Five Hospitals, One Goal: Maximum Energy Savings

The CHU is a group of five main hospitals in Quebec City. Upgrades to three of the sites were completed in 2015. Centre hospitalier de l'Université Laval (CHUL) (pictured) is the largest.

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PHOTO CREDIT: CENTRE HOSPITALIER DE L'UNIVERSITÉ LAVAL (CHUL)

Between 2010 and 2017, the CHU de Québec–Université Laval (Quebec City University Hospital Center) underwent major asset renewal across three of its sites (and a fourth one was completed as of press date). The CHU has slashed its energy consumption by 30%, generating $2.9 million in annual savings, and reducing its greenhouse gas emissions by 52% (12,000 metric tons per year).

The CHU chose a performance contracting model and used an integrated approach to completely rethink the way they consume energy. This resulted in maximum energy savings and energy efficiency incentives, which were used to pay for a large portion of the asset renewal required in the hospitals.

Project Sites

The CHU is a group of five main hospitals in Quebec City, with an annual energy bill of $9.5 million.

Upgrades to the three sites (*Photos 1, 2* and *3*) were completed in 2015, with two full years of performance monitoring.

The sites are located in a different neighborhoods and do not share a common district network. All were treated as separate projects. The largest site, and the first to be upgraded, was CHUL with a gross surface area of 1,375,434 ft² (127 778 m²) and a net surface area of 1,031,946 ft² (95 868 m²). Upgrades to the two remaining sites began a year later.

Needs and Requirements

Although each site had particular needs, a few common drivers were present among all three sites:

- Renewing HVAC assets and addressing deferred maintenance resulting from years of government budget cuts to the hospitals' technical services;
- Achieving sustainability goals, including reduced water and energy use, lower GHG emissions, and eliminating certain refrigerants;
- Reducing maintenance costs for HVAC systems;
- Maintaining comfort for the patients and staff;
- Meeting energy efficiency targets set by the Quebec government for healthcare facilities; and
- Designing with a focus on results.

To achieve its goals, the CHU issued a public request for proposal (RFP), seeking a design-build firm that could also contractually guarantee the project cost, the financial

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Building at a Glance

The CHU de Québec

Location: Quebec City

Owner: CHU de Québec–Université Laval

Principal Use: Healthcare services

Includes: Emergency and specialized healthcare services, administration, food services, etc.

Employees/Occupants: 10,000

Gross Square Footage: 3,192,144

Conditioned Space Square Footage: 3,192,144

Substantial Completion/Occupancy: December 2014

Occupancy: 100%



The CHU is a group of five main hospitals in Quebec City. Upgrades to three of the sites were completed in 2015. Each site is in a different neighborhood and they do not share a common district network. The largest site, and the first to be upgraded, is Centre hospitalier de l'Université Laval (CHUL) Photo 1 (Left). The two remaining sites, Hôpital de l'Enfant-Jésus (HEJ) Photo 2 (Center) and Hôpital du Saint-Sacrement (HSS) Photo 3 (Right), were upgraded at the same time one year later.

incentives and the annual savings over the entire payback period. The project's simple payback period (excluding financing rate) was 6.5 years. One of the financial metrics used to choose the winning firm was net present value (NPV), which highlighted the project with the greatest overall value for the CHU, accounting for all expenses and savings over a 20-year period.

Over the following months, the chosen firm became an extension of the CHU's technical services department, doing extensive surveys of the HVAC systems and prompting feedback from the CHU's operating staff. The project team was focused on achieving substantial results, and took a holistic approach to the buildings, seeking every opportunity to improve the ventilation systems, heating and cooling networks, lighting, and centralized control systems.

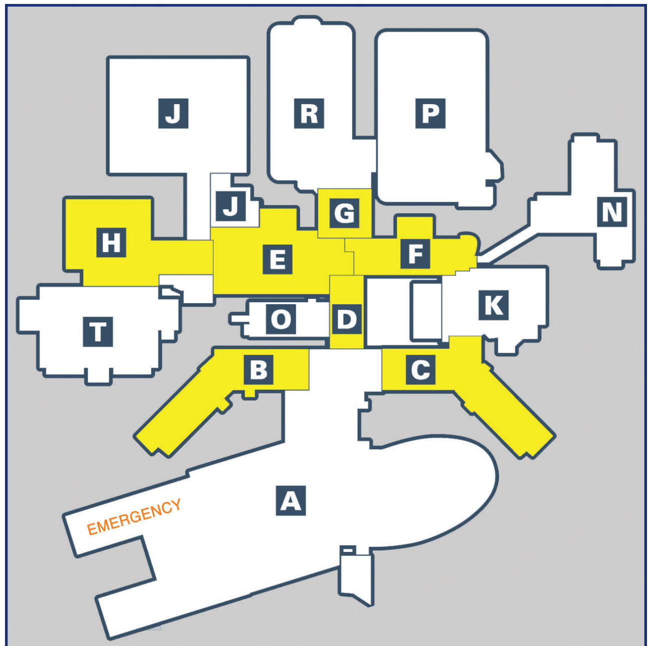
A central aspect to the design was converting the hospitals' steam heating systems to hot water, making it possible to add high-efficiency heat pumps. The design for each site focused on maximizing heat recovery and minimizing energy losses throughout all networks (steam, hot water, chilled water).

Once the design for the deep energy retrofit was finalized, the project team provided a detailed description of the energy conservation measures and the contractually guaranteed financial figures. This allowed the CHU to secure its financing and get started with the implementation phase.

Throughout the entire transition time of the construction period, the design-build firm supported the CHU's operating staff to ensure the most efficient operation without compromising the comfort of patients and staff.

Key Measures Implemented

Eighteen energy conservation measures were implemented at the CHU, some of which involved deep



CREDIT: ECOSYSTEM

FIGURE 1 Blocks within the CHUL, converted from steam to hot water heating networks.

transformational changes, and a highly collaborative approach from all stakeholders to minimize service disruptions and maintain a high level of service and patient care.

Steam to Hot Water Conversion of the Heating System

Steam requirements for heating were removed from all three sites (*Figure 1*). By switching the heating system from steam to hot water, this reduced network thermal losses and eliminated certain inefficiencies associated with steam networks such as steam traps leaks, boiler blowdown and flash steam from atmospheric condensate tanks.

Extensive engineering was deployed to understand the heating loads of the buildings before sizing any new piping and network components.

The conversion required changing coils in some ventilation systems as well as changing radiators in other areas. For the CHUL hospital, 900 aging steam radiators were replaced by new hot water radiators. These radiators were spread over six floors and in various departments, and communication with the technical services department and medical staff was key to prevent any service disruption for the patients.

Some existing steam piping was reused, depending on its condition, and new piping (especially return piping) was installed to create new hot water and warm water heating networks. Both the hot and warm water networks focused on using the lowest water temperature possible to meet the heating loads. To achieve this, the various coils and radiators were sized to provide enough heat with a lower water temperature in the 120°F to 150°F range (49°C to 65°C).

PHOTO CREDIT: ECOSYSTEM

PHOTO 4 The CHUL's closed loop geothermal field consists of 60 boreholes 600 ft (183 m) deep.

On one of the three sites (HSS), the chilled water network is used as a warm temperature heating network during winter, using warm water supplied by the heat pumps.

One of the most interesting design intricacies was to connect as many loads as possible in series, from the hottest water temperature requirement to the lowest, which enabled a greater temperature differential. Having the return temperature as low as possible allowed the design team to take full advantage of new heat recovery heat pumps to supply the major part of the heating load during shoulder seasons, and still a fair part during the cold winter months.

The new central hot water network primarily uses two-way valves, making it a variable flow network where the main pumps are controlled by VFDs.

Steam requirements for other needs, such as humidification, sterilization, food services or laundry, were addressed by a smaller steam network or independent equipment.

Heat Recovery and Geothermal Heating

To counterbalance the winter's lower cooling load (and heat recovery potential), the project design took advantage of a few strategies. On all three sites, heat pumps were installed to maximize heat recovery and take advantage of Hydro-Quebec's clean and inexpensive electricity. In many areas, chilled water loops were unified to maximize the heat recovery potential. Heat recovery coils were also installed in some ventilation exhausts and boiler chimney stacks. Existing direct contact heat exchangers on chimney stacks were optimized by connecting them on the chilled water loop rather than on the heating network return.

Dedicated geothermal heat pumps were also installed and properly sized for the geothermal underground exchanger. The design team opted for a horizontal underground heat exchanger for one site while the other two sites saw vertical boreholes drilled 600 ft (183 m) deep in their parking lots (*Photo 4*). Between all three sites, this underground network adds up to around 33 miles (53 km) of piping (see *Recovery and Heating* and *Figure 2,* Page 60).

In some buildings, the design team opted to connect two heat pumps in a cascade system configuration. The dedicated geothermal heat pumps' condensers was connected on the evaporator side of the building's main heat recovery chiller. This configuration made it possible to run the geothermal heat pump at a very low discharge temperature on the condenser side (in the 45°F to 60°F range [7°C to 15°C]), improving its COP, while providing an additional warm temperature heat source recovered by the main heat recovery chillers.

Solar Power for Fresh Air Preheating

For the CHUL, a 2,475 ft^2 (230 m^2) solar wall was installed to preheat the fresh air used in some ventilation systems (20,800 cfm [9815 L/s]). In optimal winter conditions, the

Advertisement formerly in this space.

Recovery and Heating

	Heat Pumps for Hot Water Network	Heat Pumps for Geothermal Heating and Warm Water
CHUL	1 × 850 tons	1 × 200 tons
HSS	1 × 190 tons	1 × 160 tons (Existing Chiller)
HEJ	2 × 190 tons	1 × 220 tons

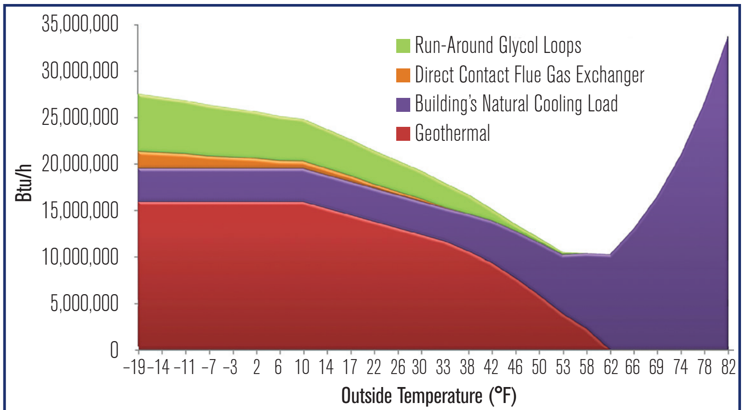


FIGURE 2 CHUL's heat recovery capability after project.

heat gain is as much as 22°F (12°C). During summer, dampers allow the fresh air intake to bypass the solar wall and enter the ventilation system without being preheated.

Labs Dynamic Ventilation

The CHUL hospital includes an important laboratory/research department with 43 hoods that ensure proper air quality. The air change per hour rate was maintained at 12 prior to the project, which, with 100% fresh air systems, resulted in high operating costs. Motion sensors were installed at each hood, allowing dampers to reduce the exhaust air speed. Also, a new air sampling system that channels air samples from various areas to a central probe station was installed. This dynamic ventilation system enables efficient monitoring of contaminants and conditions in large areas. The limited number of probes/sensors is reducing maintenance costs and recalibration required for such components. Sensors in the centralized probe station can be changed periodically, ensuring they are always well calibrated. With this new system, as well as motion sensors on each hood and variable speed drives on the ventilation fans, evacuation rates under normal operation are reduced, but if air contaminants are detected, fresh air and evacuation rates can increase rapidly. This translates to significant energy savings on air conditioning (heating, cooling and humidification).

Site EUI

	Before	After
CHUL	257.2 kBtu/ft^2	177.9 kBtu/ft^2
HSS	205.1 kBtu/ft^2	158.5 kBtu/ft^2
HEJ	214.9 kBtu/ft^2	159.4 kBtu/ft^2

Optimization of the Various Networks (Chilled Water, Steam and Hot Water)

Most of the chilled water networks were optimized to modulate according to the building's cooling load. Using variable speed drives, the chilled water pumps now reduce their speed during low demand periods. This prevents excessive heat from the pumps dissipating in the chilled water networks, which represent an additional cooling load for the chillers. Thus, these optimizations generate savings from both the pumps and the chillers.

Controls and Buildings Optimization

New controls and graphic displays were implemented where needed, along with the new probes and sensors required to optimize and manage the new systems.

A complete optimization of the systems was conducted at all three sites, including a review of the operating schedules and the reduction of simultaneous heating and cooling, which occurred on some sites and reduced comfort levels for building occupants.

Beyond Impressive Results

After more than two years of completed performance monitoring, the numbers affirm that the contractual targets set with the design-build firm were met. The site energy use intensity of the three CHU sites combined dropped from 238.1 KBtu/ft^2 to 166.4 KBtu/ft^2 (2.70 GJ/m^2 to 1.89 GJ/m^2), a 30% reduction, well beyond the 14% government target.

Critical HVAC equipment was also replaced, including 12 boilers, a chiller and a cooling tower, resulting in improved redundancy and continued reliability for building occupants. Greenhouse gas emissions were reduced by 52% from 24,731 to 11,814 metric tons in 2015.

Figure 3 shows the energy consumption comparison for all three sites. The energy use intensity factors before and after the project are shown in *Site EUI* above.

Although not monitored, many measures are generating water savings, including the steam to hot water conversion of the heating network, through reduced network losses and boiler blowdown. The use of heat recovery chillers translates into a reduced use of the cooling towers, which are huge water consumers. The geothermal fields, also used to reject heat during the summer, further reduce the use of the cooling towers.

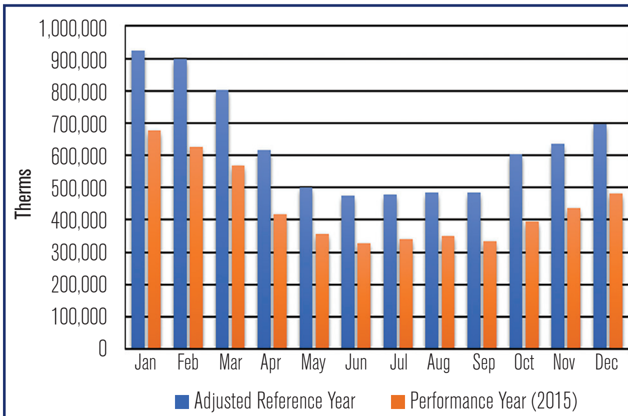
Some of the older chillers that used R-11 have been replaced. The replacement chillers and heat pumps all use R-134a refrigerant, in compliance with the Montreal Protocol.

Operation and Maintenance

The new installations were designed to improve energy efficiency and address the CHU's needs in terms of maintenance and ease of operation.

The steam to hot water conversion of the heating networks reduces the number of parts to maintain, such as steam traps and pressure reduction valves, across all three sites. Old radiators and steam networks supplying the patient rooms often failed, requiring urgent work that compromised the patient experience. The new hot water network is reliable and easier to maintain.

The design-build firm provided specific training sessions for the operating staff of the CHU for all new equipment, as well as for efficient building operation strategies and centralized control upgrades. The project was well documented with project manuals, including each system's spec sheet, technical drawings, user manual, control strategies and manufacturer's guarantee.



Note: Electricity consumption increased 4.4%, natural gas consumption decreased 53% and Oil#2 consumption decreased 56%. The adjusted reference year refers to what the building would consume in the current year (2015) if no project had been implemented.

FIGURE 3 Energy consumption comparisons of all sites and all energy sources combined.

Innovation

The project took advantage of proven technologies, and the true innovation here lies more in the business model, which focused on aligning the interests of all parties, creating a highly collaborative environment with a focus on delivering measurable results, rather than simply delivering energy efficient features. ■

Lessons Learned

There are many ways to accomplish large projects like these, and each approach has its pros and cons. For projects specifically targeting energy consuming HVAC systems, the CHU felt that paying a firm to achieve results, rather than simply deliver a project, would compel all the parties involved to a more collaborative approach, hence better integrated solutions.

Attract the Best and Most Committed Firms in the Industry Attracting design-build firms willing to contractually guarantee the project cost, financial incentives and annual savings requires a very specific type of RFP, involving more time to build a proper reference year, among other considerations.

Get the Most Value Out of Your RFP To help you get the most from a performance contracting project, prior to the RFP, have a thorough knowledge of your building, including existing capital plan requirements such as aging HVAC equipment replacement. The extra effort spent prior to issuing the RFP will pay dividends in the future.

The procurement process should also allow bidders the freedom to come up with innovative solutions, as long as existing environmental conditions remain equally as good, or are improved.

Using the net present value (NPV) calculation over 20 years is helpful to compare various projects with different return on investment (ROI) periods. Ensure that bidders enter the useful life of industry recognized equipment in their NPV calculation, along with the appropriate annual maintenance cost, which can at times negate any maintenance cost gains from removing older equipment.

Throughout the Design Phase, Bear in Mind Future Building Operations With projects based on the unification of many networks, be sure to consider isolation devices (such as valves or heat exchangers) and strategies to isolate portions of the network in case of maintenance issues.

Transparency With a Clear M&V Plan During the performance follow-up period, a well-documented measurement and verification (M&V) plan is the key to preventing unnecessary negotiations between parties. A thorough knowledge of your building will equip you to set the best M&V strategies for various energy conservation measures.

Investing in Your Operating Staff Major infrastructure upgrades bring on new operating strategies. You should require a comprehensive training program from the firm you choose to work with.