Rooftop wind turbines that tower above the Twelve | West building in Portland, Ore., may capture the immediate attention of visitors. But, the people who shop, live or work at the mixed-use high-rise benefit from other sustainable features, including chilled beams. The building in the emerging West End neighborhood demonstrates that it is possible to attain design goals of openness, transparency and providing connections to the urban and natural environment while advancing sustainable performance.

Creating a Connection

The double-LEED certified building is located in Portland’s emerging West End neighborhood with the vibrant mixed-use Pearl District directly to the north, the downtown business district to the east, and the city’s arts and university districts to the south. The site, which was previously used as a parking lot and included a derelict one-story building, was chosen because of the central, transit-rich location and because of the potential to help connect these different districts and inspire further dense development in Portland’s urban core. The location also offers views of the city, surrounding hills, Forest Park, the Willamette River, as well as Mt. Hood and the Cascade Range in the distance.

The design team placed a high priority on visual and physical connections with the urban and natural environment through the use of transparency, operable windows, and balconies. While the goal of transparency came with performance impacts, the consultant team worked to balance the trade-offs. Because it was essential that building performance drive the design rather than be applied as an afterthought, the team engaged in numerous cycles of design and analysis to support the evolution of fully-integrated design and performance concepts.

Orientation, Enclosure

These concepts begin with the building massing and orientation, which is 21’ off an east-west axis and responds to the city’s street grid. This minimizes the challenging daylighting and solar heat gain effects of the east and west façades. The enclosure design is based on an assemblage of glass planes, which are extended beyond the face of the building to articulate the planes and shelter a series of balconies. Although the building appears at first glance to have all-glass façades, it actually benefits from a
significant amount of opaque wall area, which is clad with stainless steel panels or fritted spandrel glazing with insulated wall behind.

The overall transparent glazing at conditioned spaces is just over 48%. The glass is a high-performance, slightly reflective low-e, insulating system (Viracon VRE1-59 with argon gas fill to improve the U-value. Overall U-value was further improved by the use of an all structurally glazed unitized curtain wall system, minimizing the amount of exposed thermally conductive aluminum framing. The unitized curtain wall offers the quality control and efficiency benefits of prefabrication, and the design and performance benefits of a fully customized system. A digitally addressable lighting interface system provides continuous dimming in the perimeter zones to optimize daylighting benefits by dimming and turning off the electric lighting as much as possible. In addition, occupancy sensors sweep lights off by zone, and all workstations employ power strips with switched and unswitched outlets on motion sensors to turn off idle and discretionary plug loads. LED desktop dimmable task lights are provided at workstations, while ambient office lighting uses T5HO direct/indirect fixtures with 60% up and 40% down. Corridor wall washers also use T5HO lamps, and recessed can downlighting and pendant globes use CFLs.

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### Lighting

- **Annual Water Use**: 5,793,260 gallons (2011)

- **Annual Energy Use Intensity (EUI) (Site)**: 44.9 kBtu/ft²
- **Natural Gas**: 11.6 kBtu/ft²
- **Electricity (From Grid)**: 20.6 kBtu/ft²
- **District Chilled Water**: 11.5 kBtu/ft²
- **Renewable Energy (Solar Thermal and Wind Turbines)**: 1.2 kBtu/ft²

- **Annual Source Energy**: 94 kBtu/ft²
- **Annual Energy Cost Index (ECI)**: $0.68/ft²
- **Annual Net Energy Use Intensity**: 43.7 kBtu/ft²
- **Savings vs. Standard 90.1-2004 Design Building**: 40.5%
- **ENERGY STAR Rating**: Not available for building type
- **Heating Degree Days (base 65°F)**: 4,752
- **Cooling Degree Days (base 65°F)**: 401
- **Average Operating Hours per Week**: Office: 60; Retail: 80; Residential: 24/7

* Chilled water data is based on actual use in ton-hours, converted to kBtu using a conservative 1 kW/ton to account for energy use at the central plant.
SUSTAINABLE FEATURES

Four wind turbines produce about 6,000 kWh of electricity per year. Monitoring of wind conditions and turbine performance will improve knowledge for future projects.

Solar thermal panels offset about 4,400 therms of natural gas use annually, almost double the predicted performance.

Roof gardens clean, detain, and filter rainwater and significantly reduce roof temperatures in warmer months.

Low-e glass admits 35% of visible sunlight, but reflects 70% of the associated heat, reducing energy use for lighting and space cooling.

Rainwater reuses for toilet flushing on the office floors and to irrigate the green roofs, reducing use of city water by 200,000 gallons per year.

Water-efficient plumbing fixtures help reduce water use by more than 44%.

BUILDING ENVELOPE

Roof
Type: Green roof assembly, fluid-applied rubber asphalt, 6 in. of extruded polystyrene
Overall R-value: R-32
Reflectance (Solar Reflectance Index): 73.4, (91) for white cement pedestal mount terrrace pavers at walking surfaces

Walls
Type: Stone veneer metal-framed solid exterior walls
Structurally sealed unitized curtain wall
Overall R-value
Solid Walls: R-26.4
Composite Curtain Wall: R-2.32
Glazing Percentage: 48% overall

Basement/Foundation
Slab Edge Insulation R-value: (2 in. Extruded Polystyrene) R-10
Basement Wall Insulation R-value: (2 in. Extruded Polystyrene) R-10
None (unheated garage)

Windows
Effective U-factor for Assembly: 0.45 overall assembly; 0.26 glazing (argon)
Solar Heat Gain Coefficient (SHGC): 0.33
Visual Transmittance: 0.53

Location
Latitude: 45.5
Orientation: 21˚ west of polar north

HVAC
Within the open-plan work space, operable windows provide supplemental ventilation for interior air quality, passive cooling and a connection to the outdoors. A system maintained at minimum dimmed lighting levels. Occupancy sensors reduce idle lighting loads on a floor-by-floor basis.

In residences, surface-mounted CFL fixtures provide functional general room lighting. Tenants may provide supplemental and/or decorative lighting.

ENERGY USE, OCT. 2009–SEP. 2010

<table>
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<tr>
<th></th>
<th>Natural Gas</th>
<th>District Chilled Water</th>
<th>Electricity kWh</th>
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49,477 410,767 2,585,813

Daylight, views, operable windows, under-floor air distribution, chilled beams, radiant heating and cooling, CO2 monitoring and low-emitting materials throughout the tower combine to make healthy working and living environments.

A blue dot indicates that the exterior conditions are too cool; a red dot indicates that conditions are too hot, and a green dot indicates that exterior conditions are favorable. Employee feedback has been positive and people appreciate the ability to open a window when they feel hot. Conditioned supply air is provided via an underfloor air distribution (UFAD) plenum, and high central returns to provide efficient and effective displacement airflow. As it is sized for static heating loads only, the UFAD system delivers air directly to the occupied zone near the floor.
at more moderate temperatures and velocities than a conventional ventilation system, using less energy and providing better occupant comfort. Dampered floor diffusers work well within all workstation areas and can be adjusted by occupants to suit their needs for airflow, cooling, and heating. Any areas affected by solar gain or added peak loads receive supplemental cooling via passive chilled beams.

Peak winter perimeter heating loads are addressed with continuous hydronic fin-tube radiators, and peak summer solar cooling loads are met with overhead hydronic passive chilled beams, both fully decoupled from the UFAD ventilation system. These chilled beams are perforated metal fins mounted near the ceiling and chilled with cold water. Rising hot air is cooled by the chilled beams and then falls again to the floor to keep inhabitants cool. Passive chilled beams save energy over conventional systems by moving energy with water instead of air and without the use of fan energy. All cooling for the building is provided from a district chilled water system, produced by a district chiller plant located just a block away. Heating is provided by a high-efficiency gas boiler within the building.

The Indigo apartments, located above the office space, are heated and cooled by individual fan-coil units, fitted with high efficiency
Electrically commutated fan motors and hydronic chilled water coils for cooling. One electronic thermostat with setback capabilities is provided per fan-coil unit, which has dual speed settings (high and low). Operable windows and roller shades offer supplemental methods of ventilation and solar shading for each tenant.

Metering
Parking areas, commercial and retail tenants are each metered separately for all utility services. Domestic water consumption and chilled water flow for cooling are master-metered for residences as well as a whole and are charged on a pro-rated basis. Apartments are individually metered for electricity use, including lighting, fans, plug loads and high-efficiency fan-coil motors.

Water
Water efficiency at Twelve | West is achieved through a combination of conservation and storm water reuse.

Due to Oregon’s restrictions on use of storm water in residential rental applications, reuse of storm water for toilet flushing was restricted to the office floors. (Local regulations have now been relaxed for residential projects of scale.) The building has a 50,000 gallon storage tank in the underground garage, part of which is dedicated to fire suppression. The remaining 22,000 gallons is devoted to reuse in irrigation and toilet flushing.

LESSONS LEARNED

Glare Control. Because desks are typically pulled away from the glazing, leaving an area for circulation and casual meeting space, few of the office occupants sit directly adjacent to the glass for extended periods of time. This works well as a strategy for thermal comfort, but does not necessarily prevent glare from light penetrating deeper into the space. As a result, blinds are often closed to control glare at the warmest time in the day and then remain down, blocking useful daylight after the glare conditions have passed. Tenant education is an ongoing effort to solve this challenge.

Urban Wind Power. The demonstration and research project resulted in loss production than anticipated, but continues to provide data and observations that contribute to future projects and policy. The technical challenges of mounting the turbines over occupied space were solved successfully with a series of three vibration dampers for each turbine attached to custom mast mounts. This measure was performed to eliminate vibration noise in some of the penthouse units in the building, located directly below the power production zones that affect turbine production.

Dwellers, but also raised the wind disturbance provided significant wind screening for terrace grating resource metering are important for a cal and electrical infrastructure that better encompasses seasonal floor surface movement.

A mix of evergreen, deciduous plants, and seasonal flowering bulbs and grasses are used in a 4,000 ft² green roof.

Advertisement formerly in this space.
This system, which gathers and filters runoff from the rooftops and condensate from the mechanical system, is projected to reuse 206,225 gallons annually, using 59% of the rainfall from the tower’s roof surface. As a result, 100% of the green roof’s irrigation needs, and 90% of the office’s flushing demands will be met by the volume of nonpotable water collected from the building. (Actual water metrics are being developed, but data is not yet available.)

The 4,000 ft² green roof helps to regulate storm water flow and provides an amenity for building residents. Storm and sanitary sewer systems development charges (SDCs) from the City of Portland’s sewer systems development charges (SDCs) from the City of Portland’s Bureau of Environmental Services were reduced by 30% as a result of the reduced combined sewer contribution. That savings covered 91% of the first cost of the system, vastly reducing the simple 10-year payback period for this investment.

On-site Renewable Energy
An efficient central boiler provides hot water to the office space, retail spaces and apartments. The domestic hot water boiler is supplemented by a 1,360 ft² rooftop solar thermal flat panel collector system, which preheats supply water.

Four wind turbines atop the building provide a second source of renewable power for the building. This represented the first U.S. installation of a wind turbine array on an urban high-rise.

The turbines rise 320 ft above the ground level and are on hinged masts so they can be serviced. Working with noted Dutch wind energy specialist Sander Mertens, the team took into account urban topography, weather data and seasonable variability of wind directions to estimate energy production.

Together with the inventors of the Gossamer Albatross (a human-powered aircraft), the design team worked in a wind tunnel to develop a general understanding of the anticipated wind behavior over and around the building roof. The 12 ft diameter horizontal axis turbines feature a passive yaw, or rotation system, that orients the turbine blades to the wind. The downward blade design eliminates the need for a tail or other orienting device. Recognizing the rigor of the design team investigation into this untested application of wind energy, the Energy Trust of Oregon and the Oregon Department of Energy funded the entire system cost of $198,000 through energy efficiency grants and tax credits. The turbines will help advance the application of building-integrated wind power in an urban setting and provide a road map for others.

The turbines were predicted to generate roughly 10,000 kWh per year—the equivalent of 1% of electrical use in the office floors, or enough to power the elevators over the course of a year. Production by the wind turbines has been approximately 60% of what was anticipated, and the system has demonstrated the complexity and challenges of urban wind production.

Wind tunnel studies predicted the minimum mounting height above the roof for the turbines to avoid turbulence effects imposed by the building. The turbines were installed at this position, but additional height to create a margin for error in the measured turbulent zone location was not possible due to physical space constraints.

Given the production data and turbine behavior, it is surmised that the turbines experience some building-induced turbulence effects in winter winds, limiting production. Production by the solar thermal system is better than expected, virtually eliminating natural gas use for hot water over a four-week period in July and August in the first year of operation.

Performance Monitoring and Occupant Satisfaction
Results from building performance tracking and an occupant satisfaction survey indicate that the building is operating well overall, and have helped identify areas for future improvements to building performance.

Twelve | West operated at an EUI of 44.9 kBtu/ft²-yr from October 2009 to September 2010, its first year of operation. This performance...
was slightly higher than predicted in the original energy models. This is nonetheless well below the Architecture 2030 target in place at the time (49.4 ft²·yr) and 40% below an ANSI/ASHRAE/IESNA Standard 90.1 2004 baseline.

The sources of energy savings are diverse, but dominated by savings in lighting throughout the building and in space conditioning on the office floors. An in-depth M&V study is planned for the future, which will identify any potential changes in operation or controls to further reduce energy use.

Survey results from the office employees indicate that the building performs well in measures of occupant satisfaction as well. The before-and-after surveys were performed in cooperation with the Center for the Built Environment, using the CBE Occupant Indoor Environmental Quality Survey tool. This standardized survey has been used on hundreds of buildings in the U.S., and offers a simple Web-based interface and sophisticated data analysis tools to simplify the survey process.

Occupant satisfaction with the new office space in Twelve | West is greater than in ZGF Architects previous office space in almost every survey category. Employee satisfaction with thermal comfort, air quality, and the overall building increased significantly in the survey results, while there were more modest gains in satisfaction with office layout and lighting.

Acoustics is one area of concern in the office space. The open office configuration and high proportion of hard surfaces combined with a virtually silent UFAD and passive chilled beam system can make for a noisy work environment for some employees. Possible means of improvement include strategically placed acoustic panels and an active white background noise system. Among the categories in the occupant survey satisfaction with the greatest increase over the previous office space was air quality, thanks in large part to the displacement ventilation system.

No formal survey has been conducted with the apartment tenants in Twelve | West, but indirect indicators suggest that satisfaction is high and many residents cite the sustainable design as a key factor for their decision to rent. Apartment lease-up (when all apartments would be initially rented) was estimated at 12 months, but occurred in six months, despite a depressed economy. Occupancy remains high, with 97% of units typically occupied and 50% tenant retention year over year.

Conclusion

Twelve | West has helped pave the way for retail and restaurant activity in the West End neighborhood, where many boutiques and cafes have opened in recent years. Employee satisfaction with the work space is high and many of the building’s energy saving strategies have been effective, including the chilled beams, daylighting and operable windows.

Above: Natural light is maximized in the apartments by orienting living and bedroom spaces along the floor-to-ceiling, glass curtain wall of the building. Operable windows and balconies are included for natural ventilation.

Right: The 700 ft² amenity room is anchored by a fireplace and includes a kitchen, community dining table and living room furniture that can be rearranged easily for a dinner party or a yoga class.

ABOUT THE AUTHORS

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