Radiant Cooling and Heating Systems Case Study

Photo: Eckert & Eckert

Photo: Loren Nelson

OVERVIEW

Location: Portland, OR

Project Size: Office only: 205,500 square feet (SF)

Construction Type: New Construction

Completion Date: 2010

Fully Occupied: Yes

Building Type: Office

Climate Zone: 4C – Mixed Marine

Total Building Cost: $78.7 Million | $384/SF

"We wanted the building to be a positive icon about the place where we live and work"

– Bill Wyatt, Port of Portland, Executive Director

PORT OF PORTLAND HEADQUARTERS

The Port of Portland Headquarters (Port building) is a three story office space with 450 Port employees built above seven stories of public parking located at the Portland International Airport (PDX). The building targeted reduced energy and carbon and is ranked in the top ten of the world's most high tech green buildings by Forbes in 2010.

The Port building was studied under a California Energy Commission EPIC research project on radiant heating and cooling systems in 2016-2017. While forced-air distribution systems remain the predominant approach to heating and cooling in U.S. commercial buildings, radiant systems are emerging as a part of high performance buildings. Radiant systems transfer energy via a surface that contains piping with warmed or cooled water, or a water/glycol mix; this study focused on radiant floor and suspended ceiling panel systems.[1] These systems can contribute to significant energy savings due to relatively small temperature differences between the room set-point and cooling/heating source, and the efficiency of using water rather than air for thermal distribution.[2] The full research study included a review of the whole-building design characteristics and site energy use in 23 buildings and surveys of occupant perceptions of indoor environmental quality in 26 buildings with 1645 individuals.

Planning & Design Approach

The building is situated in front of the PDX main terminal on top of a new 1.2 million square foot (SF) parking structure. The design approach was inspired by the form of an airplane hull with an exterior curved lapped glass curtain wall, as well as the need for higher employee satisfaction with few enclosed offices. The new offices reflect a 21st century culture—"One Port"— in an effort to increase collaboration and foster a team environment. Cost-effective design solutions were a primary concern, as well as telling the Port of Portland story through environmental graphics, artwork and the building shape. During design the team performed a cost valuation of the radiant system versus other HVAC[3] systems and concluded radiant would provide the most lifetime cost savings. The 205,500 SF office was built at a construction cost of $78.7 million/$384 SF and has annual whole building energy costs of $0.94/SF.

1 Thermally Activated Building Systems (TABS) and Embedded Surface Systems (ESS) are located in the floor. Note: Chilled beams also use water distribution but typical 'active' beams provide cooling predominantly by convection by blowing building ventilation air across cooling coils, and were not the study focus.
2 Water transfers thermal energy about 7 times more effectively than air. CBE Brower Study, CEC EPIC 2011 http://escholarship.org/uc/item/7tc0421f#page-1
3 Heating Ventilation and Air Conditioning (HVAC)

nbi new buildings institute

CBE Center for the Built Environment

Team/Owner Details

Owner: Port of Portland

Architect: ZGF Architects

Structural Engineer: PAE Engineers

MEP Engineering: Northwest Engineering Service, Inc.

Landscape Architect: Reed/Mayer

General Contractor: Hoffman Construction Company

Wastewater System Engineer: Aqua Nova Engineering

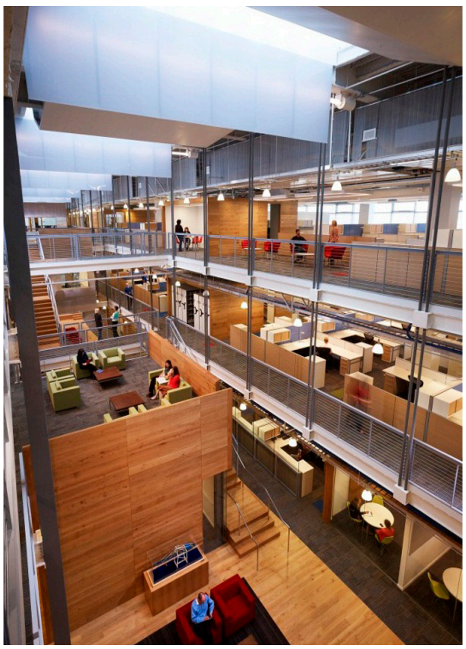

Photo: Eckert & Eckert

Radiant System

The engineering team designed 56,000 SF of metal radiant ceiling panels in all office occupied areas to meet heating and cooling needs. Every radiant zone is independently controlled via a four pipe system. The radiant system is active 24/7 with space temperature setback during unoccupied periods.

Ventilation

Radiant systems are typically coupled with a separate air system for ventilation. The dedicated outdoor air system (DOAS) at the Port Building meets ventilation needs and provides dehumidification. The efficiency is improved by the inclusion of heat recovery from the building exhaust air and a supply air temperature control system that varies based on outdoor temperature.

Cooling and Heating Plant

Two hundred geothermal wells reaching 300 feet below the surface provide ground source heating and cooling to heat pumps that serve the radiant distribution system, a common solution that is complementary with radiant systems. For peak periods, an auxiliary cooling tower supplements any additional cooling needs. A ‘Living Machine’ system is used for wastewater treatment and provides recycled non-potable water to the cooling towers.

Building Energy Use

The Port Building has an Energy Use Intensity (EUI) of 46 kBtu/ft^2, which is a reduction compared to the energy use from the average office EUI performance of the national CBECS[4] and California CEUS[5] datasets by a wide margin (>40%) as seen in Figure 1. While those datasets include a mix of construction ages the Port of Portland building also uses 30% less energy than an office built to the Oregon code in 2010 (ASHRAE 90.1) and the Building Performance Dataset (BPD)[6] offices in its climate zone by 28%. It uses only 15% more energy than the ASHRAE best-practice energy efficiency standard 100 for offices in its climate zone. Through a range of factors, including the selection of a radiant system for heating and for cooling, the Port building energy use is very low for its type and design.

Energy Use Intensity (EUI)[1]: 46

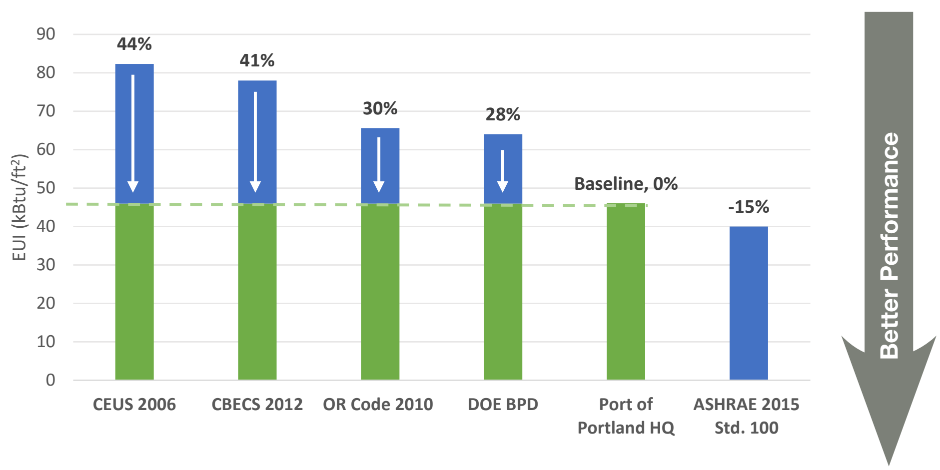

Figure 1: Percent difference of Port of Portland measured energy performance compared to office energy use benchmarks.

1 Energy Use Intensity (EUI) is a common metric to measure energy consumption in kBtu/square foot/year

4 U.S. Energy Information Agency Commercial Buildings Energy Consumption Survey (CBECS)
5 California Commercial Energy Use Survey (CEUS)
6 U.S. Department of Energy Building Performance Dataset (BPD)

Ceiling tile sections have been lowered to show the metal hydronic radiant panels used for heating and cooling the office.

Photo: Webly Bowles

"There are a lot of things to consider when you're building at an airport, inside the building, it was about helping the staff realize that they could work in an open plan. We had a lot of focus groups and work sessions. There was a lot of staff involvement and a lot of listening to the staff. In the end, they've found that they can make decisions much more quickly and are much more efficient than they ever dreamed possible in this building."

—Sue Kerns, head of interiors for ZGF

Research Data Set Energy Use

The Port building is part of 23 radiant buildings in the full research study where the bulk of the buildings were clear leaders compared to peers in both CBECS and the BPD. Two thirds received an Energy Star score of 90 or above, signifying that these buildings outperform 90% of comparable buildings. The study set is on par with the high efficiency target set by ASHRAE in Standard 100 and several buildings even reached zero net energy (ZNE)[7] performance levels (~25 EUI) demonstrating the use of radiant in high performance buildings.

Thermal Comfort Feedback

Overall, the thermal comfort feedback from the occupants in the Port building is positive. 68% of the occupants reported that they were satisfied (green portion of graph), 8% reported that they were neutral, and 24% reported that they were dissatisfied. The satisfaction reported at the Port of Portland was higher than the full occupant survey research dataset overall (n=28 buildings, 1800 individuals). The full occupant survey analysis shows that radiant and all-air buildings have equal indoor environmental quality, including acoustical satisfaction, with a tendency towards equal or improved thermal comfort in radiant buildings. The full report detailing the occupant satisfaction will be available in Fall 2017 at www.cbe.berkeley.edu.

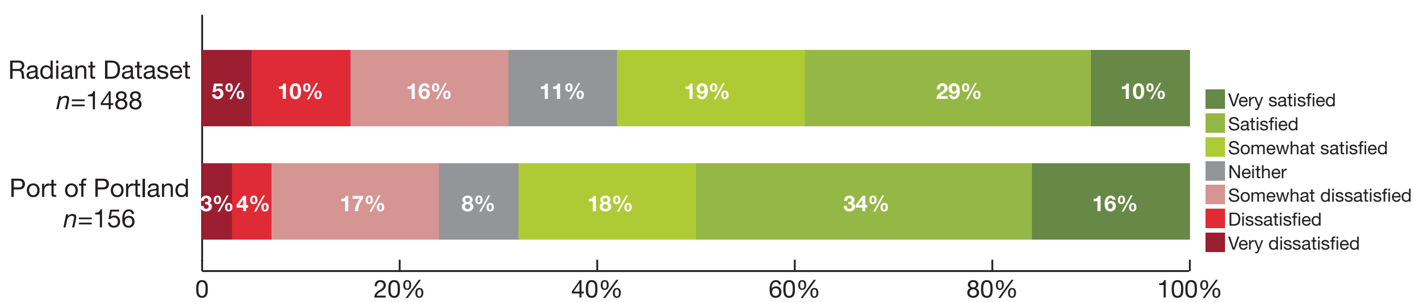

Figure 2: Results on thermal comfort question within the CBE occupant satisfaction survey. *Credit: Caroline Karmann*

7 ZNE buildings annually produce onsite energy from renewables equal to or greater than their annual energy use.

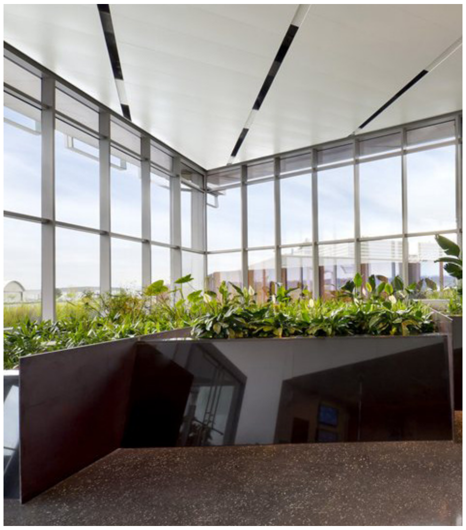

Photo: Living Machine Systems, L3C

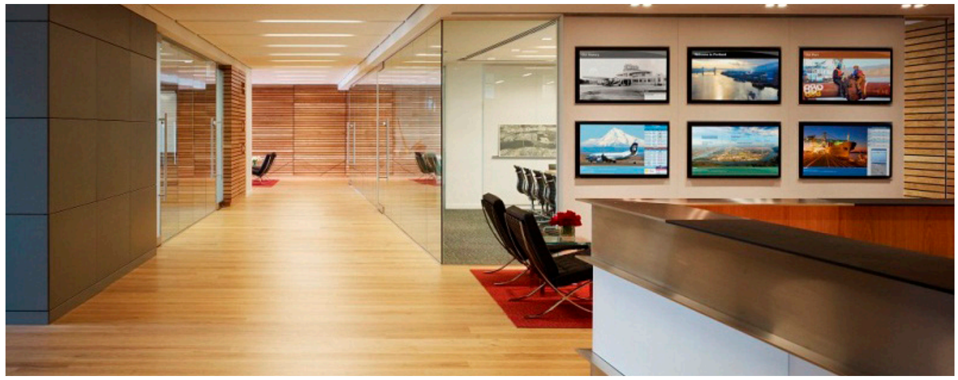

Photo: Eckert & Eckert

The Port of Portland building and the full research set use 28-44% less energy than national benchmarks, and radiant is part of that outcome.

This case study is part of a project focused on energy and occupant factors within the larger study Optimizing Radiant Systems for Energy Efficiency and Comfort. Case studies and the full research findings on energy use and occupant perceptions of the indoor environment will be available in Fall 2017 at cbe.berkeley.edu/research/optimizing-radiant-systems.htm and at newbuildings.org. The larger study will include design optimization, cost assessment and savings opportunities and will be available on the CEC EPIC site in 2018 at energy.ca.gov/research/new_reports.html.

Funder: California Energy Commission (EPIC Project 14-009)

Research Lead: UC Berkeley Center for the Built Environment (CBE)–F. Bauman

Energy Use: New Buildings Institute–C. Higgins, K. Carbonnier

Occupant Satisfaction: UC Berkeley CBE–C. Karmann

Additional Team: TRC–G. Paliaga | CBE–S. Schiavon, P. Raftery, L. Graham

Additional Efficiency Strategies and Features

Lighting and Daylighting

Lighting design was optimized with side light from windows and sensor placement. Each fixture includes daylighting and occupancy sensing in the open office as part of the controls system. The project utilized automated exterior shades and light shelves to balance and control daylight, glare, and heat gain. Task lighting is also used at individual workstations to reduce the need for overhead lighting.

Envelope

An EnergyStar rated reflective roof membrane and high-performance glazing minimize heat gain and energy demand for the building. The roof of the 9th floor of the building features an extensive eco-roof that reduces the building's heat-island effect and provides a significant area for rainwater treatment. A Tidal Flow Wetland Living Machine® aids in the wastewater treatment.

Plug Loads

Due to the nature of the office occupancy and the low-energy design and technologies, the plug loads are by far the biggest energy end use of the project. The building has installed circuit-level metering in occupied spaces that provides information about energy use at the space level to the operator and gives tenants real time feedback about their plug energy use via central dashboard displays. In addition, all loads must be connected to advanced power strips that have occupancy sensors to reduce energy use during unoccupied periods.

Role of Radiant in High Performance

Although a radiant system is not solely the driver of good energy performance it can be an important part of an integrated approach from design and technology selection through to occupancy and operations. In California, low-energy outcomes rely on strategies to address the HVAC system which represents the highest proportion of commercial building energy use (32%).[8] This research found the majority of the study set buildings (96%) were pursuing high levels of LEED certification, where reduced energy is a requirement. This mirrors the findings in the largest database of ZNE buildings where more than half of ZNE buildings in North America use a radiant system,[9] and in a survey of 29 advanced ZNE and near ZNE buildings in California where 11 include radiant systems.[10] The Port of Portland building and the full research set use 28-44% less energy than national benchmarks, and radiant is part of that outcome.

8 California Commercial Energy Use Survey (CEUS) 2006 http://www.energy.ca.gov/ceus/
9 New Buildings Institute Getting to Zero Database http://newbuildings.org/resource/getting-to-zero-database/
10 TRC and PG&E, ACEEE 2016 http://aceee.org/files/proceedings/2016/data/papers/3_636.pdf