First Place: Public Assembly, Existing

The Biodôme, part of Montréal Space for Life, the largest natural science museum complex in Canada, houses five different ecosystems, which vary greatly in temperature, humidity and light requirements for hundreds of animal and plant species within its walls.

Geothermal for 5 Ecosystems

By André-Benoît Allard, Eng., Member ASHRAE

The Biodôme is part of Montréal Space for Life, the largest natural science museum complex in Canada, which also includes the Botanical Garden, the Insectarium and the Rio Tinto Alcan Planetarium.

The Biodôme is a unique building filled with flora and fauna from five different replicated ecosystems from the Americas. Although these ecosystems are all under one roof, they vary greatly in terms of temperature, humidity and light requirements for hundreds of animal and plant species living within the dome. Four of the ecosystems—the Laurentian Maple Forest, the Gulf of St. Lawrence, the Sub-Antarctic Islands and the Labrador Coast—must be cooled year-round while the Tropical Rainforest must be heated.

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Project Drivers

The Biodôme is deeply committed to protecting the environment and biodiversity. In addition, the building's energy costs were consistently high because the building had some zones that required constant heating while others required the removal of excess heat. It was supplied with chilled water (yearly average 330 tons) and steam (yearly average 3,000 lb/h [0.38 kg/s]) by the neighboring building. The electric demand for the building was approximately 3,200 kW.

Finally, the electromechanical equipment used for heating, cooling, and lighting required major upgrades. Therefore, the institution decided to go forward with an ambitious energy-efficiency retrofit project aimed at significantly reducing energy consumption and greenhouse gas emissions.

The chillers—or heat pumps—use R-134a. A 250 ton (879 kW) heat pump is dedicated to the Sub-Polar Regions where a colder water-glycol mixture is needed.

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Project Description

An energy saving retrofit was performed on the building from 2008 to 2010. The project was carried out as an energy performance contract in partnership with a firm of energy-efficiency professionals.

Implemented in close partnership with the Biodôme's technical services staff, the project was designed to dig deeper into the existing energy infrastructure to reduce costs, upgrade equipment and improve conditions for the collections and for the people in offices and public areas.

The $8.1 million project reduced energy costs by 52% and greenhouse gas emissions by 80%. Project costs are being repaid within a 5.2-year period by guaranteed energy savings and $1.6 million in government and utility incentives.

The project was carried out as an energy performance contract, with the energy services firm providing all services for a lump sum. All energy savings and incentives were contractually guaranteed.

The process began with the compilation and analysis of all the building's energy bills from the last five years. One of these years, considered the most representative, was selected as the "base year." The preliminary study and the detailed study fully met the requirements of sections 5.3 to 5.5 of Standard 100-2006, *Energy Conservation in Existing Buildings*, and "Level 3—Detailed analysis of capital intensive modifications." Finally, this scope of services included a project performance monitoring phase and a guarantee by the energy services firm of finan-

A retrofit completed in 2010 resulted in reducing energy costs by 52%.

Building at a Glance

Montréal Biodôme, a Space for Life institution

Location: Montréal, QC, Canada

Owner: Ville de Montréal

Principal Use: Environmental museum with living collections

Includes: Replicated ecosystems, live flora and fauna, offices

Employees/Occupants: 850,000 visitors per year, 150 – 250 employees (varies by season)

Occupancy: 850,000 visitors per year

Gross Square Footage: 372,000

Conditioned Space: 372,000 ft^2

Substantial Completion/Occupancy: June 1992

National Distinctions/Awards: Federation of Canadian Municipalities (FCM): Sustainable Communities Award and Green Championship Award cial savings over a period of five years from the provisional acceptance of the project.

Heat Recovery and Transfer Between Ecosystems

Central to the retrofit is an energy recovery and energy transfer system between the various ecosystems that is used to cool and heat other parts of the building. The heat recovery system includes four heat pumps with a total rated capacity of 1,450 tons (5100 kW). This design allows for completely secure operation, even if one of the heat pumps suffers a technical problem.

The chillers—or heat pumps—of the new power plant use R-134a. The plant has three 450 ton (1583 kW) heat pumps used for cooling, and a fourth 250 ton (879 kW) heat pump is dedicated to the Sub-Polar Regions of the building where a colder water-glycol mixture is needed. This configuration allows the three heat pumps to work in a better efficiency range. The heat pumps are used in cooling and heating through recovery techniques. Cold and heat are distributed throughout the building through a water-glycol mixture system completely redesigned to maximize the heat recovery potential of the heat pumps.

New heating coils were installed in the ventilation systems and chosen to maximize the use of the low-temperature water-glycol heating system and maximize the heat exchange and temperature difference (ΔT) between the supply and return

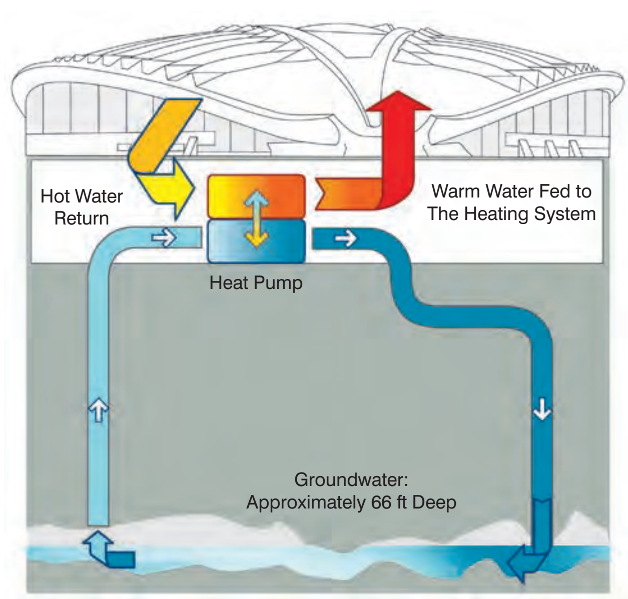

Figure 1: Groundwater is used for heating and cooling. In winter, the groundwater's heat is used for heating the building. In summer, excess heat from the building is transferred to the groundwater (winter mode).

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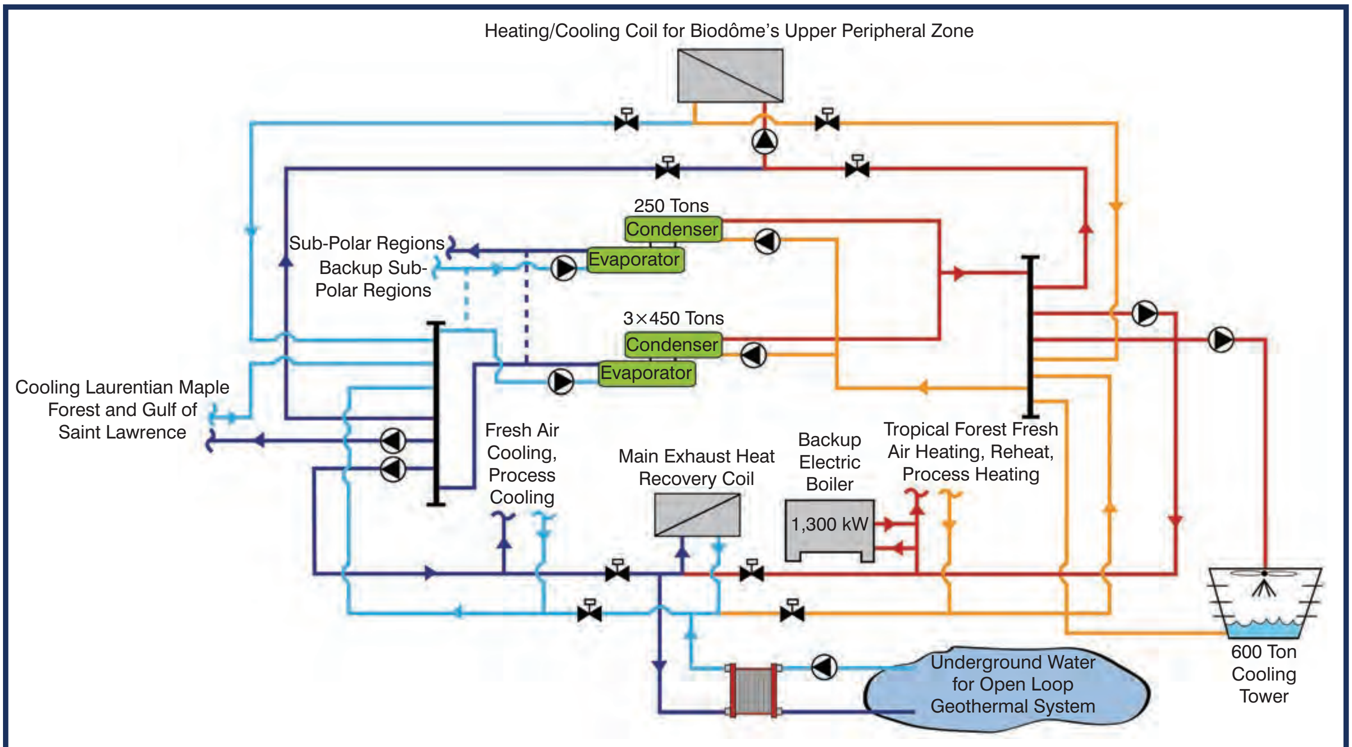

Figure 2: The Biodôme uses one of the largest open-loop ground-source heat pump systems in Canada.

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of the heating system. This design allows for the Biodôme to fully meet the needs for heating and cooling year-round using the heat pumps and eliminating the use of steam.

	Adjusted Base Year	Year Monitored	Amount Saved	Savings
Electricity (kWh)	20,417,631	18,014,152	2,403,479	11.8%
Electricity (kW)	4,324	3134	1,190	28%
Steam (mlb)	25,702,000	0	25,702,000	100%
Chilled water (mBtu)	34,834,244	0	34,834,244	100%
Total energy (GJ)	144,118	64,850	79,268	55%

Table 1: Energy savings of base year and monitored year compared.

Summer Heat Recovery

The marine and polar zones are mechanically cooled year-round by the heat pumps for cooling purposes and dehumidification. The energy recovered is used for reheating and processes. During summer, the cooling capacity is more than sufficient to provide most of the building's heating. Note that the Tropical Rainforest requires heating most of the year. The surplus energy is discharged by the heat pumps into the main exhaust air system, in a cooling tower, as well as in the geothermal open loop system.

Winter Heat Recovery

The building's peripheral heating was previously provided by electric baseboards and electric coils through the ventilation. It is now provided by the glycol-water mixture in addition to heat recovered by the heat pumps. In winter, the warm water-glycol mixture flows through the ventilation air-conditioning coils. The heating is largely provided by the ventilation. The electric baseboards, although retained, are used much less.

The heating capacity of the heat pumps depends directly on the building cooling load. During winter, capacity decreases; some alternatives had to be developed to maximize the production of hot water by the heat pumps.

The natural cooling of many ventilation systems (using cold outside air) was reduced in favor of mechanical cooling. Air-conditioning coils (heat recovery) were installed in the common exhaust duct of several ventilation systems. These systems discharge between 50,000 and 80,000 cfm (23 597 and 37 755 L/s) of hot air. Any shortfall is compensated by heat from the open-loop ground-source heat pumps.

Open-Loop Ground-Source Heat Pump System

The Biodôme uses one of the biggest open-loop ground-source heat pump systems in Canada, with water drawn from the underground water some 98 ft (30 m) below the building at a rate of 720,000 gallons/day (2 725 495 L/day). Depending on the time of the year, the system meets heating and cooling needs that the heat recovery system cannot meet alone. During the summer, it is possible to transfer the heat from the heat pumps to the underground water and store the heat for the heating season.

Optimized Lighting

Despite the Biodôme's impressive fenestrated roof, artificial lighting is essential. Lighting greatly affects the quality of life for residents of ecosystems. Adequate lighting levels are specified by the institution botanists and zoologists, as specifically mentioned in Section 6.6.2 of Standard 100.

Optimization of ecosystem lighting cut associated electric demand from 1,070 kW to 489 kW.

For the Sub-Polar Regions alone, the lighting demand and consumption were both reduced by 75%. Existing lighting was completely converted to new T5 HO tube fixtures. In the three other ecosystems, the new lighting system allows a better adjustment of light intensity according to the amount of natural sunlight from the glass roof. This was made possible by a combination of new 1,000 W high pressure sodium and metal halide lamps that meet the needs of particular plants and animal biological cycles. New ballasts were also installed away from the ecosystems and sunlight, which reduced premature aging of ballasts that used to buzz and disturb the peace and quietness of the ecosystems. The placement of the fixtures was modified to avoid light loss in the structure.

In administrative and offices spaces, all T12 tubes and magnetic ballasts were replaced with high-efficiency low factor ballasts and 28 W T8 tubes. Therefore, this point meets Section 6.6.5.4 of Standard 100.

Optimization of Fans and Pumps

Thirty-six fan and 19 pump motors have been replaced by high efficiency motors. A number of motors were resized, depending on the load they carried, as stipulated in Section 7.5.2 of Standard 100. They are powered by variable frequency drives.

Fan speed is adjusted according to each ecosystem's unique schedule and temperature setpoint. The fresh air supply in certain sectors such as the Tropical Rainforest is controlled by CO_2 sensors.

Energy Savings

The Biodôme now consumes only electricity. The building's energy intensity decreased from 367.15 Btu/ft^2 to 164.62 Btu/ft^2 (4170 kJ/m^2 to 1870 kJ/m^2) (calculated using gross area), representing a 55% reduction in energy consumption.

Conclusions

Although this building is filled with unique characteristics and living collections, the principles of technological innovation could be applied to almost any large building. This case is a good example of an approach that aligns the interests of industry professionals to those of the clients: it stimulated teamwork, innovation and exceptional results. Most importantly, this case demonstrates clearly that projects to reduce greenhouse gas emissions can also be very profitable for building owners. ■