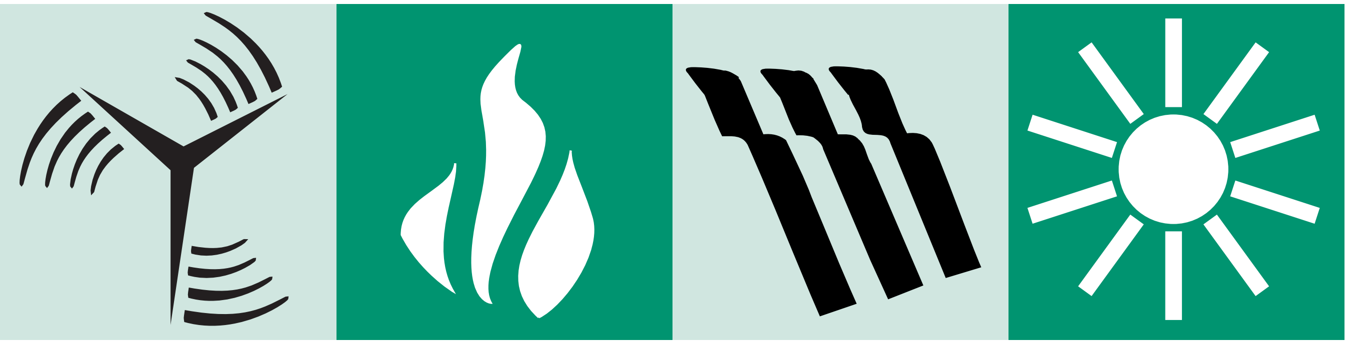

LABORATORIES FOR THE 21ST CENTURY: CASE STUDIES

Eckert and Eckert/PIX03055

FRED HUTCHINSON CANCER RESEARCH CENTER, SEATTLE, WASHINGTON

Introduction

The Fred Hutchinson Cancer Research Center (FHCRC) in Seattle is a multi-phased urban campus of laboratory buildings that is well designed and master planned. Construction began in 1990 and is planned to continue through 2004. The buildings are designed to allow maximum flexibility for research. They are attracting world-class scientists because of their many amenities, including a strong connection to their natural environment. This study is one in a series produced by Laboratories for the 21st Century, a joint program of the U.S. Environmental Protection Agency (EPA) and the U.S. Department of Energy (DOE). It is geared toward architects and engineers who are familiar with laboratory buildings. These case studies exemplify the "Labs 21" approach, which encourages the design, construction, and operation of safe, sustainable, high-performance laboratories.

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EPA United States Environmental Protection Agency

United States Department of Energy FEMP FEDERAL ENERGY MANAGEMENT PROGRAM

This case study describes energy and water efficiency features in Phases 1 and 2 of the development, which represent 532,000 gross ft^2 of space. These buildings are using approximately 33% less electrical energy than they would have without the energy efficiency features, as designed to meet Seattle energy-code requirements in the years they were designed. The savings include a 26% reduction in energy use designed into the buildings and 7% in additional savings through retrofits added since occupancy.

These factors contribute to the savings:

- Energy efficiency features were designed into the state-of-the-art buildings, including variable-air-volume systems, high-efficiency lighting systems, motion sensors, temperature setbacks, variable-speed drives, high-efficiency chillers, and high-efficiency motors.
- As technology continues to improve, additional state-of-the-art measures and energy-saving strategies have been tested and installed in the buildings.
- A staff of 22 operating engineers provide ongoing recommissioning of energy-using systems in the facilities and a consistent message to the scientists regarding the importance of conserving energy, not only to be environmentally sound but also to be fiscally responsible. Each of these aspects is described in more detail below.
- A local utility with a progressive program, including financial incentives, encourages energy efficiency.

In addition, the building is located in a climate that is ideal for laboratory building operation because the outside air is temperate most of the year, and the large quantities of air needed to meet ventilation requirements do not need to be excessively heated or cooled, humidified, or dehumidified.

> *"The Fred Hutchinson Cancer Research Center is the most complete lab project that I've ever seen. It integrates a very complex building type completely with a very tight site—the courtyards, the entries, the views—everything seems to fit. It has a definite humanistic touch. The other important aspect is the mechanical system; the interstitial application and the creative use of the interstitial spaces for interaction areas added a layer to the project that made it head and shoulders above other projects that we saw."* 1994 Laboratory of the Year Jury, *R&D Magazine*

Project Description

The Zimmer, Gunsul, Frasca Partnership of Seattle, Portland, and Los Angeles designed the buildings as biomedical research laboratories. The laboratory planner was McLellan and Copenhagen, Inc., of Cupertino, Calif., and Seattle; and the mechanical/electrical engineer was Affiliated Engineers, Inc., of Madison, Wis., and Seattle.

Function

The FHCRC, established in 1975, is one of more than 40 comprehensive cancer research centers in the United States. Using basic and applied research, its mission is to eliminate cancer. It is internationally recognized for its pioneering efforts in bone marrow transplantation. Today, the FHCRC has the largest bone marrow transplant program in the world.

The center fosters an interactive and cooperative spirit among four scientific divisions—Basic Sciences, Human Biology, Clinical Research, and Public Health Sciences.


Eckert and Eckert/PIX03052

FHCRC Lab interior

Size/Cost

Phase 1 consists of two buildings, the Wintraub Basic Sciences Building and the Hutchinson Human Biology Building. The total size of Phase 1 is 305,449 gross ft^2. Phase 2 consists of one building, the E. Donnell Thomas Clinical Research Building, which is 227,153 gross ft^2. As a laboratory building, approximately 95% of its gross floor space requires 100% outside air. There are approximately 200 fume hoods in the buildings. The cost of construction for Phase 1 was \$199 per gross ft^2. The cost of construction for Phase 2 was \$243 per gross ft^2 (excluding underground parking). Table 1 shows the breakdown by function.

Building Schedule

The campus is being designed and constructed as a multi-phased development. It began with a program and a master plan for the entire complex to address a build-out of 2.1 million gross ft^2. The site occupies 14.3 acres near Lake Union shoreline, centrally located between downtown Seattle and the University of Washington, where

Table 1. FHCRC Space Breakout

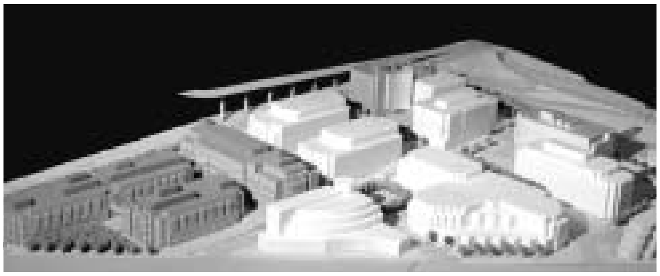
(Net ft^2, unless otherwise noted)

Function	Phase 1	Phase 2	Total	Percentage(1)
Labs	54,024	51,641	105,665	31
Offices	17,179	30,035	47,214	14
Lab support	41,668	28,178	69,846	21
Specialized lab	17,945	5,843	23,788	7
Common areas	39, 709	18,185	57,894	17
Mechanical room	14,593	21,315	35,908	11
Total net ft^2	185,118	155,197	340,315	
Other(2)	120,331	71,956	192,287	
Total gross ft^2	305,449	227,153	532,602	

Notes:

1. The percentage shows a breakdown of the net square feet only. Net ft^2 equals gross ft^2 minus "other".
2. "Other" includes circulation, toilets, lobbies, stair towers, elevator shafts, mechanical and electrical rooms and shafts, and structural elements like columns. For these combined buildings, the ratio of net to gross ft^2 is 63%. This ratio of net to gross ft^2 is average for laboratory buildings. Interstitial space is not included.

many of the center's scientists have affiliations. The urban, academic campus consists of interrelated yet separate buildings that can stand alone but are connected aesthetically to future phases. Phase 1 was completed in 1993, and Phase 2 was completed in 1997. Phase 3, the Seattle Cancer Care Alliance Ambulatory Care Building, was completed in January 2001. The last phase of construction should be completed in 2004. This will finalize consolidation of all scientific divisions on a common campus.



Chris J. Roberts/PIX3054

Model showing completed buildings and planned build-out.

Lab Layout/Design

One of the goals of the design concept was to create an environment that fosters interaction among scientists from a wide range of fields. A floor plate of 20,000 ft^2 was determined to represent the optimum travel/sight distance between opposite sides of the floor, balanced against density for meaningful interactions. Phase 1 consists of three 3-story lab buildings. Phase 2 is a single 5-story lab building. Buildings are joined by a common atrium and a mid-level sky bridge and courtyard at ground level. Each floor accommodates labs, offices, and shared lab support space for six principal investigators, grouped together around common research activities. All buildings are situated over three below-grade levels of support and lab functions. These support levels house shared resources, cell analysis (which include electron microscopes, image analysis equipment, and flow cytometry), a primary mechanical room, hazardous material storage and recycling, loading dock, facility management offices, security, fire control, and parking.

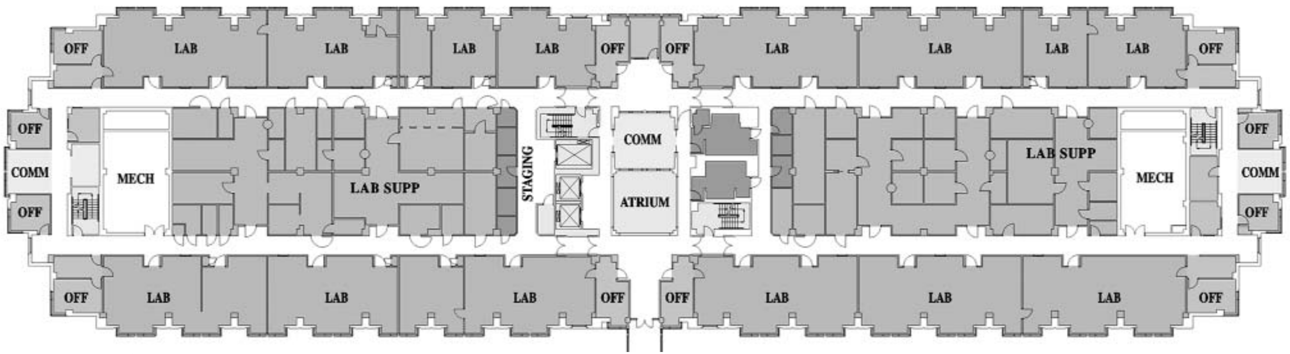
Laboratories are planned as 10 ft. 6 in. by 22 ft modules. The modules also operate in the lab support core area. A modular design approach was selected to minimize the cost of change. Labs are located along the perimeter walls, and lab support spaces are found in the core of the buildings. (See a typical floor plan on page 4.)

Utility Servicing

A central feature of the center's lab buildings is the interstitial design that creates an accessible space devoted to mechanical and electrical systems between lab floors. The interstitial floor consists of a load-bearing, walk-on concrete deck. The deck is penetrated by plywood-covered openings at regular intervals on a grid corresponding to the lab-planning module that allows utility connections to the lab and lab support spaces. The floor-to-floor height is 17 ft 10 in., and the interstitial floor has a height of 7 ft 4 in. According to the architects, when zoning permits a greater overall building height, the optimal floor-to-floor dimension for an interstitial building is 19 ft.

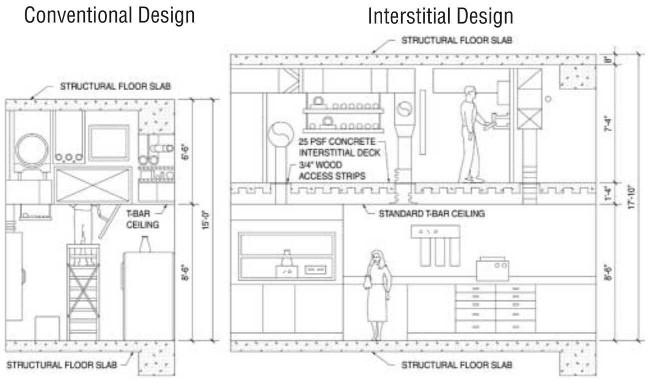
FHCRC Vice President of Facilities and Operations Guy Ott is a strong advocate of the concept that interstitial buildings don't have to cost more. In these laboratories there were savings in construction that offset the added costs of the interstitial floors. Savings included the ability to "fast track" the construction by scheduling tasks that cannot be accomplished concurrently in a conventional project, such as the build-out of finished labs and support systems while simultaneously constructing the mechanical and electrical work in the interstitial space. In addition, because the mechanical and electrical trades people could work on the interstitial floors rather than on ladders and scaffolds, their rates were lower.

A recent study commissioned by the biotech firm Amgen and conducted by the Project and Cost Management Company of Encino, Calif., has recently validated Ott's theory. FHCRC agreed to participate in the blind study on construction costs of laboratory buildings.



A typical partial floor plan.

Zimmer, Gunsul, Frasca Partnership



A cross section comparing a conventional design to an interstitial design.

Zimmer, Gunsul, Frasca Partnership

Interior view showing interstitial space.

J.F. Housel/PIX03052

The study compared cost data on the Thomas building construction with cost data on eight other laboratory buildings. No one conducting the study knew which buildings used interstitial design. The Thomas building's hard-construction costs were within 1% of the lowest project cost. For hard and soft costs combined, FHCRC was 18% lower in overall costs when compared with eight conventional lab projects. A separate study also showed that from an operations standpoint, the building engineers could cover more areas in interstitial facilities. The average area serviced by a building engineer is 20,700 ft^2. At FHCRC, operating engineers are responsible for approximately 40% more building area than peer institutions as a result of the interstitial design. Therefore staffing needs are lower than those at comparable research centers.

Design Approach

Goals for Building Energy Efficiency

As a component of its primary mission, FHCRC has taken a comprehensive approach to the prevention of environmental damage and conservation of resources in the 25 years that it has been in existence. During the planning stages, the goal was to design a building that performed better than the standard required by the existing Seattle energy code. During design for Phase 1, the Seattle energy code was slightly less restrictive than ASHRAE standard 90.1-89. Over time, the Seattle code changed, and now it is slightly more restrictive than ASHRAE 90.1-89. One incentive for this was the Energy Smart Services program offered by the local municipal utility, Seattle City Light (SCL). The program has been in operation for more than 20 years and offers financial incentives for commercial, residential, and industrial customers to install energy efficiency measures. The incentives vary by technology. For example, for lighting measures the incentive is calculated as $0.14 multiplied by the estimated first-year savings resulting from the measures. For heating, ventilation, and air-conditioning (HVAC) measures, the savings are calculated as $0.23 times the estimated savings from the measure. SCL offers these financial incentives because they believe that efficiency is more cost-effective and environmentally responsive than building new generating facilities.

The center is committed to excellence in energy efficiency and has won both energy efficiency and architectural awards for its buildings.

Other Decision Criteria

For this urban campus, there is an emphasis on using public transportation and providing racks for bicycles. In addition to energy efficiency, there is an interest in water efficiency and the quality of water leaving the site, which are important issues. A series of holding tanks on the site will allow the center to dilute lab water and to monitor its waste water to ensure that it has the correct pH level prior to disposal.

Technologies Used to Reduce Energy and Water Usage

Overview of Strategies

The facility's energy-smart design employs nine different energy conservation measures in Phase 1 and Phase 2 to reduce energy consumption and lower operating costs. The installation of these measures resulted in a cash rebate from SCL of nearly $900,000. Electrical energy consumption from the measures designed into the buildings resulted in a 26% savings. The savings were estimated for each measure by FHCRC engineers and submitted to SCL.

Features incorporated into the existing building

Since a laboratory building by code requires 100% outside air, measures that reduce the air heating and cooling requirements offer the best opportunity for energy savings. The variable-air-volume system in Phase 1 set the minimum air flow rate at 10 air changes per hour (ACH). When Phase 2 was built, new standards allowed minimum air flow rates to be set at 6 ACH. At that time, resetting air flow rates for Phase 1 to 6 ACH resulted in significant savings. A recent study found that the variable-air-volume boxes are operating at the minimum most of the time (6 ACH).

Other measures were also designed into the buildings. Lighting measures include energy-efficient lamps and ballasts and programmable lighting controls with on/off controls, motion detectors, and photocells. The glazing in the building is low-emissivity (low-e) glass with a shading coefficient of 0.44 and a U-value of 0.41. The glazing area represents 20% of the wall area. High-efficiency chillers consist of three 600-ton electric centrifugal machines with an efficiency of 0.54 kW/ton. Variable-speed pumping is used to control the secondary chilled water and water heating systems. FHCRC takes advantage of "free" cooling for the electron microscopes, lasers, and cold room refrigeration by using the cooling tower and a heat exchanger in lieu of chilled water. This eliminates the need to run a chiller during the winter season. FHCRC also incorporated 16 high-efficiency motors and pumps into the design, and it uses two-speed fans in lieu of single-speed fans for ventilating the underground garage, where the high-speed fans are used only when the carbon monoxide level is above 100 ppm.

Table 2. Measures

Measure	Phase 1	Phase 2
Energy-efficient office lighting	●	●
High-efficiency motors	●	●
High-efficiency chillers	●	●
VAV system in the labs	●	●
VSD pumping	●	●
Improved air volume control of fume hoods	●	●
Central lighting control	●	●
Cooling tower 2-speed fans	●	●
Garage ventilation	●	●

When the buildings were designed, the boilers selected for heating were designed to run on both natural gas and oil. This allowed FHCRC to negotiate a gas contract based on an interruptible rate structure with its utility. The utility company notifies the center when to switch to oil. This rate structure has saved on heating fuel costs.

Retrofit measures

Since occupancy, facility engineers at FHCRC have continued to look for opportunities to save energy. To date about 30 additional energy and water efficiency measures have been undertaken. Savings per measure range from under $1,000 per year to over $70,000 per year. These measures are estimated to save an additional 7% in electrical energy savings in addition to gas and water savings. Since occupancy, some of the retrofits and operational savings include reducing minimum variable-volume lab air change rates in Phase 1 from 10 to 6 ACH; replacing exit signs with light-emitting diode (LED) exit signs that save energy and reduce maintenance costs associated with failed ballasts and lamps; fixing leaks in air compressors; using a 1°F lower daytime temperature in winter (2°F higher in summer) and a 2°F lower night-time temperature in winter (3°F higher in summer); and turning off all lights at 9 p.m. instead of the current 10:00 p.m. (with an override feature).

Eight of the measures involved water efficiency. Annual water usage had been reduced by 10 million gallons in 2000, compared with 1998 usage. The greatest savings in water resulted from adding retrofits to reduce sterilizer water use and water waste. Originally, water flowed to the sterilizers 24 hours per day to cool the waste water from 180°F to 140°F, but the sterilizers weren't operating 24 hours per day. The retrofit measures allow the incoming water to run only when the sterilizers are on. This saves on water and sewer expenses. Sewer costs are three times higher than water costs.

FHCRC facility staff are also proposing a modification that will reduce heating and cooling requirements even further. Any time that a lab or office is in use, manual wall switches turn on the lights. At 9:00 p.m. every day, if lights are inadvertently left on, the existing lighting control system turns all lights off as an energy-saving feature. Current sensors will be added to lighting circuits in labs and office areas to determine occupancy schedules for each space.

Energy will be saved in two ways during unoccupied hours, as determined by the individual lab light operation. Temperatures will be set back during unoccupied heating hours and will be set up during unoccupied cooling hours. Additionally, the minimum air change rate will be reduced to 4 ACH during these hours. This will reduce the quantity of outside air that is heated and cooled. The energy management control system will set temperatures to daytime setpoints and increase minimum air change rates back to six at 8:00 a.m. each morning and will change them back to unoccupied setpoints at 7:00 p.m. unless the light for a particular space is still on.

Another interesting measure that has been tested for only one of the air handlers and implemented for Phase 1 and Phase 2 buildings is a variable-volume, variable-pressure system. Testing showed that the energy for ventilation could be reduced by 1/3. The purpose of this measure is to reduce fan energy in laboratory air handling units (AHU) by the addition of variable-speed drives and automatic controls to reduce fan discharge static pressure. Laboratory AHU are variable-air-volume by design and utilize fan inlet cones to vary the fan volume by restricting the air intake to the fan wheel. They operate 24 hours every day. Each AHU has two fans and motors that operate together. Supply air is provided at a constant 2.0 in. static pressure.

The proposed measure will save a significant amount of the fan energy by modifying two existing control strategies:

- ***Fan volume control:*** The fan inlet cone will no longer vary the fan volume. Its control will be reconfigured to be fully open when the fan operates and to fully close when the motor is off. The fan motors will receive variable-speed drives to vary the fan speed to meet the fan volume requirements.
- ***Variable pressure control:*** Instead of operating the AHU at a constant supply air pressure, the fans will provide the lowest air pressure possible and still satisfy all of the individual zone supply air boxes. The supply air distribution system will be modeled to determine critical locations for remote duct static pressure stations. These pressure stations are monitored continuously to ensure that their air pressure requirements are met while providing the lowest possible air pressure from the AHU fans.

On-going maintenance, recommissioning, and feedback to the researchers

Maintenance of equipment at FHCRC is a top priority. A three-person team is dedicated to ensuring that maintenance is performed on a regular, continual basis. Filters are changed on time, belts are properly adjusted and set points and equipment are periodically checked to ensure they are set and operating properly. In 2000, the team performed over 1,500 preventive maintenance operations totaling over 5,000 hours. This ranged from a complete overhaul of seven boilers to regular filter replacement on 19 large air handlers, ranging in size from 35,000 cubic feet per minute (CFM) to 52,000 CFM, and on numerous small ones.

Recommissioning of all air handlers, controls, and energy-using equipment is also a key priority for FHCRC. On a biannual basis, FHCRC does a complete recommissioning of equipment in all its lab spaces. This is done in partnership with Siemens Building Technology, the building control system provider. It involves checking all the air handlers and controls regularly and recommissioning all energy-using equipment in the labs on an every-other-year cycle.

The facilities engineering staff works closely with the researchers to ensure that they understand the importance of energy efficiency. For example, if a fume hood in a lab is open for an extended period, a signal will flash in the control room or an alarm will sound. When this happens, a facility engineer will discuss the impact of energy use with the researcher.

A newsletter is issued to the research staff from the Facilities Engineering Department on a monthly basis to educate the staff about how the building uses energy, how much energy is used, and how the staff can participate in good energy management. The Feb. 6, 1997, newsletter noted, "…the position of the sash in any lab hood will affect utility costs significantly. A typical lab hood operating in its full open position will consume $3,800 annually in heating, cooling and fan energy costs, whereas it only uses $1,700 annually in its minimum position." The newsletter also gives the scientists feedback on the cost savings resulting from various operational methods in response to various efficiency retrofits.

Measurement and Evaluation Plan/Approach

The staff monitors daily natural gas usage and plots their electric energy use on a monthly basis. In addition for each energy efficiency measure proposed, data specific to that measure are monitored two weeks in the pre-retrofit phase and two weeks following installation.

Building Metrics

Key metrics are shown in Table 3 for both design and actual consumption for the year 2/1/2000–2/1/2001. The design data are broken down for end uses; the actual data are for the building as a whole. For both ventilation air and plug loads, the design data for the Phase 2 building are lower and represent a lesson learned based on actual operating experience.

Summary

The FHCRC has won numerous awards for both its architecture and its energy efficiency. As illustrated in this case study, its success is due to a combination of factors that include designing and building flexibility and energy efficiency into the buildings from the start, ensuring optimal performance of buildings through a combination

Table 3. Building Metrics for FHCRC

System	Key Design Parameters	Annual Energy Use (based on design data)(1)	Annual Energy Use (based on measured data)(2)
Ventilation (sum of wattage of all the fans and the exhaust fans)	Phase 1 = 1.26 W/cfm Phase 2 = 1.01 W/cfm Phase 1 = 3.0 cfm/net ft^2 Phase 2 = 2.4 cfm/net ft^2	35.8 kWh/gross ft^2 (Phase 1 = 66.2/net ft^2 of lab area and Phase 2 = 42.4/net ft^2 of lab area(3)	Not separately metered
Cooling plant	Chiller efficiency = 0.54 kW/ton	8.8 kWh/gross ft^2(4)	Not separately metered
Lighting	Phase 1 – 2.7 W/net ft^2 Phase 2 – 2.0 W/net ft^2	6.4 kWh/gross ft^2(5)	Not separately metered
Process/plug	Phase 1 – 15–30 W/net ft^2 Phase 2 – 8 W/net ft^2	26 kWh/gross ft^2(6)	Not separately metered
Heating plant			180,936 Btu/gross ft^2
Total		77 kWh/gross ft^2 (estimated based on design data for electricity only)	48.7 kWh/gross ft^2 (actual for electricity only) 166,087 Btu/gross ft^2 for electricity 347,023 combined site Btu for electricity and gas(7) Actual annual cost for electricity and gas equals \$2.61/gross ft^2 (off utility bills)

Notes:

1. The estimated annual use was calculated based on the design data. In order to convert the data from net to gross ft^2, the ratio of 0.64 was used and a weighted average in terms of gross ft^2 was used to convert data from Phase 1 and Phase 2 to total gross ft^2, where Phase 1 = 57% of gross ft^2 and Phase 2 = 43%.
2. The actual data was taken from utility bills dated 2/1/2000 thru 2/1/2001.
3. For Phase 1: (1.26 W/cfm x 3.0 cfm/net ft^2 x 8760 hours/1000) x 2 = 66.2 kWh/net ft^2. For Phase 2: (1.01 x 2.4 cfm/net ft^2 x 8760 hours/1000) x 2 = 42.4 kWh/net ft^2. The equations were multiplied by 2 to account for supply and exhaust. (taking a weighted average and converting to gross ft^2 = 35.8 kWh/ gross ft^2).
4. 0.54 kW/ton x 3000 tons (for both phases) x 2890 hours / 532,602 gross ft^2 = 8.8 kWh/ gross ft^2 (Assumes cooling runs approximately 33% of the hours in a year).
5. 1.54 W/gross ft^2 x 4140 hours /1000 = 6.4 kWh/gross ft^2 (assumes lights are on 100% for 50 hours per week and on 25% for the balance of the time)
6. Assume 8W/net ft^2 or 5W/ gross ft^2 operating 60% of the year. 5W/gross ft^2 x 5256 hours/1000 = 26 kWh/ gross ft^2.
7. The actual is presented in site Btu, which is off the actual energy bills (to convert to source Btu, the site Btu for electricity is multiplied by 3).

Note: Seattle has 4908 heating degree days and 190 cooling degree days.

Table 4. Other Key Design Parameters

Function	Phase 1	Phase 2
Mechanical power	30 W/net ft^2	14 W/ net ft^2
Chiller capacity	1,800 tons (3 at 600 tons each)	1,200 tons (2 at 600 tons each)
Steam boilers	400 bhp (2 at 200 each)	
Hot water boilers	3 at 250 hp each (or bhp)	2 at 250 hp each (or bhp)
Electrical service	2,400 kVA transformers	2,500 kVA transformers
Emergency power	1,500 kW diesel generator	1,500 kW diesel generator
Overall HVAC requirements	3.0 CFM/ net ft^2	2.4 CFM/ net ft^2

of sound maintenance practices, recomissioning and operator proficiency, and striving for continual improvement in terms of staff support, equipment performance, and incorporating state-of-the-art innovation and energy strategies. The tangible benefits of this approach are significant energy savings and a well-maintained, efficiently operating building.

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This case study would not have been possible without the assistance of Jim Walker, Bob Cowan, and Guy Ott. Nancy Carlisle of NREL also contributed to this case study.

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