Energy Use, Occupant Surveys and Case Study Summary: Radiant Cooling and Heating in Commercial Buildings

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Introduction

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 and separate ventilation through a dedicated outside air system. 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[1]. They can also offer peak demand reduction, load shifting, and improved comfort compared to conventional all-air systems.

The California Energy Commission (CEC) EPIC program funded a radiant research project from 2016-2018 to better characterize the energy use, occupant perceptions, opportunities for improvement, and provide data and resources to increase market adoption of radiant for both heating and cooling. The Center for the Built Environment (CBE) at UC Berkeley managed the full research project titled *Optimizing Radiant Systems for Energy Efficiency and Comfort*. Within this project New Buildings Institute led Task 5: *Energy Analysis and Occupant Surveys of Radiant Buildings* and conducted the energy analysis and CBE led the occupant satisfaction survey and assessment.

The Task 5 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. The following reports from the Task 5 study are available: 1) Energy Use of Radiant Buildings, 2) Occupant satisfaction with thermal comfort and acoustic quality in buildings using radiant and all-air systems and 3) Nine Building Case Studies of Radiant Heating and Cooling at www.cbe.berkeley.edu and www.newbuildings.org.

This summary provides an overview of the Energy Report Results and of nine case studies on buildings with radiant heating and cooling systems conducted in Task 5.

Study Goals

The goals for the Task 5 Study are largely separated between energy and occupant satisfaction. For energy, the primary goal is to report actual whole building energy usage of existing buildings that have both radiant heating and cooling systems and to compare the research buildings with other benchmarks of energy performance as a means to support large-scale energy savings potential estimates in California. A secondary energy goal is to provide real-world examples of successful radiant buildings which aid designers and overall market transformation.

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[1] Water transfers thermal energy about 7 times more effectively than air. CBE Brower Study, CEC EPIC 2011. http://escholarship.org/uc/item/7tc0421f

The primary goal of the occupant satisfaction portion of this project is to compare the Indoor Environmental Quality of radiant buildings and all-air buildings, particularly for thermal comfort and acoustic quality. Gathering feedback from occupants in the field adds to the overall body of knowledge and provides valuable feedback to designers and operators to optimize existing and future radiant buildings.

Building Selection

To screen for eligible buildings, the research team did an extensive search from various database, research sources and through leading design and engineering firms and manufacturers. This study focus was specifically on high thermal mass radiant systems — referred to as thermally activated building systems (TABS). A TABS system has radiant tubing embedded in a structural slab. Also included are radiant systems with tubing embedded in topping slabs separated from structural slabs by insulation — referred to as embedded surface systems (ESS). In addition, buildings that met thermal needs with piping located in metal panels suspended from the ceiling (ceiling panel systems) were also included. The research looked throughout North America for commercial buildings of all major types over 5,000 square feet (ft^2). One significant limitation to the study set size was reductions in the initial lists of radiant buildings due a limited proportion of a building using radiant (e.g. lobby only) or radiant being used for heating only, rather than heating and cooling. Through this effort the team identified about 140 buildings and obtained contacts at 50 of these buildings. The research team was able to obtain data and/or occupant surveys in approximately half of these study candidates.

Full Study Findings

Energy Use

Radiant systems are often thought to lead to lower energy use compared to all-air systems. In this project, we collected the building characteristics and the whole building actual energy use data from building owner, operators and design firms to help test this claim. The data analysis methodology utilized standard energy performance metrics and datasets from which to a) represent the research dataset energy performance and b) compare it to national benchmarks and calculate energy use differences. Energy is reported in Energy Use Intensity (EUI, $kBtu/ft^2$). Normalized building performance is reported with EnergyStar scores[2].

Dataset Energy Results

By all comparison metrics, the 23 radiant buildings in the full research study outperformed benchmark values. Most buildings exceeded EnergyStar certification performance requirements, with two thirds receiving an EnergyStar score of 90 or above, signifying that these buildings outperform 90% of comparable buildings. The bulk of the buildings were clear leaders compared to peer buildings in both CBECS[3] and the Buildings Performance Database (BPD)[4]. The median

[2] https://www.energystar.gov/buildings/facility-owners-and-managers/existing-buildings/use-portfolio-manager/understand-metrics/how-1-100
[3] CBECS: https://www.eia.gov/consumption/commercial/
[4] BPD: https://bpd.lbl.gov/

EUI of the research dataset is 38 kBtu/ft^2, meaning that half the studied buildings were in the top 25% of these peer groups. The research dataset uses 32% and 31% less energy than the CBECS and BPD medians, respectively, as shown in Figure 1, and the study set is on par with the high efficiency target set by ASHRAE in Standard 100. Several buildings even reached net zero energy performance levels (~25 EUI) demonstrating the use of radiant as a path to high performance buildings.

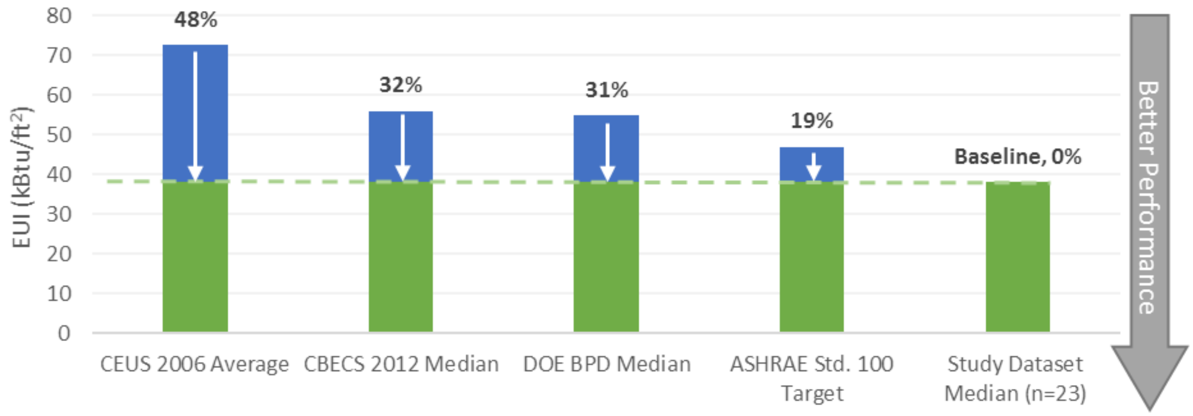

Figure 1: Office energy use benchmarks compared to the full research dataset.

Occupant Satisfaction

As seen in this research and in other published literature, radiant conditioning systems offer opportunities to achieve higher energy efficiency. Yet, little is currently known about how radiant systems affect the Indoor Environmental Quality (IEQ) in buildings. In this project, we set out to make a significant contribution to the body of knowledge on this topic by surveying occupants in these radiant buildings.

Occupant Survey Methodology

We used the online CBE Occupant Indoor Environmental Quality Survey administered by the Center for the Built Environment, University of California Berkeley, to perform the data collection. The survey is composed of a set of basic questions about occupant demographics followed by nine core categories of indoor environmental quality, including: thermal comfort, air quality, acoustics, lighting, cleanliness, spatial layout, office furnishing, and general building and workspace satisfaction. Each of these categories were measured on a 7-point scale, ranging from 'very dissatisfied' to 'very satisfied', with a neutral point in the center. Participants completed the survey online after receiving an invitation via email. The survey was designed to take approximately 10-15 minutes to complete.

With this new body of occupant survey data, the UC Berkeley team meticulously analyzed the results and compared them to a comparable subset of non-radiant or "all-air" buildings from the CBE database of past occupant surveys. The resulting comparison set included 26 radiant buildings (1645 occupants) and 34 specifically selected all-air buildings (2247 occupants).

Occupant Survey Results

The primary focus of the occupant satisfaction survey is to compare the radiant and all-air datasets, specifically focusing on thermal and acoustic satisfaction. The analysis by the UC Berkeley team found no statistically significant difference in acoustic comfort between the two datasets. For thermal comfort, the team observed the following:

A) Occupants of buildings conditioned by radiant systems showed a higher mean and median temperature satisfaction than occupants from all-air conditioned buildings (See Figure 2 and Figure 3).

B) In a space using a radiant system, a person has a 66% chance of having an equal or higher temperature satisfaction than in an all-air conditioned building.

The 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.

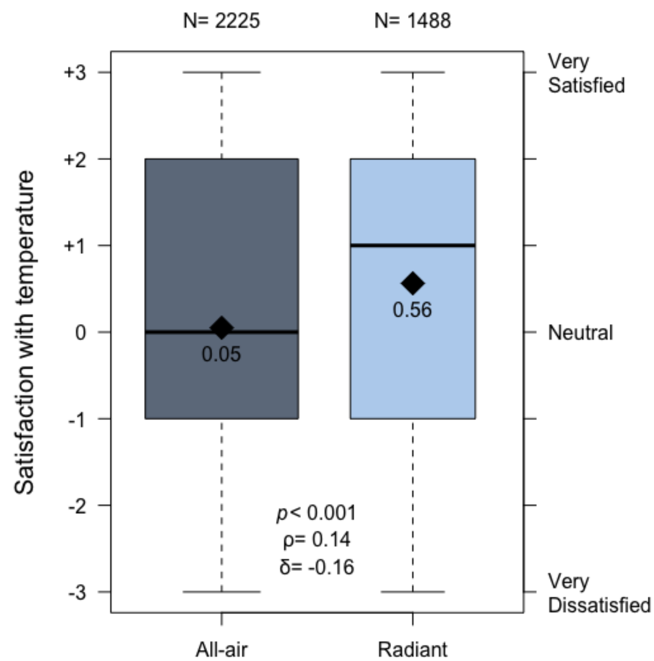

Figure 2: Boxplot of temperature satisfaction for the two groups. Diamond dots represent mean values.

Key Takeaways

Although a radiant system is not the sole driver of good energy performance it can be an important part of an integrated approached from design and technology selection through to occupancy and operations. In California, low-energy outcomes rely on strong strategies to address the HVAC systems which represent the highest proportion of commercial building energy use (32%)[5]. This research found the majority of the study set buildings (96%) were pursing high levels of LEED certification, where reduced energy is a requirement. This mirrors the findings in the largest database of Zero Net Energy (ZNE) buildings where more than half of ZNE buildings in North America use a radiant system[6], and in a survey of 29 advanced ZNE and near ZNE buildings in California where 11 include radiant systems[7].

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

For occupant satisfaction, though not definitive, the radiant dataset did show a tendency to perform at least as well as all-air systems in terms of thermal comfort. Acoustically, there was no significant difference observed in this study between the two system types.

The work on both the energy and occupant satisfaction portions of this project offer significant and substantive contributions to the limited body of knowledge pertaining to radiant buildings. Real-world data is challenging to collect, but offers important feedback to researchers and building designers alike. The conclusions from this project will guide future research priorities and provide designers with examples of successful designs and actionable advice from radiant building occupants.

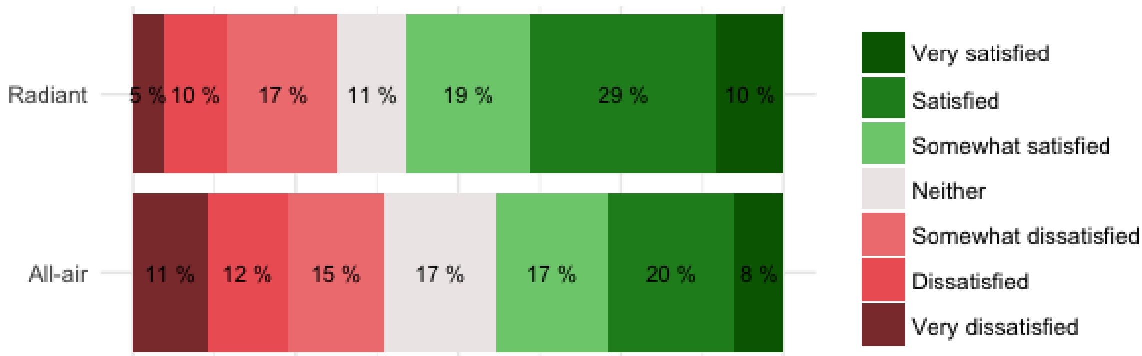

Figure 3: Occupant response distribution of temperature satisfaction for radiant and all-air systems

Case Study Summary

The research team did a deeper look at nine buildings that were part of the Task 5 study on energy use and occupant satisfaction. The case studies provide base information on the building characteristics, present the individual building energy use compared to benchmarks, highlight strategies used to achieve high performance energy outcomes and, in most cases, include results of the portion of the occupant survey related to thermal comfort.

As discussed above regarding the full research dataset these buildings are targeting very low, and in some cases zero net energy (Bullitt Building) and many incorporate some level of renewable energy onsite. These performance goals drive the design team to go beyond the standard 'air-in-a-box' method for cooling commercial buildings which is dominated by Rooftop Unitary Package Units and Variable Air Volume systems that distribute thermally tempered air and ventilation air through duct work. These 'forced-air' systems use extensive energy for the fans that push and pull this air throughout the building and within the system. Radiant systems eliminate the fan energy for heating and cooling and the ventilation is usually provided through a Dedicated Outside Air System (DOAS) which often includes heat and/or energy recovery.

These case studies have many commonalities to achieve their low-energy use goals such as reducing the overall building energy load through advanced envelope materials and insulation, high performance glazing, reduced ratio of windows, and exterior and interior shading. The integrated approach for reduced building loads also includes passive solutions first such as natural ventilation and the use of daylighting before the technology solutions are applied. The design teams applied advanced lighting, occupant and building-level energy monitoring and controls, and radiant systems with DOAS to meet their thermal comfort needs.

Case Study Buildings

Table 1: Summary of Radiant Heating and Cooling Building Case Studies.

Building Name	City	State	Type	Size (ft^2)	EUI[8]	EnergyStar Score	Year Built	Occupant Survey
Bullitt Foundation Cascadia Center for Sustainable Design and Construction	Seattle	WA	Office	52,000	12	99	2013	Yes
Colorado State University Powerhouse Energy Campus	Fort Collins	CO	Education	95,000	28	98	1936	Yes
Edith Green Wendell Wyatt Federal Building	Portland	OR	Office	440,000	32	97	2013	No
Lovejoy Opsis	Portland	OR	Office	10,000	48	68	1910	Yes
National Renewable Energy Laboratory (NREL) Research Support Facility (RSF)	Golden	CO	Office	360,000	36	98	2010	Yes
Oregon Department of Transportation Building	Salem	OR	Office	147,000	36	96	1950	Yes
Pomona College, Millikan Science building	Claremont	CA	Education	75,000	52	92	2015	Yes
Port of Portland	Portland	OR	Office	205,000	46	85	2010	Yes
Reliable Controls Headquarters	Victoria	BC	Other	16,150	48.2	98	2012	Yes

The following section provides a snapshot of each building on energy use and occupant thermal survey results.

[8] Whole building site energy use intensity (kBtu/ft^2).

1. Bullitt Foundation Cascadia Center for Sustainable Design and Construction

[View the full case study >>]

The Bullitt Center in Seattle, Washington is a six-story, 44,700 square foot office building. The Bullitt Foundation, a nonprofit philanthropic organization with a focus on the environment, worked with local real estate firm Point32 to develop the $32.5 million building. The building was the vision of Denis Hayes to create "the greenest urban office building in the world" and it received the Sustainable Building of the Year award from World Architecture News in 2013 and many subsequent green building awards.

Photo: Miller Hull Partnership.

Building Energy Use

The Bullitt Center building has a whole building site Energy Use Intensity (EUI) of just 12 kBtu/ft². This is an exceptionally low energy use and aligned with the zero net energy and LBC goals whereby 100% or more of the building's annual energy use is offset by the rooftop photovoltaics (PVs). This low-energy use is 80-86% less than the average office EUI performance of the national CBECS[5] and California CEUS[6] datasets and offices in the same climate zone within the Building Performance Dataset (BPD) as seen in Figure 4. While those datasets include a mix of construction age the Bullitt building's energy use is also significantly lower than a new code building in the same year and ASHRAE's best-practice energy efficiency standard 100 targets by 70-71%.

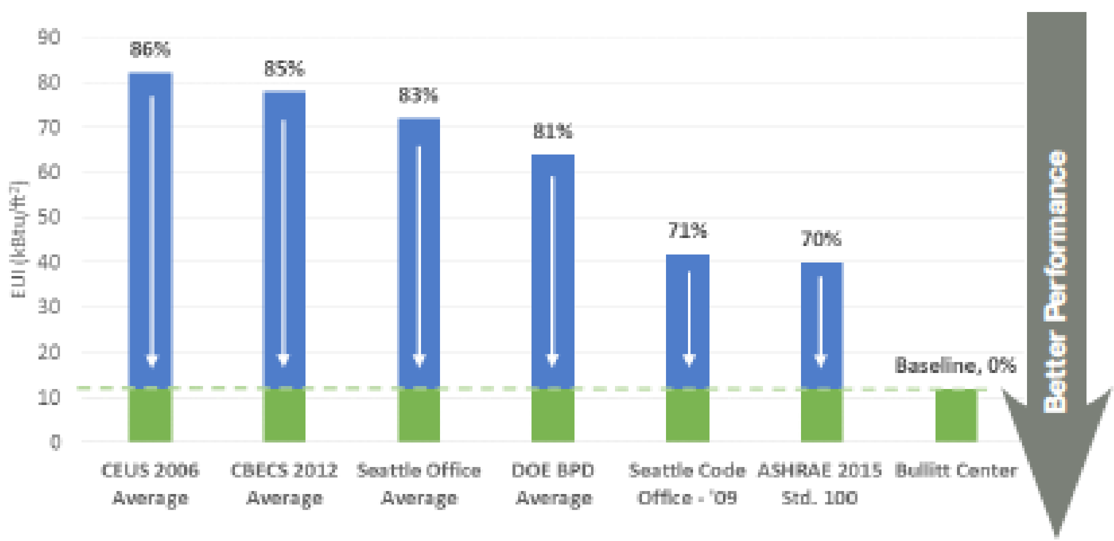

Figure 4: Percent difference of energy use intensity benchmarks compared to the Bullitt Building measured performance.

Occupant Thermal Comfort Feedback

The satisfaction reported at the Bullitt Center was lower than expected for a radiant building in this climate zone. Continued studies will work to refine the reasons for the modest satisfaction rate in this otherwise renowned building design. In the Bullitt Center 63% of the occupants reported that they were satisfied, 4% reported that they were neither satisfied nor dissatisfied and 34% reported that they were dissatisfied (Figure 5).

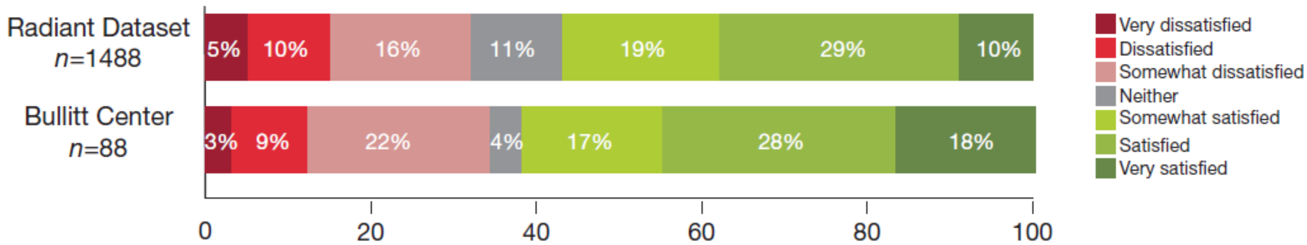

Figure 5: Results on thermal comfort question within the CBE occupant satisfaction survey. Credit: Caroline Karmann.

2. Colorado State University Powerhouse Energy Campus

View the full case study >>

Photo: Fort Collins Utilities' Integrated Design Assistance Program.

The Colorado State University (CSU) Powerhouse Energy Campus is a 65,000 square foot (SF) addition to the 1930's 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.

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.

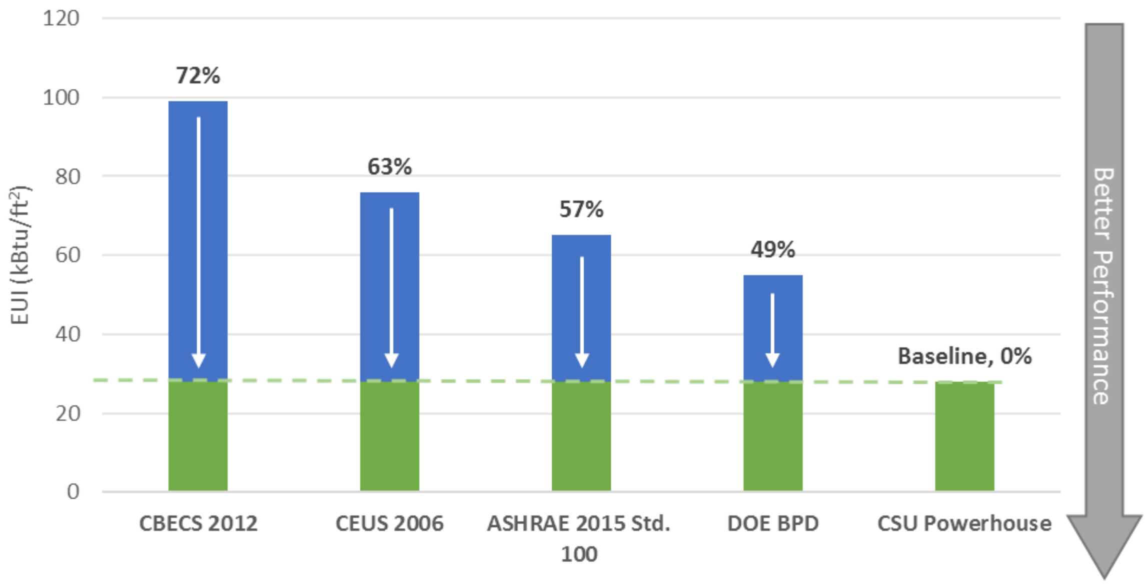

Figure 6: Percent difference of energy use intensity benchmarks compared to the CSU Powerhouse measured performance.

Occupant 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%.

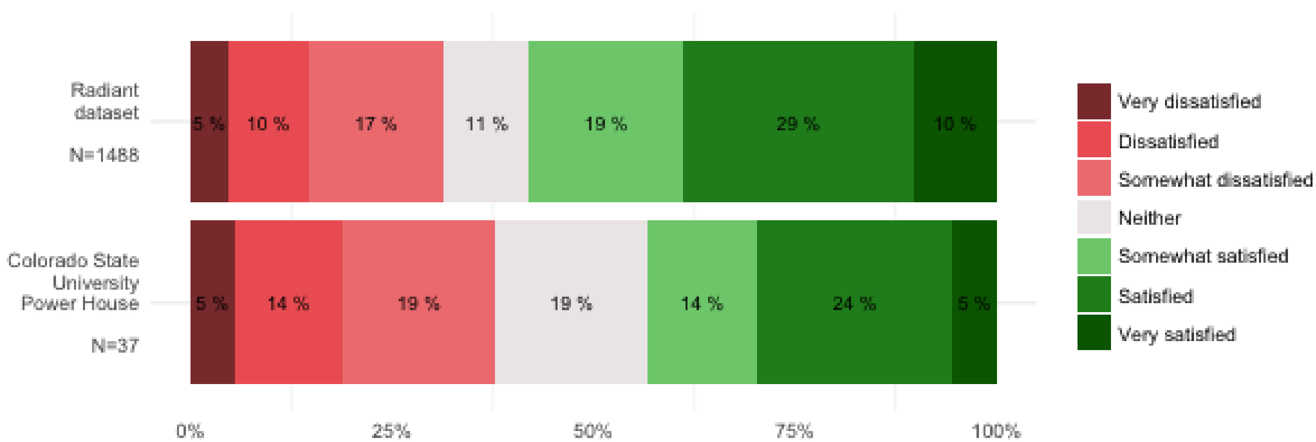

Figure 7: Results of thermal comfort satisfaction within the overall CBE occupant satisfaction survey. Credit: Caroline Karmann.

3. Edith Green Wendall Wyatt Federal Building

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Photo: Nic Lehoux Architectural Photography.

The Edith Green-Wendell Wyatt Federal Building (EGWW) is an 18-story, 512,474 square foot office building located in Portland, Oregon. The building houses more than 16 federal agencies, 1,200 federal employees and is operated by the U.S. General Services Administration (GSA). This building was renovated from 2009-2013 and is now one of the most energy efficient large office buildings in the country with updated mechanical, electrical, plumbing and controls systems, which earned the building LEED Platinum Certification. Radiant ceiling panels were selected to heat and cool the building.

Building Energy Use

The EGWW building has a whole building site Energy Use Intensity (EUI) of 32 kBtu/ft². Despite the large square footage of the EGWW, the building's energy use is significantly lower than the office-only EUI of the national CBECS 4 and California CEUS 5 existing building datasets by approximately 60% as seen in Figure 8. The EGWW energy use is also lower than the national Building Performance Dataset (BPD) EUI for offices in the same climate zone and the modeled energy use of a new building built to Oregon code by about 50%. The building's EUI of 32 kBtu/ft² is also 20% better than the ASHRAE energy efficiency Standard 100 for mixed-use offices, which represents the 25th percentile of lowest energy use targets in the same climate zone. Through a range of factors, including the selection of a radiant system for heating and cooling, the EGWW energy use is exceptionally low for its type and size.

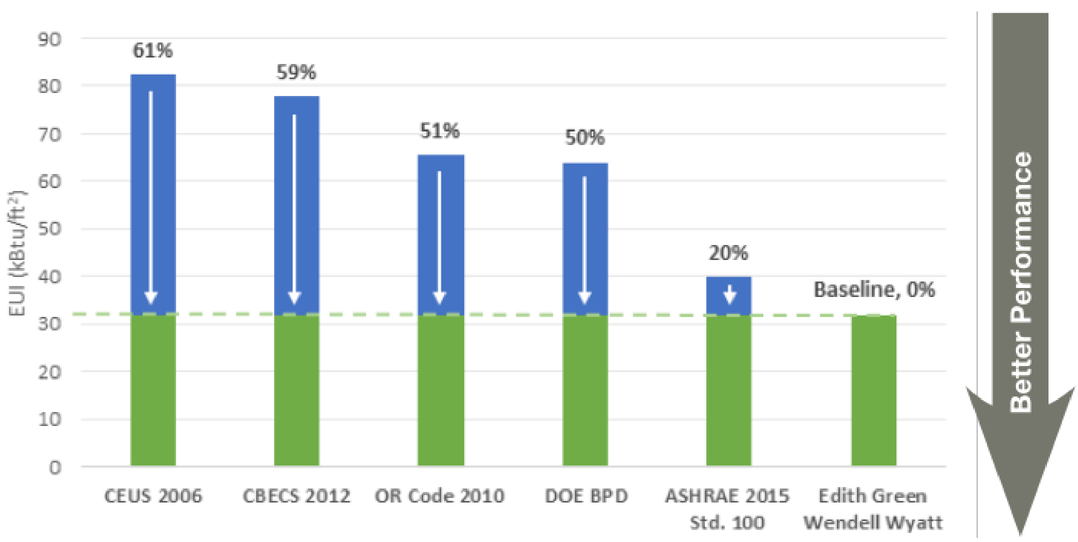

Figure 8: Percent difference of energy use intensity benchmarks compared to the Edith Green Wendell Wyatt Building measured performance.

Occupant Thermal Comfort Feedback

There was no occupant survey of indoor environmental perceptions done through the California Energy Commission EPIC research project for EGWW, but the GSA notes that through their own satisfaction survey that "the buildings boasts an occupant satisfaction of 75%".

4. Lovejoy Opsis

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The Lovejoy Opsis Building in Portland, OR, is a two-story, 19,460 square foot 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.

Photo: 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 9. The energy use is also 25% lower than the national Building Performance Dataset (BPD)[7] 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.

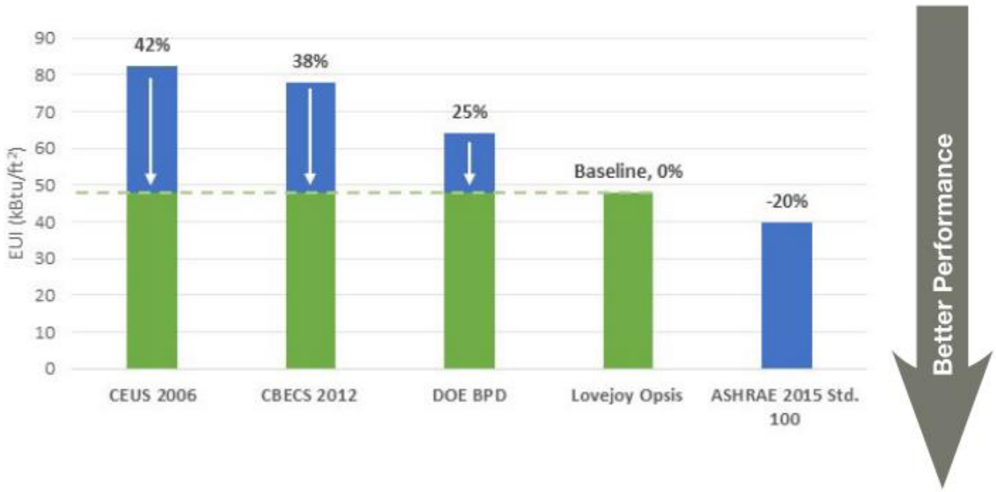

Figure 9: Percent difference of energy use intensity benchmarks compared to the Lovejoy Opsis Office measured performance.

Occupant 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."

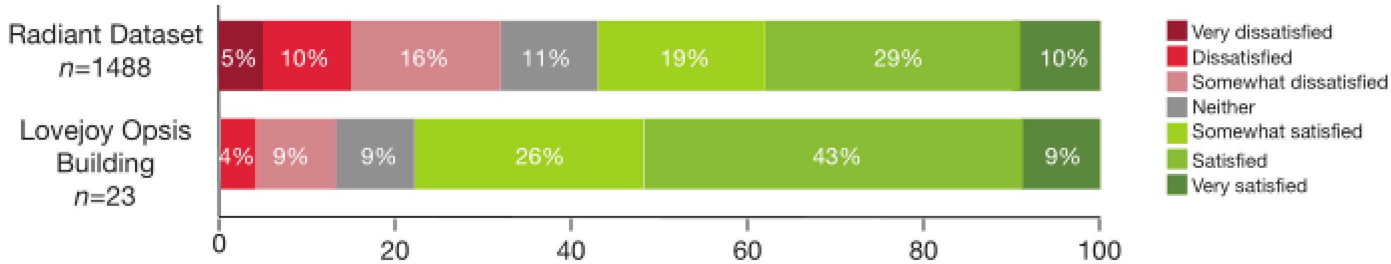

Figure 10: Results of thermal comfort satisfaction within the overall CBE occupant satisfaction survey. Credit: Caroline Karmann.

5. National Renewable Energy Laboratory (NREL) Research Support Facility (RSF)

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Photo: Stantec.

The Research Support Facility (RSF) is a 222,000 square foot, four story office building located on the campus of U.S. Department of Energy's (DOE) National Renewable Energy Laboratory (NREL). Built in 2010, the building is one of the largest LEED® Platinum certified buildings in the nation, and was designed to be a zero net energy (ZNE) building. The project serves to align with DOE and NREL's long term goals of clean energy and resource minimization.

The office building housing 800 staff was designed to meet NREL's ZNE goals by adapting an integrated approach to climate-responsive design and high performance building systems. The building integrates passive strategies by optimizing the building form and design to incorporate natural ventilation, daylight and thermal mass. A low energy HVAC system supports the passive strategies. Open offices spaces are served by hydronic radiant slab ceilings paired with a dedicated outdoor air systems for ventilation and dehumidification. A traditional VAV reheat system serves non-office spaces.

Building Energy Use

The RSF has a whole building site Energy Use Intensity (EUI) of 36 kBtu/ft². This low-energy use is 51-56% less than the average office EUI performance of the national CBECS and California CEUS datasets and of offices in the same climate zone within the Building Performance Dataset (BPD), as seen in Figure 11. While those datasets include a mix of construction ages, the RSF is also performing better than ASHRAE's best-practice energy efficiency standard 100 targets by 14%.

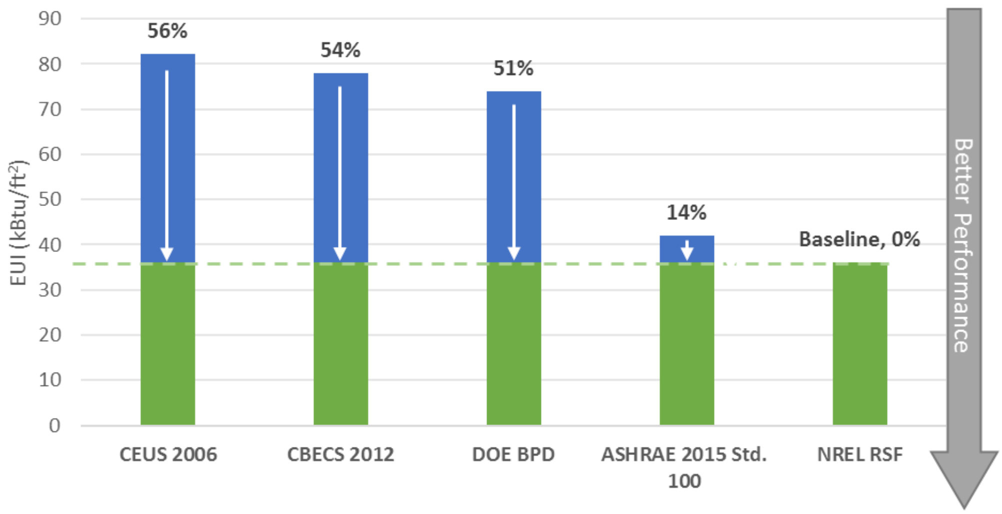

Figure 11: Percent difference of energy use intensity benchmarks compared to the NREL RSF measured performance.

Occupant Thermal Comfort Feedback

Overall, the thermal comfort of the occupants in the RSF is very good. 68% of the occupants reported that they were satisfied, 11% reported that they were neither satisfied nor dissatisfied and 22% reported that they were dissatisfied. The satisfaction reported at the RSF was higher than the sample dataset overall and higher than comparable all-air buildings.

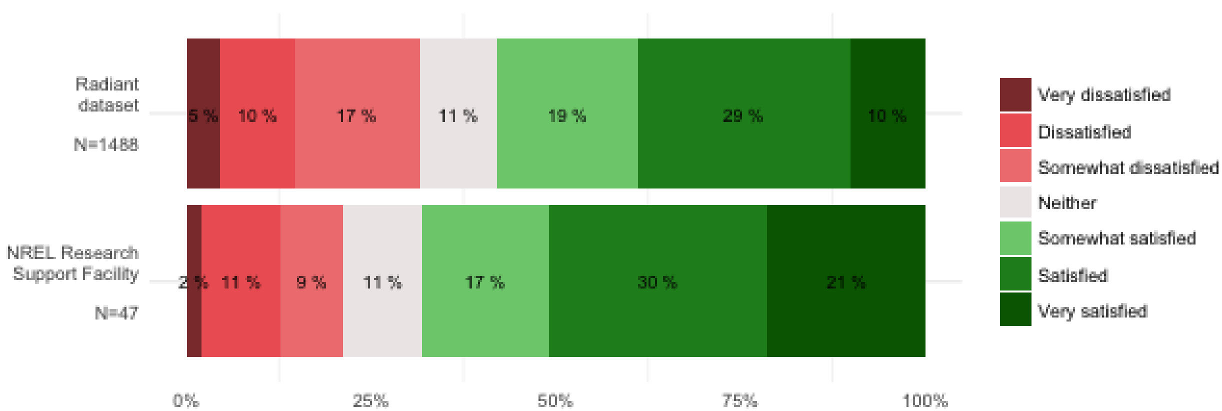

Figure 12: Results of thermal comfort satisfaction within the overall CBE occupant satisfaction survey. Credit: Caroline Karmann.

6. Oregon Department of Transportation (ODOT) Building

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The Oregon Department of Transportation (ODOT) headquarters is a 5 story, 147,000 square foot (SF) office building housing 460 employees. The headquarters is a retrofit of a 1950's 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.

Photo: SERA Design.

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 the 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.

Building Energy Use

The ODOT building has a whole building site Energy Use Intensity (EUI) of just 36 kBtu/ft^2. This low-energy use is 44-56% less than the average office EUI performance of the national CBECS dataset, current Oregon code levels, and offices in the same climate zone within the Building Performance Dataset (BPD), as seen in Figure 13. 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%.

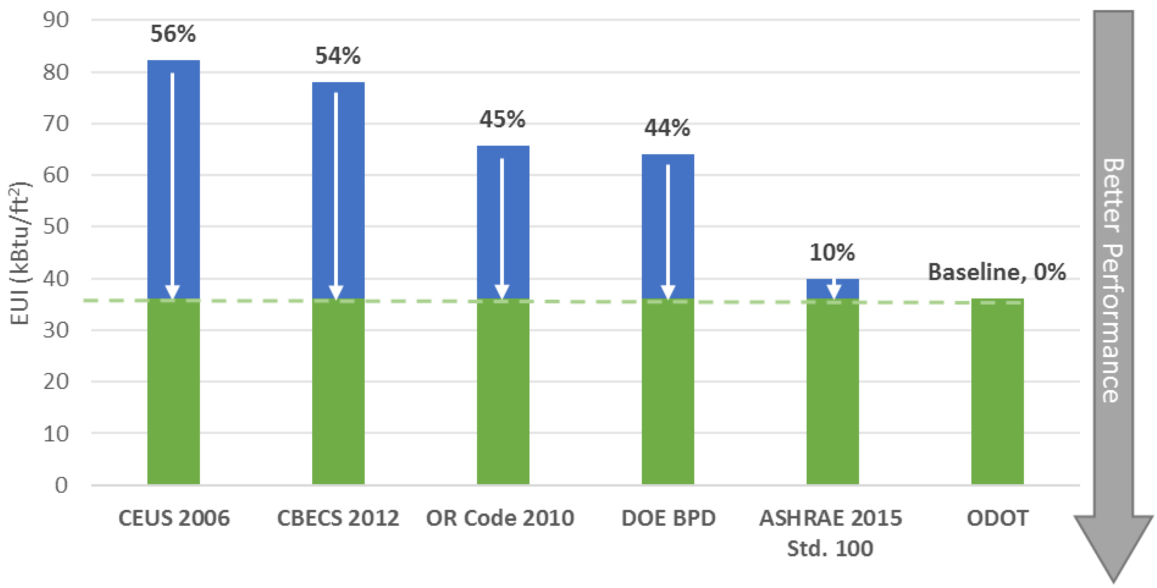

Figure 13: Percent difference of energy use intensity benchmarks compared to the ODOT building measured performance.

Occupant 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%.

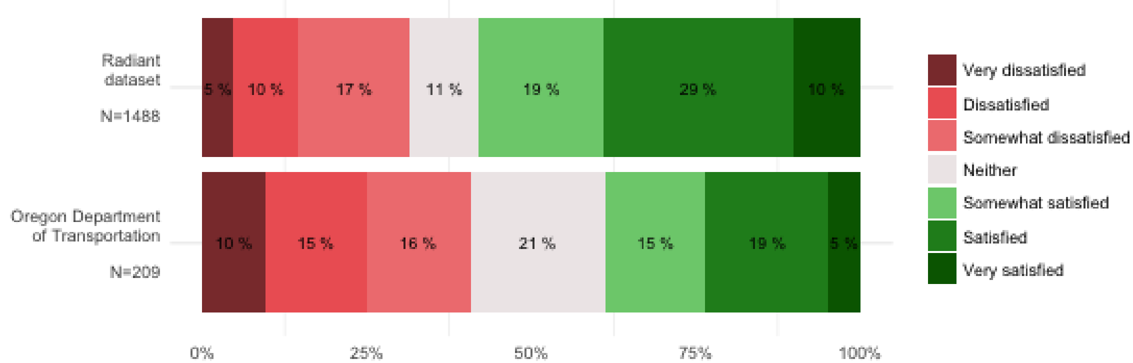

Figure 14: Results of thermal comfort satisfaction within the overall CBE occupant satisfaction survey. Credit: Caroline Karmann.

7. Pomona College, Millikan Science Building

View the full case study >>

The Pomona College Millikan Laboratory and Andrew Science Hall (Millikan Building) is a 3-story, 75,000 square foot building comprised of physics laboratories, machine shops, a computer lab, teaching spaces, faculty and administration offices and student common areas located in Claremont, California.

Photo: Jim Simmons.

Building Energy Use

The Millikan building has a whole building site Energy Use Intensity (EUI) of 52 kBtu/ft². Despite the inclusion of the very high energy use of labs and shops, Millikan Building's energy use is significantly lower than the office-only EUI of the national CBECS 4 and California CEUS 5 datasets by more than 30% as seen in Figure 15. When compared to other mixed-use lab and office buildings with nearly equal ratios of these uses, and in similar climate zones, the Millikan Building is using an impressive 75% less energy. Further, the building achieved significant savings (68%) compared to its pre-retrofit levels. Through a range of factors, including the selection of a radiant system for heating and for cooling the office portion, the Millikan Building energy use is very low for its type and design.

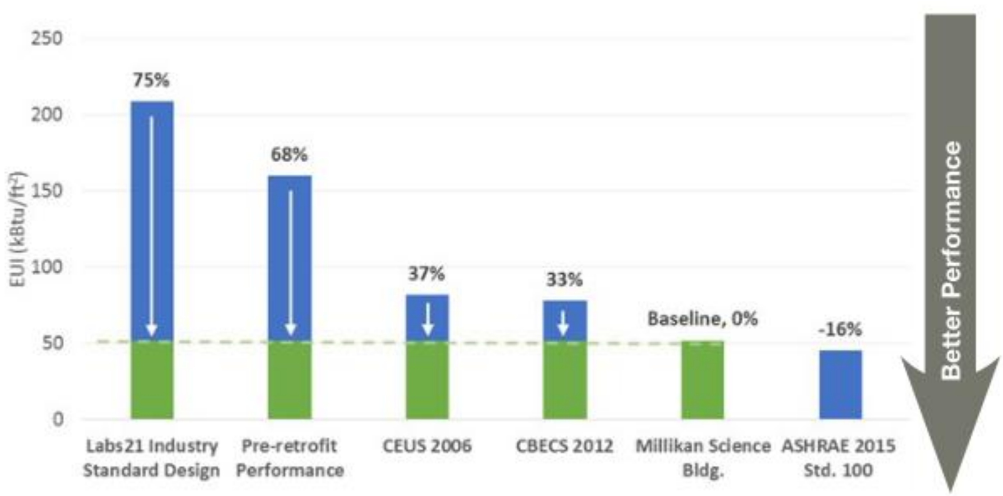

Figure 15: Percent difference of energy use intensity benchmarks compared to the Millikan Science Building measured performance.

Occupant Thermal Comfort Feedback

Overall the thermal comfort of the occupants in the Millikan building is exceptionally high. 84% of the occupants reported that they were satisfied, 8% reported that they were neither satisfied nor dissatisfied and only 8% reported that they were dissatisfied. The satisfaction reported at the Millikan building is much higher than the full study sample dataset overall.

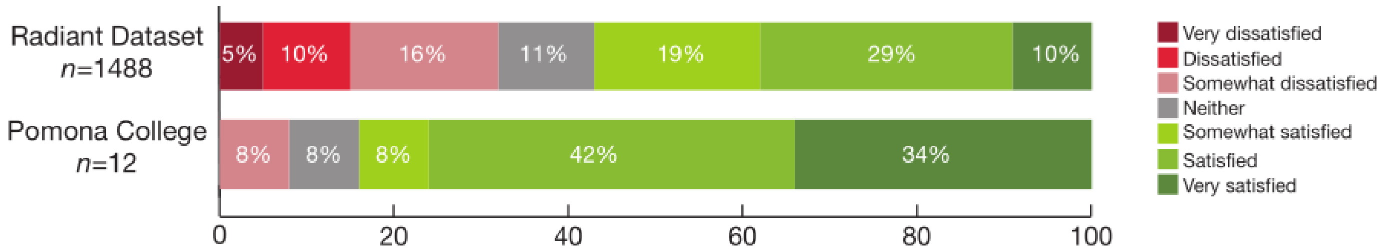

Figure 16: Results of thermal comfort satisfaction within the overall CBE occupant satisfaction survey. Credit: Caroline Karmann.

8. Port of Portland

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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.

Photo: Loren Nelson.

Building Energy Use

The Port Building has an Energy Use Intensity (EUI) of 46 kBtu/ft², 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 17. 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)[4] 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.

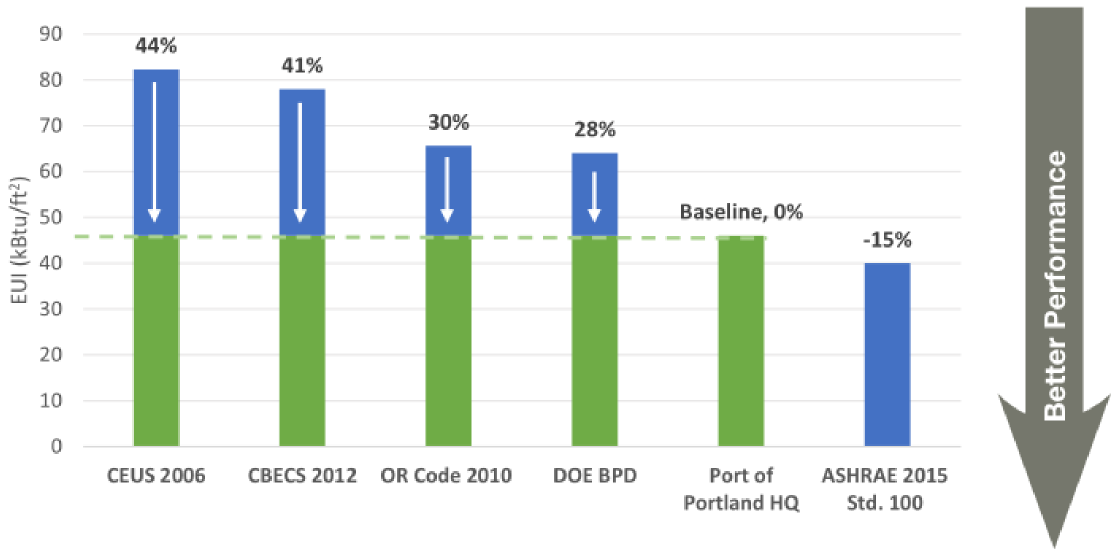

Figure 17: Percent difference of energy use intensity benchmarks compared to the Port of Portland HQ measured performance.

Occupant 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).

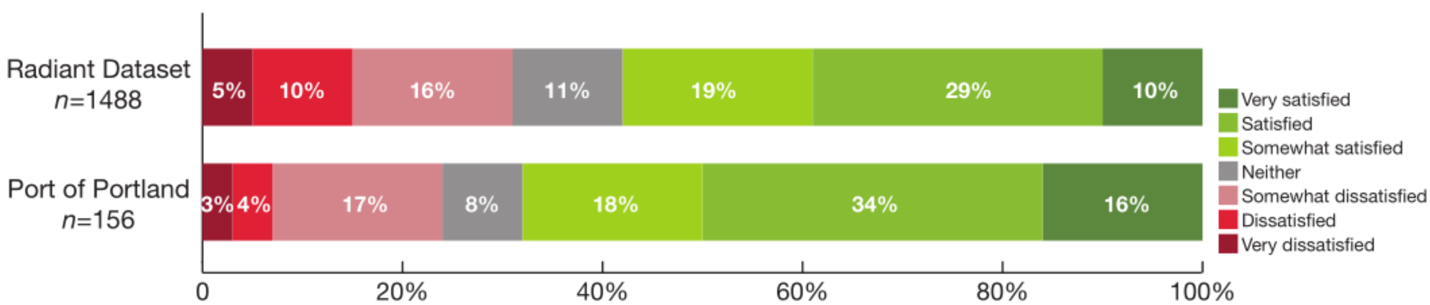

Figure 18: Results of thermal comfort satisfaction within the overall CBE occupant satisfaction survey. Credit: Caroline Karmann.

9. Reliable Controls Headquarters

View the full case study >>

Photo: D'Ambrosio Architecture + Urbanism.

The Reliable Controls Headquarters annex is a four story office building housing 80 employees. The 16,000 square foot (SF) building is LEED Platinum certified, designed to operate using 50% less energy than standard ASHRAE 90.1(1999) building.

The project was built as an expansion to accommodate the firm's research and development wing. The building integrates passive technologies and radiant space conditioning systems to considerably reduce the energy consumption of the building. The energy conservation measures, coupled with an extensive storm water management and soil erosion strategy contributed to exceeding the points for LEED platinum target and managed to reduce the water consumption by 60%.

Building Energy Use

The Reliable Controls HQ has a whole building site Energy Use Intensity of 48 kBtu/ft^2. This low-energy use is 25-41% less than the average office EUI performance of the national CBECS[9] dataset, the California CEUS[10] dataset, and offices in the same climate zone within the Building Performance Dataset (BPD)[11], as seen in Figure 19. While those datasets include a mix of construction ages, the Reliable Controls HQ energy use is also on par with ASHRAE's best-practice energy efficiency standard 100 EUI target for this building type and climate zone.

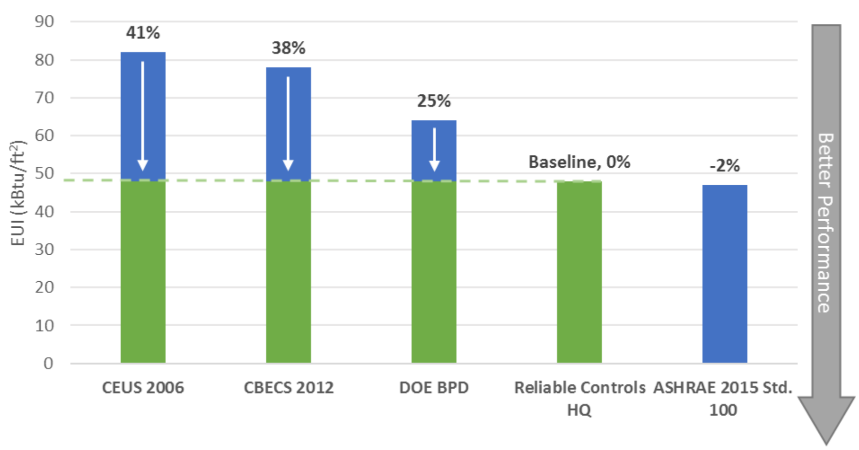

Figure 19: Percent difference of energy use intensity benchmarks compared to the Reliable Controls HQ measured performance.

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[9] U.S. Energy Information Agency Commercial Buildings Energy Consumption Survey (CBECS)
[10] California Commercial Energy Use Survey (CEUS) 2006 http://www.energy.ca.gov/ceus/
[11] U.S. Department of Energy Building Performance Dataset (BPD)

Occupant Thermal Comfort Feedback

Overall, the thermal comfort of the occupants in the Reliable Controls HQ is relatively high as compared to the other radiant buildings in the studied dataset. 64% of the occupants reported that they were satisfied, 11% reported that they were neither satisfied nor dissatisfied and 25% reported that they were dissatisfied. For additional comparison, the average size of the satisfied group for all buildings surveyed by the Center for the Built Environment (CBE) is 40%.

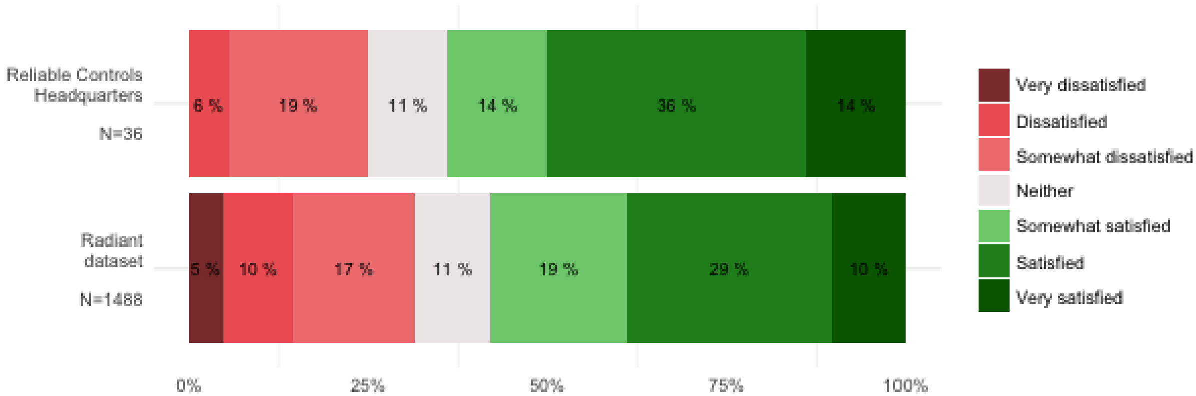

Figure 20: Results of thermal comfort satisfaction within the overall CBE occupant satisfaction survey. Credit: Caroline Karmann.