Radiant Cooling and Heating Systems Case Study

Photo: SERA Design

OVERVIEW

Location: Salem, OR

Project Size: 147,212 ft^2

Construction Type: Retrofit

Completion Date: 2012

Fully Occupied: 92%

Building Type: Office

Climate Zone: ASHRAE 4C

Total Building Cost: $69 million / $470/ft^2

OREGON DEPARTMENT OF TRANSPORTATION (ODOT) HEADQUARTERS

The Oregon Department of Transportation (ODOT) Headquarters is a 5-story, 147,000 square foot office building housing 460 employees. The Headquarters is a retrofit of a 1950s building and features hydronic radiant systems, photovoltaic panels, rainwater harvesting, waste water treatment and ground-source heat pumps. These technologies enabled the building to achieve LEED Platinum certification in 2012.

Designed by SERA Architects and engineered by Stantec and PAE Engineers, the renovation project reorganized ODOT's workspaces, providing the employees with improved daylight, indoor air quality and collaboration spaces, while optimizing the HVAC systems to ensure energy efficiency. Originally targeting LEED Gold rating, the building exceeded energy performance expectations and secured a LEED Platinum certification and Energy Star certification. The project received design assistance from Oregon's Energy Efficiency Incentive Program in 2012.

Planning and Design Approach

The Headquarters, also known as the T-Building, was built in 1950 and had never been remodeled, leaving seismic hazards and outdated mechanical systems. The retrofit addressed the seismic hazard through strategically placed concrete columns and sheer walls for the elevator shafts. A gut remodel of the building provided an opportunity to upgrade the building envelope to tighter, more insulated and moisture-resistant assemblies.

The project team envisioned a retrofit emphasizing energy efficient mechanical systems to help achieve the LEED Gold target. SERA Architects stressed the importance of the project team to work comfortably with new and progressive technologies, including the radiant conditioning system.

STATE OF CALIFORNIA ENERGY COMMISSION

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CBE CENTER FOR THE BUILT ENVIRONMENT

Team/Owner Details

Owner: Oregon Department of Transportation

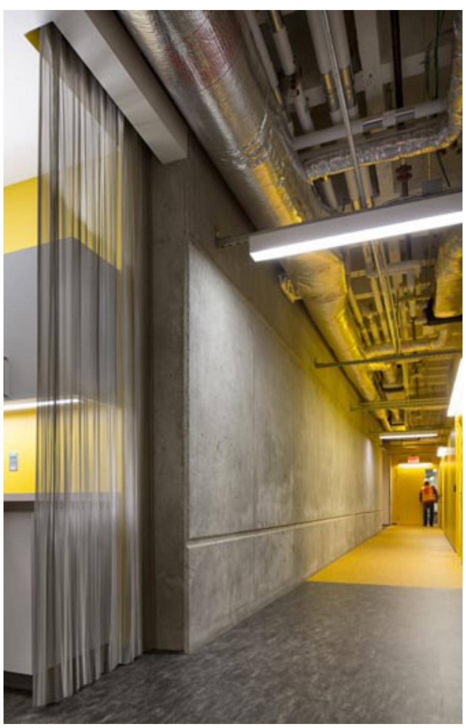
Architect: SERA

MEP Engineering: Stantec, PAE

General Contractor: Hoffman Construction

"The client needs to be comfortable with the technical prowess of the design team to be able to deliver more progressive technologies."

–*Stuart Colby, SERA Architects*



Increased floor to ceiling height by reducing duct sizes. Photo: SERA Design

Prior to selecting the radiant systems, the project team conducted a cost comparison with conventional systems. The team managed to complete the project 20% lower than the planned budget. High efficiency mechanical systems were optimized for site conditions to reduce the ongoing energy costs and achieve energy performance 26% better than code, as projected through building simulations.

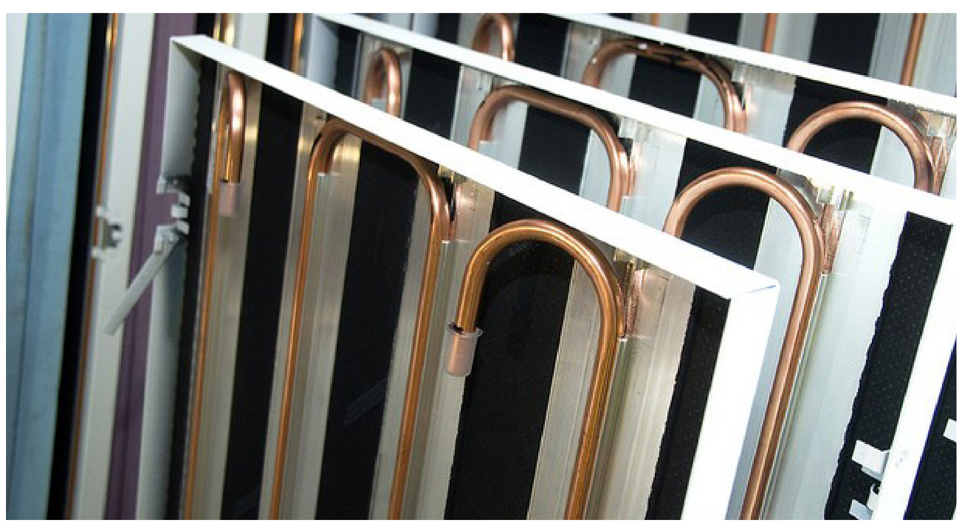
The team worked with building information modeling and laser scan in the early stages of the reconstruction to perform a detailed investigation and identify potential issues commonly encountered in retrofit projects.

Radiant System

The ODOT retrofit replaced conventional window air conditioners with radiant ceiling panels for heating and cooling throughout the open office spaces. The radiant system receives hot water from two central gas-fired boilers and cold water from the three chillers. The central chiller provides chilled water at a higher set point to minimize condensation risk. Non-office spaces, such as break rooms, lobbies and conference rooms, are supplemented with variable refrigerant flow (VRF) systems to respond to a higher variety of occupancy loads.

Ventilation - Supplemental Cooling

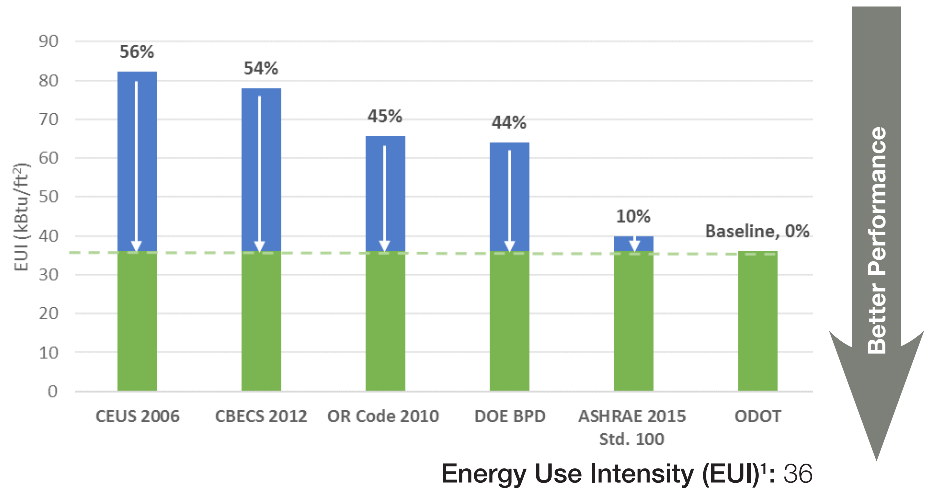
The radiant ceiling panels are supplemented with upsized variable speed Dedicated Outdoor Air Systems (DOAS) for ventilation and dehumidification. The open office spaces and the non-office spaces are each provided with a DOAS enabled with air-to-air heat recovery. The pairing of DOAS and radiant systems provided an opportunity to reduce duct sizes and increase the floor-to-ceiling height. Air supply is provided through overhead mixing diffusers with valve controls for each zone.



Radiant tubing used in office spaces. Photo: Better Buildings for Oregon

Building Energy Use

The ODOT building has a whole building site Energy Use Intensity (EUI)[1] of just 36 kBtu/ft². This low-energy use is 44-56% less than the average office EUI performance of the national CBECS[2] dataset, current Oregon code levels and offices in the same climate zone within the Building Performance Dataset (BPD)[3], as seen below. While those datasets include a mix of construction ages, ODOT's building energy use is also lower than ASHRAE's best-practice energy efficiency standard 100 targets by 10%.



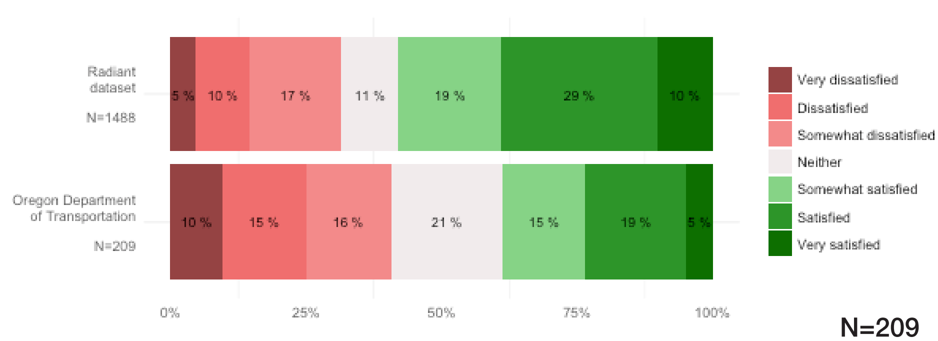
Percent difference of office energy use intensity benchmarks compared to the ODOT building measured performance.

> "The value of designing well-built [reconstructed] buildings is simply not understood in the marketplace. We really need to expand the understanding of this point by the public and legislators to create a 'new normal' to really understand what the payback should look like in a 50- to 100-year building."
>
> –*Clark Brockman, SERA Architects*

Thermal Comfort Feedback

Overall, the thermal comfort of the occupants in the ODOT building is slightly lower than the other radiant buildings in the studied dataset. 39% of the occupants reported that they were satisfied, 21% reported that they were neither satisfied nor dissatisfied and 41% reported that they were dissatisfied.

These results may not be manifested in practice, however. Post-occupancy, the facility management received the lowest amount of hot and cold calls from the occupants as compared to other ODOT facilities. For additional comparison, the average size of the satisfied group for all buildings surveyed by the Center for the Built Environment (CBE) is 40%.



Occupant thermal comfort feedback for the ODOT Headquarters.

> "The industry needs a way to talk about the value of existing buildings and why we should keep them."
>
> –*Stuart Colby, SERA Architects*

[1] Energy Use Intensity (EUI) is a common metric to measure energy consumption in kBtu/square foot/year
[2] U.S. Energy Information Agency Commercial Buildings Energy Consumption Survey (CBECS)
[3] U.S. Department of Energy Building Performance Dataset (BPD)

Reorganized interior office spaces.
Photo: Better Buildings for Oregon

Additional Efficiency Strategies and Features

Design and Envelope

The retrofit reorganized office spaces for the ODOT Headquarters to accommodate at least 17% more employees, concentrating multiple offices into one. Major renovation of the 60-year old structure allowed for upgrading the building envelope, while also retaining the building's original marble façade, except for patch repairs. The design team made a conscious effort to salvage materials from the existing structure for reuse in the retrofit.

Occupant Controls

Reorganizing the office spaces provided an opportunity to restructure occupant controls and reduce plug loads. The retrofit incorporated energy management systems such as plug load controls and individual occupant controls for lighting. The windows and internal shading devices are manually operable.

Rainwater Harvesting

Reducing water consumption was one of the most important goals contributing to LEED Platinum certification. The building has installed 10,000-gallon rainwater harvesting cisterns in the basement that provide water for flushing and landscape, allowing a 50% reduction in the overall water consumption.

Rainwater cisterns in the basement.
Photo: Better Buildings for Oregon

Role of Radiant in High Performance

Although a radiant system is not the sole 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%)[4].

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[5], and in a survey of 29 advanced ZNE and near ZNE buildings in California, where 11 include radiant systems[6]. The ODOT building energy use is exemplary and the radiant system is part of the integrated approach that achieved that performance.

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

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. Additional 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)

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