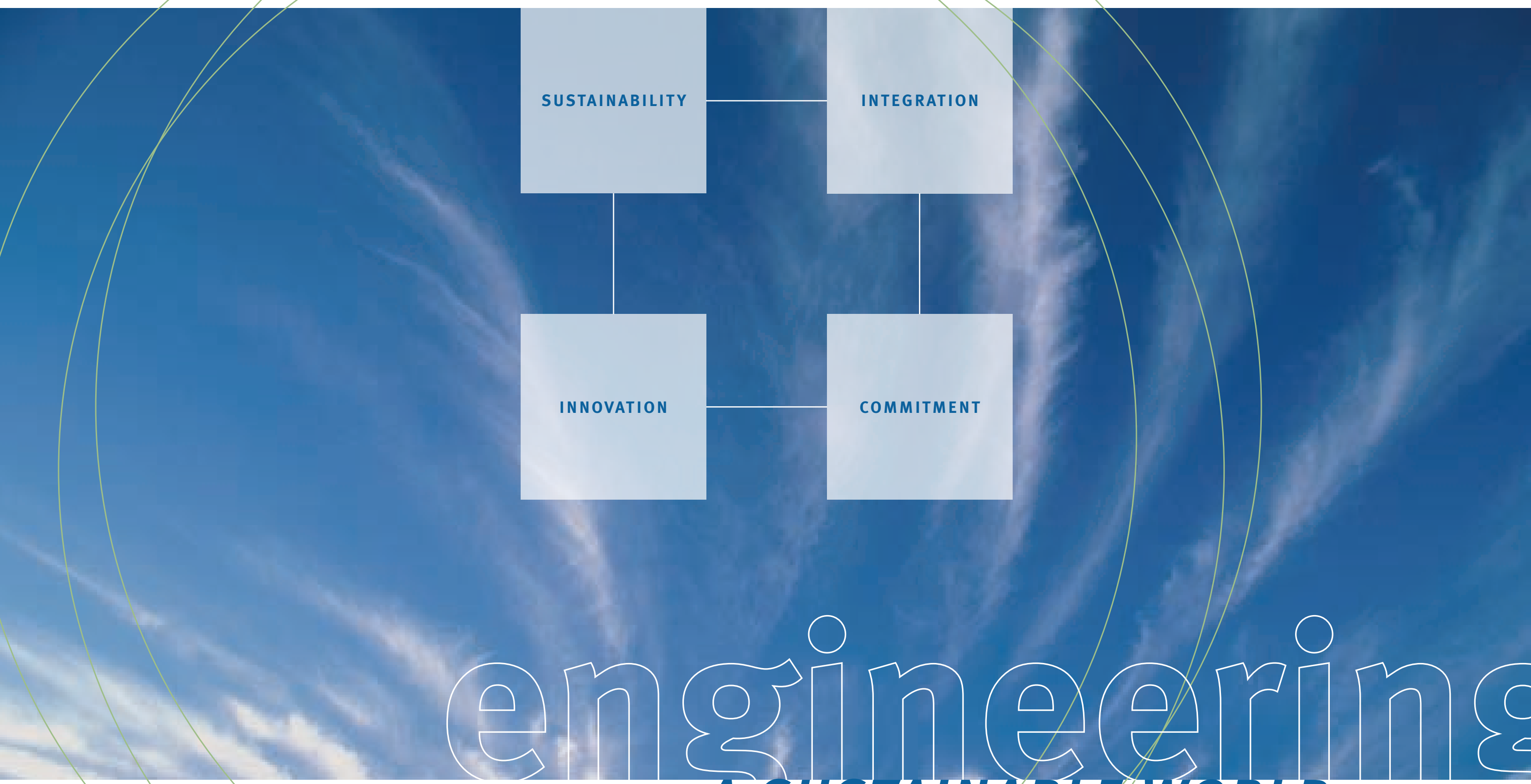


A SUSTAINABLE WORLD

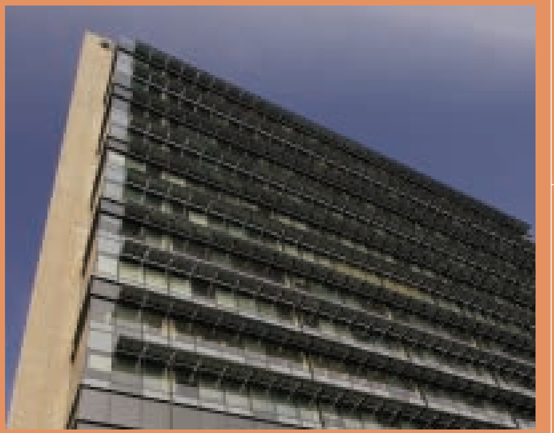
DESIGN PROCESS AND ENGINEERING INNOVATIONS FOR
THE CENTER FOR HEALTH & HEALING AT OREGON HEALTH & SCIENCE UNIVERSITY

FEBRUARY 2007
US Green Building Council awards **LEED Platinum Certification**

INTERFACE
ENGINEERING

On February 22, 2007, the US Green Building Council (USGBC) announced that Oregon Health & Science University's Center for Health & Healing received a LEED Platinum Certification. The Center achieved every point that was attempted, receiving a total 55 LEED credits-three more than necessary for the LEED Platinum designation.

SALLY PAINTER



OHSU PROJECT TEAM

Gerding Edlen Development
Dennis Wilde, Sr. Project Manager
Renee Worme, Sustainability Coordinator

GBD Architects
Phillip Beyl, AIA, Partner-in-Charge
Stephen Domreis, AIA, Partner-in-Charge, interiors
Kyle Andersen, AIA, Project Lead Designer
Ronald Huld, AIA, Project Architect

Peterson Kolberg Associates
surgery and imaging architect

The Estimé Group, *laboratory architect*

KPFF, *structural engineer*

Otak, *civil engineer*

Walker Macy, *landscape architect*

Hoffman Construction, *general contractor*

Brightworks, *LEED Consultant*

THE CENTER FOR HEALTH & HEALING
AT OREGON HEALTH & SCIENCE UNIVERSITY
PORTLAND, OREGON

Total Project Costs

$145.4 million approved budget

Building Program

- The Center for Health & Healing is a 16-story, 400,000 sq.ft. building that will house physician practices, outpatient surgery, a wellness center, research labs and educational space. A three-story underground parking garage will provide 500 new parking spaces for patients.
- Eight levels are devoted to physician practices, surgery and imaging across a wide range of specialties and programs. They include dermatology, family medicine, internal medicine, spine neurology, neurosurgery, cardiology, oncology, surgical oncology, digestive health, ENT (ear, nose and throat), plastic surgery, physical therapy, ophthalmology, urology and fertility.
- Three floors will house a comprehensive health and wellness center. The center will include a full gymnasium, a four-lane lap pool, a therapy pool, cardio and weight training areas, multipurpose studios and a day spa.
- Four levels are dedicated to educational and research activities, including laboratory space for the biomedical engineering program.
- The ground floor will house retail space, including a pharmacy, optical shop and cafe.

THIS IS NOT JUST THE STORY OF A BUILDING, BUT ALSO OF A PROCESS THAT IS CHANGING THE DESIGN PROFESSIONS AND THE GREATER URBAN LANDSCAPE. USING AN INTEGRATED DESIGN PROCESS, THE OWNER, ARCHITECT, INTERFACE ENGINEERING AND THE ENTIRE TEAM HAVE SHOWN THAT SUSTAINABLE DESIGN NEED NOT COST MORE. OREGON HEALTH & SCIENCE UNIVERSITY'S CENTER FOR HEALTH & HEALING WILL BE THE MOST RESOURCE-EFFICIENT, LARGE-SCALE BUILDING IN THE REGION, AND ONE OF THE GREENEST ANYWHERE.

WITH THE WORLD'S SUPPLY OF FOSSIL FUELS increasingly depleted, the price of energy rising and the international community taking steps to combat global warming, America's green building movement has rapidly matured over the last decade, from a pioneering niche market to an ever more viable portion of the mainstream. And since the late 1990s, Portland has developed a reputation as a sustainable building pioneer. By 2005, Portland had more projects registered with the U.S. Green Building Council's LEED (Leadership in Energy and Environmental Design) rating system for high-performance buildings than any other city.

Despite this pedigree, however, Portland has never seen a local building achieve the highest LEED rating—Platinum. And many of its Gold and Silver-rated projects are relatively small in scope. But that may soon change as the city's sustainable architecture ascends to a new scope and level of sophistication.

In 2005 Portland saw groundbreaking for what will become one of the most sustainable new urban neighborhoods in the country. The South Waterfront is a former industrial area along the Willamette River just south of Portland's downtown. In a pioneering public-private partnership, the city has teamed with its largest employer, Oregon Health & Science University (OHSU), and Portland's most successful and environmentally progressive development companies to build a dense urban enclave with housing, green spaces, commercial and retail buildings, and an expanded campus for the school.

The South Waterfront exemplifies Portland's commitment to preventing urban sprawl by revitalizing underutilized inner-city areas, all the while guided by state-of-the-art sustainable design principles. To minimize dependence on automobiles, the neighborhood will also be connected to the surrounding area by two types of mass transit: a streetcar, which has been an enormous success in other parts of the city, and an aerial tram (only the second in the United States).

One of the first buildings to rise from this former shipyard will be the most resource efficient large-scale building in the region, and one of the greenest in the country—the Center for Health & Healing. It is a mixed-use facility for wellness, medical research, clinics, surgery, classrooms and ground floor retail. The 400,000 sq.ft., 16-story building will be next to a new aerial tram connecting South Waterfront with OHSU's main campus on a hilltop about a mile away.

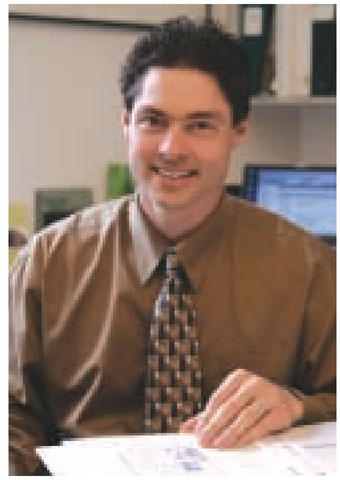
Upon its completion in 2006, the Center for Health & Healing expects to apply for a Platinum LEED certification. Although only a handful of buildings in America have attained the Platinum rating, none is of the size and complexity of the Center. This is a very special building.

Led by principal Andy Frichtl, PE, Interface Engineering began to work with Gerding Edlen Development, GBD Architects and Hoffman Construction early in the design process, sparking a process of integrated design—fundamental to any successful green building project. And the results speak for themselves. The Center is expected to achieve energy savings at an astonishing 61 percent greater than what Oregon code (and the LEED version 2.1 ASHRAE standard) requires and to use 56 percent less water than a conventional building.

With this process of integrated design, the team has also proven that green design need not cost more. In fact, despite boasting an array of solar panels, natural ventilation, radiant heating/cooling, rainwater harvesting and water re-use systems, and even its own microturbine power generation plant, the Center is expected to cost 10 percent less than original $30 million budget forecasts for mechanical and electrical systems based on a conventional design.

In this publication, we explore how integrated design practices have fostered one of the most innovative green buildings in the country. Along the way, we show how architecture and engineering are becoming ever more efficient, sophisticated and responsive to the local environment and to the ever-changing needs of building owners and occupants. This is not just the story of a building, but also one of a process that is changing the design professions and the greater urban landscape for the better.

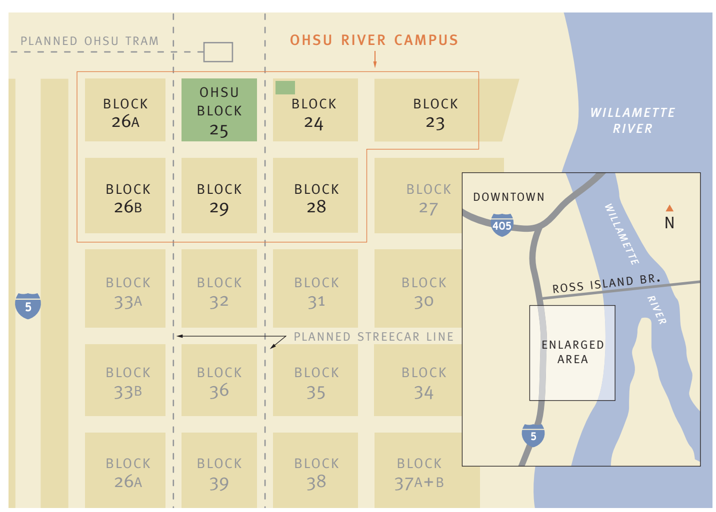
ANDY FRICHTL, TEAM LEADER



The information age is coming to a close. We have certainly learned how to obtain and move information very quickly. Now we are moving into the creative economy, where we have to find ways to do more with less. This can be accomplished by integrating building features to serve multiple purposes and using creative solutions which save energy and water with less upfront costs. This is what fascinates me. This is where my passion lies.

ANDY FRICHTL, PE, PRINCIPAL, INTERFACE ENGINEERING, INC.
2005 "ENGINEER OF THE YEAR," NORTHWEST ENERGY EFFICIENCY ALLIANCE (BETTERBRICKS PROGRAM)

SOUTH WATERFRONT SITE PLAN, PORTLAND, OREGON



OHSU Commons plays an important part in the revitalization of Portland's close in South Waterfront district, occupying seven blocks in the central portion. Connected to downtown by a streetcar and to the main OHSU campus by an aerial tram, the River Campus will provide employment for thousands of Portland residents.

PROJECT GOALS

From the beginning, it was clear that the Center for Health & Healing would be a vital building for the client and the community. A variety of uses, with different mechanical and electrical needs, had to be accommodated: ground floor retail, medical clinics, surgery suites, a wellness center, administrative offices, teaching classrooms and research facilities. Befitting OHSU's mission of promoting good health, it was also crucial that the building maintain optimal air quality and natural light. Indeed, the Center would be a symbolic new front door to OHSU.

Principal Andy Frichtl, PE, led the Interface Engineering team. A senior mechanical engineer with 17 years of experience at the firm, Andy directs Interface's energy-efficiency, green design and building commissioning efforts. Previously he served as lead principal for the firm on such pioneering sustainable projects as the LEED Gold Ecotrust building (Jean Vollum Natural Capital Center) in Portland, the Pacific Gas Transmission Building (now home to David Evans and Associates) and the Oregon Department of Human Services building renovation in Salem.

With an initial budget of $30 million for mechanical, electrical and plumbing (MEP) systems, the building's performance goals were ambitious: energy savings of 60 percent or more versus Oregon energy code and the ASHRAE 90.1-1999 standard, a 25 percent reduction in initial MEP capital costs versus a standard building and a significant reduction in potable water usage. The building also needed to maintain its structural and mechanical flexibility for future uses while providing a competitive rent structure. Further, the Center for Health & Healing was expected to achieve at least a Silver LEED (Leadership in Energy and Environmental Design) rating from the U.S. Green Building Council in order to qualify for the Oregon Business Energy Tax Credit.

BIG HAIRY AUDACIOUS GOALS (BHAGs)

Dennis Wilde, senior project manager for Gerding Edlen Development, drove this project to a successful design outcome by setting major goals for all members of the design team—what management guru Tom Peters calls "Big Hairy Audacious Goals." To create high-performance buildings, a design team, just like a child in school, must be challenged to achieve "stretch" goals, but without the crutch of a larger budget. Through successful experience with a number of prior green building projects, Gerding Edlen Development knew that engineers could achieve high levels of building performance on a conventional budget, while meeting all aspects of the building program, so they required such performance on this project.

Some of the BHAGs included:

- 60 percent energy savings below Oregon Energy Code and the ASHRAE 90.1-1999 standard for LEED prevailing at the time of building design
- Reduce initial MEP budget by 25 percent

During the process, the team added the following goals:

- 100 percent capture and re-use of rainwater falling on the building
- 50 percent or more reduction in total use of potable water in the building
- Provide a significant amount of power and chilled water on-site from a central utility plant
- Treat all sewage on site and re-use that water for non-potable uses

PROJECT APPROACH

Interface Engineering has a format for energy-efficient and water-conserving design that it follows in most projects with sustainability goals and integrated design objectives.

- Obtain building program early and develop time-of-use daily, seasonal and annual use patterns
- Estimate energy-end uses by type, e.g., lighting, heating, cooling, ventilation, plug loads, pumps and motors, and then attack the largest end uses most aggressively
- Develop a plan to reduce demand of various end-uses, e.g., through more efficient building envelope, higher efficiency chillers and boilers, and efficient lighting with daylighting controls
- Harvest available natural resources, including sunlight, wind, natural ventilation, rainwater and lower groundwater or ground temperatures
- Consider energy storage systems to capture economic rewards for off-peak electricity use and to reduce the required size of HVAC systems
- Maximize efficiency of specified mechanical and electrical systems within budget constraints
- *Right-size* systems by replacing overly conservative design practices with good analysis of actual requirements
- Allow for easy expansion of mechanical and electrical systems to serve changing uses of the space

INTEGRATED design PROCESS

A sailboat exemplifies integrated design; it's hard to tell where the architecture ends and the engineering design begins. It's powered solely by natural forces and requires almost no use of fossil fuels after construction. As does a building, it requires intelligent operators, someone to steer and someone to set the sails; then it can even sail upwind with ease.

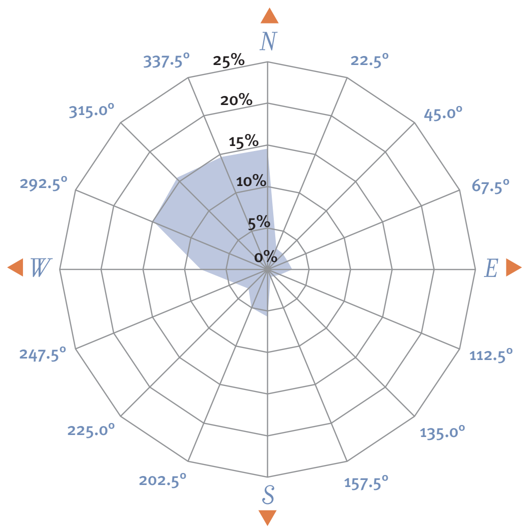
THE PROJECT KICKED OFF IN AUGUST OF 2003 with a two-day charrette to identify integrated design goals, with final designs for the core and shell due approximately one year later. During that time, Frichtl and Interface worked in close collaboration with the developer, Gerding Edlen Development, GBD Architects, KPFF structural engineers and Hoffman Construction to achieve a building that not only would meet these bold objectives, but even surpass them. The charrette goal was to share ideas about how the Center for Health & Healing could be designed for optimal building performance.

Certain architectural goals had to be met: ease of circulation, ample natural light, a sense of openness for the varying activities, and a flexible structure that allowed for change in building uses over time.

Harnessing the Elements

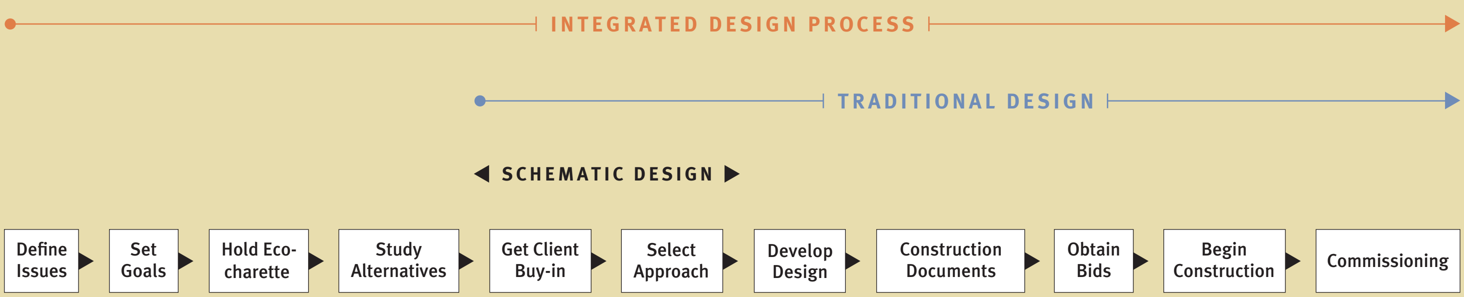
Within that context, the team sought to take advantage of free resources from the natural environment, including sun, rain, wind and groundwater. Obviously, sunlight is an ideal source for daylighting, heating and electricity if the corresponding energy conversion technology can be harnessed cost-effectively.

WIND-ROSE DATA



A "wind rose" shows both wind direction and frequency; in this case, we see Portland's prevailing north/northwest winds, during the cooling season hours from April to September.

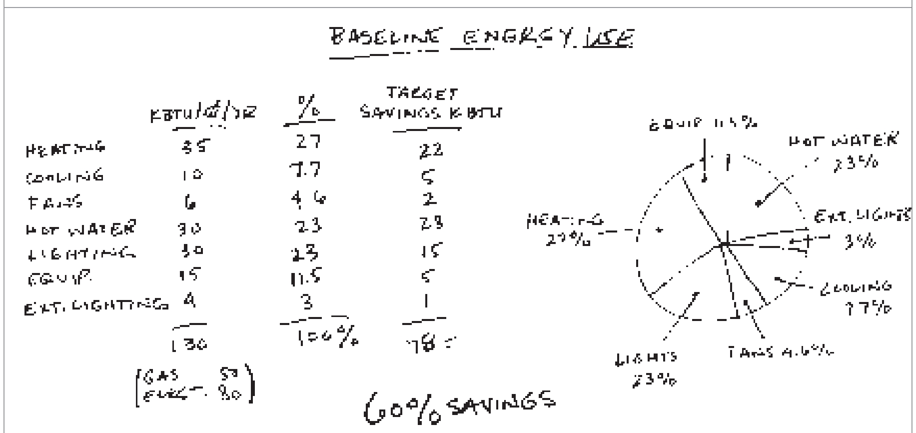
The integrated design process differs from traditional design in two important respects: first, goal setting for sustainable design starts early in the process, during programming and conceptual design; second, the entire design team is involved in the process much earlier than normal, so that engineers can input to architectural choices that affect energy use, water use and indoor air quality, for example. Specific technologies such as green roofs, photovoltaics and rainwater reclamation require input from several disciplines very early in design.



Wind-rose data from the Portland airport (a diagram of wind directions at various hours during the year) showed that during office hours (8 AM to 5 PM) in spring and summer, wind almost always comes from the north and northwest. This could help provide predictable natural ventilation. The data also indicated where the building would likely experience high and low air pressures. Portland's moderate humidity levels and generally mild temperatures also meant cool air could be used for night flushing in the summer, to pre-condition buildings for cooling the next day.

As a result of the charrette, the developer-architect-contractor-engineer team agreed several ideas merited further study. Rainwater could be captured for re-use in toilet flushing. A microturbine system for the adjacent central utility plant and photovoltaic panels on the building's south side could both bring tax credits for energy production. All of these measures were ultimately incorporated. Another energy-generation source was explored but deemed unsuitable—roof-mounted, vertical-axis (*Savonius rotor*) wind turbines.

EARLY ENERGY ESTIMATE



Back of the envelope estimates such as this for energy efficiency goals allowed Interface's team to respond to rapid turnaround times for key design decisions.

Eco-charrettes involve many participants from diverse backgrounds, in facilitated decision-making sessions.

Portland's abundant rainfall (36 in./yr. average), coupled with a large building roof area, indicated a potential for reclaiming rainwater for building water uses. And high groundwater due to the site location (beside the Willamette River, at the bottom of Marquam Hill) required building de-watering on a constant basis, but also allowed the project to take advantage of plentiful water supply at cool temperatures for use in building water reuse systems, landscape irrigation and for cooling tower make-up water.

Getting It Right, from the Start

The collaborative spirit of the integrated design charrette helped give birth to some of the original design concepts for this sophisticated, high-performance building. Interface was brought into the project after schematic design had already begun. Decisions on major energy-using systems had to be made in fewer than six weeks, not enough time to complete a rigorous computer energy model. Based on his experience, Frichtl was able to prepare a *back-of-the-envelope* analysis of where energy use could be cut to achieve the desired 60 percent savings. For example, lighting, domestic water heating and building heating constitute nearly 75 percent of energy use for a standard building of this type, and Frichtl targeted them collectively for a 60 percent reduction. Key design decisions were made early in the process, and Interface's engineers' intuitions proved right on almost every count.

ECO-CHARRETTE CLIMATE DESIGN DATA

Temperatures

- Average annual temperature: 60˚F
- Average winter lowest temperature: 20˚F
- Average low in December and January: 37˚F
- Average summer highest temperature: 98˚F
- Average high in July and August: 79˚F
- Diurnal range: 20˚F (or more)
- Summer design high temperature: 90˚F
- Winter design low temperature: 10˚F

Wind

- Summer winds from north or northwest, daytime hours
- Spring to fall winds during daytime are mostly north or northwest
- Winter storms from southwest

Sun Angles at Noon

(Portland is 45.5˚ north latitude)

- Summer solstice: 68˚ from horizontal
- Fall/spring equinox: 44.5˚
- Winter solstice: 21˚

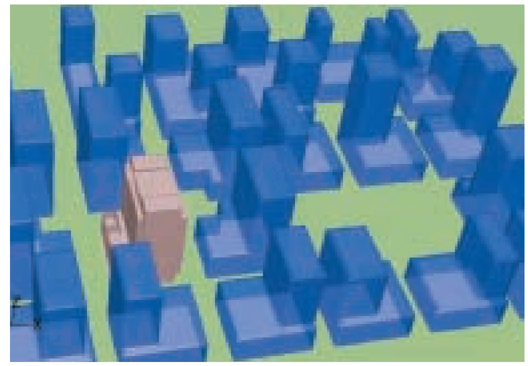
Annual Rainfall

Average is about 36 in., with recent years below that by 15 percent or more. Annual rainfall follows typical West Coast patterns and is heavily seasonal, with 86 percent falling from October through May.

Rainfall by month in inches (1961–1990 averages):

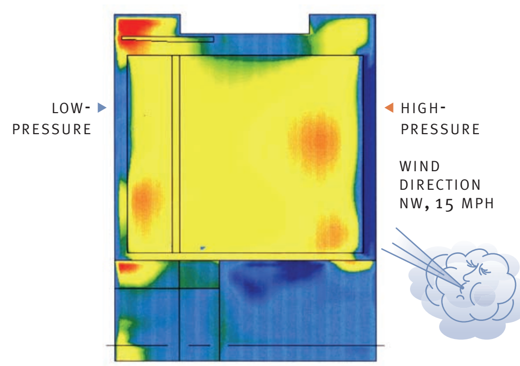
January: 5.35	July: 0.63
February: 3.85	August: 1.09
March: 3.56	September: 1.75
April: 2.39	October: 2.67
May: 2.06	November: 5.34
June: 1.48	December: 6.13
	Annual: 36.30"

CFD MODEL GEOMETRY



Interface's energy engineers built a computer model to test the potential for natural ventilation of the building. We had to model the entire district, including a number of tall buildings planned around this project. This model can be used for analyzing future buildings in the area. Funding provided by BetterBricks, a program of the Northwest Energy Efficiency Alliance.

CFD MODEL: WIND PRESSURE



Computational Fluid Dynamics (CFD) models provide a way to assess natural ventilation potential by examining wind pressures on each building face. In this case, we found out that future upwind buildings would actually create negative pressures on the upwind face of the building, leading us to focus our natural ventilation efforts on the east and west stairwells, where maintaining internal temperature control is not as critical.

"ENGINEERS ARE THE UNSUNG HEROES OF THE DESIGN INDUSTRY. THEY DON'T STRUT AROUND IN TAILORED SUITS AND THICK EYEGLASS FRAMES OR DISCUSS THE METAPHYSICAL MEANING OF THEIR BUILDINGS.

THEY DON'T BASK IN THE MEDIA'S SPOTLIGHT, NOR SERVE AS THE 'FACE' OF A PROJECT: THE FIGUREHEAD PUBLICLY EXALTED FOR ALL THE WORK.

INSTEAD, ENGINEERS ARE THE BEHIND-THE-SCENES GUARDIANS: THEY MAKE SURE OUR BUILDINGS STAY UP AND TUNNELS DON'T COME CRASHING DOWN.

THEY TEND TO THE NITTY-GRITTY DETAILS, THE BONES AND SKELETONS THAT MAKE GREAT WORKS POSSIBLE.

THEIR ROLE MAY NOT BE AS SEXY AS THAT OF, SAY, AN ARCHITECT OR PRODUCT DESIGNER, BUT WITHOUT THEM DOING THEIR JOB, WE'D BE METAPHORICALLY—AND LITERALLY—SUNK."

JULIE TARASKA, EDITOR
‹METROPOLISMAG.COM›
AUGUST/SEPTEMBER 2005

COMFORT

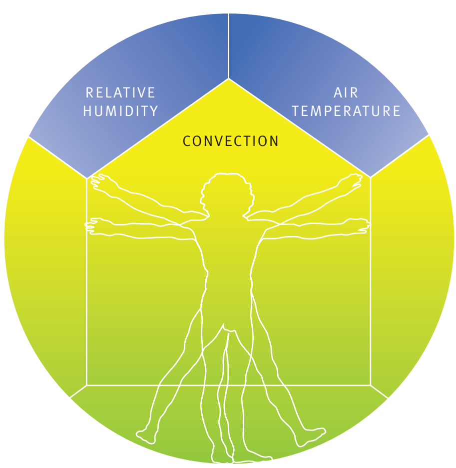
PRODUCTIVITY

HEALTH

DESIGN CHALLENGE: people

First and foremost, buildings are for people to live, work, learn and play in. In our design work, Interface strives to create building environments that are comfortable, healthy and productive places. For this project, our challenge was to provide for people's needs while still meeting aggressive criteria for resource conservation, cost savings and green building certification.

ELEMENTS OF OCCUPANT COMFORT



Occupant comfort is a function not only of air temperatures, but of relative humidity, air movement, mean radiant temperatures and clothing worn. Assuring comfort is an essential element in creating productive work environments.

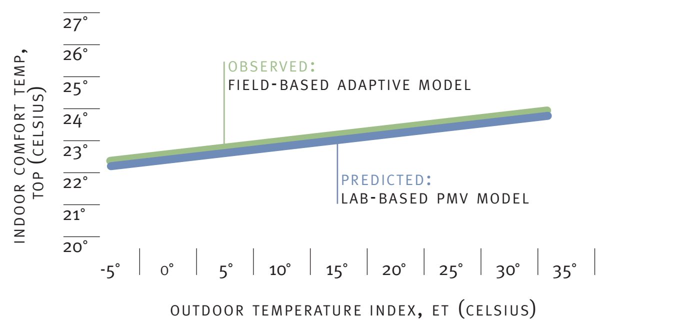
COMFORT

To achieve dramatic reductions in energy use sought by the client, the building team individually tailored heating and cooling strategies to different portions of the building.

For example, traditional HVAC systems maintain interior air temperatures in a range of about 70–75˚F. This requires larger, more tightly controlled heating and cooling systems than may be necessary for all but a few peak periods in summer or winter. In certain spaces through which people pass relatively quickly (stairwells, lobby, corridors), the team had more latitude to widen acceptable temperatures to a broader range, sometimes as much as 64–79˚F. As a result, smaller and more affordable systems at the Center for Health & Healing were selected for these spaces at significant cost savings.

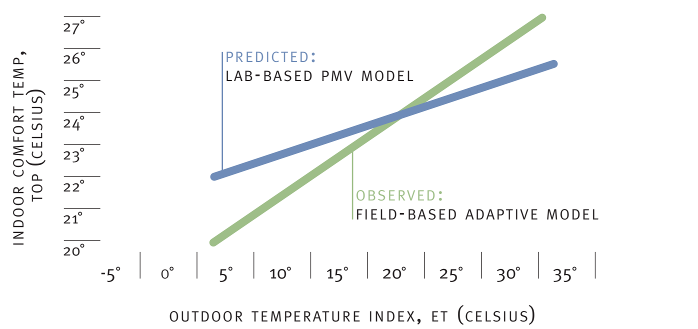
The relaxed temperature range in the stairwells and lobby comes not just from adjusting the thermostat, but from using radiant heating/cooling and natural ventilation instead of relying solely on traditional air conditioning and forced ventilation.

COMFORT IN BUILDINGS WITH CONVENTIONAL HVAC



Studies at the University of California, Berkeley show that comfortable temperatures rise only slightly as outside temperatures increase, in conventional overhead distribution HVAC systems.

COMFORT IN BUILDINGS WITH NATURAL VENTILATION



Studies by the same group at UC Berkeley of buildings with natural ventilation show a much wider band of acceptable temperatures for human comfort, ranging from 68°F to over 80°F.[1]

Radiant space conditioning utilizes the temperature of surfaces such as walls and floors, which tend to have less temperature fluctuation. Studies also show that people in naturally ventilated spaces are psychologically more accepting of a wider warm-cold spectrum throughout the day. So while the stairs and lobby might have a higher or lower mercury reading than the rest of the building, they would feel just as comfortable.

At the same time, heating and cooling strategies constitute just one aspect of the overall building design, and thus must be weighed against other factors. For example, concrete has ideal thermal properties for maintaining a narrow temperature range. But it also has loud acoustic properties when exposed without floor coverings. When and where to use concrete in the building, then, is not just a comfort-related decision, but also an aesthetic and economic one.

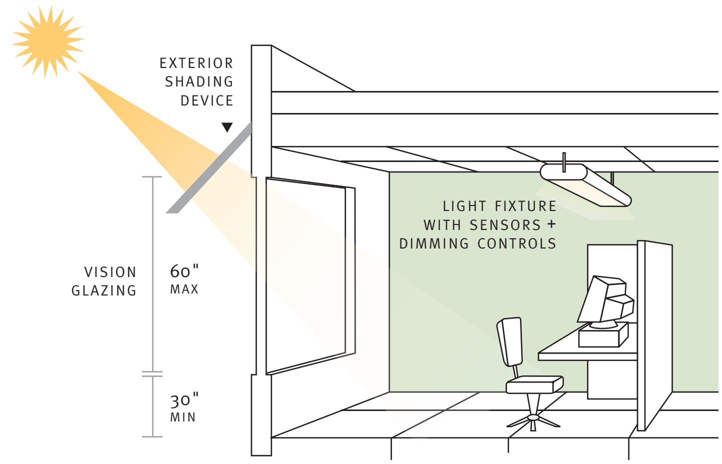
Balancing these competing concerns is what integrated design is all about. Because the developer, architect, contractor and engineer addressed these issues together at an early stage, the building achieves occupant comfort with far greater energy efficiency and at far less cost.

[1] Source: *High-Performance Schools Best Practices Manual*, Appendix C, p. 22. ‹www.chps.net›.

PRODUCTIVITY

Over the past decade, studies have shown what many of us already intrinsically sense: human performance, whether children in classrooms or adults in offices, is improved by regular access to natural light, views to the outdoors and natural ventilation. Whereas a previous generation of architecture may have restricted visual access for fear of occupant distraction and excessive energy use, today we know people are healthier—both physically and psychologically—when connected visually to the external environment.

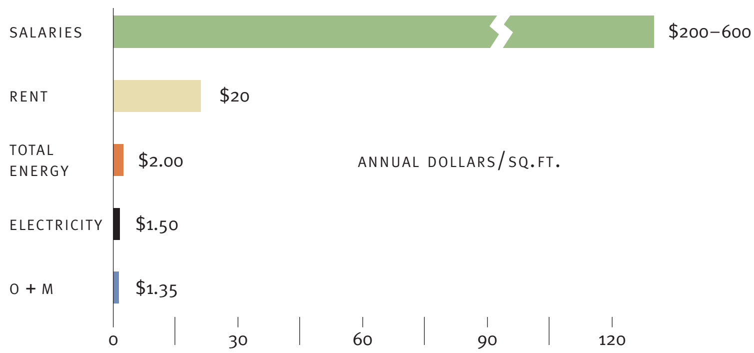
DAYLIGHTING DESIGN



Daylighting design attempts to provide natural light for occupied spaces without glare or unwanted heat gain in summer, while allowing winter sun into the building. Many studies have shown that adequate daylighting creates more productive environments.

Assuring occupant comfort also makes good business sense. As the accompanying chart illustrates, far more money is spent in a typical business on salaries and benefits (an average of $200–600/sq.ft.) than on the physical space itself ($15–25/sq.ft.) or on energy and water ($2–3/sq.ft.). As a result, investing in a building's human factors, such as daylight, air quality, and access to views of the outdoors, can pay immense dividends. There is a more subtle benefit, too: inviting interior spaces and healthier environments can also help recruit and retain key personnel.

RELATIVE COSTS FOR BUILDING OPERATIONS



People costs for salaries and benefits range from $200–$600/sq.ft., dwarfing rent and operating costs. Therefore, increasing productivity even one percent often can increase an organization's income as much as reducing energy costs by 100 percent.

Because the climate west of the Cascade mountain range is generally very mild, the Center for Health & Healing team saw a particular opportunity in using natural ventilation and outside air for *free* cooling. In particular, we were attracted to cooling down a building prior to each day's occupancy, and then using an economizer cycle during hours of occupancy. Taking advantage of an economizer cycle, in which the HVAC system utilizes a greater portion of outdoor air when outside temperatures are low and humidity is favorable, can bring about significantly reduced cooling costs in this building.

The goal, then, was to bring indoors and filter healthy natural air, and to do so using as little fan energy as possible (instead relying on air pressure and the inherent thermal energy of warm air rising). But a combination of high pressure on the north side of the building from prevailing winds and low pressure to the south made it difficult to move air naturally through the building without a fan assist. The depth of the building and additional space layout issues further complicated this. And, since we expected future large buildings on the north and west of this building, we also had to contend with reduced air pressures on the upwind side at ground level shown by the CFD model.

Ultimately, the team settled on a compromise: to use natural ventilation (the so-called *stack effect*) in stairwells, with microclimate analysis determining inlet and outlet points for vents, and to use fan-forced ventilation for the rest of the building. This decision also met the need for widely varying uses and air pressure requirements of the interior spaces and rooms. We were also able to incorporate radiant heating and cooling for the atrium at no net cost increase using piping in the first-floor slab.

HEALTH

Nearly 50 percent of the Center for Health & Healing's space is devoted to medical practices. An additional 12 percent consists of outpatient surgery facilities. Maintaining optimal air quality in both spaces was a vital health objective for this project.

Air quality starts with filtration. Interface specified a MERV-13 (minimum efficiency reporting value) filter for exam and clinic areas that removes more than 90 percent of all particles larger than one micron (about one-fiftieth the width of a human hair). This level of filtration—by comparison, a standard building filters about 70 percent of particles above 3 microns with a MERV-8 filter—gives healthier air with relatively few additional costs.

Two core principles guided the mechanical system design: optimum health and reduced energy use. After using a method of analysis called computational fluid dynamics (CFD) to study airflow, Interface selected a *displacement ventilation* system for the patient examination rooms that achieves both. This approach was also applied to interior office spaces.

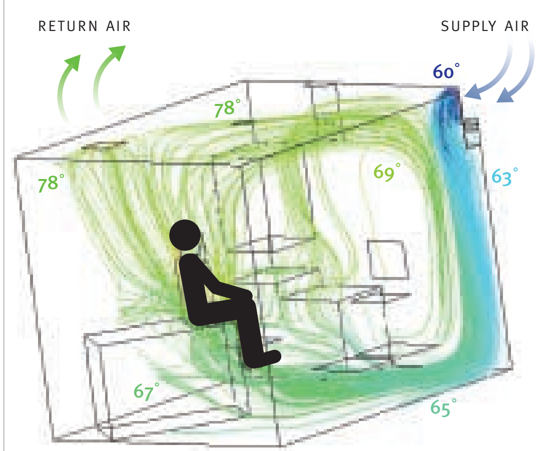
Displacement ventilation drops cool air from the high point of an interior wall at relatively low speeds in a *waterfall* effect. Because cool air is denser than warm air, it pools at floor level. But as it senses a warmer object, such as a human body, the air rises. Yet it remains cool enough to cool the space's occupant, with temperatures typically rising from 60˚F at the inlet to 78˚F as it exits on the other side of the room at the ceiling.

Using displacement ventilation, air will cool the doctor and patient primarily, but will not cool the entire space and then reheat the air, as is common. Therefore, less air flow into the room is needed to maintain comfort and, correspondingly, less energy is used, as fan energy is reduced by two-thirds and re-heat of incoming air is eliminated.

Additionally, displacement ventilation does not require air as cool to achieve that same human comfort. Whereas traditional ventilation systems produce air at 55˚F to bring overall temperature of a space to, say, 75˚F, displacement ventilation requires 60˚F (or greater) incoming air to do roughly the same job. In the Pacific Northwest, that means it is possible to incorporate outdoor air more often in cooling a building, potentially for hundreds of more hours per year, when the outside air temperature is between 55˚F and 60˚F.

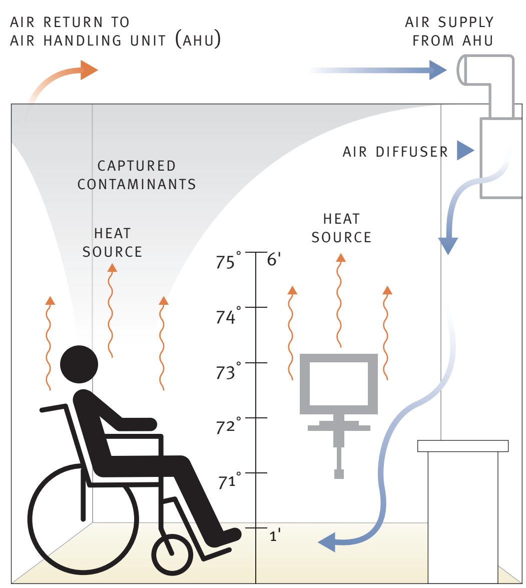
Another benefit of displacement ventilation is that there are typically fewer contaminants in the air. This was of particular interest to OHSU's physicians, who saw optimal indoor air quality in the clinics as indispensable to their mission of promoting health.

AIR FLOW IN EXAM ROOMS



In this displacement ventilation system, there is a "waterfall" effect, as cool incoming air falls down the walls, pools on the ground and rises as it is heated by people, computers and lights.

AIR TEMPERATURE IN EXAM ROOMS



By raising supply air temperatures to 63˚F, we create an approach that is far more energy-efficient and results in a much more comfortable exam room, with less air movement.

Interface prepared a computer analysis showing air flow in the displacement ventilation system. We used the same type of airflow analysis done on the macro level outside the building on a micro level here. From the simulation, one can see how temperatures move through the space, with cold air dropping to the floor, being heated by the body temperatures and then exiting through the return air grille across the room. This results in a more comfortable exam room, with much less air movement and less energy use.

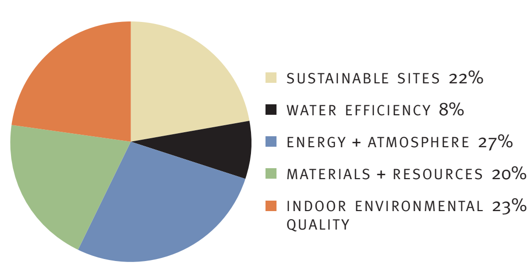
DESIGN CHALLENGE: LEED

Meeting the LEED (Leadership in Energy and Environmental Design) certification requirements of the U.S. Green Building Council was a key project goal. Achieving the highest possible LEED certification level—Platinum—involves unique design challenges that go beyond today's best practices and ask engineers to think *outside the box* toward more integrated design and restorative practices.

FROM THE BEGINNING, the owner and developer insisted on a sustainable design that would reduce operating costs, improve occupant comfort and health and reduce consumption of natural resources. Collectively these measures also become a valuable benchmarking tool. The developer set a goal of attaining a LEED Silver certification from the U.S. Green Building Council. A LEED rating of Silver or better would qualify the project for the Oregon Business Energy Tax Credit, worth somewhat less than $1.00/sq.ft. to the project, or about $300,000.

GBD Architects, Gerding Edlen Development and Hoffman Construction each brought significant experience with local LEED-rated projects, such as the five-block project in Portland known as The Brewery Blocks. Interface Engineering had also gained valuable LEED experience with the Jean Vollum Natural Capital Center (the first Gold-rated building in the western United States), the Silver-rated Clackamas High School and the Bronze-certified Marion County Courthouse Square project in Salem, Oregon. Interface has subsequently completed two more LEED-certified projects in the Portland area, through the first half of 2005.

LEED RATING SYSTEM



The LEED rating system assigns relative weights to five categories, and also allows a few *extra credit* points (not shown here) for innovative design ideas or exceptional achievements in credit categories.

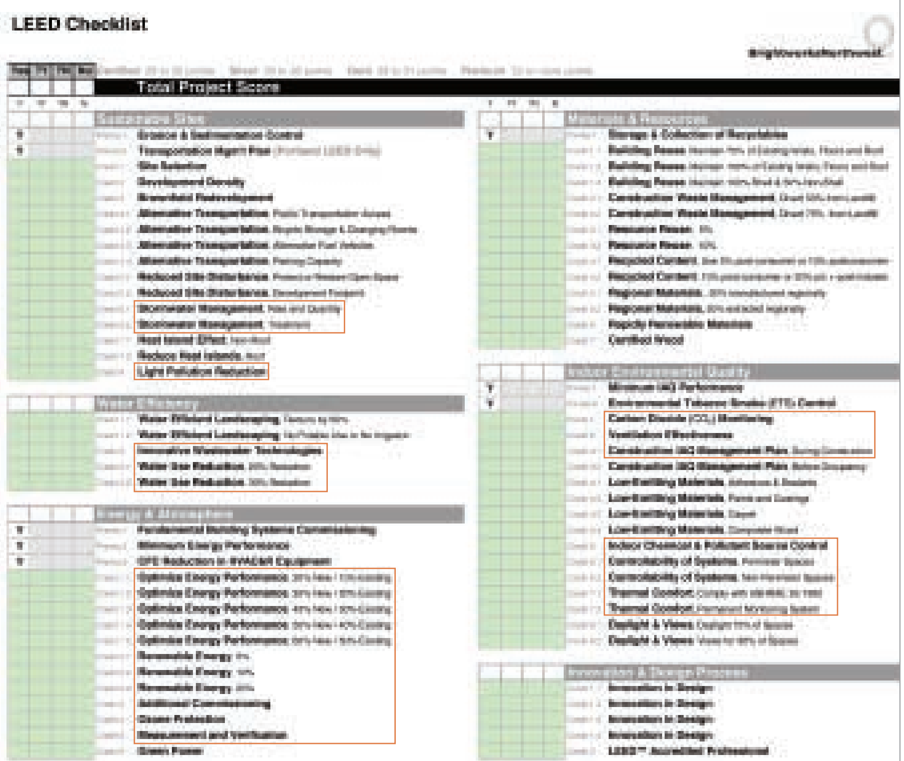
Next to the architect, the MEP engineer arguably has the biggest role to play in meeting LEED goals. As many as 27 possible points on the LEED scorecard for the Center for Health & Healing (enough to achieve the Certified label) directly relate to work performed by Interface: HVAC and natural ventilation systems with corresponding controls, stormwater management, sewage conveyance, efficiency of water and energy usage, choice of refrigerants, light-pollution reduction, daylighting integration with electric lighting, renewable energy sources, indoor air quality, thermal comfort and potentially one or more *innovation* points.

Early meetings around the LEED goals largely consisted of assigning responsibility for achieving points on the LEED scorecard and evaluating costs. But LEED is not simply a guideline to follow. As developer, architect, contractor and engineer worked together to choose materials and methods for the building, the LEED system became a *de facto* design tool. The building envelope's energy-efficiency measures affect the size of an HVAC system, which in turn affects the air distribution system and costs, for example, and rainwater collection equipment requires consideration of locating underground storage tanks and providing a dual plumbing system.

As the project went along, therefore, more and more sustainable features became possible through the synergies fostered by an integrated design approach. Soon it became apparent that the building could not only meet Silver LEED standards with relative ease—no small feat given its large scale and diverse program elements—but was poised to potentially reach the LEED pinnacle: a rare Platinum rating. That would confirm the building as one of the most sustainable, high-performing buildings ever constructed.

A number of the required points needed for the Platinum rating require specific actions during construction, something that will not be completed until the summer of 2006. We expect the final rating on the building to be verified by the end of 2006.

STANDARD LEED VERSION 2.1 CHECKLIST


LEED Checklist

Total Project Score

The project's LEED consultant kept track of potential credit points throughout the process. Interface's work could affect (either solely or as a team member) points in the highlighted categories. The LEED checklist is a key tool for the integrated design process, keeping track of major decisions, design responsibilities and documentation needs over a three-year design and construction period.

Business Case for High-Performance Green Buildings

Mechanical and electrical engineers should always be concerned about designing with an economy of resources and about providing energy efficiency, water conservation and indoor air quality measures that have economic validity and add value to the building.

The business case for high-performance buildings, however, rests on more than just payback of energy and water conservation measures, or return on investment from on-site power production or wastewater treatment. Some of the key arguments for high-performance green buildings that apply to this project include:

1. Reduced upfront capital costs through integrated design measures and outside-the-box engineering thinking
2. Reduced operating (utility) costs for energy and water (value of \$1–3/sq.ft./yr.), often with very high returns on incremental investments

3. Increased worker productivity through daylighting, views of the outdoors and a healthy indoor environment (even a one percent productivity gain is worth $2–4/sq.ft./yr.)
4. Increased ability of firms to recruit and retain a high-quality workforce, especially in the service and knowledge economy
5. Reduced potential liability for future problems with indoor air quality, mold growth and sick-building syndrome
6. Through green-building certification, provide a visible commitment of an organization's commitment to sustainability, with valuable gains in community public relations, marketing and occupant morale
7. Increased real estate value through reducing operating costs and occupant turnover, resulting in increased net operating income (NOI)
8. Making good use of financial and tax incentive programs offered by utilities, nonprofits and local, state and federal governments
9. More predictable operating results and increased occupant satisfaction through building commissioning and integrated design measures

GBD ARCHITECTS

While many of these benefits are hard to measure at this time, we believe that the examples of cost reduction measures provide a valuable first step in assessing the economic success of the design effort. At this time (fall of 2005), construction is well underway, all strategies have been fully priced by the contractor, and we anticipate no significant cost increases or value engineering measures that would materially change the systems originally designed.

In mid-2003, the state of California commissioned the most detailed study to date of the financial benefits of green buildings. This report concluded that the majority of the benefits result from increases in productivity and well-being in such buildings as shown in the table below.

FINANCIAL BENEFITS OF GREEN BUILDINGS

CATEGORY	20-YEAR NET PRESENT VALUE $/SQ.FT.
Energy savings	$ 5.80
Emissions savings	1.20
Water savings	0.50
Operations and maintenance savings	8.50
Productivity and health value	36.90–55.30
Subtotal	*52.90–71.30*
Average extra cost of building green (not present in this project)	(-3.00– -5.00)
Total 20-year net benefit	*49.90–66.30*

Source: ‹www.cap-e.com›.

"...ACTUAL ENGINEERING PRACTICE PRESENTS [AN INTRIGUING AND] DIFFERENT POSSIBILITY...SAVING EVEN MORE ENERGY CAN OFTEN 'TUNNEL THROUGH THE COST BARRIER,' MAKING THE COST COME DOWN *AND THE RETURN ON INVESTMENT GO UP.*

[THE MAIN WAY] TO ACHIEVE THIS MORE-FOR-LESS RESULT [IN A NEW BUILDING]... IS TO INTEGRATE THE DESIGN OF AN ENTIRE PACKAGE OF MEASURES, SO THAT EACH MEASURE ACHIEVES MULTIPLE BENEFITS, SUCH AS SAVINGS ON BOTH ENERGY AND EQUIPMENT COSTS."

FROM *NATURAL CAPITALISM*, BY PAUL HAWKEN.
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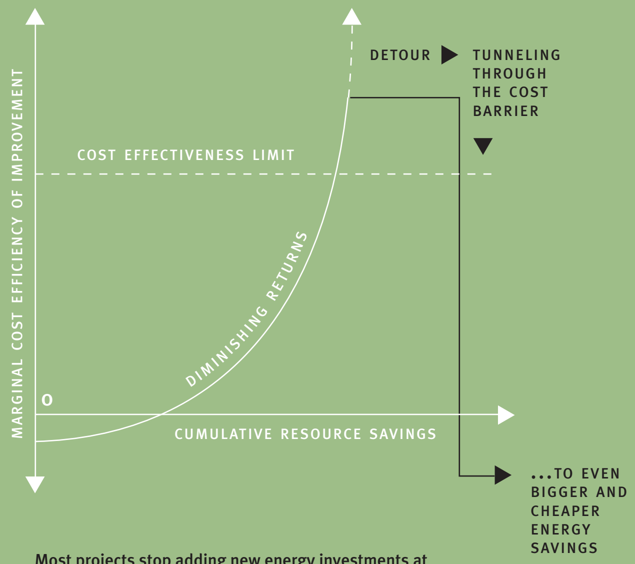


Most projects stop adding new energy investments at a pre-determined limit, such as "payback" in so many years. By looking at the whole system, we can often do much better, at a lower total cost.

ENERGY STRATEGIES

LIGHTING CONTROLS/DAYLIGHTING

CHILLED BEAMS

FIRE + LIFE SAFETY

ARCHITECTURAL INTEGRATION

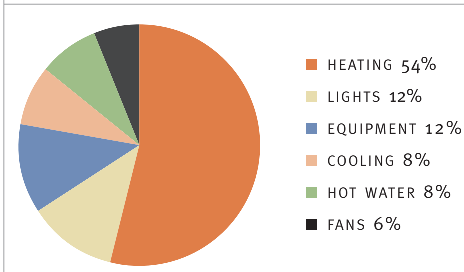
DESIGN CHALLENGE: energy EFFICIENCY

The mandate for energy savings 60 percent greater than code (based on the LEED 2.1 standard, ASHRAE 90.1-1999) at the Center for Health & Healing could only be met by scrutinizing every aspect of the building's energy usage. Luckily, such intensive thinking using energy modeling is the basis for every sustainable project at Interface Engineering.

ENERGY STRATEGIES

During an integrated design process there is always a give-and-take among architect, contractor and engineer during conceptual design and schematic design phases. Energy modeling uses a basically agreed-upon building orientation and massing to create a *baseline* model of the proposed project. This model incorporates a prescriptive code-compliance approach for the basic building envelope and systems to meet comfort conditions for a given climate and other factors. From this baseline, Interface's engineers propose and test energy efficiency measures (EEMs) or groups of measures as potential solutions. The graphic shows the results of the baseline energy model, according to the ASHRAE 90.1-1999 standard.

BASELINE ENERGY ESTIMATE



The baseline energy model shows end uses of energy (heating, lights, equipment, cooling, hot water and fans) that apply to a building that just meets the energy code. This is the baseline for assessing our energy performance, once all efficiency measures and solar contributions are analyzed. From the chart, it's easy to see that heating dominates the energy use for this building, requiring more than half the total energy of the base building.

Modeling: A Design Tool
For some, energy modeling largely confirms decisions that have already been made. But for Interface, it becomes a design tool that can prompt new strategies, systems choices and material selections. Modeling will never yield perfect data, but it's very close to actual performance (typically within about 5 percent for commissioned buildings), providing a snapshot of a building's performance before design is completed—a crucial tool, therefore, in reaching a higher level of efficiency, while keeping costs under control.

Normally in an integrated design project, the engineering team should have input on site selection, building massing and orientation. With the Center for Health & Healing, as it happened, the architects designed the long axis of the building almost exactly east-west, an orientation ideal for taking advantage of passive solar heating in winter. To limit building heat gain from summer sun, thereby reducing the required size of the HVAC system, the design team studied overhanging sunshades, which the team later decided would be an ideal location for solar electric panels, or photovoltaics. Solar electric systems receive strong financial support in Oregon, and Interface often assists clients in identifying available funding sources for supporting renewable energy and other sustainable approaches, in this case the Oregon Business Energy Tax Credit and grants from the Energy Trust of Oregon.

A key question, though, was how shading from future buildings would affect the Center for Health & Healing's access to sunlight. Therefore, GBD Architects conducted extensive daylighting studies with a district model showing all planned development around the building. The BetterBricks Integrated Design Lab in Portland employs a heliodon that allows designers to study shading at any hour of the year.

SOLAR MODEL STUDIES

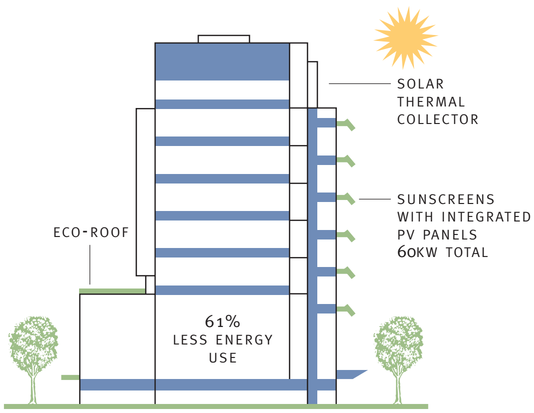
Supported by the Northwest Energy Efficiency Alliance, the BetterBricks Daylighting Lab provides advanced studies for buildings. GBD Architects provided a model of the OHSU building and the anticipated River District buildings, which were then exposed to simulated sunlight at several times each day, during a number of periods of the year, including both solstices and both equinoxes. The photographs by GBD show (A) December 21 at noon; (B) September–March 21 at 9 AM; and (C) September–March 21 at 5 PM.

RESULTS OF THE PRELIMINARY SOLAR STUDY

Examining the building model in a district context allowed us to make a number of early design observations which guided our decisions in the subsequent design phases. We were particularly interested in the solar exposure of the south façade, given the expected 325-ft. height of a planned building immediately to the south of the Center for Health & Healing. These observations show the power of early modeling studies of buildings in an urban context.

- South façade receives full sun all day in summer
- South façade receives full sun only after 1 PM in winter
- South façade windows need shading devices all year round, even when the block to the south is developed with a full height tower (325 ft.)
- East and west stair towers receive full sun for four hours per day year-round, providing good thermal dynamics for natural ventilation air movement
- North courtyard receives almost no direct sunlight during fall and winter months, making it a cool, shaded place during those months
- If buildings to the west are kept low, this will allow some direct afternoon sunlight to reach the north courtyard on summer afternoons, making it a more pleasant space

CONCEPTUAL DESIGN FOR ENERGY EFFICIENCY



With a goal of saving 60 percent of the energy of a conventional building, we knew we'd have to look at dozens of energy-efficiency measures, as well as capture and use as much solar energy as possible. Eventually, 42 specific energy-efficiency measures were incorporated into the building.

Using that information, the building was designed so that windows could be shaded during peak light and heat times in the summer, but would let sunlight in during the fall, winter and spring months when heating is needed in Portland. (The model studies showed that there was still a lot of shade on the lower part of the building in the spring and fall months.) So sunshades and photovoltaic panels were included only above the fourth floor. Nonetheless, we determined that there still was substantial solar *income* for the majority of the year; also we did not want to lose the *free* solar energy falling on the sunshades; hence the inclusion of photovoltaic panels.

And speaking of taking advantage of natural resources, the regional climate is always a factor in a building's energy-efficiency strategies. Because the area west of the Cascades enjoys mild weather, and also because energy is moderately priced in Portland compared with national averages, the design team had to be conscious of including the most cost-effective measures that would result in an ultra-sustainable building mostly geared toward longer-term savings. Because OHSU expects to occupy this building for a very long time, however, the development team made the economic decision to embrace sustainable design and its resultant reduced operating costs.

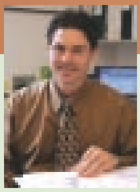
To reduce a building's overall energy use the engineers first examine end uses for energy: heating and cooling, lighting, plug loads (from computers, printers, etc.), fans, water heaters, motors and pumps. To achieve a 60 percent reduction in energy use versus applicable codes, the law of averages dictated that energy for some end uses would have to be cut by more than 60 percent.

In cooling a building, it's always more efficient to keep heat from ever entering than it is to flush that heat out with refrigerated air. So the sunshades were a start, keeping heat from entering the building during summer. The building's thermal mass (particularly its concrete) could also be harnessed to keep temperature fluctuations within a narrow range. The groundwater that had to be pumped offsite anyway could also lend some of its coolness, as we shall see.

Because energy prices are more expensive at certain peak hours (and likely to grow at a faster rate), the Center for Health & Healing also takes advantage of what is known as the *thermal flywheel* concept. Through various forms of energy storage, cheap heat generated by the microturbines 24/7 is stored until needed, then used to warm the building or create hot water. Led by Andy Frichtl, Interface first took advantage of the thermal flywheel in 1997 with the eight-story Pacific Gas Transmission Building (now headquarters for David Evans & Associates), which won a regional "Architecture + Energy" award for its innovative ice-storage system, the first in Portland. In that system, electricity is used to make ice at night, which is then melted to provide cooling during the day.

"...SAVING A LOT OF ENERGY, OR ANY OTHER RESOURCE, AT LOW COST IS LIKE EATING A LOBSTER. TO DO IT SUCCESSFULLY REQUIRES BOTH A GRASP OF SYSTEM ANATOMY AND ATTENTION TO DETAIL. THERE ARE BIG, OBVIOUS CHUNKS OF MEAT IN THE TAIL AND FRONT CLAWS. THERE'S ALSO A ROUGHLY EQUAL QUANTITY OF TASTY MORSELS HIDDEN IN CREVICES, REQUIRING SKILL AND PERSISTENCE TO EXTRACT BUT WORTH THE EFFORT."

FROM *NATURAL CAPITALISM*, 1999 BY PAUL HAWKEN, AMORY LOVINS AND L. HUNTER LOVINS



ANDY'S DESIGN POINTS▾

RIGHT-SIZING: Carefully analyze demand and take advantage of energy storage opportunities, reducing HVAC system sizing without sacrificing comfort.

COST-TRANSFER: Through creative design of HVAC systems and use of incentives, savings can flow to other parts of the building project.

USE FREE ENERGY: Assess the free resources available to the project: sun, wind and water, along with seasonal air, groundwater and earth temperatures.

REDUCE DEMAND: High-performance buildings first cut demand for heating, cooling, lighting, fan energy and other major users of energy, so that the supply systems can be smaller and therefore less expensive.

LOAD-SHIFTING: Thermal energy storage systems act to shift loads from peak to off-peak periods, so that loads can be met with cheaper power sources and peak systems can be down-sized.

CHALLENGE STANDARD PRACTICE: Good engineering design should always start with the basics of comfort and health, and not be afraid to challenge codes where necessary with performance-based designs.

UTILIZE RADIANT SPACE CONDITIONING: Often we can meet comfort standards at a lower cost by employing radiant heating and cooling instead of convective heat transfer.

RELAX COMFORT STANDARDS: Approaches such as natural ventilation and radiant space conditioning achieve thermal comfort without conforming rigidly to a 73˚F ± 2˚F approach common to conventional systems.

Assume Nothing, Prove Everything

The next approach was to *right-size* the HVAC system. Most mechanical engineers deliberately build oversized systems to assure comfort at all times. The Center for Health & Healing's system, however, is a more literal reflection of need. This is a divergent approach from traditional mechanical design. But Frichtl's motto for this project was "Assume nothing, prove everything!" The Center is foremost an envelope-intensive building, not system-intensive. The building's energy-efficient windows, extra wall insulation, concrete floors at ground level and other features provided a solid envelope to maintain a mild temperature range. The natural ventilation approach utilized in stairwells also brings reduced loads by cutting the available space that requires mechanical heating and cooling.

Based on the energy modeling results, which corroborated our design intuitions, Interface felt confident in selecting an HVAC system with less extra allowance for peak heating and cooling loads. (The system has a built-in capacity for expansion later.) In return, we expected to reap substantial savings, both in capital and operating costs.

RIGHT-SIZE SYSTEMS

The success of integrated design efforts depends on engineers' willingness to make systems only the appropriate size, an approach called *right-sizing*. In their landmark book, *Natural Capitalism*, Hawken and the Lovins' take standard engineering to task for optimizing sub-systems while "pessimizing" whole systems. In our approach to this project, we looked for right-sizing opportunities such as:

- Eliminate excessive *safety factors* which build unneeded cost and inefficiency into systems, often called the "belts and suspenders" approach to design (using both to hold up your pants, where one alone will do the job)
- Challenge standard practice: Calculate demand from basic principles, rather than using traditional HVAC design rules of thumb which contain many hidden assumptions and safety factors
- Assume nothing, prove everything!
- Build in expansion capabilities, rather than trying to accomplish everything at the beginning
- Challenge restrictive codes which add cost without benefit, through successful appeals

Additional efficiency comes from a variety of sensors and controls. Inside meeting rooms, for example, carbon dioxide sensors (CO_2 concentration is a sign of human occupants) reduce ventilation systems when the spaces are empty. In laboratories, building relief air is recycled for use as exhaust make-up air, and exhaust air is recycled to pre-heat building outside air. Photo-electric sensors turn lights on and off according to the amount of natural daylight in a room. Daylighting incorporated into the design is expected to save $20,000 per year in energy costs. Garage lighting levels were also reduced, to bring $21,000 in annual savings.

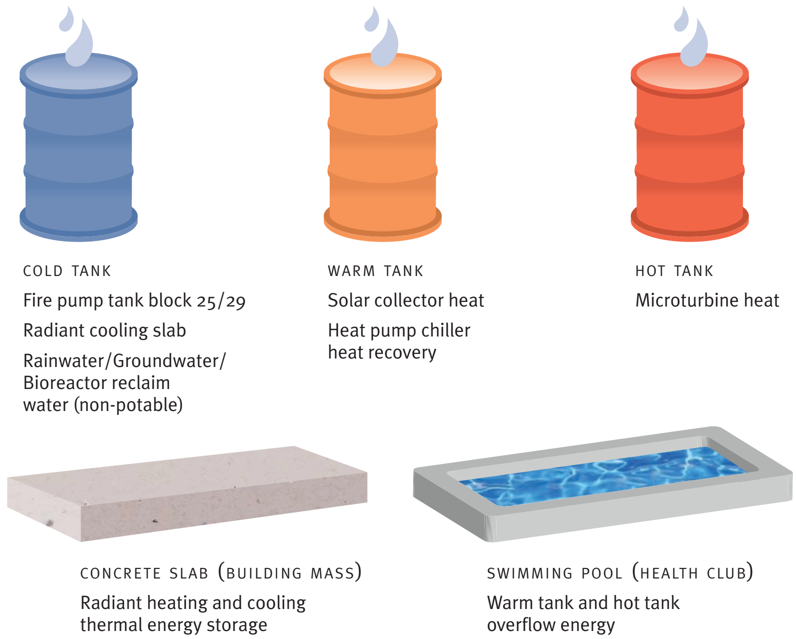
Embrace Every Opportunity

A number of other individual measures and systems will also add to the efficiency goal: a revolving door for the atrium entry, premium high-efficiency fans, a heat recovery system, low-pressure air filters, high-efficiency transformers, and a solar water heater. Then there's the chilled water plant, which will bring nearly $128,000 in annual savings with a payback of just three and a half years.

And whether it's a single-family home or a 400,000 sq.ft., multi-use medical building such as the Center for Health & Healing, efficient windows virtually always pay for themselves. With incentives figured in, the payback for high-efficiency glazing chosen for the building is about three years—and as energy costs rise, the savings will accelerate in the future.

It takes a wide spectrum of efficiency measures to surpass a standard building by more than 60 percent. Some measures brought small gains in efficiency, while others were large. But all were of equal importance to an integrated design team that embraced every opportunity for making the building perform better.

THERMAL ENERGY STORAGE CONCEPTS



For this project, we provided a series of thermal energy storage tanks and systems, including the concrete slab of the first floor and the swimming pool in the health club. Thermal energy storage helps to smooth out the demand for gas and electricity in the building, lowering energy costs, and allowing us to reduce the size of the HVAC system.

Integrated Energy Storage Systems

A final effort to achieve synergies came from incorporation of energy storage systems into the design. From the image, you can see that there is a *hot-water* storage tank containing heat from the microturbines. There is a warm water storage tank with energy from the solar thermal collector outside floors 15 and 16, and from heat recovered from the heat pump chiller. Finally, there is a cold-water storage tank using all the cool water from the recovered rainwater and pumped groundwater, held in the fire storage tank below the building. Each of these energy storage systems is used to provide "cheap" heating or cooling to some aspect of the building's energy demands. In addition, the concrete slab of the building mass provides thermal energy storage and allows the building to remain cooler on warm days than it would otherwise be. Finally, the swimming pool in the health club is used as a *heat sink* with waste heat from the microturbines, thereby getting more energy out of each therm of gas burned to make electricity.

Other energy efficiency measures come from architectural choices, including the envelope measures such as high-performance windows and extra floor insulation. For this building, the team decided on added insulation in walls and floors, going from a standard R-19 to R-21 in the walls and from 5-in. to 12-in. expanded polystyrene (EPS) below the floor.

RADIANT HEATING AND COOLING

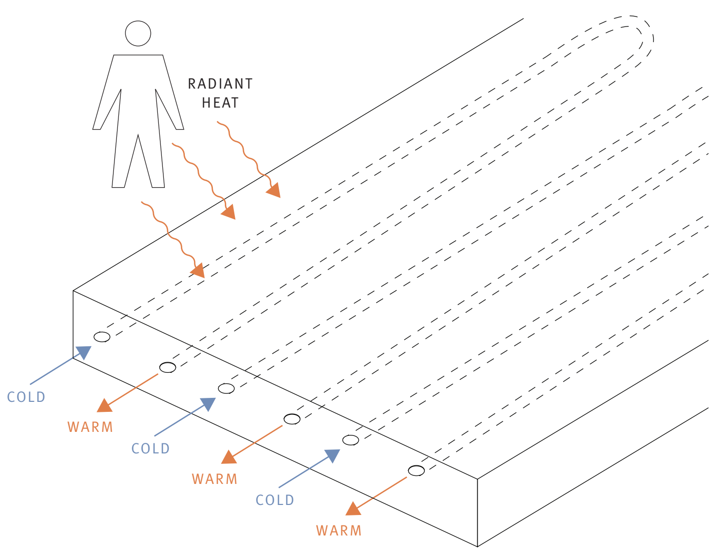
We incorporated radiant heating and cooling systems into the first floor slab to provide a more comfortable environment without having to move large volumes of air. Radiant space conditioning also provides more comfort at a broader range of air temperatures than air movement alone.

RADIANT THERMO-ACTIVE SLAB

At the beginning of design, the team looked seriously at natural ventilation for the building lobby and atrium, but decided that the combination of huge louvers, noise and other esthetic considerations mitigated against this approach. With an abundance of free cooling water from pumped groundwater and reclaimed rainwater, the radiant cooling approach suggested itself naturally.

Given the huge concrete slab on the ground floor, we were able to use a radiant floor heating and cooling system, which displaced cooling tonnage and was cost-neutral against a standard VAV-system for heating and cooling the lobby space. In addition, this approach requires no fan energy for mechanical cooling, just for ventilation. Temperature control in this pass-through space is not as critical, so the radiant approach also works well. The concrete slab also acts as a place to store excess heating and cooling energy.

RADIANT THERMO-ACTIVE SLAB/COOLING MODE



Radiant heating and cooling is accomplished by burying tubes in the first-floor slab, then circulating warm or cool water through them depending on the season. In summer, cool water circulates through the slab prior to the next day's occupancy. In winter, warm water begins to circulate about 6 AM, so that the slab is at the right temperature as people arrive for work or visits at about 8 AM.

ENERGY-EFFICIENT DESIGN MEASURES

Sometimes good engineering requires a project designer to take advantage of all feasible measures to achieve high-performance goals, in this case 60 percent energy savings over both the Oregon Energy Code and LEED version 2.1's requirement—ASHRAE 90.1-1999. Key strategies we chose include:

- Radiant cooling for the atrium and lobby ground floor, using reclaimed rainwater and ground water in the concrete slab
- Radiant cooling with overhead chilled beams
- High-efficiency (95 percent) boilers and chillers to reduce energy input for primary building conditioning
- Double-fan variable air volume (VAV) air handlers and variable frequency drives (VFD) on most pumps and motors, both serving to match supply and demand more carefully
- Demand-controlled ventilation (DCV) using carbon dioxide sensors and occupancy sensors, so spaces are not over-ventilated or over-lit when not in use
- Heat recovery systems, including from laboratory and general exhausts and returning gym air through the locker rooms
- Displacement ventilation for core exam/office areas to reduce air contaminant levels and to eliminate the need for reheating supply air
- Load shifting using a system of hot water storage and cold water storage, both serving to reduce peak-period demands (when power is more costly)
- Passive heating/cooling and natural ventilation of stair enclosures
- Energy-efficient lighting fixtures and controls, incorporating daylighting wherever feasible
- Night-flush pre-cooling with outside air up until one hour before daily occupancy
- Economizers for free cooling using outside air whenever possible, taking advantage of the generally cool daytime temperatures year-round in Portland
- Process water heat recovery, for pre-heating hot water for the building
- Occupancy sensors in lab exhaust systems to avoid dumping conditioned air outside when labs are not in use
- Measurement and verification plan for all energy and water-using systems, incorporated with building automation system, to allow troubleshooting of future energy use anomalies
- Building commissioning, including field verification of all energy-using equipment, to ensure operation according to design intent, as well as peer review of design intent during design development and construction documents phase

JAMES CRIDLAND

Clackamas High School, LEED Silver.

LIGHTING CONTROLS/DAYLIGHTING

Lighting represents about 23 percent of total energy use in a standard building of this size. Interface's designers set an early goal of reducing lighting energy consumption by 50 percent over the ASHRAE 90.1-1999 standards.

To meet this challenge, Interface set out to use a combination of innovative light fixtures and lighting controls that met the needs of a medical office and research building while still meeting energy conservation goals.

In the many exam rooms of the facility, the standard of two 1-ft. x 4-ft. lensed fluorescent luminaires were replaced with a single, multi-lamp 48-in. diameter lensed *skydome* that mimics the natural light common to the perimeter offices of the building. A combined wall switch/occupancy sensor turns on half of the lamps only when the room is occupied, and an automatic switch labeled "exam lights" permits the remaining half of the lamps to be turned on when higher light levels are needed.

Seeking to gather energy savings where possible, the designers specified reduced lighting levels for lobbies and other pass-through spaces. Hallway occupancy sensors and local daylighting sensors switch off normal and emergency lighting in these areas when there is either sufficient natural light or the spaces are otherwise unoccupied. Significantly reduced outdoor lighting with cutoff fixtures further reduces energy consumption, easily meeting the LEED requirements for eliminating light pollution.

Other innovative design solutions included:

- Multi-lamp high bays in the athletic club, tied to daylighting controls, switch down lighting levels as natural lighting becomes sufficient
- Occupancy sensors in stairwells switch lighting on and off to follow an occupant up or down, allowing the lighting to stay on for the minimum time needed for egress. (During the evening, this will give the building a dynamic appearance)
- Perimeter offices with occupancy sensors have a daylighting control activated, keeping room lighting off whenever there is sufficient natural light

As a result of these extensive energy conservation measures, energy modeling for the project predicts a total reduction of lighting energy use by 45 percent, approaching the original design intent. This alone represents a reduction of 16 percent in total electrical energy use for the project.

HIGH-EFFICIENCY T5-HO LAMPS

T5 high-output lamps use less material than conventional T8 lamps for the same light output. They create a more intense light source so need to be used where glare would not be an issue.

CHILLED BEAMS

One of the technology innovations we employed at the Center for Health & Healing is the use of chilled-beam systems for passive convective cooling. These systems consume less energy than traditional air-conditioning systems, and the corresponding HVAC system can be more than three times smaller than a more conventional approach using forced air movement for cooling. They allow reduced floor-to-floor height, since ductwork is eliminated, and can reduce the size of mechanical shafts and the space needed for fan rooms.

CHILLED BEAM

Chilled-beam systems, (depending on whether they are active, passive or multi-modal) consist of an assembly of copper tubes and aluminum fins in the ceiling, through which water circulates, to raise or lower space temperatures as desired. Induced thermal currents help move air in the space, without the need for fans.

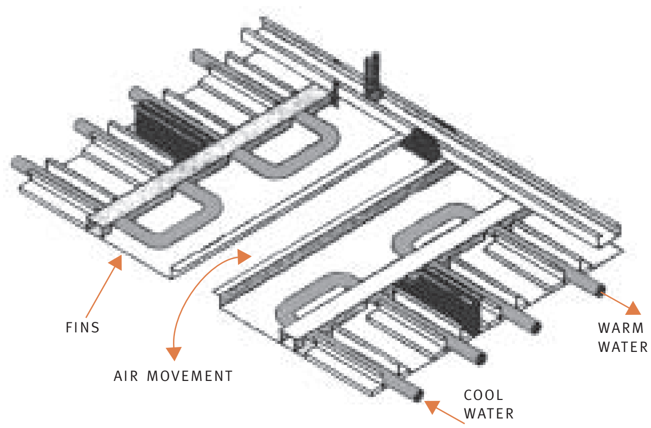
Chilled beams combine convective cooling systems with displacement ventilation to reduce energy use, improve comfort and reduce the architectural impact of ductwork and other mechanical systems. These systems are used throughout Europe but seldom have been considered in the United States.

How do they work? Chilled beams sometimes combine with a fan that passes air through the beam, cooling the room air. This system enhances the natural convection effect of warm air rising and cool air falling. The beams also cool objects in the room by absorbing their radiant energy.

Conditioning with chilled beams typically provides 20 percent to 30 percent energy savings over conventional air-conditioning systems. The beams may be active (utilizing fans) or passive, just relying on natural convection currents. The beams can be used for limited perimeter conditioning or as a main cooling system. The beams can provide heating as well, but are typically used only for cooling.

This building utilizes both passive and active chilled-beam systems, combined with displacement ventilation and baseboard convective heat, to provide thermal comfort and a mostly passive HVAC strategy. Chilled beam systems can cost $100–$250 per lineal ft., but using them results in reduced HVAC and building system costs, along with reduced architectural and structural cost, providing economic justification.

CHILLED BEAM DIAGRAM



TROX USA, INC.

Chilled beams are a newer technology that provides not only the energy efficiency of a radiant cooling system, but also an alternative ceiling treatment for designers. The OHSU building incorporates hundreds of chilled beam modules and represents a major energy-efficiency innovation.

DESIGN SYNERGY:

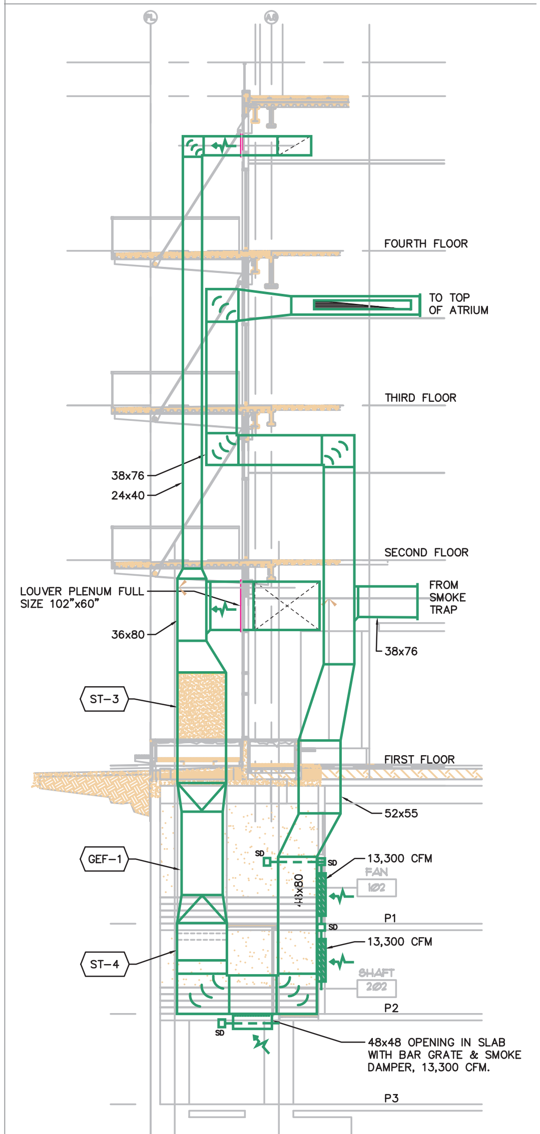
FIRE + LIFE SAFETY

The three-story atrium comprising the Center for Health & Healing's dramatic ground-floor entrance brought with it the challenge of efficiently controlling smoke in the case of a fire. A standard solution would be to place the required large exhaust system on the roof. This, however, would not only have cost significantly more, but would also disrupt the aesthetic configuration of ceiling treatments and the rooftop garden, for a system that one hopes will never be used.

Following the lead of Interface's senior mechanical engineer John McMichael, PE, early in the design process, the team hypothesized that piggybacking atrium exhaust with the 33,000-cfm garage exhaust system could be a viable alternative. After all, the two-block underground garage was large enough to require correspondingly sizeable fans. The damper position would merely need to be controlled so that it would exhaust smoke in case of a fire. The garage exhaust system does not need to operate during a smoke event, and people are not likely to be running to their cars if there is a lot of smoke in the building!

The building thus takes a performance model approach instead of a prescriptive approach to fire and life safety. Since the design provided for a two-floor balcony from the athletic club hanging over the atrium, there were additional complications: code requires smoke to be a minimum of 10 feet above the highest walking surface. To get around having this restriction apply to these balconies, Interface performed a *timed egress* analysis to show that people could exit these balconies before the smoke reached them. This allowed the combined exhaust system concept to be taken forward and proven to fire officials, because it was such a variance from the norm. Fortunately, approval was granted for this synergistic approach, reaping a large upfront cost savings, estimated at close to $200,000.

INTEGRATED GARAGE EXHAUST/SMOKE EVACUATION SYSTEM



To reduce the size of fans required for smoke evacuation from the atrium and health club, and to avoid the cost of a separate system for smoke control, Interface combined both into one system for the first three floors. Garage exhaust is the normal operation, but during a fire or smoke emergency, a damper closes that exhaust and opens the atrium exhaust ducts. Interface worked with the City of Portland to take this performance approach to fire protection.

DESIGN SYNERGY:

ARCHITECTURAL INTEGRATION

Sometimes mechanical engineers get asked to do the impossible, like squeezing a large fan into a small space! At this project, the developer faced both height limits and rooftop profile restrictions that would have required giving up more than 10,000 sq.ft. of the 16TH floor to a mechanical room to house a typical-sized fan for a building this large.

HUNT AIR

Building Height Limits

A standard-size mechanical penthouse on top of the building would have violated the height limits and profile requirements imposed by Portland's design review process. The value of this space is not only the lost rent (assume $200,000 for this space, at $20/sq.ft. rent net of incremental expenses), but the reduction in building value. In this case a fan room on the 16TH floor would have reduced the overall value of the real estate by up to $2.0 million ($200,000 annual loss divided by 0.10, assuming a *cap rate* of 10 percent.)

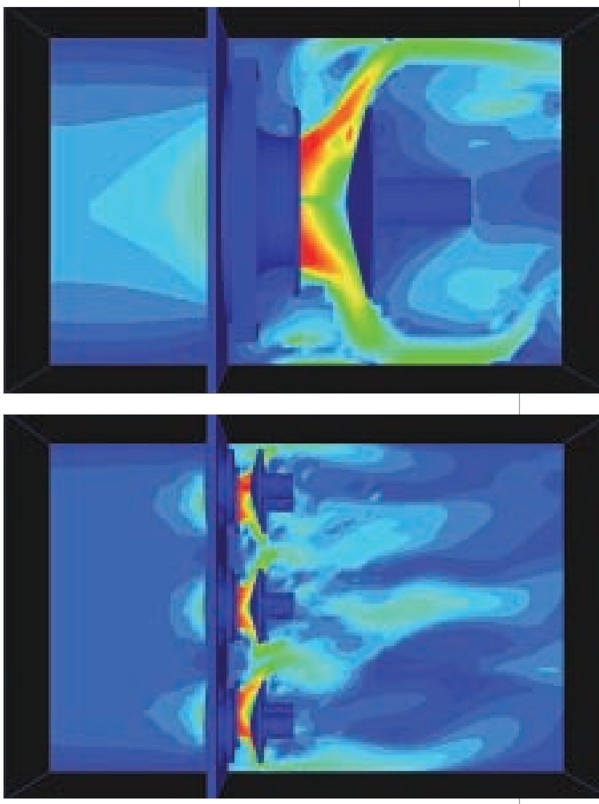
Fan-wall Technology

After investigating options, Interface Engineering came up with an emerging approach of grouping a number of smaller fans into a *fan-wall* array on the rooftop penthouse. This approach is actually more energy efficient, because in this case, a group of smaller fans has a higher efficiency than an equivalent larger single fan. For this project, we used CFD modeling by the fan-wall vendor to determine that the air flows through the fans would use less energy overall and could be accommodated in a much shorter-length fan room.

Fan-wall technology offers many advantages over traditional air handler design:

Smaller fan sections. A fan-wall array of any capacity or pressure requires a maximum airway length (depth) of 36 in. compared to three or four times that amount for traditional systems.

CFD MODELS OF AIR FLOW



HUNT AIR OF TUALATIN, OREGON. U.S. AND FOREIGN PATENTS PENDING

CFD models were used by Hunt Air to study the air flow through a large fan (top) and an equivalent series of smaller fans (bottom), to help reduce the length of the rooftop mechanical "penthouse." The fan wall array consists of 75 smaller fans that provide all the air movement for the building.

Greater flexibility in sizing. Fan-wall technology offers greater flexibility in unit sizing. Designers are able to incorporate lower profile units where height restrictions are involved.

Higher efficiency and lower connected load. Fans and motors are sized for optimum efficiency, which often results in a lower connected load and reduced size, as well as lower cost of the electrical service.

Redundancy. Fan-wall technology provides greater reliability due to increased redundancy of fan components.

Lower first cost. The fan-wall array requires less cabinetry, less fan and motor support framework, and no sophisticated spring isolation system or sound trap, reducing initial costs and fan horsepower.

WATER CONSERVATION

WASTEWATER MANAGEMENT

DESIGN CHALLENGE: water EFFICIENCY

Many people think that water supply will be one of the major environmental and infrastructure issues of the next 50 years. Even in a wet climate such as Portland, it's important to take steps now to cut building water use and to reuse as much water as possible, effectively closing the *water cycle* within the building itself.

WATER CONSERVATION

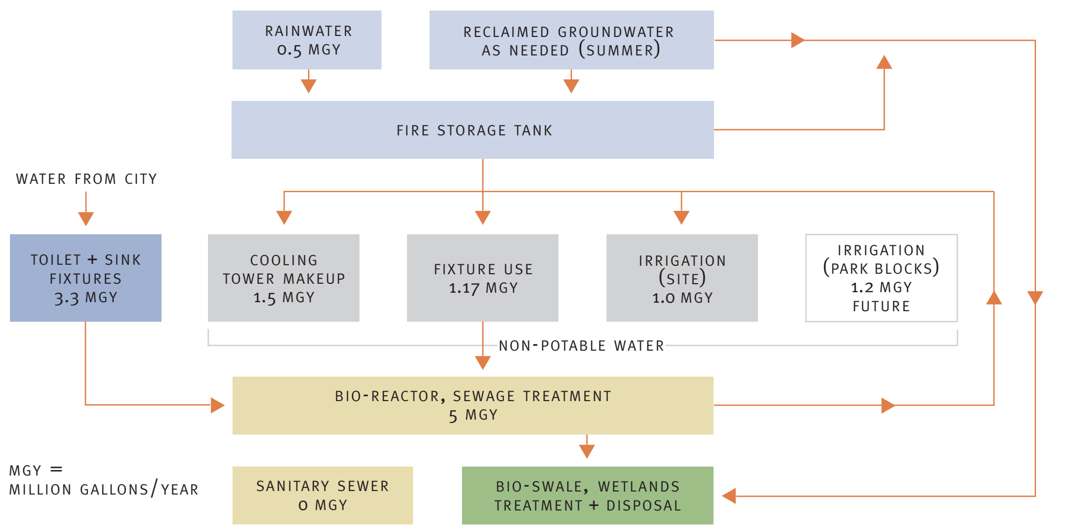
Water conservation is getting to be more of an issue for building design throughout the U.S. even in places like Portland, where one of the largest rivers in North America, the Columbia, flows right past the city. Many people advocate using reclaimed rainwater to supply building water needs, and this is being done in Portland on a variety of Interface Engineering projects.

Going back to basic principles, the design team was determined to use as much of this *free* resource as possible: both rainwater and the local groundwater that has to be pumped continuously (at a rate of up to 200 gallons per minute) to de-water the building site.

However, contrary to its popular image as a rainy city, Portland receives less cumulative annual rainfall (36 in.) than cities like New York (almost 50 in.). The territory west of the Cascade Range is actually mostly dry for up to four months of the year (only 5 in. of rain falls from June through September in a typical year). Thus, it would be difficult for reclaimed rainwater to supply more than a fraction of the Center's total water needs without very large storage tanks.

Rainwater captured on the roof of a building this size in Portland, for example, provides about 500,000 gallons per year, only enough water for the needs of a two-story structure. Given the estimated 1,600 average users on a daily basis, the sixteen-story Center for Health & Healing will use an estimated 3.3 million gallons of potable water per year for sinks, toilet fixtures and showers in the clinics, offices and health club. An additional 1.7 million gallons is required for flushing toilets and urinals in the building's *core*. These uses total 5.0 million gallons, after considering the use of water-conserving fixtures. Thus, the available rainfall is only about 10 percent of the building's requirements.

BUILDING WATER CONSERVATION FLOWS



In a large building in Portland, rainwater falling on the roof can only supply about 10 percent of water use, even with low-flow fixtures. In this project, rainwater reclamation combines with on-site sewage treatment and pumped groundwater to supply about 56 percent of total water use. Potable water is used primarily for drinking, food preparation and hand washing, while toilets and urinals in the building core are flushed with reclaimed water, which also supplies the radiant heating/cooling system, site irrigation and the *make up* water evaporated from the cooling tower.

Economic Incentives for Conservation

Portland has comparatively high local fees for water usage. And with the Center for Health & Healing's total annual sewage contribution estimated at five million gallons (enough to trigger sizeable annual charges), there was a strong economic incentive to move forward with a rainwater reclamation system. Interface has created more of these systems for large buildings than any other engineering firm on the West Coast. In addition, the City of Portland levies *system development charges* (impact fees) that also made it attractive to seek a design that contributed as little wastewater and stormwater as possible to the city's overburdened combined sewer system.

Seeking water efficiency 50 percent greater than code requirements (based on the Energy Policy Act of 1992), not to mention eight LEED points potentially available for water efficiency and stormwater management measures, the integrated design team resolved to make the Center for Health & Healing among the most water-conserving buildings in the region.

The goal early on became to keep all rainwater on-site. This was facilitated by the inclusion of 20,000 sq.ft. of *green roof* area on various floors of the building shown on page 30.

Providing enough water for all of the non-potable flows for this project required some way to recycle the 5.0 million gallons per year of wastewater. An on-site bioreactor for sewage treatment is something that had not yet been done in the western United States for such a large building. But after visiting New York City to tour a LEED Gold-rated, high-rise residential project that similarly utilized an on-site sewage treatment plant, the design team became convinced it would work at the Center for Health & Healing.

The team began by analyzing end uses for water, just as had been done with energy efficiency. Research showed that the primary uses came from sinks, toilets and urinals, with showers (particularly in the large health club on site), kitchens, landscape irrigation and the cooling tower also drawing water. A first step, therefore, was to select lower-water-using fixtures for sinks, urinals and showers. Sinks use only 0.5 gallons per minute (gpm) in the core toilet rooms, while urinals use 0.5 gallons per flush, and showers in the health club are rated at 2.0 gpm. In the exam rooms, the water flow for hand-washing sinks was reduced from 2.5 gpm to 1.5 gpm. While slightly more expensive than standard fixtures, they collectively will save about 37 percent more water than a conventional design.

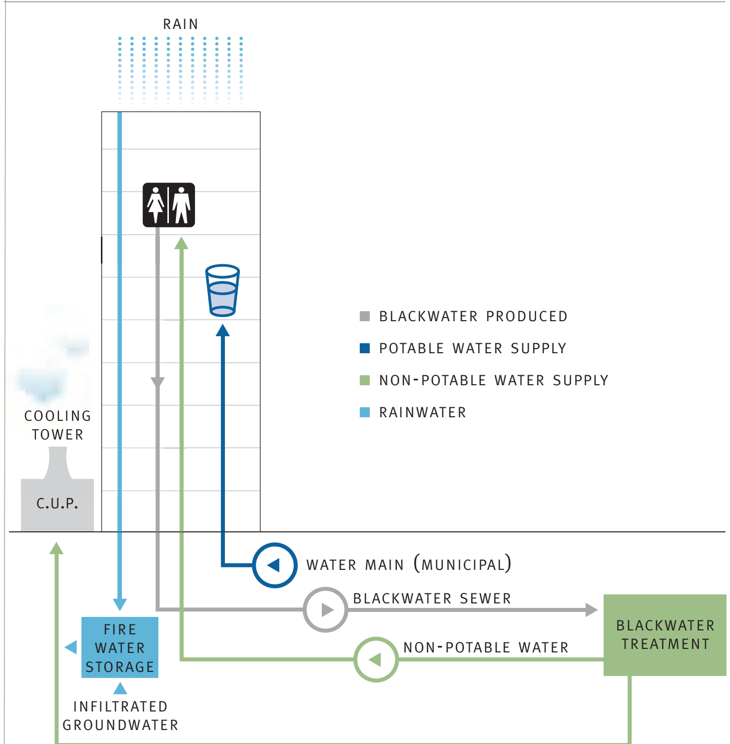
Sometimes one has to inform the public when trying new things in green buildings!

With potable water at a premium, the Center's ambitious conservation scheme mandated the cooling tower and landscape irrigation system use non-potable water. This is accomplished through a combination of rainwater, a small amount of pumped groundwater (primarily in summer when rainwater is largely unavailable) and a large volume of treated sewage, the last of which comes courtesy of the on-site bioreactor.

To account for the two types of water being used, the team had to design a plumbing system that would pass a tough city inspection, with 100 percent separation of potable from non-potable water, in pipes or storage tanks. Owing to consideration of users' sensibilities, non-potable water is only being used in the building's core water closets and urinals, and not in the clinics or exam rooms. Because they would be using non-potable water, health code regulations even required that signs be placed on all toilets and urinals warning users not to drink water from them!

With the building reusing so much of its own water, this required on-site storage and treatment. The 22,000 gallon fire-suppression storage tank—which building code requires for high-rise buildings—could simply be made bigger, so that 16,000 gallons of water is still reserved for a fire but plenty is also available for future re-use. But that, too, brings an integrated design benefit: the inherent coolness of the water meant it could be circulated through the building's radiant slab as a way to cool part of the building.

TOTAL WATER SYSTEM MANAGEMENT



All water and wastewater flows into and out of a building can be managed as a closed system, with only a slight amount of sewage solids ever leaving the building, if conditions are favorable. This form of *whole-systems thinking* leads to dramatic capital and operating cost reductions in many cases.

WATER CONSERVATION STRATEGIES

DESCRIPTION	BASELINE (MILL. GAL./YR.)	% DEMAND REDUCTION	DESIGN RESULT (MILL. GAL./YR.)	WATER SOURCE
Fixtures utilizing potable water	5.0	37	3.3	Potable
Cooling towers	1.5	0	1.5	Non-potable
Project irrigation	1.0	0	1.0	Non-potable
Total water use	*7.5*		*5.8*	
Total potable	*7.5*		*3.3*	
Total potable reduction			*56%*	
Incl. future Park Blocks irrigation	1.2	0	1.2	Non-potable
Total	*8.7*		*3.3*	
Total potable reduction			*62%*	

When analyzing water flows, it's important to aim for maximum conservation before trying new forms of supply. In this building, most of the water conservation came from reducing faucet flow rates, since a medical building involves a lot of hand washing. Use of lower flow toilets and urinals is a secondary source of conservation. The system can also accommodate irrigation of planned neighborhood parks in the future.

Rainwater harvesting does require additional expenditure. Extra storage tanks and plumbing lines are necessary to separate potable and non-potable water. The sewage is further treated with filtration and ultraviolet light, and a backup system was included as well. The system also included some premiums for additional structural steel for the green roof. These extra capital costs have to be compensated for, and the savings from reduced water usage is typically not enough (even though in the future, water, like energy, is likely to become more costly). In this case, the city's impact fees and high usage charges for wastewater and stormwater discharge add enough savings to justify the system on a first-cost basis.

The Center will be a model building for water conservation—from the day its doors first open—taking advantage of free resources to achieve virtually unprecedented resource efficiency in a building this size.

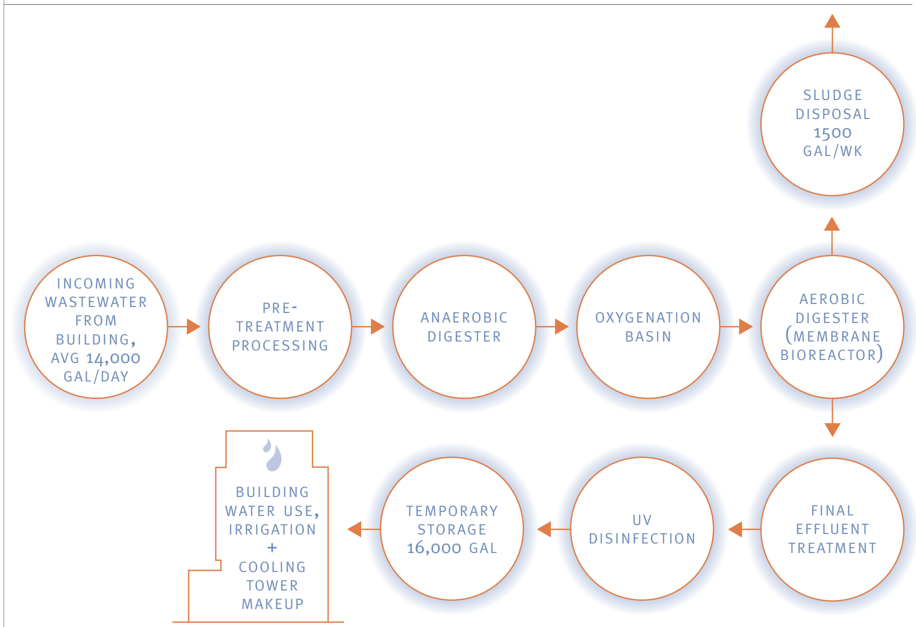
WASTEWATER MANAGEMENT

We first sought to minimize the amount of wastewater generation—to save money on *system development charges* (impact fees) and ongoing water use charges. And then, to capture the wastewater volumes (about 14,000 gallons per day, on average) for re-use in the building for toilet flushing, cooling tower makeup water and landscape irrigation. Reusing the reclaimed water even for toilet flushing and cooling tower makeup water meant treating the water to *Class 4* standards—near drinking water quality.

The project sought out a third-party provider to build, own and operate the treatment plant, in exchange for a negotiated fee for wastewater treatment. Designed by Albany, Oregon-based Vision Engineering, the process selected for this project was based on the availability of third-party financing, a small system footprint, low maintenance, simple operation and superior effluent quality for re-use. The diagram at left shows the flow of wastewater through the system.

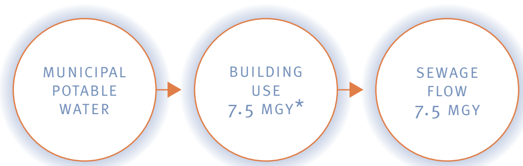
The system is located in the basement of the building and is hooked up to the local sewer system in case of emergency or for periodic sludge discharge. The process itself requires very little operator attention. With the exception of solids (sludge) handling (a biweekly discharge to the sanitary sewer or to a vacuum truck) and biannual membrane cleanout, the plant will operate virtually unattended.

BIOREACTOR FLOW DIAGRAM



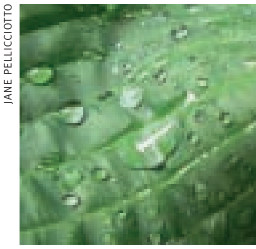
The sewage treatment plant in the basement provides both anaerobic (without oxygen) and aerobic (with oxygen) treatment of wastes, before final *polishing* and disinfection. The resulting Class 4 water is drinking water quality. A small amount of sewage solids needs to be discarded every two weeks. The system operates automatically except for periodic maintenance and repairs.

CONVENTIONAL WATER USE



Conventional buildings operate totally on potable water, typically treated and filtered, for moving human and food preparation waste out of the building into the sewer system. In Portland, a long-standing problem of combined sewer overflows in winter means that every new building without on-site water recycling adds to the pollution of nearby rivers.

* MGY = million gallons/yr.


JANE PELLICCIOTTO

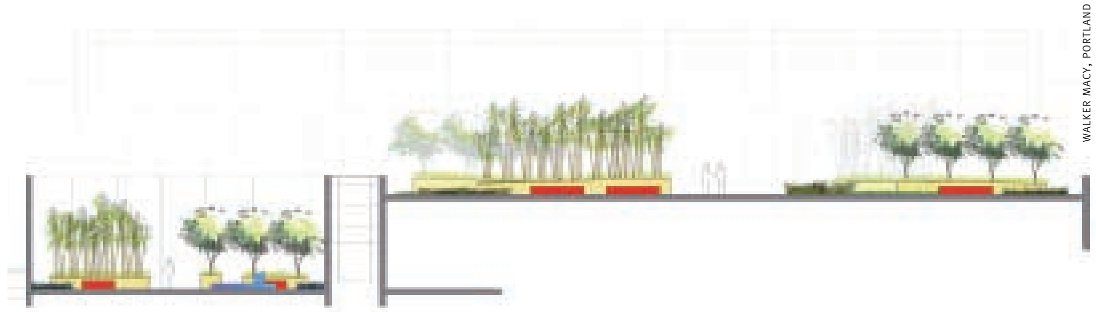
DESIGN CHALLENGE:

ENVIRONMENTAL IMPACTS

This high-profile building incorporates many measures to reduce impacts on the larger environment. Some of these directly interact with Interface's design work, while others result from the work of the architects, interior designers, civil engineers and landscape architects. The building contains the following additional significant environmental measures:

- Green roof of 20,000 sq.ft. (more than 50 percent of the total roof area) for stormwater management, rainwater harvesting and temperature moderation, also providing some wildlife habitat in a dense urban environment
- Managing all stormwater runoff from hardscape areas on-site with the use of bioswales and other *green streets* approaches that treat stormwater as well as excess pumped groundwater
- HCFC-free chillers that reduce the impact of energy use on the ozone layer
- Inside the building, use of high percentages of recycled content and locally manufactured materials, as well as more than 50 percent use of certified wood products
- Low-VOC paints, sealants, carpets and interior finishes, including a building flush-out prior to completion, to eliminate contaminants in the air stream
- Construction waste management, reducing landfill disposal needs by 95 percent

ECO-ROOF DESIGN


WALKER MACY, PORTLAND

Eco-roofs provide many environmental benefits, including reducing wastewater peak flows, adding insulation to the roof and creating some wildlife habitat in the city. The eco-roof at this building covers more than 50 percent of the total roof area.

CENTRAL UTILITY PLANT

MICROTURBINES

DESIGN CHALLENGE: on-site POWER

At Interface Engineering, we're aiming squarely at the target of *zero net energy* buildings, first by using free energy from sun, wind and water; second, by reducing demand through energy-efficiency measures; and third, by investigating and designing innovative on-site energy production systems that will supply the remaining needs.

Innovative Energy Production Systems

There is a strong argument for having buildings produce more of their own energy needs. First, we eliminate all the losses in the electric power system that result when electricity is produced at remote sites, since a large part of the thermal energy in natural gas, oil or coal fuel sources is wasted at the point of combustion, and then further energy is lost in the transmission of electricity and through transformers that *step down* the voltages to levels buildings can use. Second, it is more responsible to produce energy close to the point of use, since fewer losses result in fewer pollution impacts. Third, the *free* thermal energy from the natural gas combustion in microturbines can be recovered and used.

Early in the design process, we analyzed several potential innovative on-site energy production strategies:

- A central utility plant serviced by five 60-kW Capstone microturbines
- Building-integrated solar electric panels on the building's south-facing sunshades, with a total of 60kW of photovoltaic modules
- A large solar air heating system using low-iron glass in front of the south-facing wall of the 15TH and 16TH stories
- A roof-top wind power system, using vertical-axis *Savonius rotor* turbines

The first three measures were adopted, but our studies showed that wind power was the least cost-effective system, so after an initial analysis, it was dropped from further consideration. In the following pages, we profile each of the three systems we decided to use and show how they work to reduce this building's energy demand on the larger electric power grid and natural gas supply system.

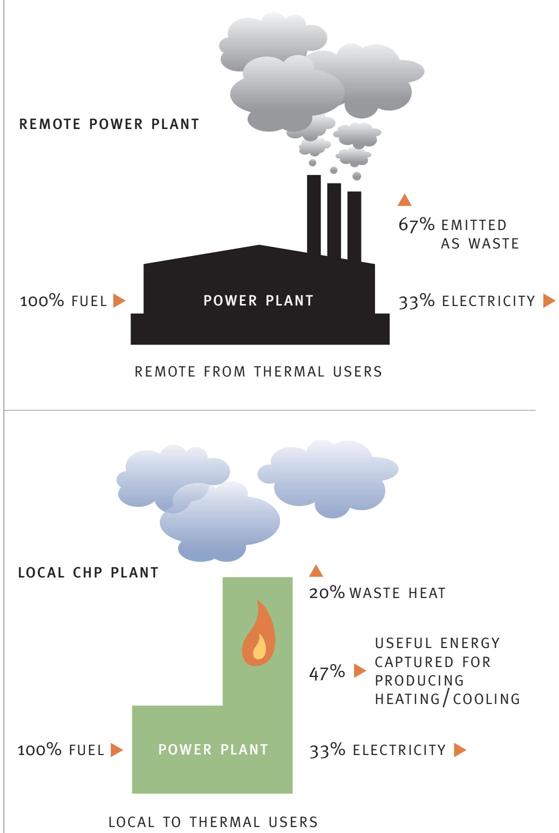
CENTRAL UTILITY PLANT

Interface Engineering designed the Central Utility Plant (CUP), intended to serve first the Center for Health & Healing and then adjacent buildings in the Central District of South Waterfront, as they come on line. The CUP is located temporarily in a building on the adjacent Block 24, with plans to relocate it in 2007 to a more permanent site in the district.

The rationale for a CUP for this project includes:

- Baseload power source for combined heat and power (CHP)
- More efficient use of fuel
- Electricity is produced at a competitive rate, but heat is generated at less than half the cost of a conventional boiler
- Up to 80 percent of the waste heat can be captured in a useful form, if used nearby
- Allows for synergy with the building's thermal mass and water storage systems
- Very low air emissions of carbon dioxide, nitrogen oxides and sulfur oxides
- Lower carbon dioxide emissions than from conventional coal or gas-fired power
- Diversity of energy uses allows equipment downsizing, so that residential and commercial loads can be serviced with a smaller system, since they occur generally at complementary times of the day and week
- Greater economic efficiency of centralized operations
- System can grow over time in a modular way as more buildings are added to the district

RATIONALE FOR ON-SITE POWER



Remote fossil-fuel power plants throw away two-thirds of the "source energy" they consume, in the form of waste heat. They also generate lots of air emissions and greenhouse gas emissions. Local gas-fired microturbine power plants can use up to 80 percent of the source energy, with fewer emissions, if a use can be found for the waste heat. With a building located next door, it's easy to use waste heat for building heating, hot water use and thermal energy storage.

Interface Engineering examined several options for providing chilled water and power from the CUP. First, we specified 1,000 tons of high-efficiency, water-cooled centrifugal chillers, rated at 0.46kW/ton, using reclaimed water from the building and pumped groundwater for cooling tower makeup water. Second, we decided to look at alternative sources of on-site power production as well, such as microturbines and solar power.

Andy Frichtl visits the microturbine installation, October 2005, with Alex Charlton of EC Power Systems.

MICROTURBINES

Owing to their market maturity, technological simplicity and much lower cost, microturbines were chosen over fuel cells for this project. We calculated that, by generating our own power on-site and using the waste heat efficiently, we were able to achieve about 78 percent efficiency of fuel conversion, as against 32 percent in a typical electric power generating and transmission system.

There are a number of benefits to using microturbines to service a building. Microturbines are compact turbine generators that deliver electricity on-site, or close to the point where it is needed. This form of distributed-generation technology first debuted in 1998. These solutions can reduce energy costs and help preserve the environment with their near-zero emissions profile.

With over 3,000 installations worldwide, Capstone Turbine Corp. is the leading provider of microturbine cogeneration systems for clean, continuous energy management, energy conservation and gas-fueled renewable energy. Interface Engineering chose to use five of their 60-kW turbines to power the CUP for this project, located on the adjacent Block 24 of the South Waterfront project area.

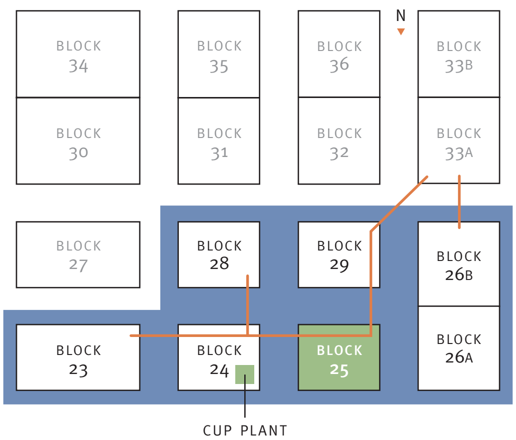
Financing. Initially, a third-party provider was engaged to work with Interface Engineering to design the CUP, to supply electricity and hot water at competitive rates to the project. However, during the design process, seeing a fairly rapid payback of its initial investment, the developer decided to retain ownership and incur the cost for the installation.

Electrical Output Use. Since the building has a continuous load of between 200-kW and 400-kW for running fans, pumps, motors, lighting, equipment and computers, we did not intend to provide power to the grid. Instead, the microturbines are connected to three of the four electrical services in the building (the PV system is connected to the fourth) and regulate power output according to demand.

Thermal Output Use. The CUP also is designed to convert waste heat from the turbine exhaust to hot water, and send it to stratified storage tanks in the garage below the building. The hot water use is prioritized first for pre-heating the hot water supply for the building. This hot water is used for all building heating needs by circulating through air handling units, fin-tube units, and room-level terminal re-heat units. It is also used to provide hot water demand for the building. If all of these needs are satisfied, then the “cheap” heat is stored in the first floor concrete radiant thermo-active slab or the health-club swimming pool.

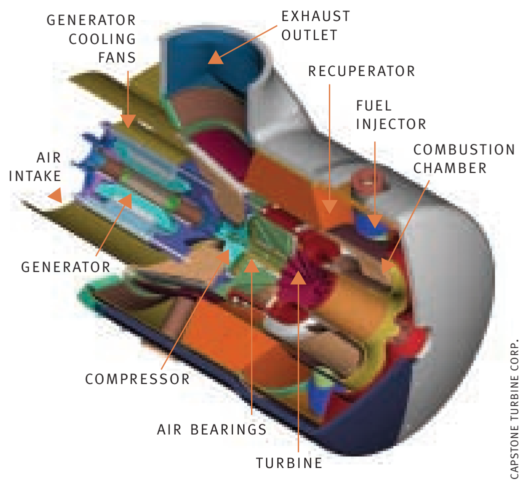
Future Expansion. The CUP size and configuration was designed for future expansion, as the South Waterfront district grows. The diagram shows how hot water lines can be extended from the current Block 24 site to other adjacent institutional, residential and commercial buildings. As the district expands, additional microturbines will be installed to meet the needs of other projects for electricity and hot water.

THERMAL ENERGY DISTRIBUTION SYSTEM



Thermal energy from the microturbines can be distributed for heating throughout the district. Orange lines indicate thermal energy distribution lines installed or planned. The Center for Health & Healing is Block 25.

CUTAWAY OF A MICROTURBINE

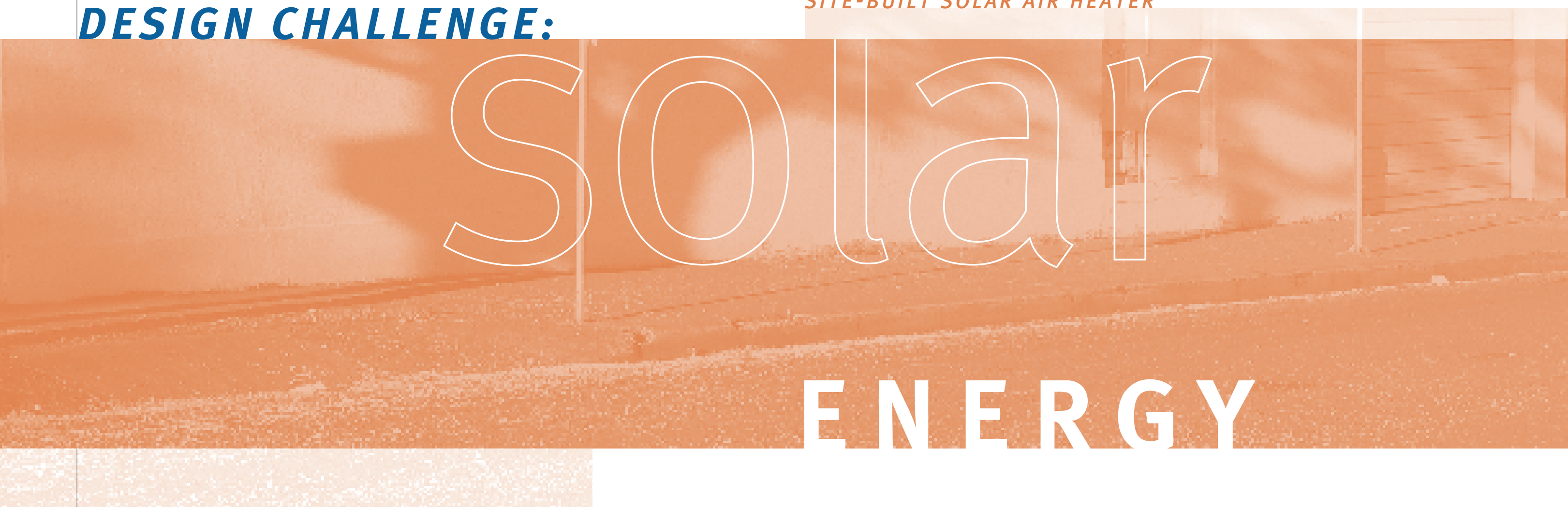


In a typical distributed generation project, microturbine power might be connected to the Portland General Electric grid by means of a system that provides *net metering* which runs the meter backwards whenever on-site power is greater than building demand. In Oregon, however, utilities do not have to provide this service for systems greater than 25kW, so it was not practical for this project to take that approach.

BUILDING-INTEGRATED PHOTOVOLTAICS

SITE-BUILT SOLAR AIR HEATER

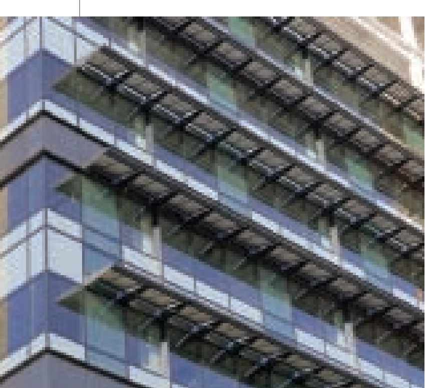
DESIGN CHALLENGE: solar ENERGY



Solar power has great potential to move our society and economy away from its strong dependence on costly, polluting and unreliable fossil-fuel sources. At the Center for Health & Healing, we explored using solar energy to supply both electricity and hot water to the building.

BUILDING-INTEGRATED PHOTOVOLTAICS

By designing sunshades into the south façade, to keep the sun off the windows in summer and lower the HVAC system requirements for cooling, a free surface became available for solar electricity-generating panels.



SALLY PAINTER

This photovoltaic (PV) system relies on the same ultra-pure silicon strip that is used for computer chips. But in this case the semiconductor-grade silicon is "doped" with various chemicals to help it become an electric power generator.

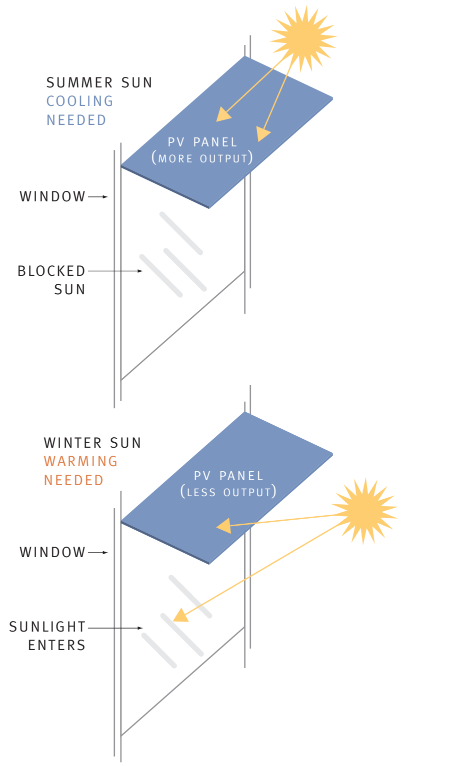
The photoelectric effect was first explained by Albert Einstein in 1905. He showed that light consisted of photons as well as waves. When photons strike the silicon surface, they transfer a portion of their energy to electrons in the material, and the flow of electrons in turn triggers electric power. Today, the photosensors used for controlling lighting in buildings and for many other uses are based on the same phenomenon of converting light into electric energy.

Not only did the team want to demonstrate the capability of this alternative energy source, which produces no greenhouse gas emissions (GHG), but there were also significant incentives for use of PV panels: state and federal tax credits, accelerated depreciation and bonus payments from the Oregon Energy Trust to account for the full value of clean power. These incentives help create a positive return on investment for building-integrated PVs, or BIPVs (panels which are incorporated into the building fabric), enough to make them a practical choice.

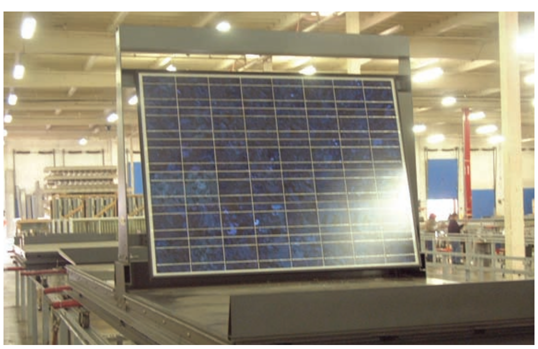
The system will produce a total of about 60kW of electricity at peak output—well below the building's minimum demand—indicating that all of the power produced will be consumed on-site, thus constituting a portion of the overall electricity picture at the Center for Health & Healing. The estimated annual net energy production in Portland is about 66,000 kilowatt-hours (kWh) from these south-facing panels, after system losses are included.

Through the model studies in Portland's BetterBricks daylighting lab, the team determined that the main PV array should start above the fourth floor, so that the panels would be exposed to full sun for most of the year, even as the district became built out over the years, with several tall buildings planned to the south of the Center.

SUNSHADE USE FOR SUMMER VS. WINTER SUN



On south-facing windows from floors 4 through 14, overhangs were designed to cut glare and reduce air-conditioning loads in summer, allowing us to downsize the HVAC system. The overhangs also provide support brackets for photovoltaic (PV) solar systems to supply 60kW (peak) of electric power to the building.



The PV modules and overhang systems were assembled at the local factory of Portland-based Benson Industries, a major supplier of curtain walls and exterior cladding to large buildings.

Before the PV system could be implemented though, the engineering task was to transfer energy from the panels into the building's electric power supply system. Because PV panels produce DC power, the power needs to be converted to AC through a device known as an inverter. This typically happens in the electrical room of the building.

SITE-BUILT SOLAR AIR HEATER

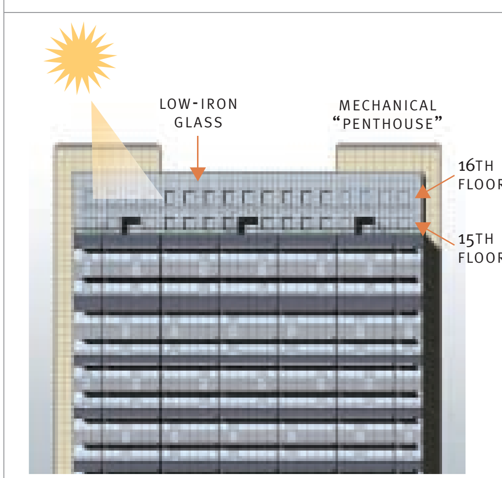
Another form of solar energy harnessed at the Center for Health & Healing is arguably the most innovative of its kind in the West. On the 15TH and 16TH floors of the building's south side, which the architects had already decided to set back from the lower floors of the building, the façade was transformed into a giant solar air heater, 190 ft. long x 32 ft. high.

Several large sheets of low-iron glass are placed 48 in. (4 ft.) from the skin and sealed tightly. Warm air then rises between the building skin and the glass and is heated by the sun shining through the glass. The total area of glazing from this site-built solar collector is 6,000 sq.ft. Remember, even on cloudy days (for which Portland is justly renowned), the sun can warm up the interior of a car with the windows closed. The ensuing *greenhouse* effect produces warm air, which is moved through the air handling units across a heat exchanger and used to pre-heat water for use in the building (for example for hand washing in bathroom sinks and exam rooms).

Although solar hot water heaters have long been used for single-family homes, they are seldom taken advantage of in large buildings, mostly because they require a large surface area. But in this case, the existing building form included an ideal location on top. And the collaborative method of the integrated design team allowed for its timely identification, analysis and incorporation into the design. With wholesale gas prices near $10 per million BTU (early fall, 2005), by utilizing other tax and financial incentives, this unique solar water heater has a positive return on investment.

One other benefit: by doubling as an extra skin, i.e., as a *Trombe wall*, the solar collector has the effect of warming the clinic and lab spaces in winter and reducing the amount of heating otherwise needed. The unit offsets about one percent of the energy use of the building, making a positive contribution to energy conservation, requires almost no maintenance, involves no replacement costs over time and has a societal benefit for all to see.

SOLAR AIR HEATER

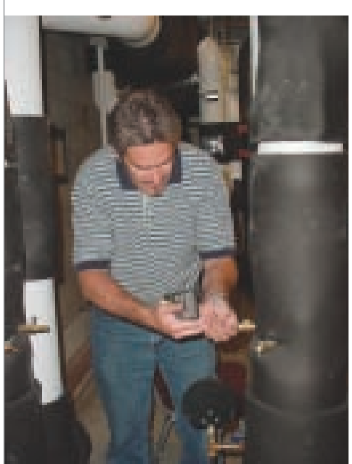


GBD ARCHITECTS

The penthouse air handling unit circulates air between the glass and the wall. Solar-heated air is then used to pre-heat water for use in the building.

BUILDING commissioning

Building commissioning is an essential step in the design and construction quality assurance process. For any project to be certified, LEED requires basic commissioning procedures. It also provides one point for certain *additional commissioning* steps. Interface Engineering commissions most of its own projects and also acts as a *third-party* commissioning agent for projects designed by others.



Steve Dacus, PE, of Interface, acts as the commissioning agent for the project.

Benefits of Commissioning

A recent (December 2004) Lawrence Berkeley National Laboratory (LBNL) study[1] meticulously compiles and standardizes commissioning data from 224 commercial buildings—by far the largest available collection of standardized information on actual building experiences.

This U.S. Department of Energy-funded study concludes that commissioning is indeed cost-effective for both new and existing buildings over a range of facility types and sizes, not only in terms of energy savings but also in non-energy benefits. Investigators found that commissioning new buildings achieved median payback times of 4.8 years, based on a commissioning cost of $1.00/sq.ft. (For this project, commissioning costs were below $0.50/sq.ft.)

Importantly, non-energy benefits contribute significantly to commissioning's overall cost-effectiveness. These benefits include improved equipment lifetimes, reduced change-orders due to early detection of problems, prevention of premature equipment breakdown by timely correction of problems, reduced operation and maintenance costs, and improved indoor environmental quality.

When these often-overlooked benefits were taken into account, the cost-effectiveness of commissioning increased considerably, particularly among new buildings. For the cases where estimates were available, one-time non-energy benefits were $1.24/sq.ft./yr. for new construction, effectively offsetting the entire cost of new-building commissioning.

[1] Available at ‹eetd.lbl.gov/emills/pubs/cx-costs-benefits.html›.

The Commissioning (Cx) Process

Commissioning involves achieving, verifying and documenting the design intent of building systems in the field. Cx assures the building owner that systems are installed appropriately and functioning at or above required efficiency levels. Commissioning typically takes place throughout the design and construction phases, and it involves working closely with mechanical, electrical and controls contractors to fix any problems that surface during the testing and verification process.

Interface has a successful history of providing Cx services to building owners, both as the primary commissioning provider and as part of a supervising design team working with third-party commissioning agents. Getting systems to operate properly involves solving many diverse challenges. In our view, design engineers are best qualified to verify performance of systems, solve problems and verify the completion of all subcontractors' work in order to deliver a system that functions well. In this way, the feedback from this process can be used in future designs.

Major building systems that require commissioning at the Center for Health & Healing include:

- Chilled water systems
- Hot water systems
- Air handling units
- Terminal units
- Radiant heating and cooling system
- Chilled beams
- Heat recovery systems
- Domestic water supply systems
- Building automation systems
- Lighting controls
- Smoke control system

Interface's commissioning process includes the following key points:

- Prepare a Cx plan and specifications
- Conduct on-site Cx meetings with contractors
- Review outstanding items for contractors' and sub-contractors' *punch list*
- Pre-functional testing, i.e., verifying switches and controls are communicating with each other
- Detailed functional tests for:
  - All mechanical systems and controls
  - Selected electrical systems and controls
  - Lighting systems and controls
  - Water reclaim systems
- Verify water and air flow balancing readings for HVAC
- Verify operator training
- Prepare Cx report for owners

The Commissioning Report

The Cx report becomes the owner's best guide for fine-tuning systems at regular intervals, training new operators and *re-commissioning* the building. The LEED additional commissioning credit also requires Interface to prepare a re-commissioning manual. We also review the commissioning report, interview building operators and trend-log the energy management system before the end of the first year of occupancy, to determine if key systems are still working as intended, and recommend further system optimization adjustments.

DESIGN CHALLENGE: economics

Incentives for Energy-Efficiency and Renewable Energy Investments

In Portland, Oregon, utility costs are generally moderate; electricity costs about $0.05/kWh and gas about $1.10/therm[1]. However, in Oregon, there are two major sources of financial and tax incentives:

- Energy Trust of Oregon pays $0.10 per annual saved kWh and $0.80 per saved annual therm, and also offered an incentive payment for solar electricity of $0.30 per annual kWh produced (recently reduced to $0.15/kWh)
- Oregon Business Energy Tax Credit offers a 35 percent tax credit (taken over five years, this credit has a net present value of about 25 percent) of the incremental cost of energy efficiency investments, including PV, and offers a LEED credit for this size building that returns between $0.75 and $2.00/sq.ft., net, based on the level of LEED-certification

There is also the new Federal law, the Energy Policy Act of 2005 (EPACT), that offers a 30 percent tax credit for photovoltaics and solar thermal systems. Federal tax law may also offer accelerated depreciation for some PV investments. The new law increases the existing 10 percent investment tax credit for commercial solar installations to 30 percent for two years with no cap on the amount of the credit. This applies to all property placed in service after December 31, 2005 and before January 1, 2008; the credit will revert to the permanent 10 percent credit thereafter.[2] EPACT also provides a tax credit of up to $1.80 per sq.ft. for energy conservation measures that will reduce modeled energy use by 50 percent over the new ASHRAE 90.1-2004 standard. If applicable to this project, the new tax credit would be worth an additional $720,000 to the building owners.

Overall Cost Impacts

This list summarizes the various cost impacts of the major design measures:

- Mechanical, electrical and plumbing (MEP) initial cost savings: $4.5 million, including tax credits and utility incentives
- Rainwater harvesting: cost-neutral
- On-site sewage treatment: cost-neutral, provided by third-party vendor
- Central utility plant: originally cost-neutral with third-party vendor, later switched to developer-financing for their own benefit
- Incremental costs of about $975,000 for energy-efficiency measures, excluding solar
- $500,000 for PV system and $386,000 for solar thermal system
- Building commissioning, required by LEED, was extra, at a cost of about $150,000 for basic commissioning (excluding smoke control system testing)

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[1] Summer 2005 commercial building costs based on Portland General Electric and Northwest Natural Gas tariffs. A therm is 100,000 BTUs.

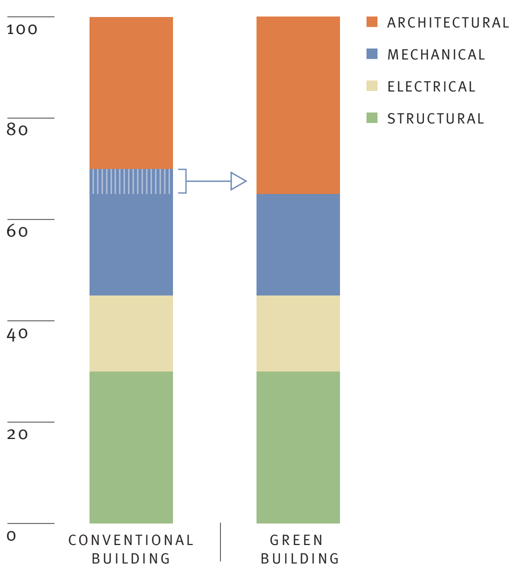
[2] "Solar Granted A Major Victory in Energy Bill," found at ‹www.renewableenergyaccess.com/rea/news/story?id=34850›, accessed 9/15/2005.

COST TRANSFER

To keep initial costs neutral or lower for high-performance buildings, designers of high-performance buildings think about how to transfer costs from mechanical and electrical systems to architectural systems, with such approaches as:

- Passive space conditioning, utilizing thermal mass and radiant systems
- Relaxed comfort standards (where feasible) to reduce HVAC equipment size and lighting levels
- Using smaller equipment-based systems requiring lots of outside energy input to more robust systems integrated with the building envelope
- Using fewer short life-span mechanical systems (25 years or fewer) in favor of longer-lived passive space conditioning, energy storage and structural thermal mass systems that might last 50 to 200 years
- Using more simple control strategies wherever possible
- Build in ability to add future capacity as needed, but defer cost for now

COST TRANSFER IN GREEN BUILDINGS



In this project, the engineers were able to reduce the initial MEP budget by about $4.5 million (net), allowing some of this budget to be transferred to architectural uses. Integrated design approaches allow this “cost transfer” to occur from HVAC, plumbing and electrical systems to other more visible benefits, while still providing for all of the service needs of a building.

KEY COST-REDUCTION AND FINANCIAL-BENEFIT MEASURES

In terms of the relative benefit of various design measures, the following were the major contributors to the initial cost savings for this project:

- Eliminating return air ducts, in favor of return air plenums, on nine floors: $1,160,000
- Oregon Business Energy Tax Credit: $801,000 (LEED Platinum)
- Oregon Energy Trust Incentives: $508,000
- Pre-cool building mass overnight, reduced HVAC system size: $400,000
- Reduce size of central air handling units with fan-wall technology: $210,000
- Bid controls at the Tenant Improvement stage (versus Core and Shell) to get more competitive bids: $200,000
- Interior atrium smoke control, combined with garage exhaust: $180,000
- Variable-flow primary chiller, vs. primary-secondary loop system: $175,000
- Reduce area of telecom rooms, based on needs analysis: $125,000
- Other measures: total of $750,000 +/-
- Grand total MEP initial cost savings: $4.5 million (15 percent of original MEP budget)

“WHEN WE STARTED DOING GREEN BUILDINGS, WE DID IT BECAUSE WE THOUGHT IT WAS THE RIGHT THING TO DO. THAT’S STILL OUR PRIMARY MOTIVATION, BUT WE’RE ALSO FINDING THAT IT’S GOOD FOR BUSINESS. WE PUT A LOT OF EFFORT INTO DESIGNING ENVIRONMENTALLY RESPONSIBLE BUILDINGS. A BYPRODUCT OF THAT IS BETTER DESIGN.”

DENNIS WILDE,
SENIOR PROJECT MANAGER
GERDING EDLEN DEVELOPMENT

Payback of Energy Efficiency Investments

Often, the cumulative results of energy-efficiency measures (EEMs) stem from a large number of small changes, brought about through careful study and specification. For this project, we list some of the many specific ideas that were implemented in terms of their relative payback at today's energy prices compared with a *base case* design, after consideration of the estimated benefit of all incentives:

EEMs that pay back immediately (after incentives)

- Utilize garage fan controls based on carbon monoxide level
- Specify premium efficiency motors
- Variable flow water heating system
- Lab exhaust heat recovery system
- Lab occupancy sensors
- Reduce garage lighting levels
- Emergency light sweep
- On/off switches for daylighting control versus dimmable ballasts
- Double fan VAV
- Fan-wall with low-pressure air filters
- Naturally ventilating the stairwells
- Radiant heating/cooling of first floor lobby

EEMs that pay back in five years or fewer

- High-efficiency chilled water plant
- High-efficiency glazing
- Water heating demand reduction from water conservation measures
- High-efficiency boiler for domestic water heating
- Carbon dioxide sensors on ventilation systems
- High-efficiency boiler for space heating
- Fan-powered VAV boxes with ECM motors and plenum heat recovery
- Retail economizer cycle operation (use outside air for cooling)
- Minimum outside air reuse in the laboratories
- Chiller heat recovery
- Chilled-beam cooling system
- Energy-efficient transformers
- Dual-bank exam lights (allowing two levels of lighting in exam rooms)
- 208-volt busway riser in place of 480-volt busway riser with distributed step-down transformers

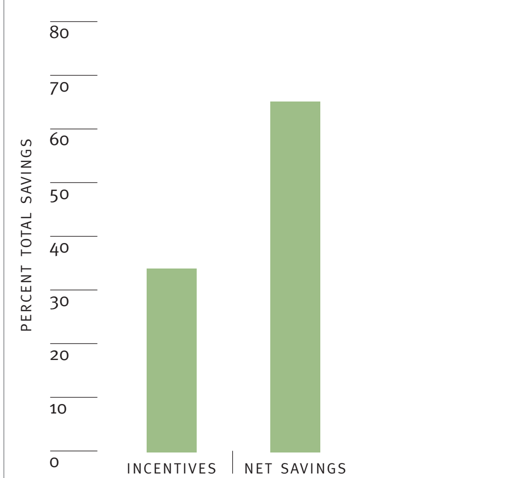
EEMs that pay back in ten years or fewer

- 300-kW microturbine plant
- Extra floor insulation (from 5-in. to 12-in. expanded polystyrene)
- Occupancy sensors to control lighting and HVAC system operation
- Optimized lighting fixture selection and layout

EEMs with more than a 10-year payback

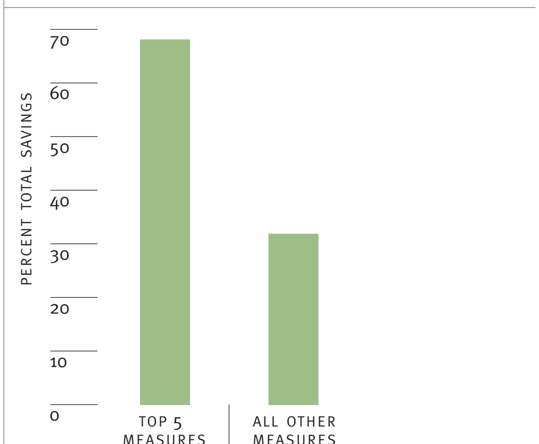
- Extra wall insulation (going from R-19 to R-21 batt)
- 60-kW PV array (with new federal tax law)
- Revolving door for atrium entry (Portland is mild winter climate)
- Solar air collector

SOURCES OF INITIAL MEP COST SAVINGS (NET)



We were able to use strong federal, state and local incentives to provide more than $1.6 million of benefit to this project.

NET CAPITAL SAVINGS FROM EEMs



In this project, five energy-efficiency measures provided more than 68 percent of the net capital cost savings for the project.

COST OF ENERGY EFFICIENCY MEASURES (EEMs)

SUMMARY OF INDIVIDUAL EEMs:	ADDED COST
Double fan VAV	$161,500
Chiller heat recovery	140,000
Hot water use reduction	89,165
Chilled beams	86,250
Fan powered VAV	85,125
Occupancy sensors	79,100
High efficiency boiler	70,000
Subtotal	*711,140*
All other measures	264,159
Total all EEMs	*975,299*

Some EEMs do cost more. We used some of the project savings to "buy" the most cost-effective EEMs.

"MOST PEOPLE AND BUSINESSES ARE TRAINED TO FOCUS ON RATES OF RETURN BASED UPON WHAT WE KNOW TODAY, BUT SHOULDN'T WE BE LOOKING AT A MEASURE THAT SAYS, 'IF WE EXTRAPOLATE OUT FIVE TO 10 YEARS FROM NOW, WHAT ARE THE RETURNS THEN?' WE THINK THAT THESE ASSETS ARE 50- TO 200-PLUS-YEAR ASSETS, AND THINK THEIR IMPACTS ON THE COMMUNITY OUR CHILDREN AND GRANDCHILDREN ARE GOING TO LIVE IN, ARE PROFOUND."

MARK EDLEN, MANAGING PRINCIPAL
GERDING EDLEN DEVELOPMENT

INCENTIVES AND TAX CREDITS

ITEM	VALUE	CONDITIONS	ESTIMATED VALUE
Oregon Business Energy Tax Credit	35% of eligible cost or specified $/sq.ft. for LEED	Take present value for five-year span of tax credit at 25.5% of eligible cost	$801,000 (Platinum)
Oregon BETC for photovoltaics	35% of eligible cost; net present value is about 25.5% of cost	Separate from LEED credit; based on cost of $500,000 (60kW system at $8.33/watt installed)	$128,000
Oregon Energy Trust (Utility)	$0.10/annual kWh saved; $0.80/annual therm saved	High-performance building track; based on energy modeling	$221,000
Oregon Energy Trust (Utility)	Microturbine incentives	New Building Efficiency Program; based on project-specific data	$100,000
Oregon Energy Trust (Utility)	Solar PV system	Based on "above market costs"	$187,000
Federal tax credit (Energy Policy Act of 2005)	Solar collectors (for water heating) and PV (for electricity)	30% of cost, less state tax and utility incentives; must be placed in service between Jan. 2006 and Dec. 2007	$56,000 (estimate)
Federal tax credit	Microturbines	Energy Policy Act of 2005 provides for 10% tax credit, up to $200/kW	$60,000
Bioreactor incentive	Bioreactor	Estimated value	$50,000
Federal depreciation	Estimated at 25% NPV	May not apply to building-integrated PV and solar thermal	Depends on tax treatment
Total value			*$1,603,000*
			$4.00/sq.ft. (Platinum)

(1) Does not include interaction of state tax credit with federal taxes, (2) Equipment depreciation may not apply to site-built and building-integrated solar collectors, (3) Actual value of tax incentives depends on many variables, including tax liability, (4) Oregon BETC may be transferred among entities at "net present value", (5) Oregon BETC LEED tax credit depends on building size and LEED certification level.

INTEGRATED DESIGN SYNERGIES

SUCCESSFUL CODE APPEALS

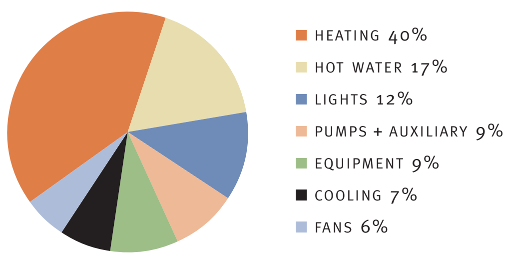
OUR GOAL WAS TO DESIGN A VERY HIGH-PERFORMANCE building on less than a conventional construction budget, one that would deliver health, comfort, productive working environments and accumulates significant resource savings over time. Here we summarize the results.

The significant results from the project fall into four major categories:

- Resource conservation
- Harnessing renewable resources
- Reducing greenhouse gas emissions
- Cost reductions

In terms of resource conservation, the project boasts an estimated 61 percent reduction in energy use for LEED regulated sources, equal to 4.3 million kWh and 470,000 therms of gas per year. In securing all 10 *energy-efficiency* points, this project accomplished a major achievement equaled by only 15 of the first 195 LEED-certified projects[1]. The focus of this publication on the integrated design process highlights a crucial approach to achieving these high levels of energy efficiency.

FINAL MODELED ENERGY USE



END USE	ENERGY USE (MILL. BTU)	ELECTRICITY	GAS
Heating	19,864		19,864
Hot water	8709		8709
Lights	5865	5865	
Pumps + auxiliary	4732	4732	
Equipment	4261	4261	
Cooling	3603	3603	
Fans	3082	3082	
Total	*50,116*	*21,543*	*28,573*

Energy use in this large, complex medical facility is estimated at about 125,000 BTU/sq.ft./yr., or about 37kWh/sq.ft./yr. By any standard, this is a very "lean" energy-using building.

[1] June 2005 analysis from U.S. Green Building Council data was provided by Greenlight Strategies, ‹www.greenlightstrategies.com›

Water conservation of 56 percent of conventional potable water demand (4 million gallons per year) is also a significant accomplishment and indicates the significance of water as a resource of growing concern. This project also shows that getting these high levels of water efficiency is only possible through integrated design and *out-of-the-box* design solutions. Water conservation is enhanced of course by collecting and using a half-million gallons per year of rainwater falling on the building's roofs and recycling all the sewage on site.

On-site sewage treatment. The project also reduces 100 percent of the potable water demand for sewage conveyance from core toilets and urinals in the building and converts sewage to usable (non-potable) water.

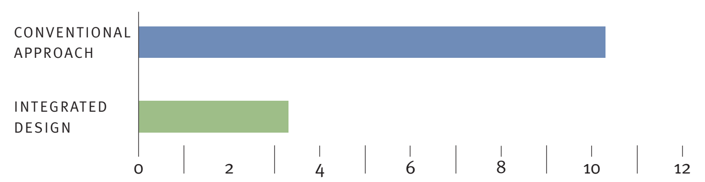
In terms of harnessing renewable resources, the solar thermal and electric systems on the building, as well as the use of passive solar design elements, effectively harness a large percentage of sunlight falling on the south side of the building, while allowing us to downsize the HVAC systems, freeing up financial resources for other sustainability investments.

Greenhouse gas emissions are increasingly the concern of mechanical and electrical engineers, as we strive to make our buildings more Earth-friendly. The City of Portland recently announced that its emission of greenhouse gases has barely grown since 1990, even with a major increase in the region's population.

By using microturbines for about one-third of the building's electrical energy needs, we are also eliminating about two-thirds of the losses in the electric grid from purchased utility power. We calculate an annual reduction of 1.26 million pounds (630 tons), or 12 percent, of carbon dioxide emissions from a similar project without microturbines, or about 20,000 tons over 30 years, the usual period for figuring such reductions. Sulfur dioxide and nitrogen oxide emissions would be reduced by about 38 percent. Of course the main source of CO_2 emission reductions is the high level of energy efficiency, which would add another 100,000 tons of emission reductions over 30 years.

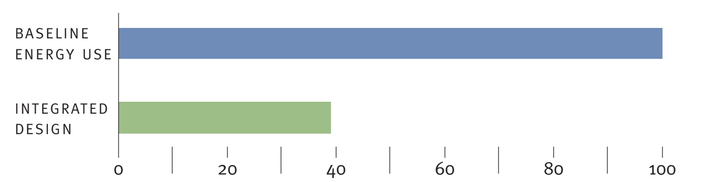
The reduction from CO_2 emissions from providing on-site power is equivalent to taking nearly 1,000 cars off the road or eliminating the emissions from about 400 average single-family homes, while the building's energy efficiency reductions in emissions is worth about 2,000 homes or about 5,000 cars off the road. Not bad for just one building!

WATER USE REDUCTION (millions of gallons/yr.)



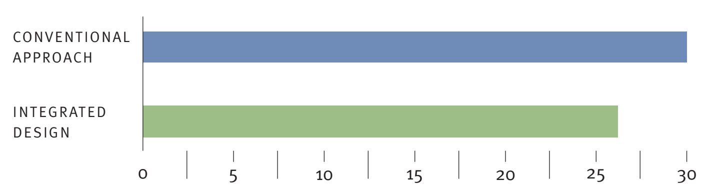
Integrated design reduced estimated water use by 68 percent, through both demand-side and supply-side measures.

ENERGY USE REDUCTION (percentage energy reduction)



Compared with a conventional building of the same size and similar activities, the Center for Health & Healing expects to use 61 percent less energy every year.

MEP SYSTEM NET CAPITAL COST REDUCTION



In millions of dollars. Interface's design approach resulted in saving nearly $4 million in the initial $30 million budget for mechanical, electrical and plumbing (MEP) systems, while providing a high-performance building for the client.

Cost Reduction

Finally, this design was ultimately about meeting the developers' cost reduction goals through innovative engineering and integrated design. We estimate a savings of about $3.5 million on easily measured reductions in mechanical, electrical and related systems, with an incremental investment of about $975,000, plus the PV system initial cost of $500,000 and the solar collector cost of $386,000.

Considering additional financial and tax incentives of $1.6 million (see chart on page 41), this leaves a net of about $3.2 million for other uses in the project. (These investments do not count the cost of the bioreactor, which is financed by third-party investors and outside the scope of our design efforts.) Saving more than 10 percent of the initial mechanical and electric equipment and systems budget of $30 million with integrated design shows the financial benefits that can be achieved in a green building project while achieving extraordinary long-term performance results.

INTEGRATED DESIGN SYNERGIES

Throughout this volume, we've been discussing the integrated design features in various systems. Here we recapitulate the results we achieved. This building has twelve major integrated design features, involving engineering and architecture working together creatively.

The rainwater/groundwater reclaim system actually performs six different functions:

- ☐ Irrigation
- ☐ Water reuse at plumbing fixtures
- ☐ Cooling tower makeup water
- ☐ Cooling water for the inlet to the microturbine
- ☐ Cooling the radiant slabs in the building
- ☐ Supplying water to the *green roof* which helps cool the building

The rainwater/fire suppression storage tank serves four different functions: fire tank for the OHSU building, fire tank for the adjacent Block 29 and parking garage, holding tank for the harvested rainwater and providing free cooling to the building through circulating cool water.

Ten other systems provide two different integrated functions:

- ☐ The solar air collector acts to preheat water for the building and functions as a two-story *double skin* on the building, moderating temperature swings in the 15TH and 16TH floors
- ☐ Natural ventilation inlets and outlets at the stairwells use the concrete mass of the building for cooling and also provides code-required pressure relief for the stairwells
- ☐ Reusing the building relief air provides both relief for the central air-handling unit (AHU) and make-up air for the laboratories
- ☐ The photovoltaic system provides electric power and performs as a sunshade
- ☐ The central fire pump serves both the main building and the adjacent building and parking structure
- ☐ Occupancy sensors act both as lighting controls and HVAC system controls

ECONOMICS OF THE OHSU HIGH-PERFORMANCE BUILDING

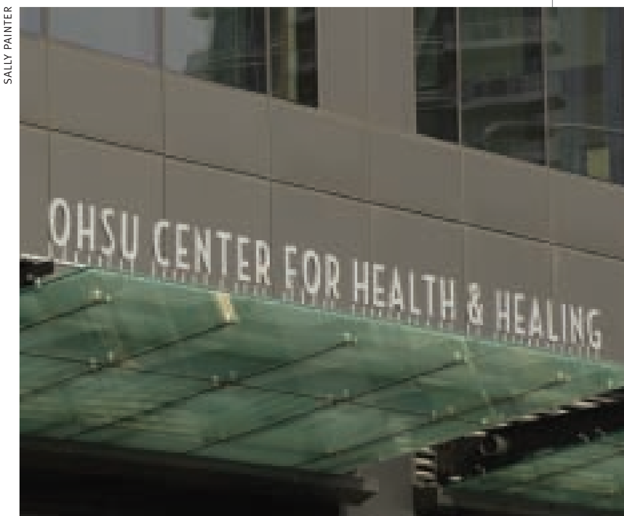
Capital cost savings	$ 3,5000,000	(estimate)
Capital cost increases	1,860,000	(estimate)
Incentives and tax credits	1,603,000	(Platinum)
(A) Net HVAC benefit	3,200,000	(estimate; Platinum)
(B) Annual operating cost savings	660,000	(estimate)
(C) Increase in building value	8,600,000	(cap rate of 10%)
- Energy savings	(6,600,000)	
- Fan-wall space	(2,000,000)	

If the OHSU building achieves the expected LEED Platinum certification and qualifies for all available tax benefits and cash incentives, the net savings to the project will be about $3.2 million. Additional annual operating cost savings for energy will add about $6.6 million to the building's value, assuming a cap rate of 10 percent, by increasing *net operating income*. Fan-wall array leasable space savings add another $2 million to building value.

- ☐ The building mass takes the concrete structural components and turns them into energy storage systems, helping to moderate building temperature swings naturally and for low-cost energy capture
- ☐ The egress lighting sweep combines both building security alarm and egress lighting functions
- ☐ Recovering waste heat from the pool cycle dehumidification for pre-heat of the building's hot water system
- ☐ The atrium smoke control system is integrated with the garage exhaust system

By thinking outside the box, the engineering design for this project was able to accomplish two goals often seen as contradictory: save money and deliver a high-performance building. In this case, they work together, in a process that has been called "tunneling through the cost barrier" (see page 15), and that demonstrates what an integrated design process can deliver.

SALLY PAINTER



SUCCESSFUL CODE APPEALS

One of the requirements for a successful integrated design project is to challenge building codes, since most of them are organized to separate rather than integrate various functions. For this project, Interface's engineers were able to work cooperatively with the City of Portland Bureau of Development Services to hash out code exceptions. The operative phrase for our engineers in working with code officials is no "surprises."

It's important to have discussions about code interpretations and "performance vs. prescriptive" approaches as early in design as possible, certainly no later than the design development phase, to make sure that the code authorities understand design intent and are willing to work with the design team to make integrated features work for all concerned.

For this project, we worked through 11 code interpretations and appeals in the following areas, all of them contributing to the success of the integrated design project. The most important of these, in terms of cost impact and resource efficiency, were:

- Non-potable water supply to fixtures; this was necessary to re-use harvested rainwater and output from the bioreactor to flush toilets and urinals
- Atrium exhaust timed egress study to demonstrate safe exiting from the athletic club balconies on the 2ND and 3RD floors, allowing us to use smaller fans for smoke control
- Elevator pressurization vs. lobby pressurization for smoke control which allowed us to pressurize just the elevator shafts, to keep smoke out and not pressurize the elevator lobbies on all 16 floors
- Fire tank/pump serve two buildings; the fire tank and pump were allowed to serve both the Center for Health & Healing and the adjacent building, thus saving money and the room another tank would require
- Garage exhaust below code, using more recent ASHRAE data based on actual emissions from newer cars rather than outdated code data
- Grease exhaust scrubber removes the need for a 16-story grease exhaust
- Non-rated emergency generator room was secured by moving a fuel source (cars) far enough away from the generator fuel tank
- Combined laboratory general exhaust and main fume hood exhaust saves money and increases public safety through greater stack plume height
- Standpipe minimum pressure at roof of 65 psig versus 100 psig conventional, to save money by reducing fire pump size

FINAL LEED SCORECARD

On February 22, 2007, the US Green Building Council (USGBC) announced that Oregon Health & Science University's Center for Health & Healing received a LEED Platinum Certification. The Center achieved every point that was attempted, receiving a total 55 LEED credits-three more than necessary for the LEED Platinum designation.

INTERFACE ENGINEERING CONTRIBUTED significantly to the LEED achievements, by securing or contributing to the realization of more than 26 points in the following LEED credit categories:

- ☐ Stormwater management and treatment (rainwater harvesting systems: two points)
- ☐ Light pollution reduction
- ☐ Alternative sewage treatment
- ☐ Water efficiency, two points for exceeding 30 percent water use reduction
- ☐ Building commissioning (prerequisite)
- ☐ Energy efficiency (prerequisite)
- ☐ CFC-free building (prerequisite)
- ☐ Energy efficiency (all 10 points, for 60 percent+ energy use reduction)
- ☐ Additional commissioning (effort shared with another firm)
- ☐ HCFC-free building
- ☐ Measurement and verification plan for energy savings
- ☐ Indoor air quality (prerequisite)
- ☐ Carbon dioxide monitoring
- ☐ Construction indoor air quality (shared with contractor)
- ☐ Indoor chemical and pollutant source control (shared with architect)
- ☐ Thermal comfort (two points)
- ☐ Innovation: water use reduction exceeding 50 percent
- ☐ Innovation: stormwater reduction exceeding 50 percent on already developed site

FINAL LEED CHECKLIST (AS OF FEBRUARY 2007)

LEED Scorecard

OHSU Center for Health & Healing - 2.21.07

BRIGHTWORKS

Yes	No	Certified 26 to 32 points · Silver 33 to 38 points · Gold 39 to 51 points · Platinum 52 or more points
55	14	**Total Project Score**

Y	N		
13	1		**Sustainable Sites**
Y		Prereq 1	**Erosion & Sedimentation Control**
1		Credit 1	**Site Selection**
1		Credit 2	**Development Density**
1		Credit 3	**Brownfield Redevelopment**
1		Credit 4.1	**Alternative Transportation**, Public Transportation Access
1		Credit 4.2	**Alternative Transportation**, Bicycle Storage & Changing Rooms
1		Credit 4.3	**Alternative Transportation**, Alternative Fuel Refueling Stations
	1	Credit 4.4	**Alternative Transportation**, Parking Capacity
1		Credit 5.1	**Reduced Site Disturbance**, Protect or Restore Open Space
1		Credit 5.2	**Reduced Site Disturbance**, Development Footprint
1		Credit 6.1	**Stormwater Management**, Rate and Quantity
1		Credit 6.2	**Stormwater Management**, Treatment
1		Credit 7.1	**Reduce Heat Islands**, Non-Roof
1		Credit 7.2	**Reduce Heat Islands**, Roof
1		Credit 8	**Light Pollution Reduction**

Y	N		
5	0		**Water Efficiency**
1		Credit 1.1	**Water Efficient Landscaping**, Reduce by 50%
1		Credit 1.2	**Water Efficient Landscaping**, No Potable Use or No Irrigation
1		Credit 2	**Innovative Wastewater Technologies**
1		Credit 3.1	**Water Use Reduction**, 20% Reduction
1		Credit 3.2	**Water Use Reduction**, 30% Reduction

Y	N		
14	3		**Energy & Atmosphere**
Y		Prereq 1	**Fundamental Building Systems Commissioning**
Y		Prereq 2	**Minimum Energy Performance**
Y		Prereq 3	**CFC Reduction in HVAC&R Equipment**
2		Credit 1.1	**Optimize Energy Performance**, 20% New / 10% Existing
2		Credit 1.2	**Optimize Energy Performance**, 30% New / 20% Existing
2		Credit 1.3	**Optimize Energy Performance**, 40% New / 30% Existing
2		Credit 1.4	**Optimize Energy Performance**, 50% New / 40% Existing
2		Credit 1.5	**Optimize Energy Performance**, 60% New / 50% Existing
	1	Credit 2.1	**Renewable Energy**, 5%
	1	Credit 2.2	**Renewable Energy**, 10%
	1	Credit 2.3	**Renewable Energy**, 20%
1		Credit 3	**Additional Commissioning**
1		Credit 4	**Ozone Depletion**
1		Credit 5	**Measurement & Verification**
1		Credit 6	**Green Power**

Y	N		
8	5		**Materials & Resources**
Y		Prereq 1	**Storage & Collection of Recyclables**
	1	Credit 1.1	**Building Reuse**, Maintain 75% of Existing Shell
	1	Credit 1.2	**Building Reuse**, Maintain 100% of Existing Shell
	1	Credit 1.3	**Building Reuse**, Maintain 100% Shell & 50% Non-Shell
1		Credit 2.1	**Construction Waste Management**, Divert 50%
1		Credit 2.2	**Construction Waste Management**, Divert 75%
	1	Credit 3.1	**Resource Reuse**, Specify 5%
	1	Credit 3.2	**Resource Reuse**, Specify 10%
1		Credit 4.1	**Recycled Content**, 5% (POST-CONSUMER + 1/2 POST-INDUSTRIAL)
1		Credit 4.2	**Recycled Content**, 10% (POST-CONSUMER + 1/2 POST-INDUSTRIAL)
1		Credit 5.1	**Regional Materials**, 20% Manufactured Locally
1		Credit 5.2	**Regional Materials**, of 20% Above, 50% Harvested Locally
1		Credit 6	**Rapidly Renewable Materials**
1		Credit 7	**Certified Wood**

Y	N		
10	5		**Indoor Environmental Quality**
Y		Prereq 1	**Minimum IAQ Performance**
Y		Prereq 2	**Environmental Tobacco Smoke (ETS) Control**
1		Credit 1	**Carbon Dioxide (CO_2) Monitoring**
	1	Credit 2	**Increase Ventilation Effectiveness**
1		Credit 3.1	**Construction IAQ Management Plan**, During Construction
1		Credit 3.2	**Construction IAQ Management Plan**, Before Occupancy
1		Credit 4.1	**Low-Emitting Materials**, Adhesives & Sealants
1		Credit 4.2	**Low-Emitting Materials**, Paints
1		Credit 4.3	**Low-Emitting Materials**, Carpet
1		Credit 4.4	**Low-Emitting Materials**, Composite Wood
1		Credit 5	**Indoor Chemical & Pollutant Source Control**
	1	Credit 6.1	**Controllability of Systems**, Perimeter
	1	Credit 6.2	**Controllability of Systems**, Non-Perimeter
1		Credit 7.1	**Thermal Comfort**, Comply with ASHRAE 55-1992
1		Credit 7.2	**Thermal Comfort**, Permanent Monitoring System
	1	Credit 8.1	**Daylight & Views**, Daylight 75% of Spaces
	1	Credit 8.2	**Daylight & Views**, Views for 90% of Spaces

Y	N		
5	0		**Innovation & Design Process**
1		Credit 1.1	**Innovation in Design:** 95% construction waste
1		Credit 1.2	**Innovation in Design:** 40% Water Savings
1		Credit 1.3	**Innovation in Design:** 50% Stormwater Capture
1		Credit 1.4	**Innovation in Design:** Exceed MRc4
1		Credit 2	**LEED™ Accredited Professional**

Interface's design work contributed 26 LEED credit points to the building's final 55-credit point total. At this time, the Center for Health & Healing is the largest and most complex building in the world to achieve a LEED Platinum certification. Overall team coordination of the LEED documentation process was facilitated by Brightworks.

None of these results could have been achieved without a strong integrated design effort, an owner, developer and architect committed to pushing the envelope for green buildings, and a strong engineering team that was willing to find every possible innovation.

When certified, this LEED-Platinum building would be one of the largest in North America to take high-performance, sustainable design into the arena of being a cost-effective solution to the myriad challenges of designing large buildings for multiple users, in a constrained urban environment.

INTERFACE ENGINEERING, INC.

INTERFACE ENGINEERING, INC., is a large multi-disciplinary West Coast consulting engineering firm with offices in Portland, Salem, Seattle/Kirkland, Sacramento and San Francisco. In business since 1969, Interface has more than 140 professional and support staff, and has significant specialty practices in fire/life safety, architectural lighting, building technologies, and commissioning. With a focus on integrated design and a passion for green buildings, Interface has completed 11 LEED certified projects and has more than 50 LEED registered projects in various stages of design and construction, as of February 2007.

Omid Nabipoor, LEED AP, President

"THE SHIFT TO INTEGRATED DESIGN BEGAN ABOUT FIVE OR SIX YEARS AGO, ALTHOUGH MANY OF THE THINGS WE'RE DOING TODAY, WE'VE DONE FOR A LONG TIME. YET, NOT THAT LONG AGO, PROJECTS WERE MORE REGIMENTED, WITH CONVENTIONAL APPROACHES. ENGINEERS TYPICALLY WEREN'T INVOLVED UNTIL WELL INTO THE SCHEMATIC DESIGN PHASE, WHEN MANY KEY DESIGN DECISIONS ALREADY HAD BEEN MADE. SOME OF THE CHANGES WE'RE SEEING HAVE BEEN SPURRED BY THE GREEN BUILDING MOVEMENT, OTHERS BY CLIENTS WHO WANT US TO CREATE A HIGHER-PERFORMANCE BUILDING AND MAXIMIZE THE COST/VALUE RELATIONSHIP. IT IS OUR GOAL TO BRING INTEGRATED DESIGN, CREATIVITY, EMERGING SUSTAINABLE TECHNOLOGY AND PRACTICAL EXPERIENCE TOGETHER IN ORDER TO MAXIMIZE THE VALUE OF OUR SYSTEMS AND BUILDINGS FOR OUR CLIENTS."

TO CONTACT INTERFACE ENGINEERING:

Omid Nabipoor, LEED AP, President
David Pickett, PE, LEED AP, Sr. Vice President
Andy Frichtl, PE, Principal

708 SW Third Avenue, Suite 400
Portland, OR 97204

Phone: 1-503-382-2266
Email: solutions@ieice.com
Web: www.interface-engineering.com

Stuart Lindsay, LEED AP, Managing Principal,
Sacramento, 1-916-288-6200

Nicholas Rich, PE, LEED AP, Managing Principal,
Seattle, 1-425-820-1542

Dale Stadler, PE, Associate Principal,
Salem, 1-503-364-5354

"IF BUSINESSES ARE NOT USING TRIPLE BOTTOM LINE ANALYSIS AS A STRATEGIC DESIGN TOOL, THEY ARE MISSING A RICH OPPORTUNITY.

THE REAL MAGIC [OCCURS] WHEN INDUSTRY BEGINS WITH ALL THESE QUESTIONS [OF ECOLOGY, ECONOMY AND EQUITY], ADDRESSING THEM UP FRONT AS 'TRIPLE TOP LINE' QUESTIONS RATHER THAN TURNING TO THEM AFTER THE FACT...

[THIS] CAN TURN OUT TO BE TREMENDOUSLY PRODUCTIVE FINANCIALLY IN WAYS THAT WOULD NEVER HAVE BEEN IMAGINED IF YOU'D STARTED FROM A PURELY ECONOMIC PERSPECTIVE."

FROM *CRADLE TO CRADLE: REMAKING THE WAY WE MAKE THINGS*, PG. 154, COPYRIGHT © 2002 BY WILLIAM McDONOUGH AND MICHAEL BRAUNGART

U.S. GREEN BUILDING COUNCIL MEMBER

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