RADIANT COOLING

ENABLING EVEN GREATER ENERGY EFFICIENCY FOR HIGH PERFORMANCE BUILDINGS

Radiant cooling offers several energy efficiency advantages

- Electricity use for fans and pumps can be much smaller than for all-air systems.
- Cooling plant efficiency can be higher than for all-air systems.
- Room air temperature is 0.25–1 °C warmer in radiant cooled spaces, which can reduce ventilation cooling needs.
- Radiant decouples ventilation from space cooling.
    a. Avoids the need for terminal reheat.
    b. Avoids energy consumed by incidental dehumidification.
- High thermal mass radiant systems can allow cooling plant operation during non-peak periods.

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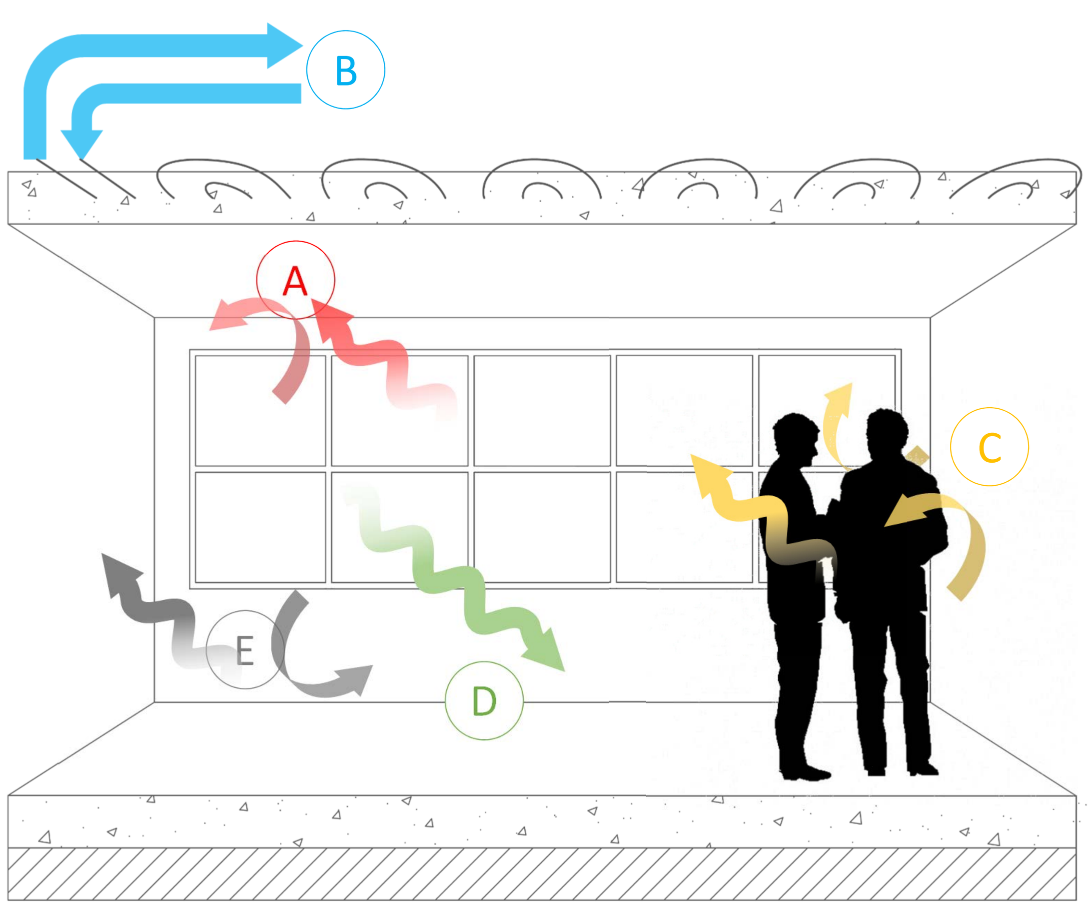
The heat transfer dynamics for radiant cooling have design and control implications



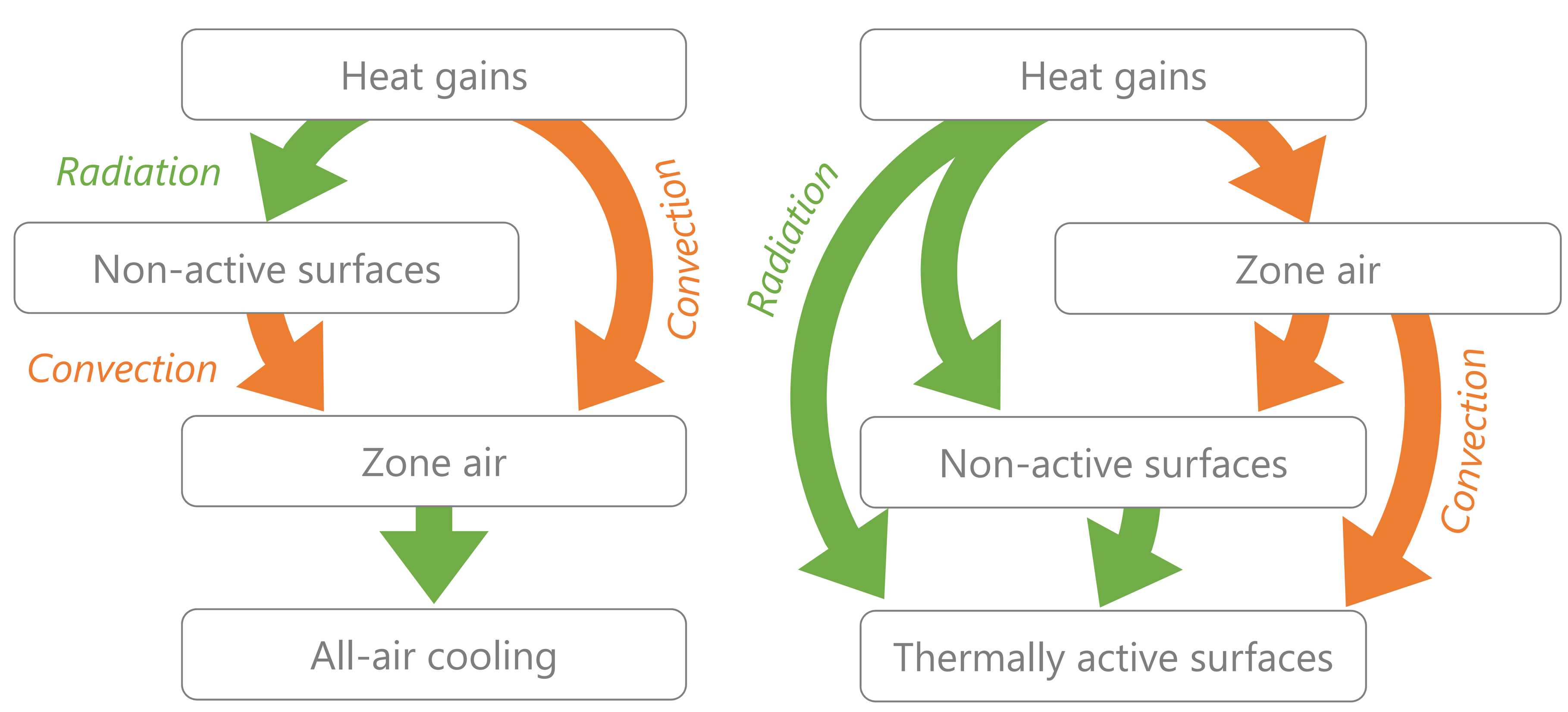
- A Space cooling
- B Hydronic cooling
- C Internal heat gains
- D Solar heat gain
- E Envelope heat transfer

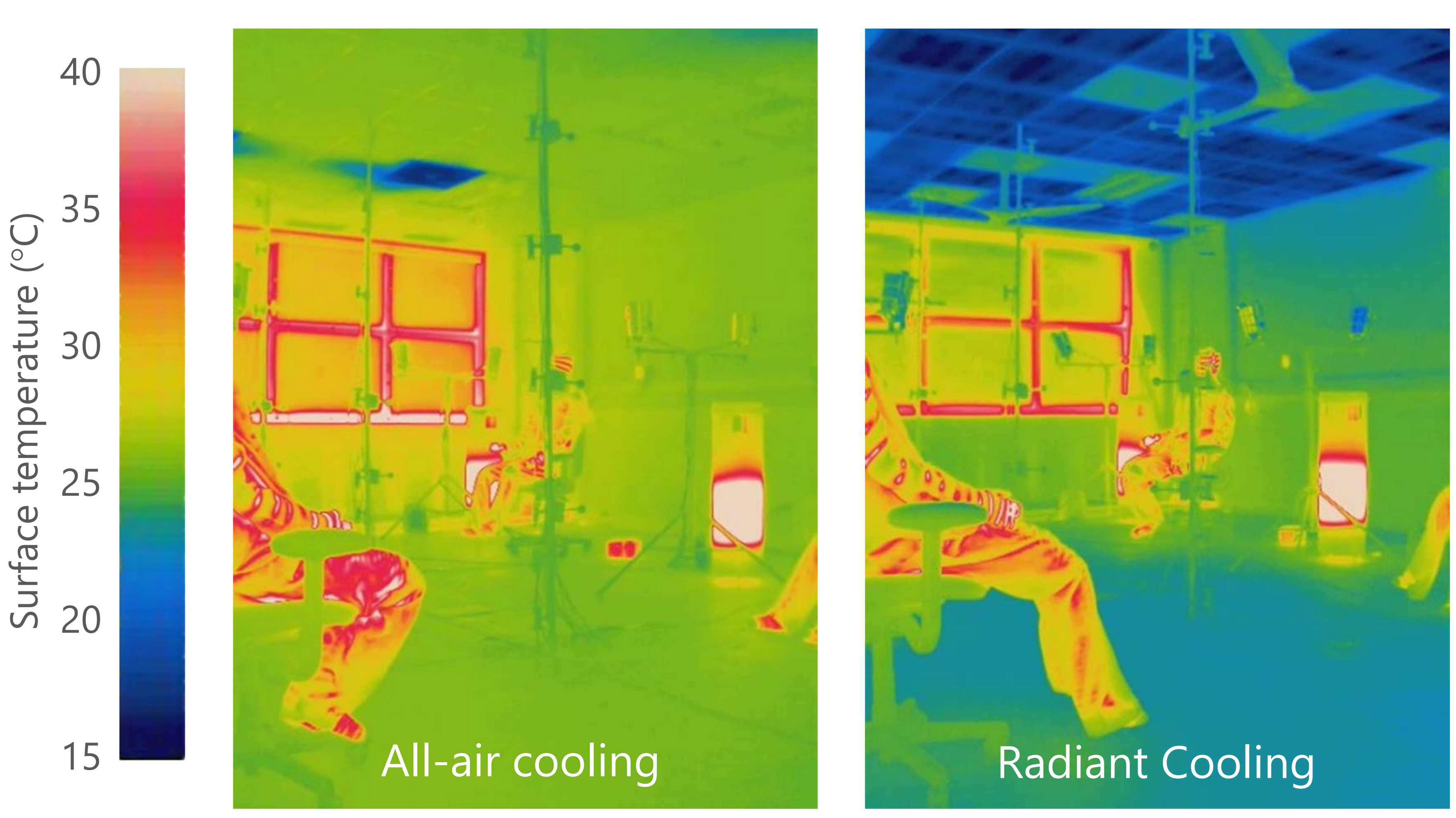
- Radiant cooling extracts heat by convection and by radiation. Longwave and shortwave radiation is absorbed from gains as well as non-active surfaces.
- The temperatures of all interior surfaces are lower in buildings with radiant cooling, and the non-active masses store less heat than in buildings with all-air cooling.
- Since less heat is stored in masses, buildings with radiant cooling have less opportunity for passive cooling, such as from natural ventilation.

- To maintain equivalent comfort conditions, the design space cooling capacity for radiant systems must be larger than for all-air systems.
- Radiant cooling must remove more heat than all-air cooling – in part because envelope heat transfer changes.
- High thermal mass radiant systems have a long response time. This enables load shifting because the hydronic and space cooling rates are decoupled.
- The space cooling rate for high thermal mass radiant systems is self-regulating – it naturally adapts in response to dynamic heat gains.
- Most high thermal mass radiant systems also include air systems to provide supplemental cooling.

Heat transfer pathways for all-air cooling

Heat transfer pathways for radiant cooling





Equal comfort. Different temperatures.

All-air cooling
Operative temperature = 26 °C
Air temperature ≈ 25.5 °C
Mean radiant temp. ≈ 26.5 °C

Radiant cooling
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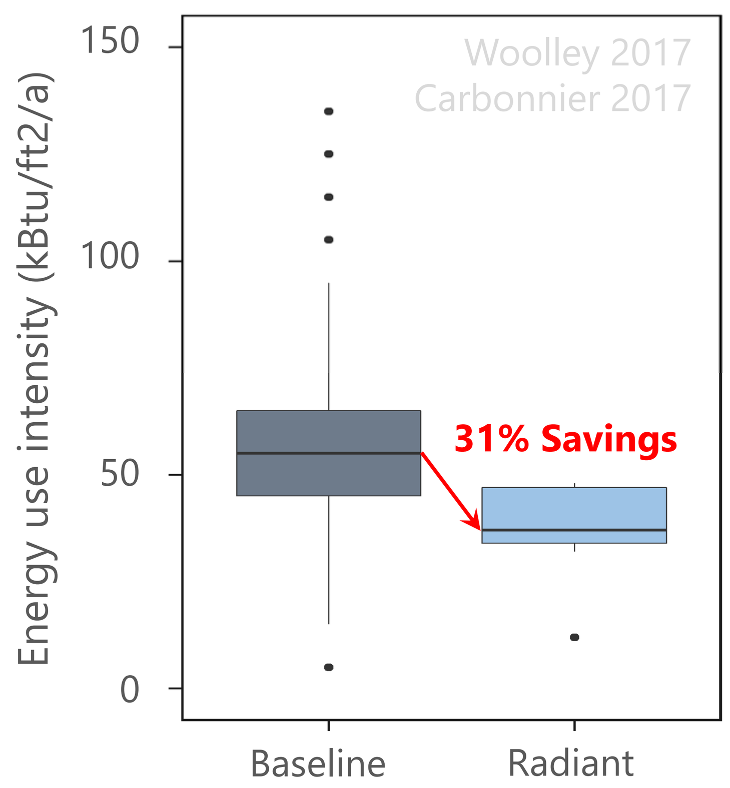
Air temperature ≈ 26.5 °C
Mean radiant temp. ≈ 25.5 °C

Buildings with radiant cooling have similar comfort and use less energy

- Radiant cooling is most common among high performance buildings. A review of 26 zero net energy commercial buildings indicates that 42% included radiant cooling or heating.
- The median energy use intensity for buildings with radiant cooling is 14–66% lower than standard buildings of comparable type and climate zone. Offices with radiant cooling use 31% less energy.
- Radiant and all-air spaces achieve similar satisfaction with indoor environmental quality. There is a tendency for occupants in radiant buildings to express greater satisfaction with temperature.

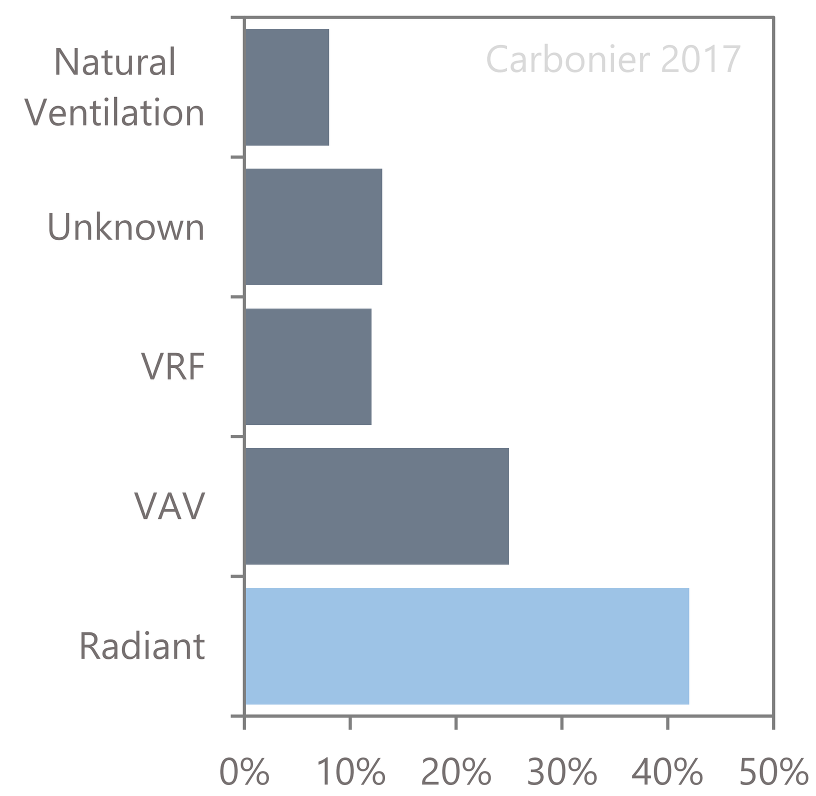
Survey of energy use

Distribution of EUI for offices with and without radiant

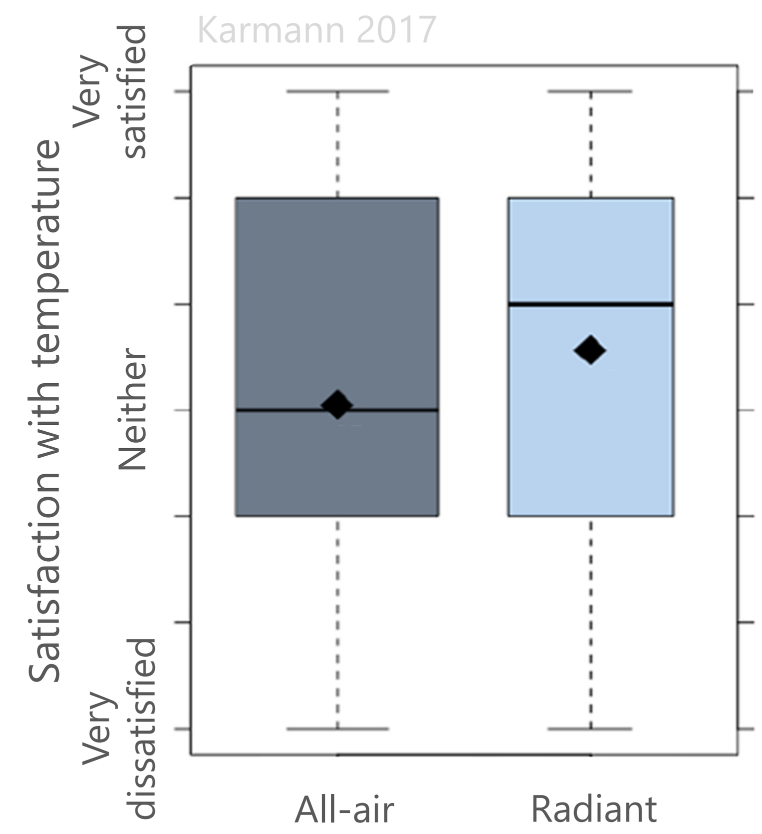


Radiant common in ZNE Buildings

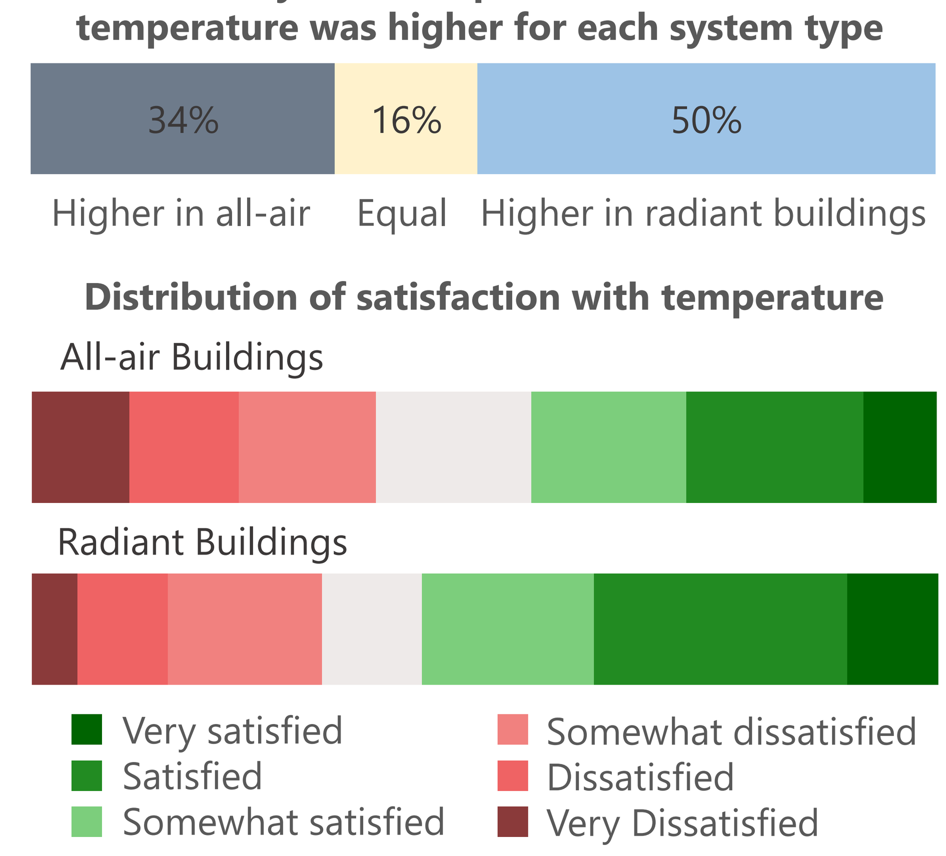
Fraction of ZNE buildings using each strategy



Survey of occupant comfort

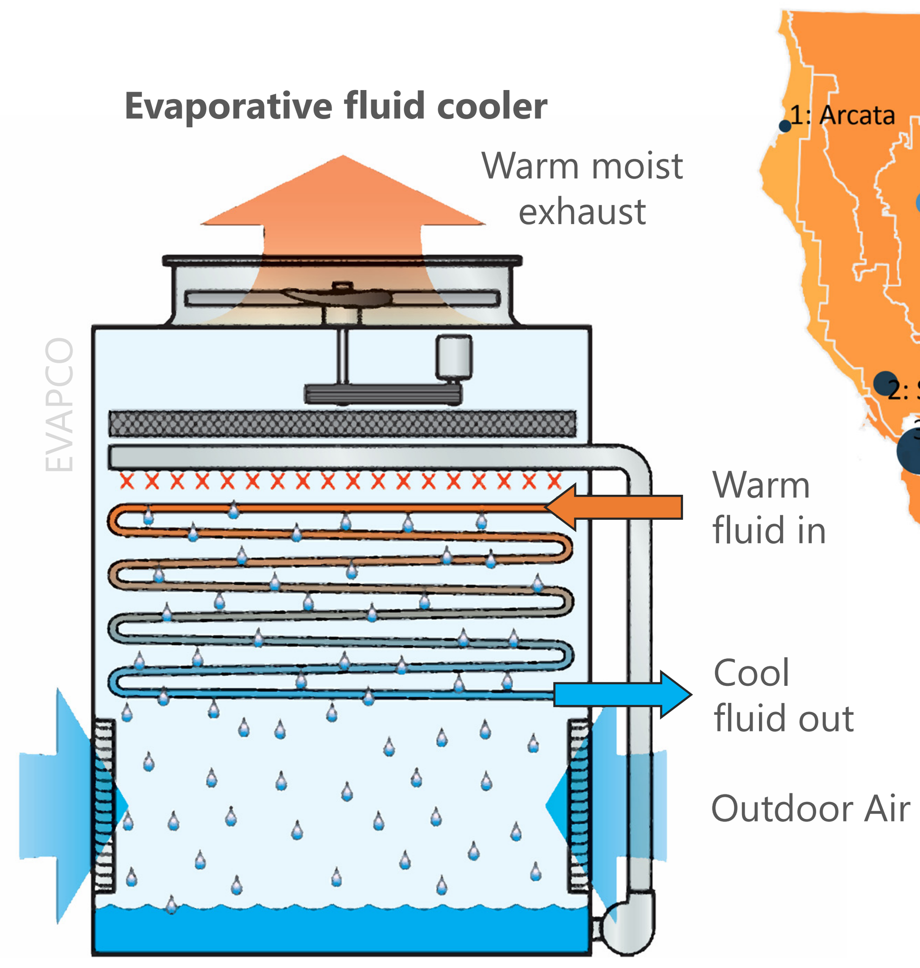


Probability that occupant satisfaction with temperature was higher for each system type

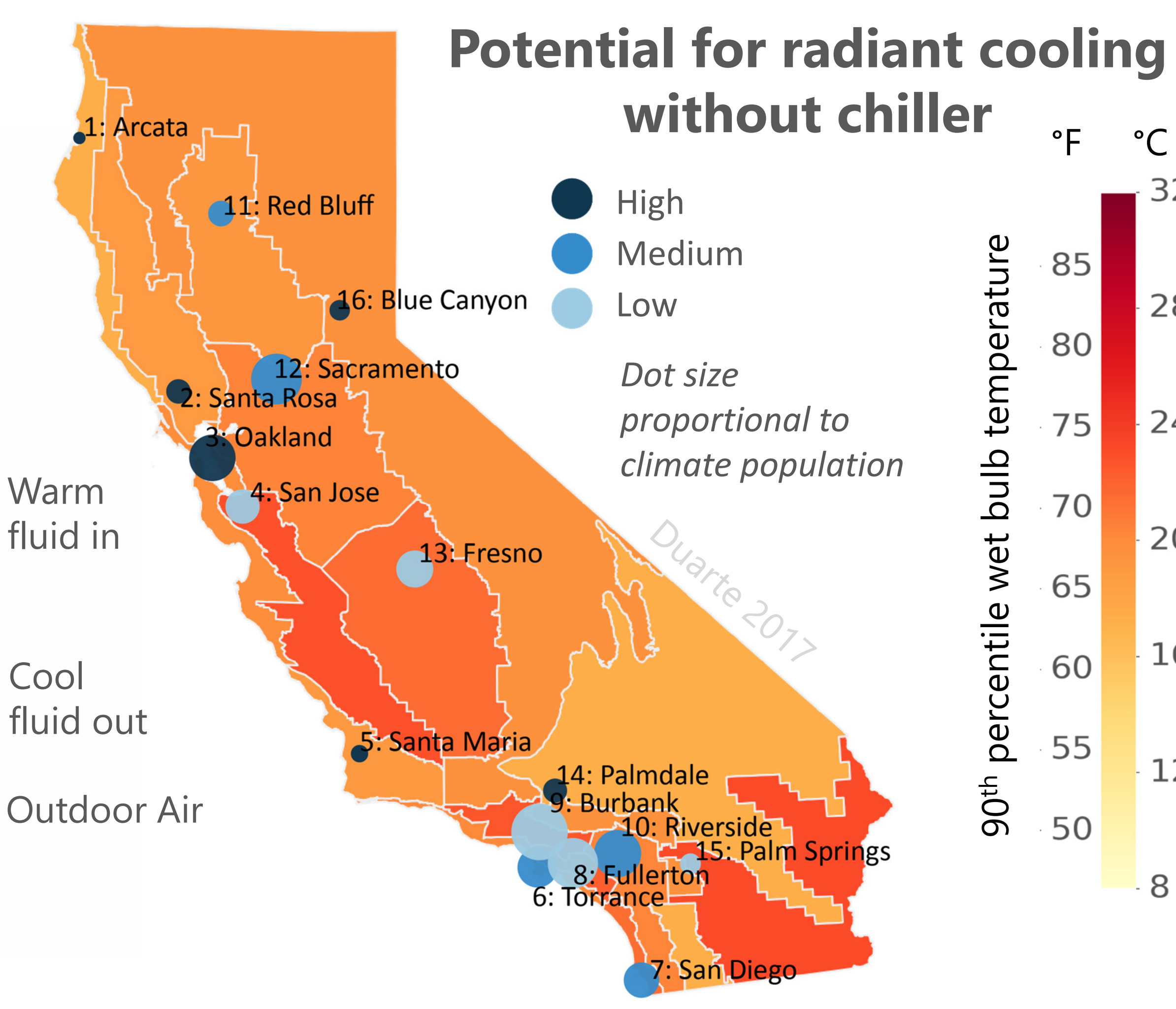


Radiant cooling reduces need for vapor compression chillers

- Radiant cooling operates with warmer chilled water than conventional all-air cooling. In favorable climates, evaporative fluid coolers can be used in lieu of vapor compression chillers.
- In such scenarios, simulations indicate 58–66% primary energy savings and 34–61% peak electrical demand savings compared to a variable-volume all-air system.
- Depending on building characteristics, this strategy has potential application in all California climate zones.

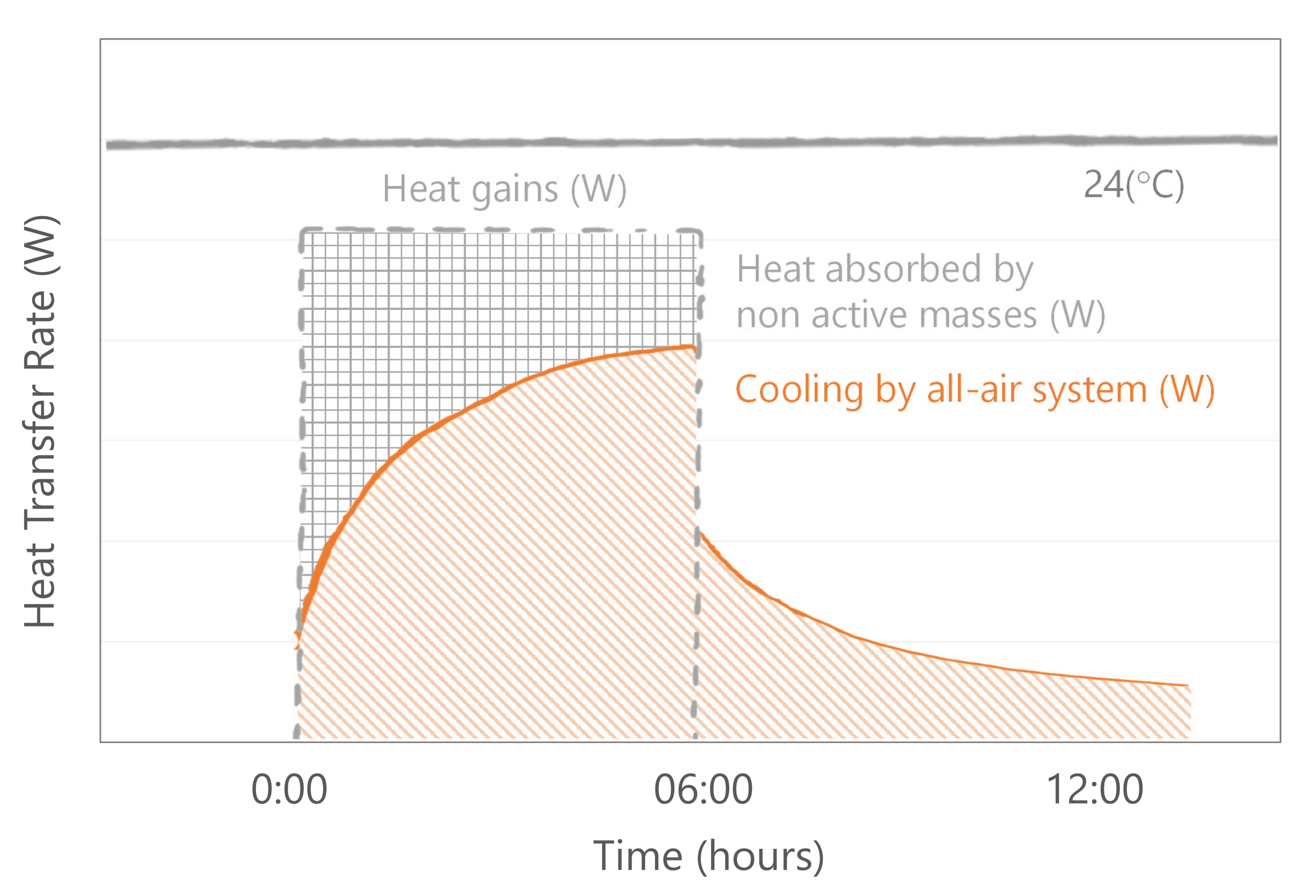


Potential for radiant cooling without chiller

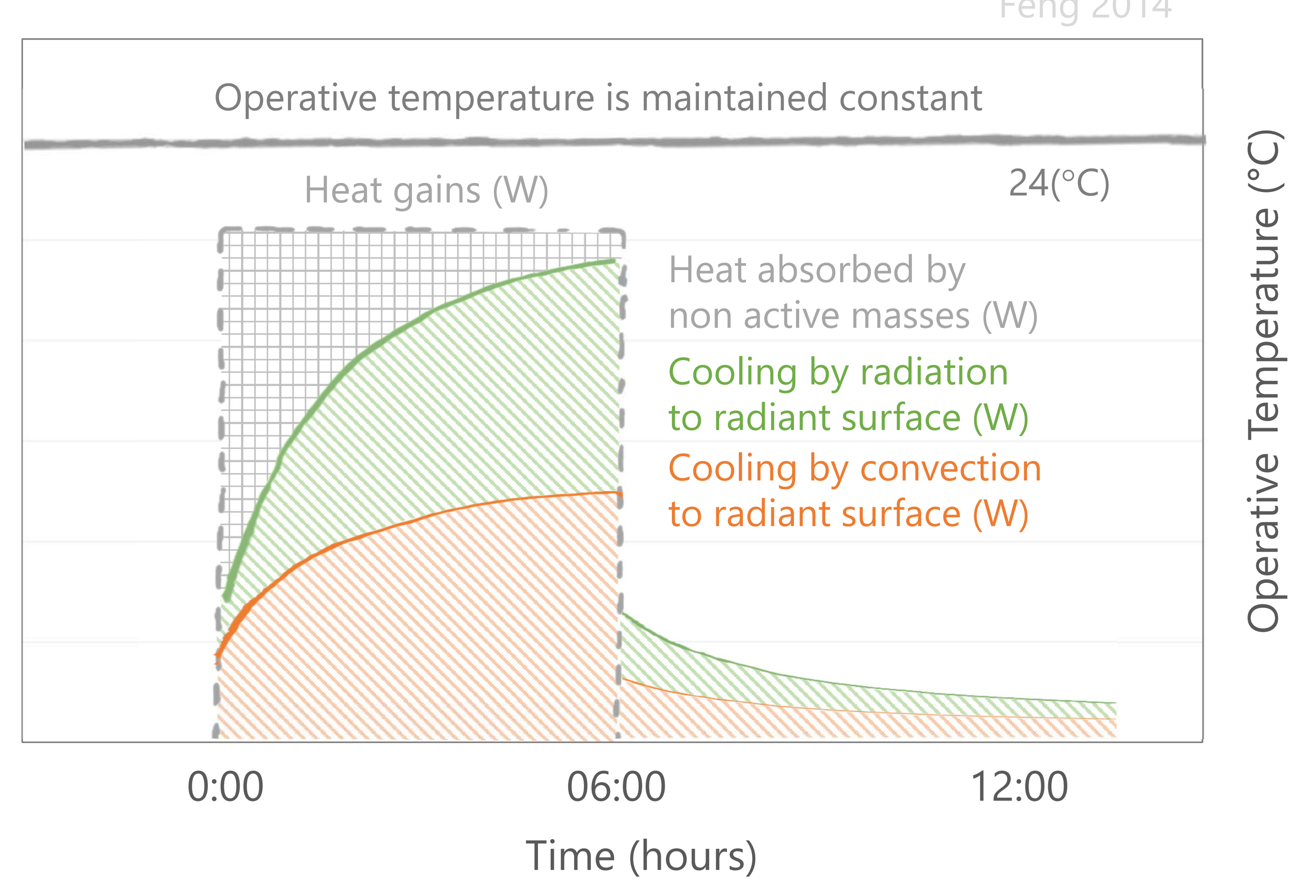


Radiant cooling demands redefinition of standard cooling load calculations

All-air cooling



Radiant cooling



CBE CENTER FOR THE BUILT ENVIRONMENT
An Industry/University Research Collaboration

TRC Results you can rely on

nbi new buildings institute

- This poster summarizes results from research conducted by the UC Berkeley Center for the Built Environment and industry partners as part of an ongoing program of study, with funding from California Energy Commission Electric Program Investment Charge (EPC-14-009) "Optimizing Radiant Systems for Energy Efficiency and Comfort"
- Research objectives include to (1) develop tools to support design and operation of radiant, (2) collect energy, cost, and occupant satisfaction data (3) advance relevant codes and standards.
- Additional information, findings, and publications available online: www.cbe.berkeley.edu/research/optimizing-radiant-systems.htm

DESIGN & CONTROL
OF HIGH THERMAL MASS RADIANT COOLING

INTERVIEWS WITH EXPERTS REVEALED CURRENT PRACTICES

Characteristics of radiant cooling that underpin design practices

- Maximum cooling capacity for radiant is lower than conventional air systems. Therefore, it is essential to first improve building envelope and reduce internal gains by way of integrated design.
- Slab surface temperature for high thermal mass radiant changes slowly. This is both an advantage and a challenge.
- Cooling capacity for high thermal mass radiant is self-regulating. Heat transfer to the cooled slab surface responds naturally to changes in heat gain.

Plumbing & Mechanical 2017

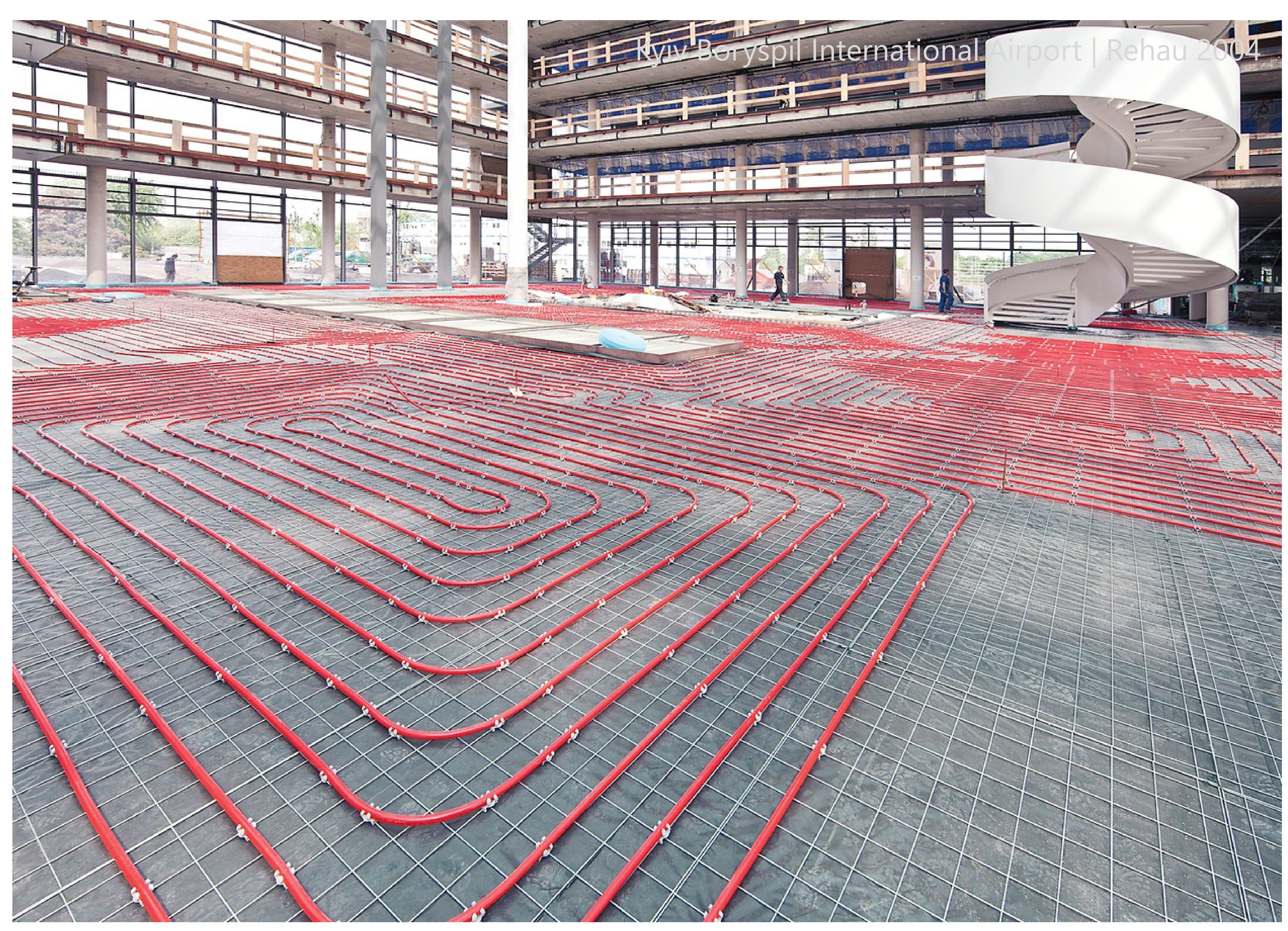
Plumbing & Mechanical 2017

Current practices that are common among radiant design professionals

- Most radiant buildings include supplemental cooling to maintain comfort in zones where gains can exceed radiant system capacity.
- Radiant buildings use dedicated outside air systems (DOAS) to provide fresh air ventilation. Often the DOAS is also used for supplemental cooling by adjusting air flow or supply temperature.
- High thermal mass radiant buildings are controlled to maintain a constant slab temperature setpoint round-the-clock. Each zone may have a unique set point that changes slowly over the year.
- Ongoing commissioning and education is usually required for the first year of occupancy. Unique settings that depend on building characteristics and climate zone require designer expertise.

Current practices that vary between radiant design professionals

- Half of interviewees use two-pipe distribution for the entire building, while others use four-pipe distribution to the zone level, or four-pipe distribution to major sections of the building with two-pipe distribution continuing to groups of zones.
- Some interviewees emphasized that active control of chilled water temperature and/or ventilation dewpoint are critical to prevent condensation. Other interviewees emphasized that no such controls are needed as long a system is engineered so as to never need to reach a condensation condition.
- Many interviewees shared that there are long periods (weeks or months) between the need for slab heating and cooling. Others allow a more rapid changeover (days or hours).



Kyiv Boryspil International Airport | Rehau 2014

AIAOC 2018

Anaheim Regional Transportation Intermondal Center | AIAOC 2018

Opportunities to improve performance of radiant buildings

- Although radiant cooling operates with relatively warm chilled water temperature, most buildings with radiant still use a chiller that cools water to low temperature; this is used for dehumidification, and for cooling in zones without radiant.
- High thermal mass radiant buildings could be controlled to precool mass overnight so as to shift electric loads, or to operate chillers during more efficient hours. However, this is not commonly implemented because the dynamic control of high thermal mass radiant buildings is not well understood.
- High thermal mass radiant buildings could be designed and controlled to use smaller chillers, but this is not commonly implemented. Better guidelines and design tools are needed.