loop geothermal heat pump at the Richard Stockton College of New Jersey was designed with monitoring wells, which provide an opportunity to assess the impact of thermal release into the environment. A study is being undertaken on the effects of thermal fluctuation on microorganisms in the three aquifers of the geothermal well field. The study was motivated by concerns over the quality of the groundwater, which serves as a source of drinking water for the region. Observed were increases in the number of microbials, and there may have been changes in the types of microorganisms present in the aquifers of the geothermal well field. This raises concerns about the possibility of promoting the growth of potential disease causing microorganisms within the water supply (Geothermal Heat Pump Consortium 2003).

With such rapid growth in the use of geothermal energy technologies, it will take time and monitoring before the full environmental impact of its use is realized.

Conclusion

Comparative information on the geothermal systems surveyed during this study is summarized in Table 1. These data indicate that the UBC Okanagan system, once completed, will be the largest of its type in Canada and the United States. Providing heating and cooling to a total of 1.2 million square feet, the system at the UBC Okanagan campus will be much larger than any other campus included in this study. However, due to the use of geothermal systems in schools becoming common-place, details of many projects may not be published or readily available online. As outlined in Table 1, there are many ways to measure the size of a geoexchange system. Quantifying systems by the size of building(s) being heated, heating capacity, installation cost, monetary savings, and savings in emissions are common. Because of this variation, it is somewhat difficult to accurately compare these systems. Further research would be required therefore, before we can claim conclusively that a project of the same magnitude as the one being developed at UBC Okanagan does not exist elsewhere.

Geothermal energy is seen as one of the most efficient and low emitting energy systems available and is used extensively at education facilities across North America. Energy efficiency, carbon emissions reduction, improved indoor air quality, and economic operation are benefits and cause for the popularity of geoexchange systems. Communities, school boards, faculty, governments, and private corporations are banding together in efforts to minimize negative environmental impacts produced by their schools and foster environmental stewardship amongst students.

Universities and schools have always been places of innovation and community leadership and have an especially important role to play in the dissemination of knowledge and ideas as they are rooted locally but are also globally interconnected (M'Gonigle 2006). A sustainable world will not exist until schools promote this idea, encourage responsible citizenship in new generations, and lead by example. By incorporating and promoting technologies and practices that minimize our impact on the planet, schools across the continent are leading the way in the sustainability movement. Geothermal energy will play an important role in the future of this movement and careful monitoring will be necessary to ensure that these systems are reducing our impact on the planet.

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