Radiant Cooling and Heating Systems Case Study

Photo: Fort Collins Utilities' Integrated Design Assistance Program

OVERVIEW

Location: Fort Collins, CO

Project Size: 65,000 ft^2

Construction Type: Expansion / New Construction

Completion Date: 2014

Building Type: University-Laboratory / Research Center

Climate Zone: ASHRAE 5B

Total Building Cost: $18.5 million

COLORADO STATE UNIVERSITY (CSU) POWERHOUSE ENERGY CAMPUS

The Colorado State University (CSU) Powerhouse Energy Campus is a 65,000 square foot addition to the 1930s Fort Collins Municipal Power Plant facility. The power plant was decommissioned in 1973, and in 1990, it was converted to a research and educational building containing the University's Engines and Energy Conversion Laboratory.

Colorado State University expanded the building in 2014 to house CSU's Energy Institute research facility. The four-story addition is a LEED Platinum certified building consisting of interdisciplinary laboratories, office spaces, classrooms, research facilities, incubators and collaborative spaces for the Institute. The Powerhouse Energy Building couples a high performance building envelope with energy efficient radiant systems to achieve significant energy savings in addition to solar and wind powered energy generation on site.

Planning and Design Approach

The 1936 power plant facility has historical significance to the City of Fort Collins. It is the only remaining Art Deco-styled industrial building in the City built as a Works Progress Administration project during the New Deal. The CSU team carefully preserved the historic elements of the facility when transforming the unused building to a center for energy research and innovation. The building's resurrection is reflective of the Institute's purpose of serving as a nucleus of research, entrepreneurship and collaboration.

CSU partnered with Fort Collins Utilities' Integrated Design Assistance Program (IDAP) to incorporate sustainable and energy efficient features into the Powerhouse expansion project. The collaborative effort dedicated a significant amount of time to research and study the existing conditions of the 80-year-old structure.

Team/Owner Details

Owner: Colorado State University

Architect: The Neenan Company

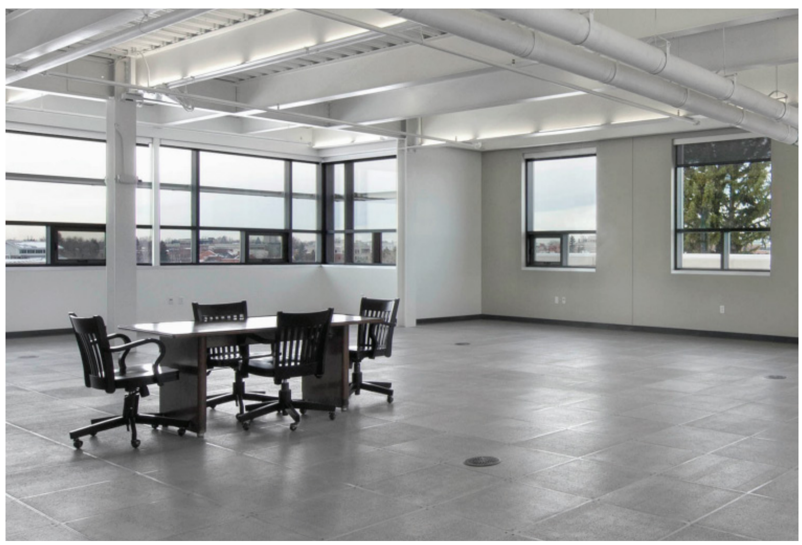
MEP Engineering: AE Associates, SRB Consulting Engineering (electrical/plumbing), CSU Mechanical Engineering Department, Lind's Plumbing & Heating, Clanton and Associates (lighting/daylighting)

The project team incorporated a high performance building envelope, efficient hydronic heating and cooling systems and underfloor air distribution. Furthermore, the Powerhouse building has 100% solid state lighting, active daylight harvesting and advanced metering and control systems. The project received $67,000 in design and performance incentives through IDAP and is expected to save the University more than $40,000 in energy costs annually.

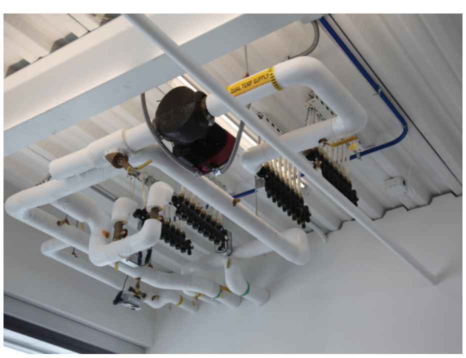
Radiant System

The radiant heating and cooling system for the Powerhouse building consists of a 26-mile network of radiant tubing through the floor slab, with the floor serving as the radiant surface on all 4 levels. Advanced controls forecast the weather to predict the heating and cooling needs of the spaces and adjust the radiant set points accordingly.

The radiant system was designed to function without a chiller. Cold water is instead supplied by a cooling tower that provides evaporatively cooled water to the system. Hot water for the radiant system is provided by a natural gas condensing boiler system using variable speed pumps. Underfloor air distribution systems provide ventilation for the radiant conditioned spaces.



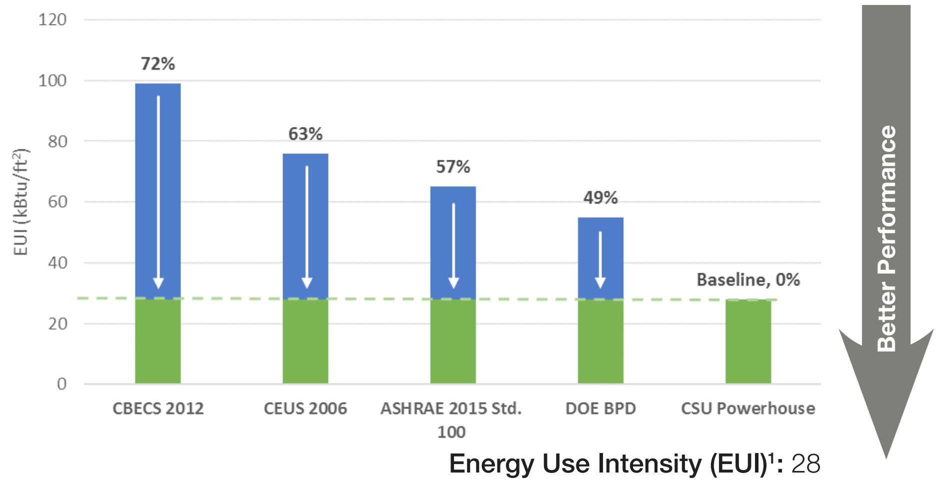
Underfloor air distribution systems support radiant conditioned spaces.
Photo: Fort Collins Utilities' Integrated Design Assistance Program



Radiant heating or cooling tubing.
Photo: Fort Collins Utilities' Integrated Design Assistance Program

Building Energy Use

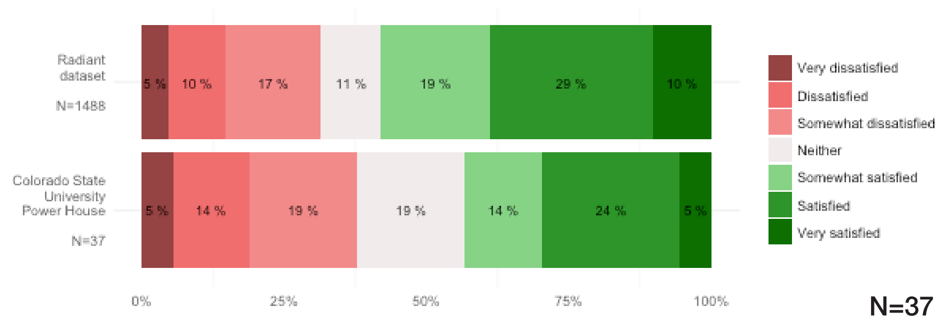
The CSU Powerhouse has a whole building energy use intensity (EUI) of just 28 kBtu/ft^2. Energy modeling of the advanced mechanical systems predicted 50-55% energy savings compared to other industrial buildings. The efficient radiant system uses only 25% of energy as compared to conventional space conditioning systems. Compared to national benchmarks, the CSU Powerhouse uses 72% less energy than CBECS 2012 data for educational buildings and 57% less energy than ASHRAE targets for education buildings in climate zone 5B.



Percent difference of educational building energy use intensity benchmarks compared to the CSU Powerhouse measured performance.

Thermal Comfort Feedback

Overall, the thermal comfort of the occupants in the CSU Powerhouse is similar to the other radiant buildings in the studied dataset. 43% of the occupants reported that they were satisfied, 19% reported that they were neither satisfied nor dissatisfied and 38% reported that they were dissatisfied. The variety of space types in this building (labs, offices, etc.) may contribute to the challenge of maintaining high comfort levels throughout the building. 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 CSU Powerhouse.

> "Colorado State design team results advanced high performance building practice by a decade, at minimum."
>
> *–Gary Schroeder, IDAP Coordinator*

> "Powerhouse Co-Directors have taken a bold step and presented us with a valuable opportunity for new development and leadership in the realm of building systems and building behavior."
>
> *–Bob Hosanna, Architect, The Neenan Co.*

Additional Efficiency Strategies and Features

Efficient Envelope

The envelope for the Powerhouse building is designed to be tight and well insulated to maximize the benefits from the radiant thermal mass. Exterior insulation is added to the concrete walls, while the windows have fiberglass frames with a high R-value of 7.5, ensuring better insulation and sealing. The windows are triple-paned and coated according to orientation to optimize the amount of solar heat gain in each zone. The use of interlocking metal panels in the facade, commonly used for commercial freezer systems, reduced air leakage through the envelope.

Lighting and Innovative Spaces

The collaborative spaces in the Powerhouse building are provided with 100% solid state lighting and active daylight harvesting. Sundolier skylight systems are used for the interior spaces, driving daylight deeper into the building core.

The roof of the Powerhouse building is equipped with a 40 kilowatt solar array and also houses an algae photobioreactor system used for research. The original smoke stacks of the municipal power plant facility have been replaced with vertical axis wind turbines and the old coal hopper has been replaced with a greenhouse that grows biofuel feedstocks for the Energy Institute's research activities.

Office and non-office spaces provided with ample daylighting.
Photo: Maximum Painting LLC

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%)[1].

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[2], and in a survey of 29 advanced ZNE and near ZNE buildings in California, where 11 include radiant systems[3]. The CSU Powerhouse low energy use is exemplary and the radiant system is part of the integrated approach that achieved that performance.

[1] California Commercial Energy Use Survey (CEUS) 2006 http://www.energy.ca.gov/ceus/
[2] New Buildings Institute Getting to Zero Database http://newbuildings.org/resource/getting-to-zero-database/
[3] 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.

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