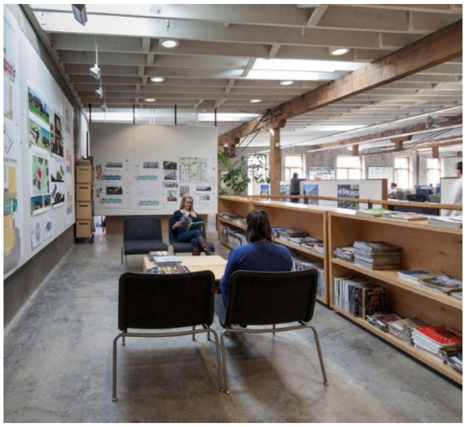
Radiant Cooling and Heating Systems Case Study



Photos: Opsis Architecture

OVERVIEW

Location: Portland, OR

Project Size: 19,460 square feet (SF)

Construction Type: Retrofit

Completion Date: 2004

Fully Occupied: Yes

Building Type: Mixed: Office

Climate Zone: 4C – Mixed Marine

Total Building Cost: $2.3 Million | $118/SF

LOVEJOY OPSIS BUILDING

The Lovejoy Opsis Building in Portland, Oregon is a two-story, 19,460 square foot (SF) retail and office building. The building was constructed in 1910 as stables for an historic Hardware Company. Opsis Architecture purchased the building and did a deep renovation to serve as an example of sustainability as well as provide rentable ground floor retail space, and a second floor office for their firm.

The Opsis 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 and Design Approach

With a commitment to sustainability in their own practice, the owner architects wanted to use the building to experience and demonstrate the technologies and practices it promotes with clients. The new space needed to be open, comfortable and achieve high performance with the addition of resource efficient features. The building was in need of a major seismic upgrade which provided a clean slate for the retrofit of the existing brick structure and an opportunity for an integrated response to advanced structural upgrades, enhanced user thermal comfort and improved energy savings.

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

STATE OF CALIFORNIA ENERGY COMMISSION

nbi new buildings institute

CBE CENTER FOR THE BUILT ENVIRONMENT

Team/Owner Details

Owner: Opsis Architecture

Architect: Opsis Architecture

General Contractor: Gray Purcell

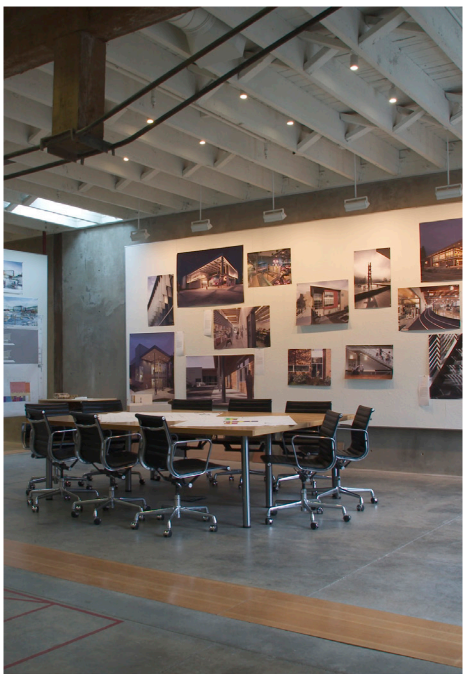
Electrical Engineer: Greenway Electric

MEP Engineering: Interface Engineering

They decided against registering the building as a historic landmark, thus giving up the associated tax credits, in order to retain the flexibility to enlarge the exterior windows and add sunshades. Opsis also chose to certify as LEED-NC Gold.

Radiant System

The thermal distribution system is composed of in-floor hydronic radiant heating and cooling slab that allows for an exposed ceiling design free of large air ducts and mechanical noise free working environment. During winter hot water runs through the pipes heating the thermal mass and radiating into the space and in the summer cool water is in the piping keeping the space near the occupants comfortable. Opsis decided on radiant distribution based on a cost analysis and the mild weather Portland receives throughout the year. By heating or cooling the slab this system operates at temperatures much closer to ambient conditions than conventional equipment. The brick and concrete surfaces throughout the space provide thermal mass that moderates temperature swings, holding in the daytime heat in the winter and nighttime cool of the summer.



Photos: Opsis Architecture

Cooling Tower

Portland summers are relatively mild with low humidity so Opsis chose a cooling tower. The cooler tower uses evaporation to remove heat across the water pipes circulating in the system as it passes through the tower. This is an energy efficient method to effectively cool the return loop water that is then returned to cycle through the floor providing occupant summer comfort.

Ventilation

Radiant systems are typically coupled with a separate air system for ventilation. In this case, CO_2 sensors are installed throughout the space that open windows if needed as first stage ventilation. Roof ventilators with dampers located opposite the operable windows promote stack effect exhaust of hot air and improve ventilation. Automated night-air-flushing reduces the starting daytime load to mechanically cool the building. There are also 12 ceiling fans in place which are all manually controlled. On the rare occurrence the temperature is too hot or too cold, a makeup air unit on the roof conditions the air and supplements the ventilation system by providing pre-cooled outside air.

Energy Use Intensity (EUI)[1]**:** 48

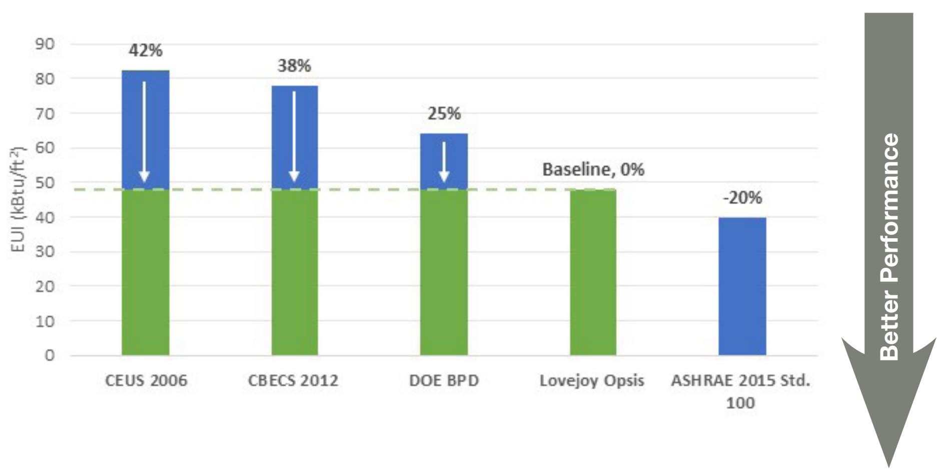
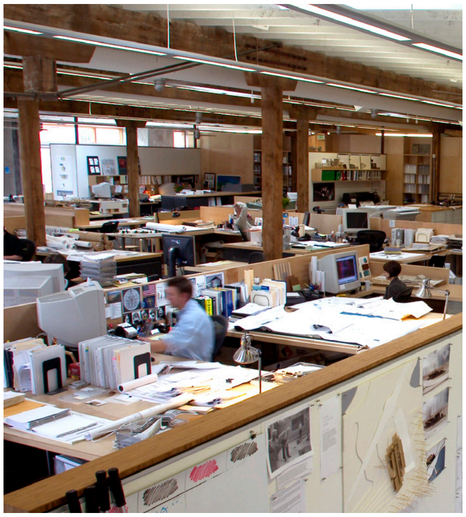


Figure 1: Percent difference of Opsis building measured energy performance compared to other office energy benchmarks.

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

3 Executive Order (EO) 13514, "Federal Leadership in Environmental, Energy, and Economic Performance". https://www.fedcenter.gov/programs/eo13514/



Photos: Opsis Architecture

Building Energy Use

The Opsis building has a whole building site Energy Use Intensity (EUI) of 48 kBtu/ft^2 which is well below the office EUI of the national CBECS[3] and California CEUS[4] existing building datasets by more than 35% as seen in Figure 1. The energy use is also 25% lower than the national Building Performance Dataset (BPD)[5] EUI for offices in the same climate zone. Only the ASHRAE energy efficiency Standard 100 for offices, which represents the 25th percentile of lowest energy use targets in the same climate zone, has a lower EUI target by -20% compared to the Opsis Building. Through a range of factors, including the selection of a radiant system for heating and for cooling the office portion, the Opsis Building energy use is very low for its type and renovation.

Research Data Set Energy Use

The Opsis building is part of 23 radiant buildings in the full CEC research study where the bulk of the buildings were clear leaders compared to peers in both CBECS and the BPD. Two thirds receiving an EnergyStar score of 90 or above, signifying that these buildings outperform 90% of comparable buildings. The research study set is on par with the high efficiency target set by ASHRAE in Standard 100 and several of the full research dataset buildings even reached zero net energy (ZNE)[6] performance levels (~25 EUI) demonstrating the use of radiant as a path to high performance buildings.

> "There can be a disconnect for architects to understand the real world and what it means to be the one to write the check. We wanted to 'walk the talk' as proponents of green building design."
>
> *James Meyer, Owner, Opsis Architecture*

Thermal Comfort Feedback

Overall the thermal comfort of the occupants in the Lovejoy Opsis office building is quite high, especially compared to the overall dataset. 78% of the occupants reported that they were satisfied, 9% reported that they were neither satisfied nor dissatisfied and 13% reported that they were dissatisfied. Something interesting to be noted about the occupant comfort in this building is that occupants report really liking the stability and predictability a radiant system provides and with specific comments that "there is not a lot of air blowing around and no mechanical noise pollution." The full report detailing the occupant survey of indoor environmental perceptions results for the full research dataset will be available in Fall 2017 at www.cbe.berkeley.edu.

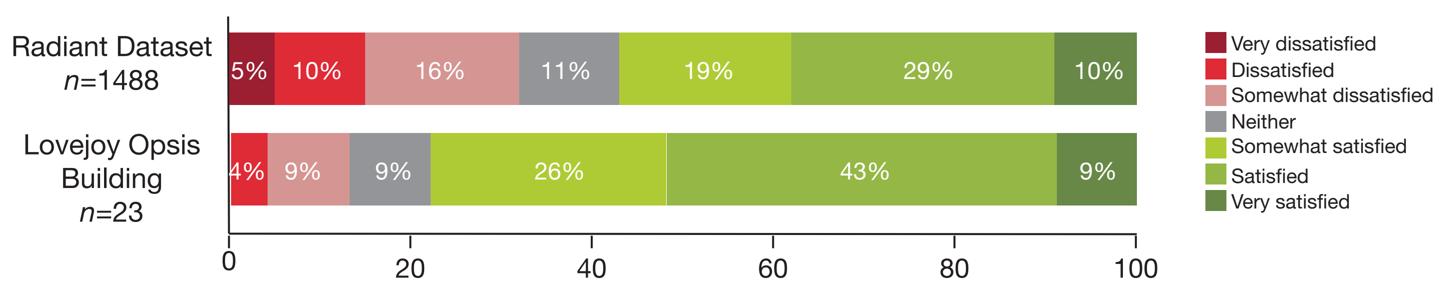
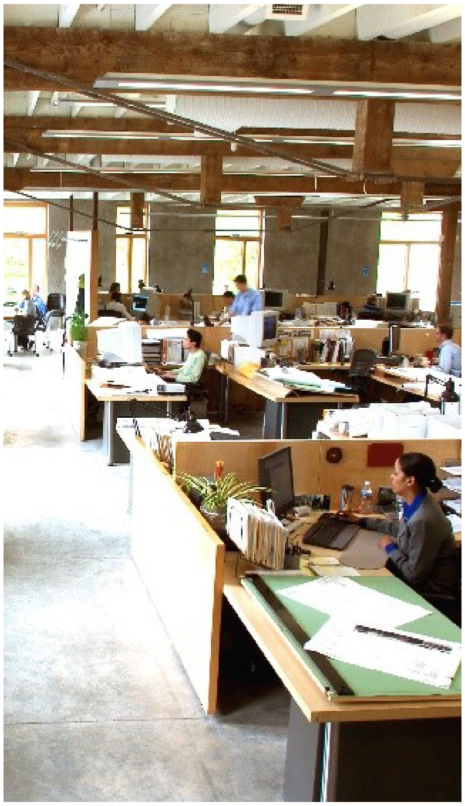


Figure 2: Results on thermal comfort question within the CBE occupant satisfaction survey. *Credit: Caroline Karmann*

3 U.S. Energy Information Agency Commercial Buildings Energy Consumption Survey (CBECS)
4 California Commercial Energy Use Survey (CEUS)
5 U.S. Department of Energy Building Performance Dataset (BPD)
6 ZNE buildings annually produce onsite energy from renewables equal to or greater than their annual energy use.



Photos: Opsis Architecture

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)

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 Energy Efficiency Strategies and Features

Lighting and Daylighting

The office building lighting system is T-8 florescent fixtures throughout with daylight sensors for automatic dimming. Additionally, 19, 3 ft. x 3 ft. skylights are distributed throughout the space. These daylights were kept small to provide better illumination overall as opposed to larger skylights in concentrated areas. Smaller skylights also didn't require any interruption of the existing structure as they were laid right over the joists. Automated exterior shades on the north and west sides of the building run off of a solar sensor so that they drop just before the sun comes directly into the building which diffuses the light and diminishes the amount of direct sun, glare and heat gain.

Envelope

As an historical retrofit the modifications to the overall envelope were minimal. The exterior brick was kept, reinforced with rigid insulation and 8" concrete walls to meet seismic upgrades and then repainted with a biophilic self-cleaning white paint that also helps to shed heat gain. Low-E high efficiency glass is used throughout the envelope to minimize heat gain.

Controls

The lighting and HVAC systems are controlled by an Energy Management Control System (EMCS) and sensors. The digital system controls lighting in response to the zoned photocell solar sensors located on the office ceiling. Automated sunshades on the west face of the building are controlled by photocell sensors set against an astronomical clock. Opsis chose to use CO_2 sensors in the office to interpret occupancy density rather than using the standard fixed ventilation rates per person based on assumed full occupancy. This system of CO_2 sensors, known as demand control ventilation (DCV), sends data to the building management system to regulate and respond to needs for ventilated air to accommodate occupant comfort and typically reduces the fan run time thus the energy use.

Renewables

A rooftop 18-panel photovoltaic system provides 2.5 kW maximum output to supplement a small amount of the building's energy use.

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%).[7] 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,[8] and in a survey of 29 advanced ZNE and near ZNE buildings in California where 11 include radiant systems.[9] Both the Opsis Building and the full research data set use far less energy than various benchmarks and radiant is part of that outcome.

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