

DESIGNING FOR OFF

BY SHAWN ORAM, P.E., MEMBER ASHRAE; AND CARMEN CEJUDO, MEMBER ASHRAE

When the Rice Fergus Miller architecture firm was looking for a new office and studio space, they chose to completely renovate an abandoned former Sears Automotive Center. The office was designed to allow systems to be turned off for most of the year, resulting in a model for clients and the community of how to meet aggressive energy and water savings targets in a major retrofit that costs less than new construction.

By 2008, Rice Fergus Miller was busting at the seams. The architecture firm's 37 employees were spread across three spaces in downtown Bremerton, Wash., a waterfront community an hour's ferry ride west of Seattle.

In addition to providing a sustainable workplace, the firm's principals were interested in helping revitalize the historic downtown district. (See *Bremerton's Economic Challenges*, Page 58.) The principals and employees identified six strategies for sustainability:

- Implement passive net zero strategies;
- Rely on local sourcing for products, craftsmen and artisans;
- Quantify the economic bottom line;
- Reduce water use;
- Build a healthy workplace; and
- Use the building as a laboratory to further sustainable design.

In October, 2008, the company's three principals and their spouses formed Fifth Street Hilltop Group and purchased the 1948 Sears Automotive Center building that had been vacant for 24 years.

Building Description

The renovated building includes 18,900 ft² of heated space over 9,000 ft² of semi-belowground parking garage on a sloping site. The above-ground portion consists of a main level, mezzanine and upper level.

The main floor is a double height space that contains all of the building's conference rooms, admin and IT staff, server rooms and main entry lobby. The main floor also includes a street front commercial tenant improvement (TI) space that

was unoccupied as of the writing of this case study.

A central open forum space was created by removing beams from the upper floor. This three-story space enhances daylighting and ventilation, giving the office an open feel.

The second floor is a wraparound mezzanine that houses building mechanical rooms, storage space, bathrooms, lockers and a TI space that is rented to a local engineering firm. The upper level is the open office plan, including 65 workstations.

Energy Goals

The primary energy objective was to convert the concrete shell into a net zero energy capable (NZE) office building. Preliminary analysis indicated that if every roof surface were covered with solar photovoltaics, the building could be NZE with the base building performing at 18 kBtu/ft²·yr. This set the design targets for each member of the project team.

Climate

Bremerton sits on the protected waters of the Puget Sound and enjoys a mild marine climate. The peak

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Above The Rice Fergus Miller renovation repurposed 93% of the building's major structural elements. Twenty-four percent of new materials were made with recycled content.

Opposite This 18 ft "super graphic" art piece located in the main level kitchen blends the building's inherited graffiti with several photos of the building pre-renovation. The graphic yields an appropriate "back alley" feeling and offers a reminder of a piece of the building's life prior to the renovation.

BUILDING AT A GLANCE

Name	Rice Fergus Miller Office and Studio
Location	Bremerton, Wash. (65 miles west of Seattle by car or 23 miles by ferry)
Owner	Fifth Street Hilltop Partners, LLC
Principal Use	Office
Employees/Occupants	45
Expected (Design) Occupancy	60
Percent Occupied	75%
Gross Square Footage	36,000
Conditioned Space	18,900 for Rice Fergus Miller office
Distinctions/Awards	LEED Platinum-NC v2009, 2011; First place, 2013 ASHRAE Technology Awards
When Built	1948
Major Renovation	2009–2011
Renovation Scope	Complete retrofit of existing concrete shell into a state-of-the-art office building
Total Renovation Cost	\$3.78 million
Cost Per Square Foot	\$105

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BREMERTON'S ECONOMIC CHALLENGES

Rice Fergus Miller decided to build its new office in Bremerton, Wash., in part to help revitalize the historic downtown district, which had been a thriving community serving the Navy shipyards workforce through the Vietnam War. However, in the 1970s the new Trident submarine fleet chose to relocate 12 miles northwest in Silverdale, Wash.

What ensued was a slow deterioration of the commercial downtown core, which the city council declared a "blighted area" in a 1978 ordinance. Construction of the Kitsap Mall in the mid-1980s drew many of the remaining retail chains and independent businesses to Silverdale.

Rice Fergus Miller's new office is in a building that had been vacant for 24 years.

summer design temperature is only 81°F, and the peak winter design temperature is 22°F. Cooling is rarely needed if operable windows are provided for natural cooling.

Typical buildings in this climate have heating balance points in the low 60's (°F). Buildings with high balance points require additional heating energy for pickup during nightly setback and weekends prior to occupied hours.

Lowering the balance point from 60°F to 45°F reduces the heating energy use by almost a factor of six when night setback heating



Rice Fergus Miller

Above The building's central forum was set up as a classroom for a recent Fire Chiefs and Commissioners conference (60 people). Rice Fergus Miller makes its office space available for use by nonprofit groups during nonbusiness hours.

Below A central staircase connects the main floor to the mezzanine and upper open office. The stair treads are made from reclaimed floor joists.

and server room heat recovery is accounted for. The Rice Fergus Miller office is set back to 60°F at night and rarely drifts below 63°F.

Design for Off

The Rice Fergus Miller Office and Studio building achieves its low energy use by "designing for off"; that is, designing efficiency and simple intelligence into the building so that systems can be turned off for the majority of the year.

The first and most important design element is the super-insulated envelope, including a relatively low glazing percentage (16%). The existing concrete walls were covered with 1.5 in. of spray foam that acts as the thermal break and waterproofing layer. The walls were then framed with 3.5 in. metal studs set 2 in. off of the face of the spray foam surface to create a 5.5 in. cavity that was filled with a Blown In Batt System (BIBS) loose fill insulation to create an R-32 assembly.

The roof had to be completely replaced and was covered with R-50 rigid insulation. The existing slab was topped with R-45 insulation.

The tilt-and-turn windows are rated at U-0.23 and SHGC-0.2.

Airtight construction and heat recovery ventilation further drive down the building's balance point so that heating systems are not needed until outside temperatures dip below 45°F (dotted line in *Figure 1*).

The HVAC design relies on occupants to play an active role in the operation and tuning of the building using a "passive-active" hybrid mechanical system. The HVAC systems are designed to turn off when the outdoor temperatures are within

WATER AT A GLANCE

Annual Water Use
Unavailable due to incomplete bills

ENERGY AT A GLANCE

Annual Energy Use Intensity (EUI) (Site)
21.2 kBtu/ft²

Electricity (From Grid) 19.6 kBtu/ft²
Renewable Energy 1.64 kBtu/ft²

Annual Source Energy 60 kBtu/ft²

Annual Energy Cost Index (ECI) \$0.53/ft²

Annual Net Energy Use Intensity
19.6 kBtu/ft²

Savings vs. Standard 90.1-2004
Design Building 79%

ENERGY STAR Rating 99

Carbon Footprint 5 lbs CO₂e/ft² · yr

Heating Degree Days (base 65°F) 4,611

Cooling Degree Days (base 65°F) 167

Annual Hours Occupied 2,800

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Rice Ferguson Miller



Rice Ferguson Miller

Top The small landscaped area at the north main entrance is irrigated with captured rainwater.

Top Right The red curtains in the open forum space provide flexibility, blocking out light when the projection wall (at right) is in use. The curtains were selected as part of the interior design concept of a black box theater (a simple performance space that usually consists of a square room with black walls and a flat floor).

Above The feature wall is a 30 ft long design element that welcomes visitors with a company time line. The wall is clad in old growth Douglas fir boards milled from 3 ft x 15 ft floor beams removed from the upper floor to create the open forum space.

the passive mode range (55°F–75°F, adjustable by occupants).

A direct digital control (DDC) system controls the building equipment based on outdoor temperatures and includes a digital dashboard system. The dashboard provides occupants instant feedback on building energy performance and status.

Large red and green lights signal the building mode to the occupants. Green lights indicate passive mode when operable windows can be used for ventilation. Occupants are not prevented from opening windows when the red lights turn on, but they now understand the energy impacts of their decisions.

Building occupants like the green/red lights. As of May of 2013, over 1,500 people have toured the building and have gained an understanding of the theory behind the hybrid passive-active design.

High Efficiency Heat Pumps

Variable capacity heat pumps (VCHP), also known as variable refrigerant flow (VRF) heat pumps, were selected for space conditioning due to their high efficiency at full and part load (COP approximately 3.7 at 47°F and 2.5 at 17°F), low fan power use and quiet operation.

VCHPs without heat recovery were selected as they integrated well into the passive/active mode concept and cost about 15% less than the heat recovery models. The heat pumps provide space conditioning for 23 independent zones during outdoor temperature extremes.

The heat pumps are controlled by thermostats with occupant overrides on programmed setpoints and are powered off when the building enters passive mode. The passive mode control scheme combined with energy recovery ventilation allows the heat pumps to be off for 70% of the year.

Hybrid Ventilation System

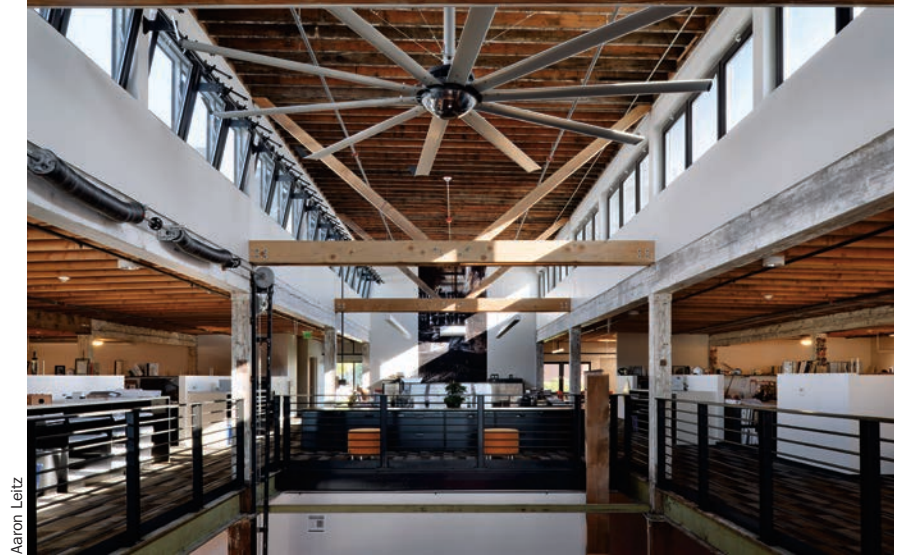
Ventilation is provided by a hybrid mixed mode system with two energy recovery ventilators (ERVs) used during active mode and operable windows used during passive mode. One ERV provides a base level of airflow, exhausting the bathrooms and supplying the main office space upstairs during occupied hours.

The second ERV provides peak occupancy ventilation designed to power on when any space's CO₂ levels exceeds 1,050 ppm. This second stage peak ERV powers off when CO₂ levels drop below 850

ppm. The ERV equipment uses an enthalpy wheel with a 76% sensible recovery efficiency.

Natural ventilation is driven by an open floor plan with a 35 ft vertical open space from the first floor to the roof monitor. Three windows in the roof monitor operate automatically in passive mode to replicate the first stage ERV ventilation system. Other monitor windows are operated by manual cranks.

A large 14 ft diameter gearless direct drive high efficiency fan operates at low speed during occupied



Aaron Leitz

Operable clerestory windows provide daylighting and natural ventilation in passive mode. The roof was rebuilt and one-third of the lumber was salvaged and reused. A greenhouse style hand crank opens 18 upper windows in one turn.

hours, destratifying the space by pushing warmer air through the 18 ft x 25 ft opening down to the lower levels. Fifteen additional ceiling fans throughout the space are controlled by occupants and provide additional air movement and mixing for thermal comfort.

Lighting and Plug Loads

Main overhead lighting is minimal as most of the office spaces are daylit from the ample clerestory windows and perimeter glazing. Artificial lighting consists of high efficacy T8s, T5s and LEDs

installed at 0.59 W/ft², including task lighting. LED task lights are controlled via occupancy sensors at desks.

All meeting rooms, bathrooms, utility rooms, server rooms and other spaces with doors are equipped with occupancy sensor controls. Lighting controls, including daylight dimming and low lighting power density (LPD) save

KEY SUSTAINABLE FEATURES

Water Conservation Rainwater harvesting for 97% of toilet flush water and 100% of irrigation. Low-flow plumbing fixtures result in 70% water use reduction.

Materials Ninety-three percent of major structural elements repurposed. Twenty-four percent of new materials made with recycled content. Locally sourced materials. Zero VOC carpet. Stairs, large internal wood wall and tables made from wooden beams that were removed.

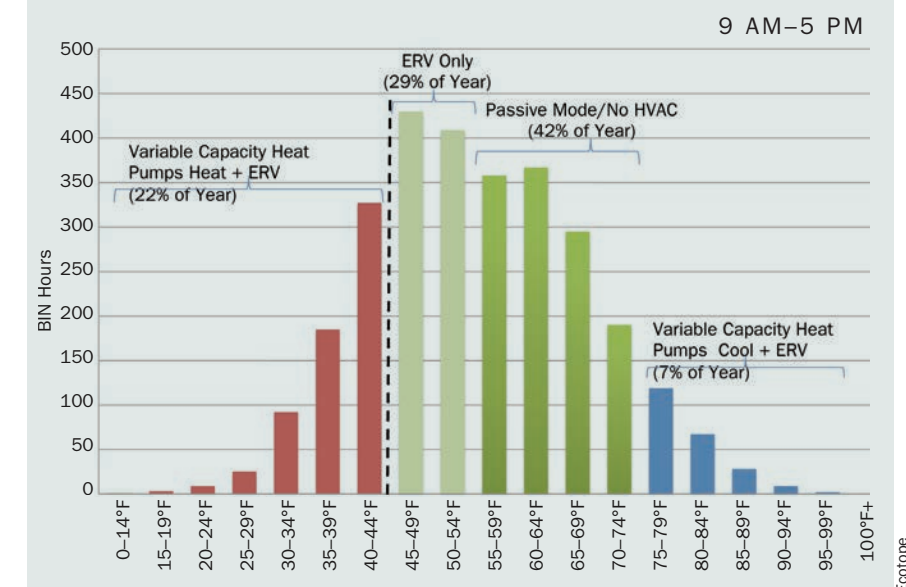
Lighting Energy Conservation Large clerestory windows provide plentiful daylighting. Occupancy and daylight dimming controls combined with high efficiency lighting design (0.59 W/ft² including task lights) provide over 65% lighting energy savings over current 2009 energy code.

Individual Controls Large red and green lights signal the building mode to the occupants. Green indicates passive mode when operable windows can be used for ventilation. Fifteen ceiling fans throughout the space are controlled by occupants and provide additional air movement and mixing for thermal comfort.

Carbon Reduction Strategies Low energy active/passive hybrid HVAC system, 9.3 kW solar PV rooftop array.

Transportation Mitigation Strategies The building is located four blocks from a bus depot and a ferry terminal for commuters traveling across Puget Sound from Seattle.

FIGURE 1 ANNUAL OCCUPIED HOURS TEMPERATURE BINS





Aaron Leitiz

The 18 ft x 25 ft central forum opening on the third floor allows for airflow and daylighting to the lower levels.

an additional 50% of the lighting energy, resulting in an effective LPD of 0.35 W/ft². Installed plug loads are 0.6 W/ft², including all workstations, servers, printers, kitchen appliances and miscellaneous items.

Designers carefully accounted for all energy using appliances in the building. For example, the drinking fountains do not include filters or chillers. All appliances are ENERGY STAR Consortium for Energy Efficiency Tier 3 (30% better than the ENERGY STAR qualifications). The elevator is a high efficiency traction model.

All printers and plotters have energy saver modes, which revert to low standby power. All workstations are powered off at night by the occupants. The workstation plug loads are the largest energy end use in the building.

Indoor Air Quality

Indoor air quality was an important programming element from the beginning. The building includes outdoor air monitoring, MERV 13 filtration, demand controlled ventilation (DCV) controls, CO₂ and CO concentrations monitoring and increased ventilation rates of 30% over ASHRAE Standard 62.1-2007 requirements.

The building is located a few blocks from the waterfront with fresh breezes tempered year-round by the inland sea. When the building opens up during passive mode, fresh air enters the space and provides several air changes per hour of outdoor air flushing throughout. Occupant feedback about indoor air quality and control of thermal comfort has been very positive.

Materials Reuse

The former Sears Automotive Center was transformed from within while paying homage to the building's industrial past with rustic wood and cool metal interiors. Because the architecture firm wanted to emphasize reuse of local materials and local craftsmanship, the team chose to reframe the roof with locally harvested and milled wood.

Salvaged Douglas fir beams from the original structure are reused as a decorative feature wall. The building's old freight elevator provides the mechanism that moves a large display and sectional fly wall in the main forum space. Altogether, 93% of the major structural elements were repurposed and diverted from the landfill. Twenty-four percent of new materials were made with recycled content.

Rainwater Harvesting

The project makes use of the plentiful rainfall (over 52 in. per year). A 6,000 gallon rainwater storage, filtration and pumping system in the garage supplies water for irrigation and toilet flushing.

The low-flow fixtures and the rainwater system offset over 60,000 gallons of potable water use annually. This represents over 70% less potable water use over a similar office building built to current code.

While the rainwater system alone saves 34,000 gallons of potable water, the city required a deduct meter on the supply to the toilets to regain sewage conveyance fees. Water prices are currently \$4 per CCF (750 gallons) and \$8 per CCF for sewage. The rainwater system saves approximately \$180 per year

BUILDING ENVELOPE

Roof

Type 8 in. polyisocyanurate roof decking
Overall R-value R-50
Reflectivity 0.79

Walls

Type Concrete covered with 1.5 in. sprayfoam continuous insulation. Framed with 3.5 in. metal studs set off 2 in. from sprayfoam to create a 5.5 in. cavity. Studs are spaced at 24 in. centers and cavity filled with loose fill Blow in Batt System (BIBS).
Overall R-value R-32
Glazing Percentage 16%

Basement/Foundation

Underfloor Slab Insulation R-value R-45 floor over parking

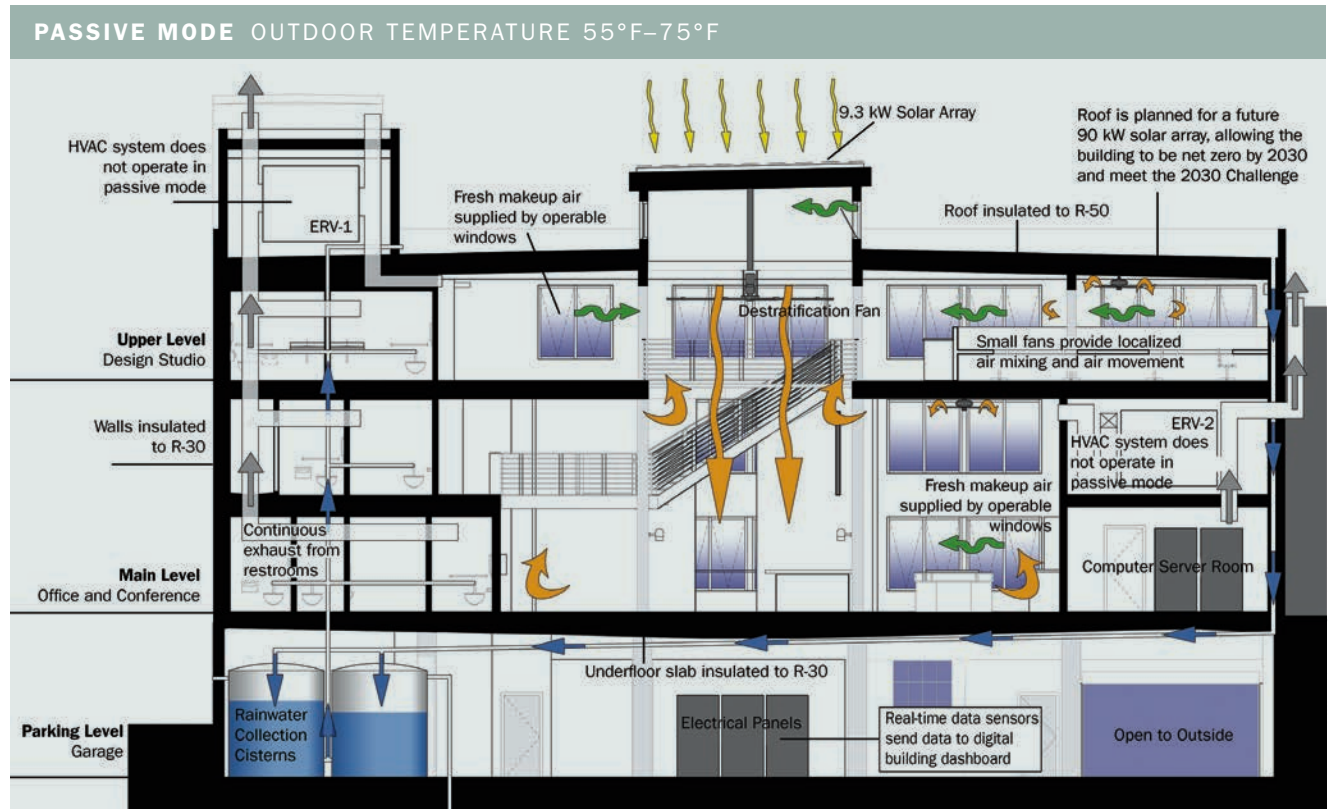
Windows

Effective U-factor for Assembly 0.23
Solar Heat Gain Coefficient (SHGC) 0.2
Visual Transmittance 0.46

Location

Latitude 47.57° N
Orientation North-south

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BUILDING TEAM

Building Owner/Representative Steve Rice, Fifth Street Hilltop Partnership, LLC

Architect Greg Belding, Rice Fergus Miller Architecture and Planning, PLLC

Designer Jeremy Southerland, Rice Fergus Miller Architecture and Planning, PLLC

General Contractor Dan Ryan, Tim Ryan Construction

Mechanical Engineer Shawn Oram, P.E.; Ecotope, Inc.

Electrical Engineer Nancy Kemna, Gerber Engineering

Energy Modeler Morgan Heater, P.E., certified ASHRAE Building Energy Modeling Professional; Ecotope, Inc.

Structural Engineer Jim Harris, PCS Structural Solutions

Civil Engineer Craig Baldwin, WestSound Engineering

Lighting Design Megan Strawn, Coruscate Lighting Consulting, LLC

LEED Consultant O'Brien & Company

in water costs, though sewage conveyance is still paid for. This makes the \$36,000 system a 200 year pay-back measure.

Actual Energy Use

The Rice Fergus Miller Office and Studio ranks among the lowest energy use buildings in the country. First year (June 2011–May 2012) energy performance shows the building operating at 23.4 kBtu/ft²·yr.

After several system and occupant behavior adjustments, the performance from March 2012–February 2013 improved to 21.2 kBtu/ft²·yr, which is 77% better than the Commercial Buildings Energy Consumption Survey (CBECS) 2003 national benchmark for office buildings of 93 kBtu/ft²·yr. The 9.3 kW rooftop solar array reduces the net EUI to 19.6 kBtu/ft²·yr.

To compare buildings to a more stable, absolute scale (as opposed to “percent-better-than-code” baseline), the New Buildings Institute has established the Zero Energy Performance Index (zEPI). The scale goes from zero to 100, with zero being a net zero building and 100 an average 2003 CBECS building. The Rice Fergus Miller Office and Studio has a zEPI of 24.

For more information on the Zero Energy Performance Index, see <http://tinyurl.com/blvctqt>.

The building was originally modeled using eQuest v3.63, PVWatts for solar PV predictions and Radiance for daylighting. Figure 3 illustrates that the building is using slightly more energy than the model prediction. This is driven primarily by the fact that computers were not turned off at night for the first year.

Environmental Impacts

Most developers would have torn down the building on this site and started over. By reusing an abandoned building, the project diverted large amounts of materials from the landfill and avoided all of the material use and carbon footprint associated with building the structure. It also saved a piece of the community’s history and demonstrated that old buildings can be among the top energy performers.

Operations and Maintenance

Since the systems are turned off for much of the time, the operating life of equipment is expected to be twice that of the same equipment in a standard building. The only regular maintenance required for the HVAC system is changing filters in the ERVs. Variable capacity heat pumps (VCHP) systems require maintenance inspections and charge checks every few years.

The rainwater harvesting system includes a self-cleaning prefilter design, which flushes roof debris into the storm sewer before it is routed to the storage cisterns. The rainwater system includes a backup connection to the city water supply through a pressure reducing valve. If for any reason (low water, pump failure, power outage, control failure) the rainwater system is not providing adequate water pressure to operate the toilets, city water will automatically take over.

Cost Effectiveness

The project achieved a remarkably affordable construction cost of \$105/ft² of floor area plus \$30/ft² in the cost of the land and existing



Workers remove the upper floor beams to create the open forum space. The 1948 vintage Douglas fir is repurposed through the space.

derelict building. If the building had been razed, demolition and construction costs would have been much higher, not to mention the embodied energy impacts.

HVAC load reduction strategies (super-insulation design, ERVs, low LPDs) have resulted in significant savings over traditional new construction projects by reducing system sizes. The VCHPs are sized at 860 ft²/ton for cooling and 1,350 ft²/ton for heating.

The incremental costs for energy efficiency measures are estimated at \$80,000. The building saves \$26,000 per year in utility costs compared to a typical Seattle office building. The

FIGURE 2 MONTHLY ENERGY END USE BREAKOUT

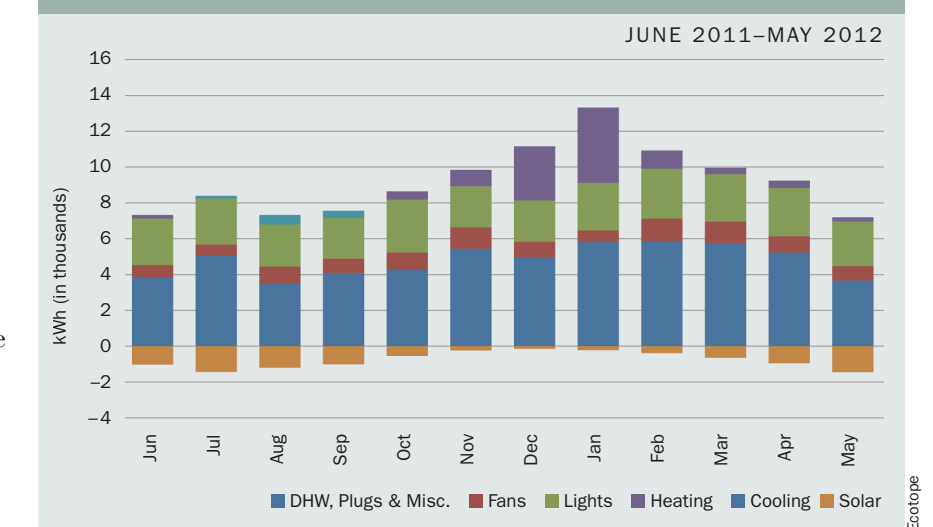
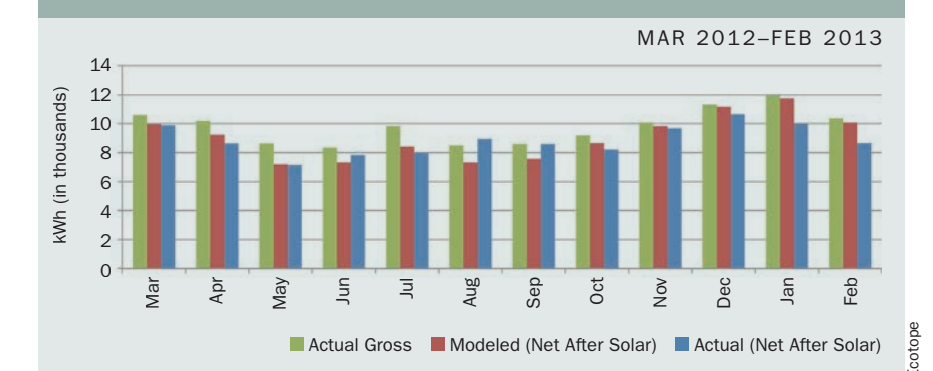


FIGURE 3 ACTUAL ENERGY USE COMPARED TO LEED MODEL



Note: In April 2012, Rice Fergus Miller began leasing approximately 1,300 ft² of tenant improvement space in the building. The space, which is used as a satellite office by another firm, includes four workstations, but it is typically only used by one or two occupants. The tenant area is submetered, but the billing information is included in the RFM main account. The resulting additional energy use is fairly negligible, and the additional square footage is not included in energy use intensity calculations.



Aaron Leitz



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Left A fly wall can be raised or lowered for projecting images or to create more intimate spaces. The fly wall uses a chain pulley system salvaged from the old freight elevator.

Above A hand crank with a long gear drive similar to those used in greenhouses controls 18 clerestory windows for natural ventilation.

electric utility provided energy conservation rebates of \$50,000. Energy cost savings and incentives allowed for a two year payback.

The building includes 9.3 kW of Washington made solar PVs, which generate 8% of the building's total annual energy use. This system should pay back in fewer than 8 years with a combination of federal grants, depreciation benefits and Washington state production incentives. Rice

Fergus Miller has committed to the 2030 Challenge and will incrementally install an additional 100 kW of solar panels over the next 15 years.

Innovation

The basic programming concept is to create a highly energy-efficient office space that can be used as a laboratory by local mechanical engineering students and other student groups of Olympic College. The laboratory concept is threaded throughout the building's operation.

Occupants can control windows, ceiling fans, adjust passive mode setpoints and override thermostat setpoints. Interactive real-time energy- and water-use dashboards allow occupants to observe CO₂ levels in all spaces, understand the energy impacts of behavioral changes and when air and rainwater filters need changing.

The dashboard allowed occupants to see the impact of turning their computers off at night. They saw a 15% energy use reduction in a single day, convincing them to adopt "off at night" as an official policy. This change has resulted in the biggest post occupancy savings impact. The dashboard also allows occupants to see fan energy savings in passive mode, which has prompted them to experiment with moving the passive mode upper setpoint from 75°F to 80°F.

Designing HVAC diversity out of the building eliminates the need for simultaneous heating and cooling in adjacent spaces. This makes the HVAC systems simpler and more efficient to operate as simultaneous heating and cooling drives up fan energy and space conditioning energy use. HVAC diversity is designed out by the following strategies:

- Extended comfort range of 68°F–78°F; and
- High density spaces include access to operable windows, ceiling destratification fans and transfer fans to move more air, keeping all spaces within the comfort criteria of ASHRAE Standard 55-2007.

For example, during the opening night reception on June 24, 2011, over 200 people filled the space

and stayed comfortable all evening using only operable windows and ceiling fans.

Conclusion

Rice Fergus Miller set bold energy, water, sustainability and community improvement goals for its new home. What sets this building apart from other net zero energy capable projects is that the design team achieved and even surpassed their targets without breaking the bank.

By implementing a "design for off" active-passive hybrid approach, the building uses mechanical systems only when and where they are actually needed. Passive design principles take full advantage of the building site and climate, allowing for minimal use of HVAC and lighting systems. ●



Rice Fergus Miller

Custom tables are made from reclaimed ceiling furring strips. Rice Fergus Miller employees near the upper floor south windows enjoy natural daylight and the comfortable interior temperatures that are typical with super-insulated buildings.

ABOUT THE AUTHORS

Shawn Oram, PE., Member ASHRAE, LEED AP is a mechanical engineer at Ecotope, Inc. in Seattle.

Carmen Cejudo, Member ASHRAE, LEED AP BD+C, provides engineering design and project management support in residential and commercial HVAC and plumbing systems design at Ecotope, Inc. in Seattle.

LESSONS LEARNED

Don't Be Afraid to Propose Innovative Ideas. This was the first rainwater harvesting system permitted in the city of Bremerton, so they required a detailed explanation of the plumbing system design, and a deduct meter on the toilet supply to capture sewage conveyance fees.

Despite Long Payback, Rainwater Harvesting System Offers Value as a Demonstration Project. The payback time frame for the rainwater harvesting system is estimated at 200 years. However, the firm felt it important as a demonstration for their clients developing projects with higher nonpotable water loads.

Solar Water Heating Omitted Due to Long Payback Period. The team considered installing a solar water heating system on the roof, but decided against it due to the long payback period. Although the showers are used by bike commuters in the summer, the hot water use is a fraction of a residential project and would have a payback of 50 years.

Complex Controls Required Extra Coordination. Controlling the building based on outdoor temperatures and tying all of the systems into two setpoints for passive mode was a challenge. It required additional coordination, but once everyone understood the design intent, it all fell into place.

Eliminate Simultaneous Heating and Cooling. This design is a big part of the building's performance. Ceiling fans and transfer exhaust fans are used in lieu of mechanical cooling.

Consider Availability of Local Knowledge and Service Technicians When Selecting Building Systems. This building team was lucky to find a local general contractor who was willing to learn about sustainability and the level of documentation needed to meet LEED performance requirements.

Commissioning Can Be Challenging in Relatively Remote Areas. For example, because of the lengthy ferry ride to Rice

Fergus Miller's office, it took several months to coordinate schedules to identify and fix a thermostat in a conference room that was wired to a heat pump in the central forum, causing the conference room to overheat.

Occupant Education Can Improve Building Performance. Occupant education such as encouraging employees to turn off workstations and put printers into sleep mode is expected to reduced the gross (pre-solar) EUI from 21.2 kBtu/ft²-yr to a projected 19 kBtu/ft²-yr for the second year of operation.

Impact on Firm, Community. The project has informed the firm's practice and has prompted clients—who can see and experience the results of the office's sustainable design—to pursue similar designs in their projects. It has also inspired the community to consider renovating other derelict buildings in Bremerton.

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