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The designers of Abbotsford Regional Hospital and Cancer Centre in British Columbia rethought hospital design to save energy.

Rethinking Hospital Design

By Paul Marmion, P.Eng., Life Member ASHRAE

Hospitals, with their high ventilation rates and 24/7/365 occupancy, consume more energy than most other building types. An acute care hospital such as the Abbotsford Regional Hospital and Cancer Centre (ARHCC), a $355 million facility with 300 acute care beds, nine operating theaters, maternity and pediatric services, medical imaging, radiation cancer treatment, and a host of secondary staff and patient services, is no exception. To reduce the amount of energy consumed within this 61 756 m^2 (664,736 ft^2) facility it was necessary to rethink the typical hospital design practice.

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The Private-Public Partnership (P3) process created an integrated team comprised of the funding agencies, the owner, architects, engineers, user groups, contractors and building operators. Their efforts resulted in an acute care hospital that uses 34% less energy than an equivalent code-compliant building, and resulted in an annual savings of $475,000, which during the 30-year contract of the P3 equals $14,250,000 that can be reinvested into patient care.

Under the P3 contract, the hospital's design had to achieve at least three LEED energy points, which required the hospital's energy performance to be at least 25% better than the ASHRAE Standard 90.1-1999, code-compliant building. At the time of design, this stipulated target was considered to be challenging for a green field acute care hospital.

To achieve the three LEED energy points and to validate the hospital's operating energy, many possible ECMs (energy conserving measures) were analyzed by the design team with the assistance of the project's energy consultant, using contractor pricing and advanced simulation software to achieve the best balance of energy efficiency and cost effectiveness.

The results of the analysis were validated using the project operators own energy database and energy analysis software. In addition to the energy design targets, the P3 contract required that the hospital's operator establish a "baseline" hospital operating energy consumption cost so that yearly energy billing reconciliations can be made to validate actual operating energy consumption of the hospital. The contract also stipulated associated rewards and penalties based on the results of the yearly reconciliation. These stringent requirements made the energy simulation work critical with real-world consequences. A summary of the initial energy study results is in *Table 1*.

The hospitals design criterion for the hospital is:

- Heating: 1% outside design temperature = –10°C (12°F) in January;
- Heating degree-days below 18°C = 3100 (5580 degree days below 65°F);
- Cooling: 2.5% outside design temperatures = 29°C (84°F) DB and 20°C (68°F) WB in July; and
- Annual Rain = 1600 mm (63 in.).


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The hospital uses less than half the energy used in the industry average.

When it comes to the energy efficiency of a building, the process starts with a high performance building envelope. For this building, the design used low-e, argon-filled glazing with selective shading coefficients for the control of the envelope's related heating and cooling loads. This is complemented by an energy-efficient lighting system with a power density of 8.9 W/m^2 (0.8 W/ft^2) compared to a typical hospital density of 15.3 W/m^2 (1.4 W/ft^2). The next step was to develop an efficient and cost-effective HVAC system that would reduce the hospital's operating energy and, at the same time, be compliant with all applicable hospital codes and standards, and meet the LEED requirements for indoor air quality and thermal comfort.

Due to the 30-year operating components of the P3 contract and operating cost guarantees, all energy-saving strategies had to be proven technologies with long-term reliability and repeatability. The use of aquifer water for heat pump heating and cooling, for example, was deemed to be too risky even though it has a fast payback and would have easily achieved the three LEED energy points.

The strategies selected included high-efficiency (85%) gas-fired hot water boilers, two at 4,900 kW and one at 2,000 kW, which can be controlled to run the boilers at optimum efficiency

Building at a Glance

Abbotsford Regional Hospital & Cancer Centre

Location: Abbotsford, BC, Canada

Owner: ARHCC Inc.

Principal Use: Acute Care Hospital and Cancer Treatment Centre (includes: 300 acute care beds, nine operating theaters, maternity, pediatrics, mental health services, medical imaging, radiation cancer treatment)

Gross Square Footage: 664,736

Employees: About 2,600

Substantial Completion/Occupancy: August 2008 while adjusting to the changing demand within the building. A further 700 kW of energy was recovered from the boiler breeching using a flue gas heat recovery system. The recovered energy is used for building reheat loads and domestic hot water heating. The incremental capital cost of adding the flue gas heat recovery system was $208,000 with a predicted annual energy savings of $36,000, providing a six-year simple payback.

	Electricity (kBtu)*	Gas (kBtu)	Total (kBtu)	Total (kBtu/ft²)	Energy Cost	Cost/ft²
Proposed	30,608,000	48,786,000	79,394,000	132	$978,108	$1.63
Reference	50,880,700	70,255,500	121,136,200	202	$1,459,750	$2.44
Savings	20,272,700	21,469,500	41,742,200	70	$481,642	$0.81

* With process/non-regulated loads removed (modeled area was 600,000ft²).

Table 1: Energy analysis results (proposed includes all ECMs applied in the final design).

Two 165 kW (900 ton) chillers are piped in a counter-flow configuration with chilled water temperature reset control to optimize energy efficiency, consuming less than 0.14 kW/kW (0.5 kW/ton) of cooling. There was no incremental capital cost of adding the counter-flow configuration, resulting in an annual energy saving of $3,400, and providing instant payback. Furthermore, the chiller plant condenser water heat recovery system recovers up to 980 kW of energy that would normally be wasted. This energy is used for pre-heating the incoming domestic hot water and achieved a simple six-month payback on the system with a $15,000 capital investment and annual energy savings of $28,000.

Air-handling unit bypass control dampers are installed on all major heat recovery coils and cooling coils resulting in a significant reduction in fan operating energy whenever the heat recovery and cooling coils are not active. The bypass dampers save approximately $1,200 per year and provide a six-year simple payback.

The 100% outside air systems serving the operating rooms, laboratory, morgue and intensive care areas comprise a significant 40% of the facility's exhaust air that is usually wasted. An exhaust air heat recovery system was added to all air handlers serving these areas and to general exhaust air systems from other areas. The recovered heat was used for preheating and precooling the 100% outside air systems. The energy required for the heating and cooling was reduced through demand ventilation control using CO_2 and occupancy sensors that turn off the lights and reduce the ventilation air supplied to non-occupied areas in non-critical clinical areas of the hospital. The hospital has a large atrium served by a mixed mode: integrated natural and mechanical ventilation system that saves energy while

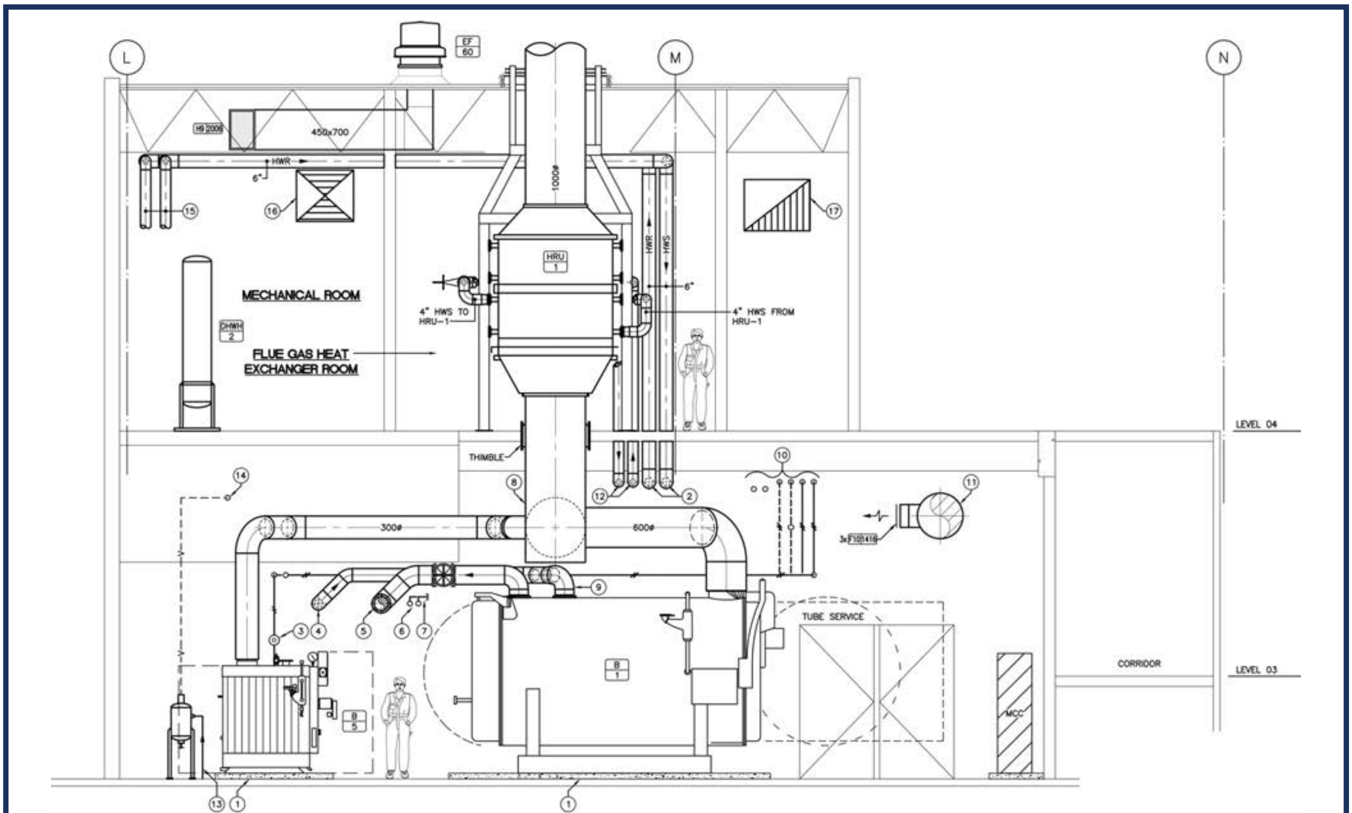
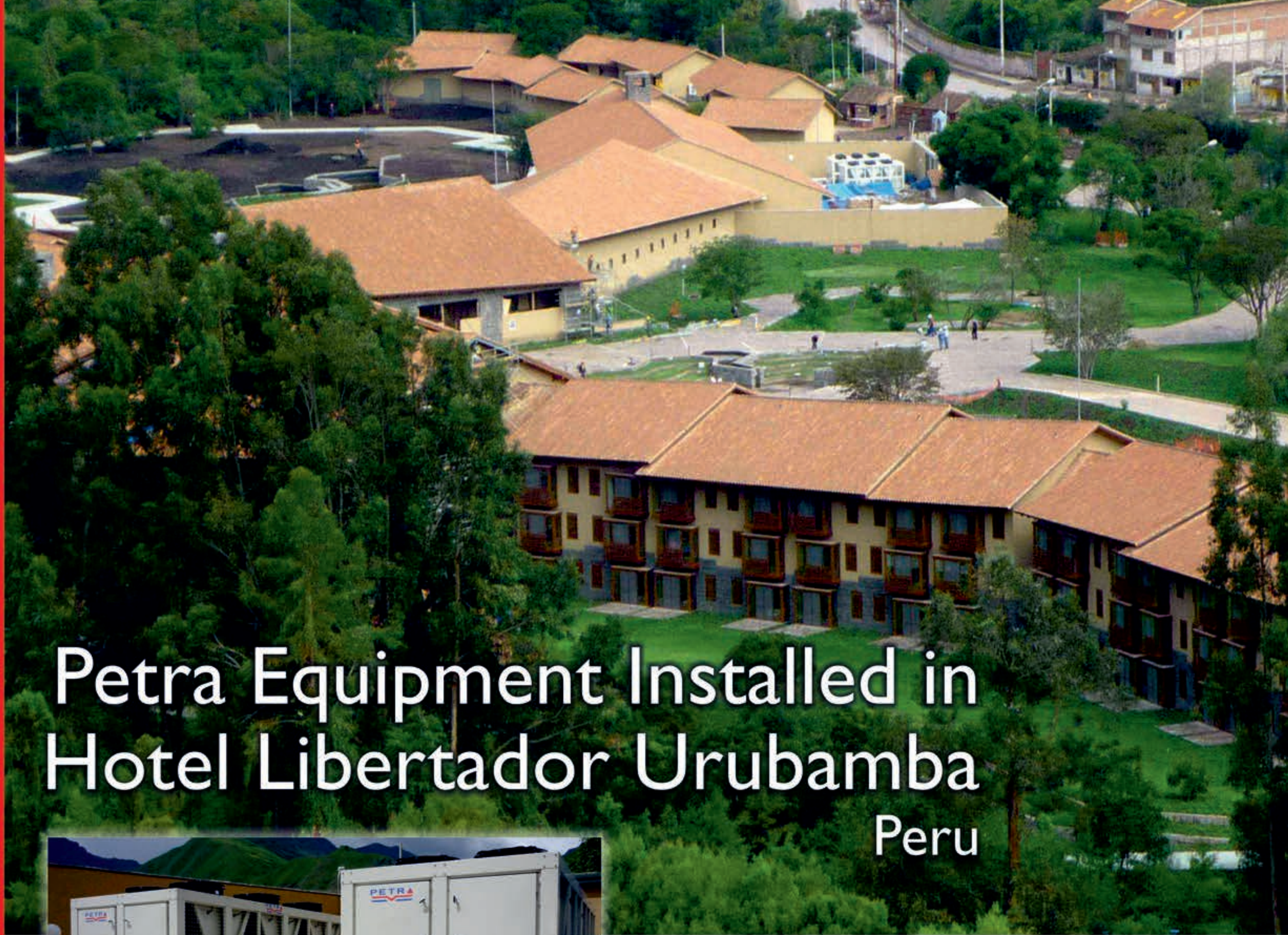


Figure 1: Dual fuel hot water boilers with flue gas energy recovery (predicted annual energy savings of $36,000).



Petra Equipment Installed in Hotel Libertador Urubamba

Peru

The Libertador Urbamba Hotel is a luxury resort and spa situated in the Urubamba Valley - the sacred valley of the Incas in Peru. This valley is the starting place for people who wish to explore the Incan civilization. The hotel is located on the banks of the Urubamba River, facing the beautiful views of the high Peruvian mountains. It contains 128 rooms and suites with other amenities and gardens covering a total area of 119,000 m sq (1,280,000 sq ft).

Petra supplied the project with Ultra Low Noise air cooled Chillers operating at (66 dbA sound level) and Petra Air Handling Units with direct evaporative cooler section. These air handling units were manufactured according to specific mechanical room footprints requirements. The evaporative media built into the air handlers supplied the project with 80% of the cooling & heating loads while the chillers supplied the remaining 20% thus achieving substantial energy saving on chiller operations.

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The project is the first acute care hospital in Canada to achieve LEED Gold certification thanks to the hard work of the integrated project team and especially the project architect who carefully managed the LEED process. In addition to the engineered aspects of the project, the design incorporates healing gardens and ponds integrated into the storm water control system, wood-based products were either 100% recycled or certified by the Forest Stewardship Council. The building also features an abundance of natural light and views of the surrounding green spaces and courtyard, enhancing the overall experience of the staff and patients alike.

To ensure that the hospital provides a healing environment, special attention was paid to the building's indoor air quality (IAQ) and thermal comfort. The hospital achieved 11 LEED Indoor Environmental Quality (EQ) credits, which includes meeting ASHRAE Standards 55 and 62.1 requirements, using low VOC-emitting materials, IAQ construction management, and controlling indoor chemical pollutants. Furthermore, the facility achieved credits for controllability of systems that allow occupants to adjust the temperature within their space.

Other LEED credits achieved included water-efficient landscaping that uses no potable water, water use reduction of 20% through the innovative use of dual flush toilets, low flow lavatory and kitchen sinks, and low flow showers, which further reduce energy consumption by reducing the volume of domestic hot water requirements of the building.

To ensure the facility can accurately measure the energy used, a measurement and verification plan was implemented allowing the building operator to track and log trending energy data for ongoing analysis. The system comes complete with maintenance software that optimizes building maintenance and operations. ARHCC's operations and maintenance personnel were fully involved throughout the design and construction process to ensure that equipment was selected and installed to facilitate safe and effective maintenance and ensure that any system failure downtime is minimized.

To meet the project's objectives to achieve cost-effective, energy-efficient, and environmentally sensitive solutions it was necessary to develop innovative approaches and strategies. To accommodate the tight design and construction schedule and project budget, the general contractor implemented a fully integrated quality control process that was used throughout the design and construction of the

hospital. To fast-track the construction period, all major equipment such as air-handling units were fabricated in the factory and tested before being shipped for installation. Flexible HVAC systems were designed to delay the ordering of medical equipment so that the most technologically advanced equipment could be purchased and installed. Non-typical rooftop air-handling units, primary ductwork, and piping configurations were used to accommodate a tight floor-to-ceiling height and accommodate the fast-track construction schedule.

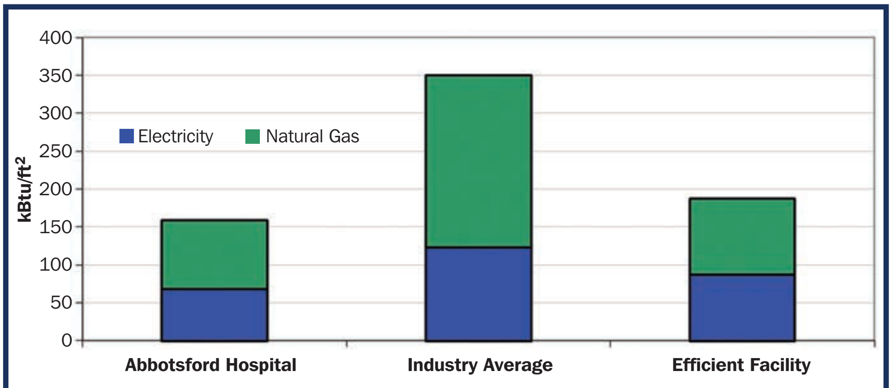

Figure 2: Comparison of annual energy use, including process/non-regulated loads.

To reduce the chance of contamination, all ductwork underwent factory biocide and particle cleaning before being sealed for shipping and installation. No internal acoustic insulation was used in the supply or return ductwork, to accommodate effective cleaning and fiber contamination after installation. This required very careful acoustic analysis that affected the selection and installation of the air-handling units, terminal units, sound attenuators, and acoustic cladding comprised of a double layer of drywall wrap in noise sensitive areas. Computational fluid dynamics (CFD) analysis was used to evaluate site airflow issues to help determine heights of the boilers, generator, and lab exhaust stacks as well as the effect of medevac helicopters landing adjacent to the hospital. The study also addressed the potential for cross contamination between the building isolation room exhaust air louvers and air intakes. Furthermore, CFD analysis was used to optimize the air-distribution system in the operating rooms, investigating a multitude of air-distribution options, resulting in the selection of HEPA terminal diffusers. A

CFD analysis was also used to refine the hospital's large atrium mixed mode ventilation system design.

The hospital has now been operating for more than three years and the energy consumption numbers have come in under the upper utility limit that is specified in the project agreement and confirmed the design objectives modeled for the regulated energy loads.

The energy consultant entered the building characteristics and billing data for the second and third years of operation into their "Energy Profile" Tool. The tool provides estimated end-use energy information as well as a benchmark derived from default indicators from the U.S. Environmental Protection Agency's (EPA) ENERGY STAR Portfolio Manager. *Figure 2* (Page 90) shows how the hospital's Year 3 energy use compares to industry standards and an energy-efficient, code-compliant facility. The tool also confirmed that ARHCC's annual CO_2 production of 3,140 metric tons is less than half that of a comparable facility, achieving CO_2 savings equivalent to taking 1,400 cars off of the road.

Natural Resources Canada (NRCan) indicates the average hospital energy use in Canada is 2.65 GJ/m², equaling 233 kBtu/ft²—a number still significantly higher than the ARHCC's utility bills.

The energy consultant also entered second year of operation billing data into the EPA's Portfolio Manager to check the relative ENERGY STAR indicators, adjusted for the specific project conditions. The ENERGY STAR Portfolio Manager analyses showed that ARHCC's operating energy intensity is 42% below the U.S. National Average—equivalent to a rating of 93 out of a possible maximum of 100.

The Abbotsford Regional Hospital and Cancer Centre is living proof that extraordinary results can be achieved when a diversified and committed team work together to rethink the typical hospital design process. The Public Private Partnership delivery method brought together the HVAC design team, with the architect, other disciplines, contractor, and operating and maintenance people to ensure that this facility will use significantly less energy than a comparable code-compliant building or benchmark building resulting in an annual savings of $475,000. A fact now confirmed by three full years of operational data.

Acknowledgments

The project team included Project Architect; MCM/STH; Project Mechanical Engineer: Stantec Consultants; Project Electrical Engineer: RADA; Project Energy Analysis: EnerSys Analytics Inc.; Project Contractor: PCL Constructors Westcoast Inc.; Project Mechanical Contractors: Lockerby and Hole and Apollo Sheet metal; Project Operators: Johnson Controls Limited Partnership. ■

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