Case Study

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RENEWABLE ENERGY

Earth
Energy
Systems

Southwestern Manitoba town simplifies ice-making while reducing costs

Miami, Manitoba Hockey Arena and Community Hall

Windows from second floor hall and viewing area overlook the ice area.
Inset: Miami hockey arena in foreground and community hall in background.

The hockey arena is the centre of activity during long Manitoba winters in the small town of Miami, in the southwestern corner of the province. Since construction of its arena in 1952, the community relied on cold prairie winds to make ice for hockey teams and figure skaters. In a typical prairie winter, the arena could be used for skating for 50 to 100 days, but often with interruptions during mid-January warm spells. As more and more surrounding towns built arenas with artificial ice, Miami was bypassed for tournaments and events.

In 1998, the community devised a strategy to keep the ice pad reliably solid for a longer season and, at the same time, slash operating costs and keep maintenance to a minimum. Using a unique ice pad design and a geothermal system, the Miami arena takes advantage of thermal storage to make ice and provide heating and air conditioning to the arena and an adjacent community hall.

Revenues have increased because ice is available up to six weeks sooner in the fall, and up to a month later in the spring and the comfort level in both buildings has been increased. The estimated payback of the geothermal heat pump strategy as opposed to the installation of a conventional ice plant is less than three years.

- Phased approach spreads out the capital cost
- $30,000 annual operating, maintenance and energy savings reduces payback to less than two years
- Energy savings provides payback of less than three years versus a conventional system
- Local mechanical contractors service system rather than refrigeration specialists
- System avoids electrical service upgrade required for a conventional ice plant
- System includes HVAC upgrade by integrating the geothermal system
- HVAC for the nearby community centre included at minimal cost
- Simple maintenance without extensive training for operators
- Eliminates annual fall start-up and spring shut-down costs of a conventional ammonia or freon ice plant
- Single system for ice-making and space heating

The Miami Arena

The building is a wood arch-rib structure, approximately 27 metres by 67 metres. One end of the building, 27 metres by 11 metres, includes a viewing area, concessions and offices on the main floor. The basement houses change rooms and the mechanical room. The second floor is approximately 21 metres by 11 metres. This area is insulated to 1952 standards, approximately R10-12 throughout. The only windows in this area face the ice surface. Two 30 kW electric furnaces provide space heating.

The unheated ice shed is not insulated, and covers an ice sheet of 25 metres by 56 metres. Windows from the viewing area and second floor hall overlook the ice.

A 929 square metre community hall was built about 24 metres from the arena in 1974. Electric heaters provide most of the space heating. Four propane fired rooftop units provide ventilation make up air and air conditioning.

The community wanted to install an ice-making system, but was deterred by high energy, operating and maintenance costs of a conventional ice plant. Several arenas using geothermal heat pump systems had been operating successfully in Manitoba for some time, so the community decided to opt for a similar system.

The project was financed through community donations, grants from various levels of government, utility incentives, future energy savings and the expected increased revenues from an arena with more ice time available.

Using thermal storage for efficient ice-making

The facility's existing sand floor was excavated to a depth of about 60 cm. Eight cm of high-density foam insulation was laid on the bottom and sides of the excavated floor. The insulation was covered with 35 cm of gravel, and 3/4" high-density polyethylene pipe was laid down, spaced 20 cm apart. An additional 20 cm of gravel was laid on top of the pipe. This design created a "thermal storage buffer" under the ice.

The patented thermal storage buffer has a number of advantages:

- The massive cold buffer helps maintain constant ice temperatures during heavy use of the ice.
- It allows the low-temperature heat pumps to chill the buffer when the ice is not being used, and to bring the heat rejected from the ice into the earth loop to heat the building.
- The cold buffer helps maintain ice for several days in the event of a power failure.

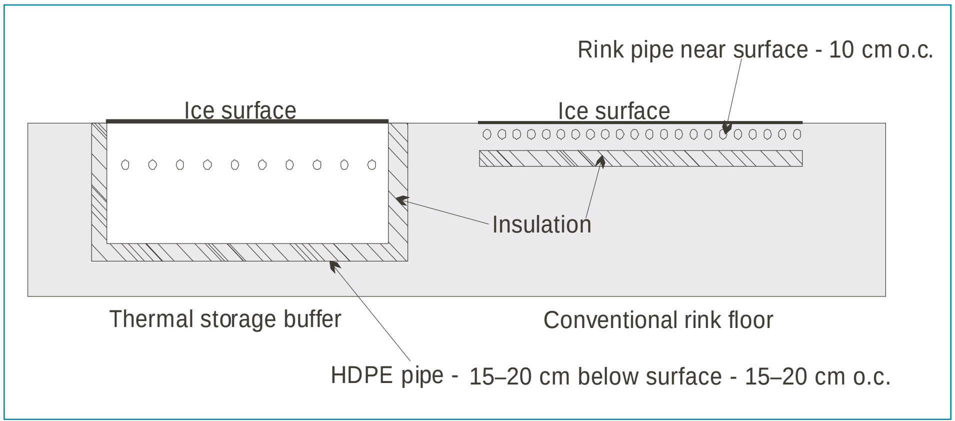


FIGURE 1: Illustrates construction of conventional rink floor and floor with thermal storage buffer. Thermal storage buffer stores 300-500 ton hours of cold, enough to maintain ice for an extended period of time if power is interrupted, or in case of pump or equipment failure. The large mass of cold helps maintain constant ice temperatures and uses less refrigeration capacity in the system. NOTE: The "thermal storage buffer" rink floor design has a patent pending.

A low-temperature water-water heat pump with a 10 kW compressor was installed in the mechanical room inside the ice shed area. The heat pump is designed to operate with water entering at temperatures as low as -29°C, using refrigeration duty compressors and a non-CFC refrigerant (R404A). The antifreeze chilled by the heat pump is circulated through the pipe in the rink floor.

Integrating a geothermal system

A vertical earth loop was constructed beside the arena by boring 48 ten-centimetre diameter holes to a depth of 38 metres in the clay soil. Three quarters of an inch high-density polyethylene pipes with U-bends were inserted into the boreholes and connected to four pairs of 61 cm supply and return lines. The supply and return lines were connected to a header in the mechanical room, with individual isolation valves on each.

Two 5-ton* forced air heat pumps replaced two 30 kW electric furnaces to heat and cool the viewing area, locker rooms and hall, using the warm earth loop as a heat source. Heat rejected by the ice is circulated through the earth loop, greatly enhancing the performance of the heat pumps heating the buildings.

During start-up in the fall, the earth loop warms to about 21°C to 27°C. As heating demand increases, the HVAC heat pumps gradually cool the earth loop to about –1°C to 4°C during the coldest part of the winter. Separate pumps circulate water from the loop through each heat pump and the low-temperature ice-making unit, minimizing electric consumption when only the HVAC units are in operation.

* 1 ton of cooling equals 211 kilojoules per minute or 200 BTU per minute of energy.

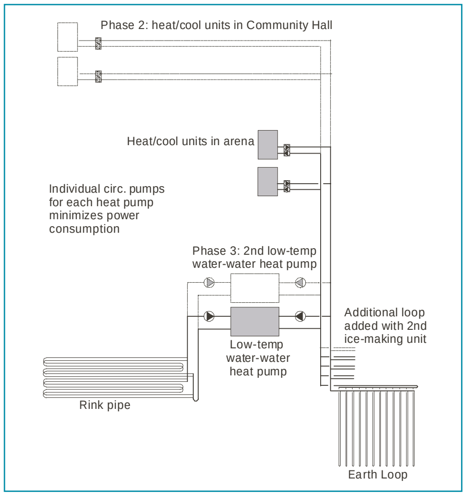


FIGURE 2: Piping schematic shows ice-making units rejecting heat to earth loop, and HVAC units drawing heat from earth loop. During start-up, the loop temperature rises to 21°C to 27°C. In colder weather, little refrigeration is needed in an unheated ice shed and little heat is rejected to the loop, while heating requirements increase, dropping the loop temperature to –1°C to 4°C. In spring, as more refrigeration is needed, heating requirements drop and the loop temperature rises again.

Design allows for phase-in over 2–4 years

The system was designed to be installed over a two to four year period, depending on the availability of funds.

The first phase was installed in 1998, and included one low-temperature heat pump to make ice, and two five-ton heat pumps to heat the lobby, locker rooms and second floor hall. Phase two included the installation of two ten-ton heat pumps in the adjacent community hall.

The third phase will include the addition of a second low-temperature heat pump to increase ice-making capacity.

Miami Arena mechanical room.

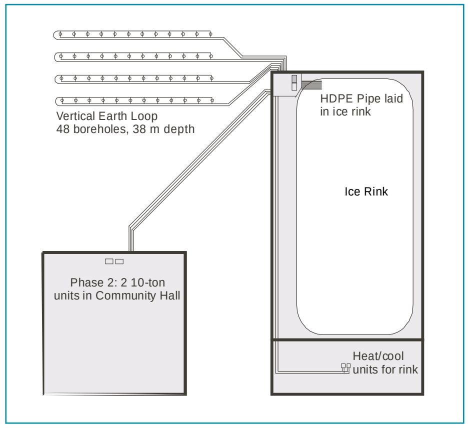


FIGURE 3: Site plan of Miami Hockey Rink and Community Hall

Future plans

The addition of a low-emissivity ceiling will enhance the performance of the system by reducing the heat gain to the ice. Adding insulation to the arena will reduce heat loss and allow the heating of the spectator area. A concrete floor can also be installed in the future in which a second layer of pipe could be laid. This will speed ice-making in the fall and allows for more flexible use of the arena in the summer.

Comparison of installation costs

Because the geothermal system includes a complete replacement of the electric heating system, the overall project costs are higher than a conventional ice plant. The following cost comparison assumes that a conventional ice plant installation would leave the existing electric furnaces and propane roof units in place.

Not only does a conventional ammonia system entail additional costs for constructing the housing for an ice plant, further costs are encountered for ventilation systems required by the safety regulations governing ammonia systems. These costs are not involved with the geothermal heat pump option, which also benefited from an incentive from Manitoba Hydro.

Energy demand with the geothermal system is actually less than the natural ice and electric heating system originally in place.

TABLE 1 Project Costs

	GEOTHERMAL SYSTEM	CONVENTIONAL SYSTEM
Low-temperature heat pump to make ice	$72,000	–
Geothermal heat pumps (HVAC & ducting)	$43,000	–
Circulation pumps (ice, earth loop)	$4,500	$5,000
Vertical earth loop	$33,000	–
Controls	$3,500	$1,500
Rink floor installation	$19,000	$30,000
Excavation for floor (supplied by community)	$15,000	$5,000
Insulation under rink floor	$16,000	$16,000
Locally supplied volunteer labour	$22,000	$18,000
Ice plant	–	$85,000
Addition to building to house ice plant	–	$15,000
Upgrade electrical service	–	$4,000
Utility incentives	($15,500)	–
Total Project Cost	$212,500	$179,500

Rapid payback for the geothermal system

The cost of installing an integrated geothermal system – one that would be used for ice-making and space heating – was higher than the estimated cost of installing a conventional ice plant because the HVAC component of the geothermal system accounted for approximately $43,000. If this fact is ignored, the cost of installing the geothermal system is similar to that of a conventional ice plant.

Calculating energy savings alone, the simple payback of the geothermal system compared to the conventional ice plant is less than three years. Remarkably, the geothermal system actually uses less energy than natural ice-making when the cost of operating the original electric heating system is considered. A conventional ice-making system requires more energy to make ice than the integrated geothermal system, and still requires electric heaters for space heating.

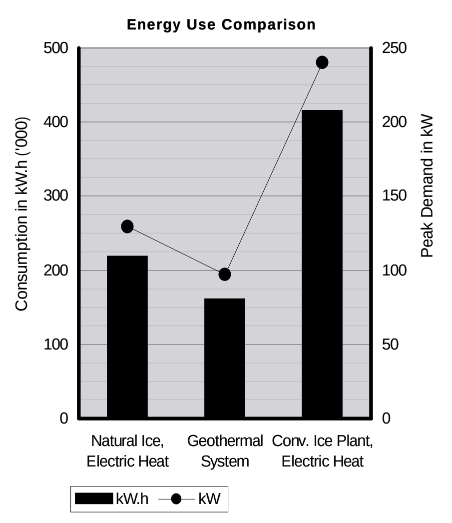


FIGURE 4: A comparison of energy usage of the Miami Hockey Rink & Community Hall in three scenarios. The first column shows the kW.h consumption and peak demand (kW) in the complex when they relied on natural ice, and electric heat was used in both buildings. The second column shows the electrical use after the installation of the integrated geothermal system and the third column shows the estimated consumption and demand had a conventional ice plant been installed and electric heat remained in place.

In Manitoba, the average cost of electricity for a building of this type is approximately $0.053 / kW.h. Operating costs for the complex under each of the three scenarios is shown in the following chart.

	NATURAL ICE, ELECTRIC HEAT	INTEGRATED GEOTHERMAL SYSTEM	CONVENTIONAL ICE PLANT, ELECTRIC HEAT
Energy Cost	$11,600	$8,500	$22,000

Integrated geothermal system offers more than just energy savings

The integrated geothermal system offers more than energy cost advantages over a conventional ice plant. Maintenance costs are significantly less. Ice plants using ammonia or freon require operators qualified under the Refrigeration Plant Operators Training Course. They also require daily monitoring, the keeping of a performance log and complex fall start-up and spring shut-down procedures.

When savings in maintenance costs are calculated, the payback for the geothermal system drops to less than two years.

TABLE 2 Operating and Maintenance Annual Costs

	CONVENTIONAL SYSTEM	GEOTHERMAL SYSTEM
Energy Cost (Rink & Hall)	$22,000	$8,500
Annual Service (startup & shutdown)	$2,500	–
Daily Maintenance (approx. 1.5 hours/day)	$4,000	–
Ice Maker — operating personnel (6 months/year)	$18,000	$12,000
6000 hour check (every 3–4 years - cost/year)	$1,500	–
12,000 hour check (every 6–8 years - cost/year)	$1,500	–
Heat pump replacement (once in 20 years)	–	$3,500
Circ. Pump replacement (once in 20 years)	$225	$130
Chiller, header, condensor (once in 20 years)	$2,800	–
Replace HVAC system (once In 20 years)	$1,500	–
Total Cost per Year	$54,025	$24,130

Reducing greenhouse gas emissions

Almost all electricity produced in Manitoba is generated by hydro-electric generating stations which do not contribute to the greenhouse effect. A reduction of energy consumption indirectly reduces greenhouse gas emissions however, because energy not used in Manitoba is sold outside the province to consumers who may otherwise use electricity generated by fossil fuels. A large producer of greenhouse gases may also wish to purchase carbon credits.

On average, one MW.h of electricity generated in Canada produces 187 kg of CO_2 emissions. The system installed in the Miami Hockey Rink and Community Hall reduced energy consumption by approximately 254.7 MW.h, avoiding 47.6 tonnes of CO_2 emissions annually.

Performance of the geothermal system

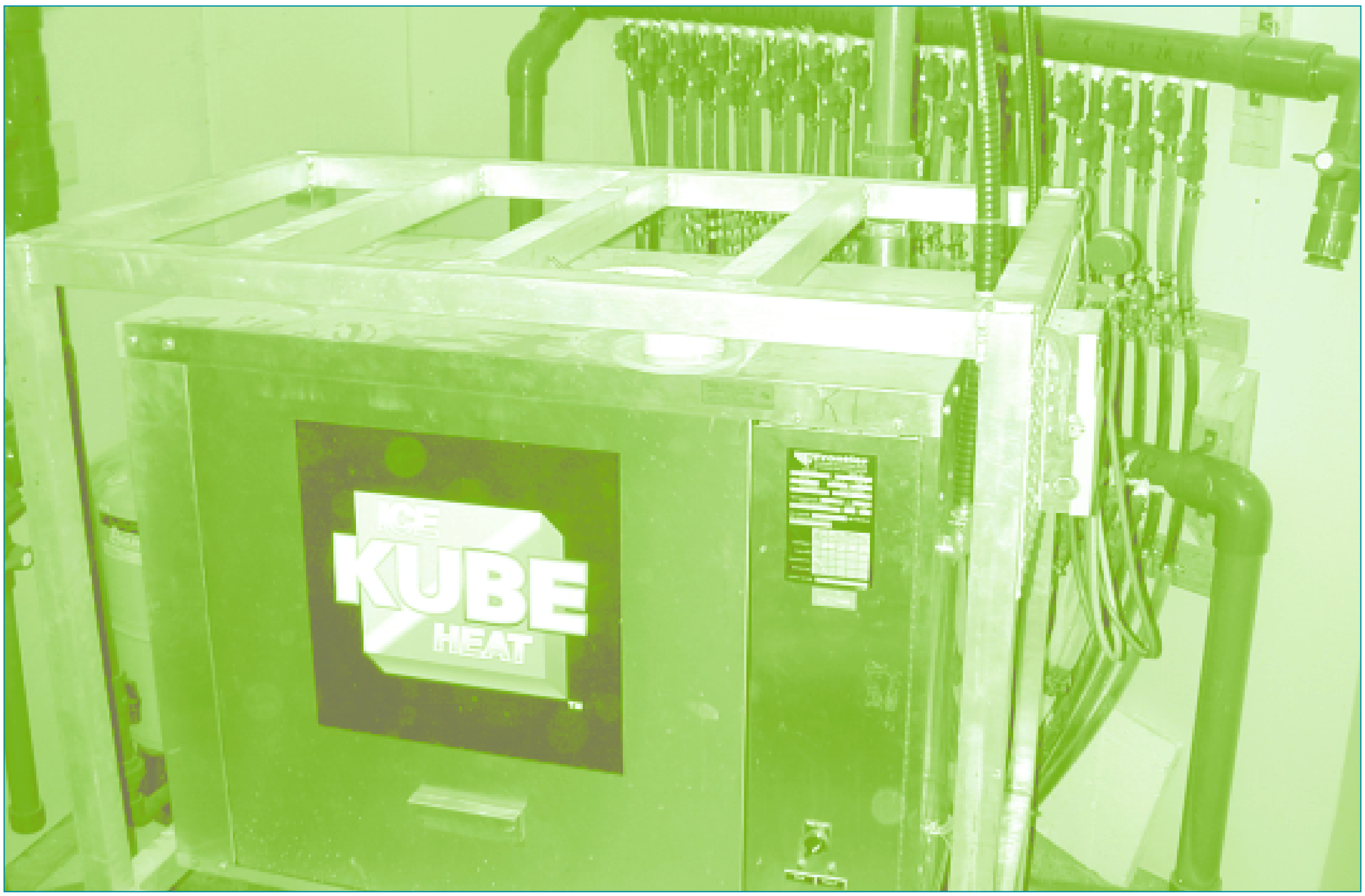
The Miami Arena can now be open for skating up to a month and a half before similar rinks relying on natural ice. The thermal buffer maintains the ice through winter warm spells and holds the ice up to a month longer in the spring.

The refrigeration capacity of the system is affected by the floor design and, consequently by the pumps circulating the chilled antifreeze. A conventional system relies on a 11-18 kW brine pump. The system in the Miami rink needs only a 1.5 kW pump to circulate the antifreeze through the floor. Higher flow rates in the conventional floor create higher friction losses in the pipe. This energy warms the fluid and has to be removed by the ice-making equipment. An extra 3-5 tons of chilling capacity is needed to remove the additional heat gains to the ice from the larger pumps, with no benefit to the ice.

New system pleases community

Since its installation in the fall of 1998, the installing contractor and the owners have had no difficulties in commissioning and operating the system. Simple control features of the new system have minimized difficulties in operating the ice-making and HVAC systems: individual digital thermostats for the heat/cool units; heat pump-controlled power supply to the circulators; and, a two-stage controller using liquid-line temperature sensors for ice-making and antifreeze circulation. The prepackaged nature of the geothermal heat pump system requires little monitoring.

Not only are the arena operators pleased with the system's low maintenance, they are delighted with the energy savings attributable to the integrated geothermal system. The comfort of the viewing area, lockers and community hall has improved. The community is looking forward to installing additional heat pumps to increase the rink's ice-making capacity and to heat the adjacent hall. Although a record warm fall in 1999 delayed the start of the second season until the end of November, the arena was able to open a month earlier than rinks relying on natural ice.



Ice-making heat pump.

Building Description

OCCUPANCY: Hockey arena & community hall

LOCATION: Miami, MB

GROSS FLOOR AREA:

ARENA:

929 square metres heated

1,589 square metres unheated ice shed

COMMUNITY HALL:

929 square metres

TOTAL:

3,447 square metres

NUMBER OF STORIES:

Arena 2

Community Hall 1

TYPE OF BUILDING CONSTRUCTION:

Retrofit

COMPLETION DATE:

Arena 1998,

Community Hall 1999

DEGREE-DAYS:

- Cooling (10°C) 0
- Heating (18.3°C) 10,860

Ground-Source Description

OVERBURDEN DEPTH: 43 metres

OVERBURDEN MATERIAL: Lacustrine clays

MEAN ANNUAL GROUND TEMPERATURE: 5.5°C

Interior System

TOTAL INSTALLED HEAT PUMP CAPACITY:

REFRIGERATION (initially/when complete):	12/24 tons
HEATING/COOLING (ARENA):	10/10 tons
HEATING/COOLING (HALL):	0/20 tons
TOTAL CAPACITY:	22/54 tons

NUMBER OF HEAT PUMPS: 3 / 6

INTERNAL FLUID DISTRIBUTION SYSTEM:

Fluid circulated to heat pumps from common ground loop header. Each heat pump will separate circulation pump.

FLOW RATE / INSTALLED CAPACITY :

11 Lpm / ton

INSTALLED PUMP SIZES REFRIGERATION UNITS:

Loop: 1.1 kW / unit

Ice: 1.5 kW / unit

HEATING/COOLING UNITS: 250 W / unit

OPERATING PUMP SIZE:

Refrigeration units:

Loop: 100 W / ton

Ice: 127 W / ton

HEATING/COOLING UNITS: 37 W / ton

ADDITIONAL SYSTEMS AND FEATURES:

- Thermal storage buffer under ice to reduce peak power demand and provide consistent ice temperatures
- Optimized rink pipe layout to reduce pump power requirements
- Ground loop used to store heat rejected from ice-making

Type of Ground-Source System

VERTICAL CLOSED LOOP:

48 boreholes to 38 metres

TOTAL BOREHOLE LENGTH (initially/when complete):

1,829 metres / 2,743 metres

TOTAL HEAT EXCHANGER LENGTH (initially/when complete):

3,658 metres / 5,486 metres

HEAT EXCHANGER PIPE: 0.75" HDPE

SECONDARY HEAT EXCHANGER FLUID:

Water and 28 % methanol (volume)

FLOW RATE THROUGH LOOP (initially/when complete):

322 Lpm / 719 Lpm

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