TRC

Construction and Energy Costs for Radiant System in California Bay Area

Symposium: Optimizing Radiant Systems

Oct 23, 2019

INTEGRATED
[RESILIENT]
SUSTAINABLE

TRCcompanies.com

Acknowledgements

- This work was done when the presenter worked at Taylor Engineering with support from Hwakong Cheng and Steve Taylor

- This study was funded by California Energy Commission Electric Program Investment Charge (EPIC) under the Optimizing Radiant Systems for Energy Efficiency and Comfort project, led by Center for the Built Environment at UC Berkeley

Agenda

- Project overview
- Case study building
- Cost data
- How to reduce construction costs
- Energy performance
- How to reduce energy costs

Project Overview

Objectives

- Provide cost data for radiant systems in California Bay Area
- **Suggest opportunities to reduce cost and improve energy efficiency**

Approach

- Provide baseline and alternative design options
- Cost estimation by contractors
- Energy performance evaluation by EnergyPlus

Background

Status of VAV

- Predominant HVAC approach
  - Optimized construction process
  - Competitive market
- Design guidelines
  - Advanced VAV System Design Guide
  - ASHRAE Guideline 36

Image: an online map of radiant system buildings

Status of radiant

- Small market share, mostly in low-energy and ZNE projects
- Limited design guidelines and tools
- Lack of familiarity by building construction industry

Case study building

Real building with radiant design

Simplified floor plan

- Open office with meeting rooms
- Total floor area 112,000 ft^2

Building features

- Solar load control
  - Window-wall ratio 40%
  - Glazing U-value 0.4 and SHGC 0.28
  - Exterior overhang
- LED lights and daylight control
- Advanced plug load control

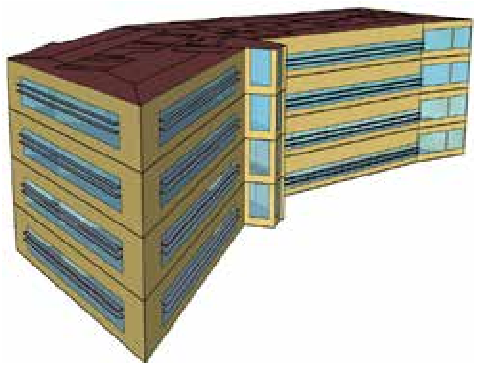
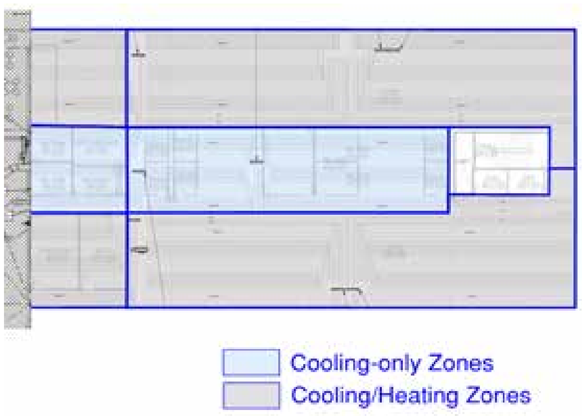


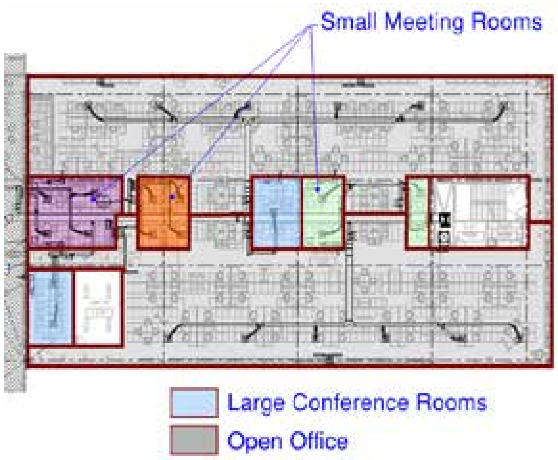
Image: EnergyPlus model of the case building

Radiant slab design

- High thermal mass radiant system with tubes in every ceiling slab
- 10 radiant zones per typical floor
- 13 DOAS VAV zones per typical floor
  - Demand controlled ventilation in large conference rooms



Radiant slab zoning plan (part of typical floor)



DOAS zoning plan (part of typical floor)

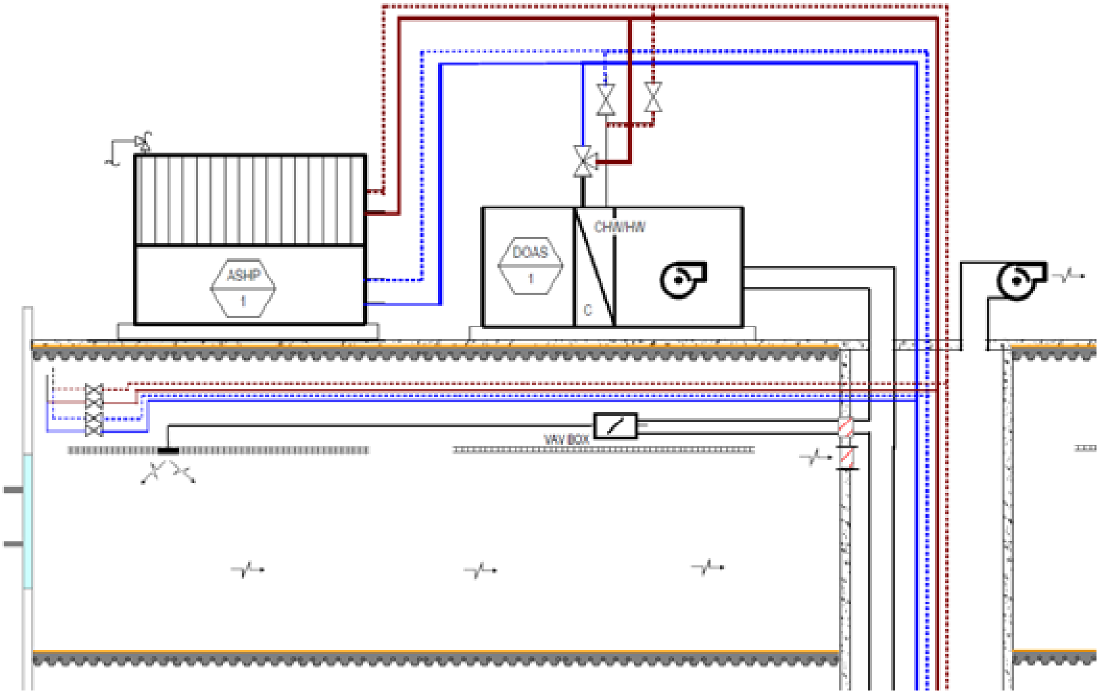
Radiant system design

Dedicated outdoor air system (DOAS)

- Design air flowrate 19,400 cfm
- Changeover heating/cooling coil

Central plant

- Four-pipe air source heat pump
- Serves both DOAS and radiant slabs to reduce cost



Radiant design schematic

Construction costs

HVAC and controls only

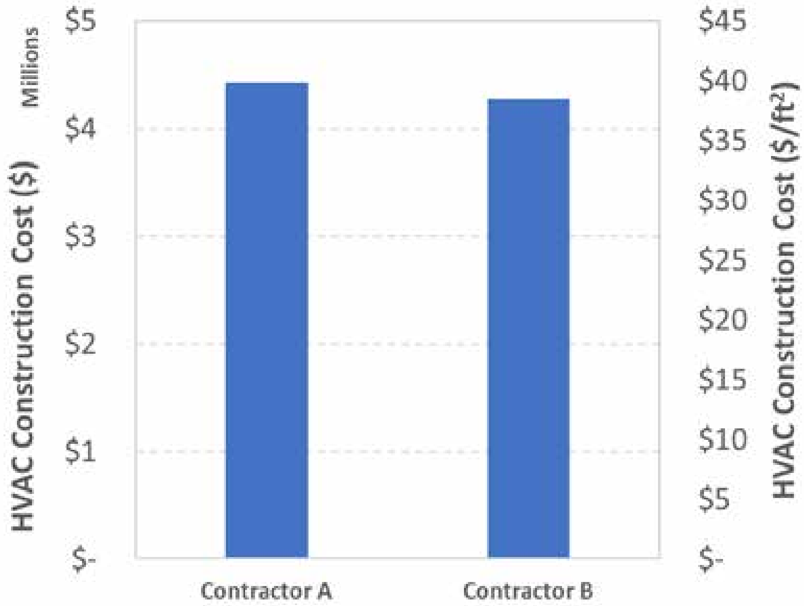
Common mechanical elements NOT included

San Mateo labor rate

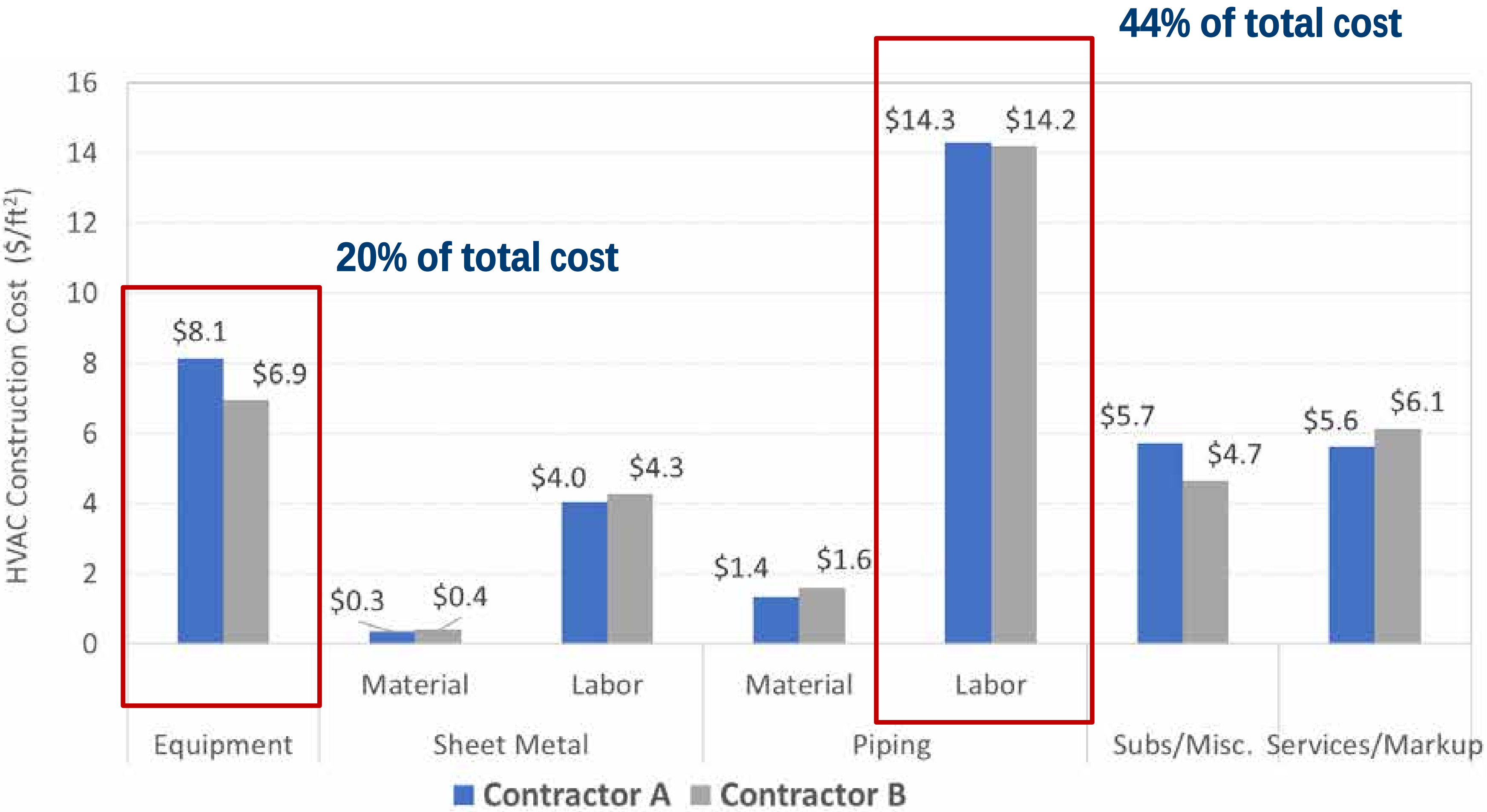
- Sheet metal: $123/hr
- Piping: $118/hr

Results

§ Average : $38.9/ft²



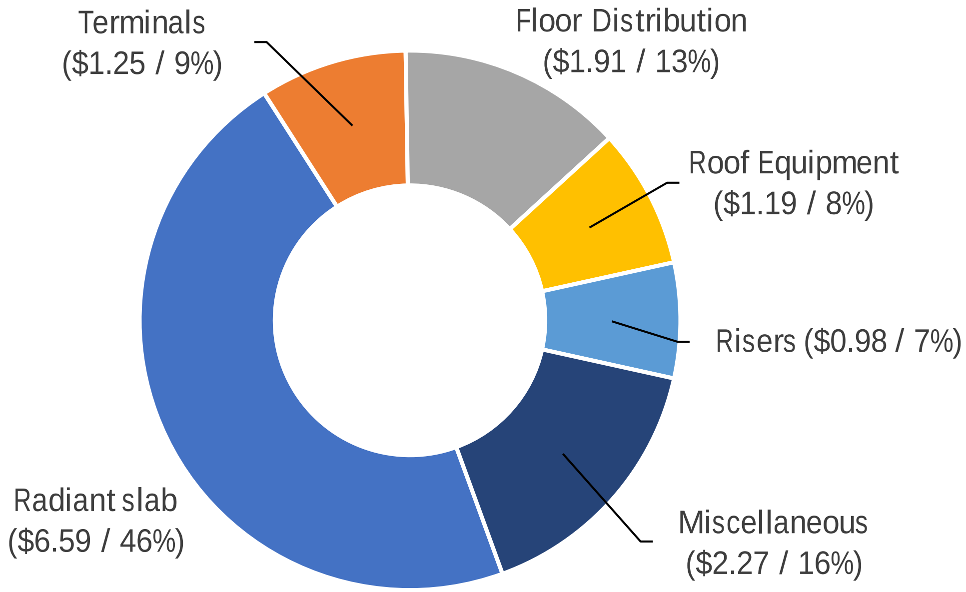
Construction cost breakdown



Piping labor breakdown

Radiant slab: $6.6/ ft^2

Floor distribution + risers: $2.9/ ft^2

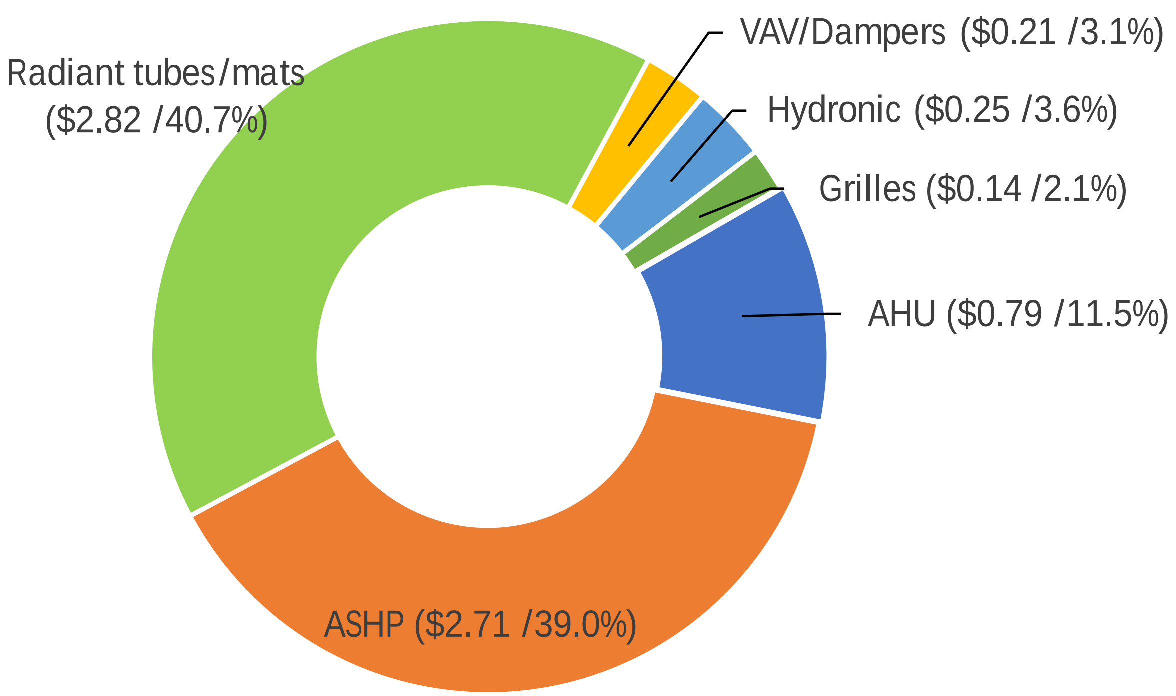


Equipment Cost

Radiant equipment: $2.82/ ft²

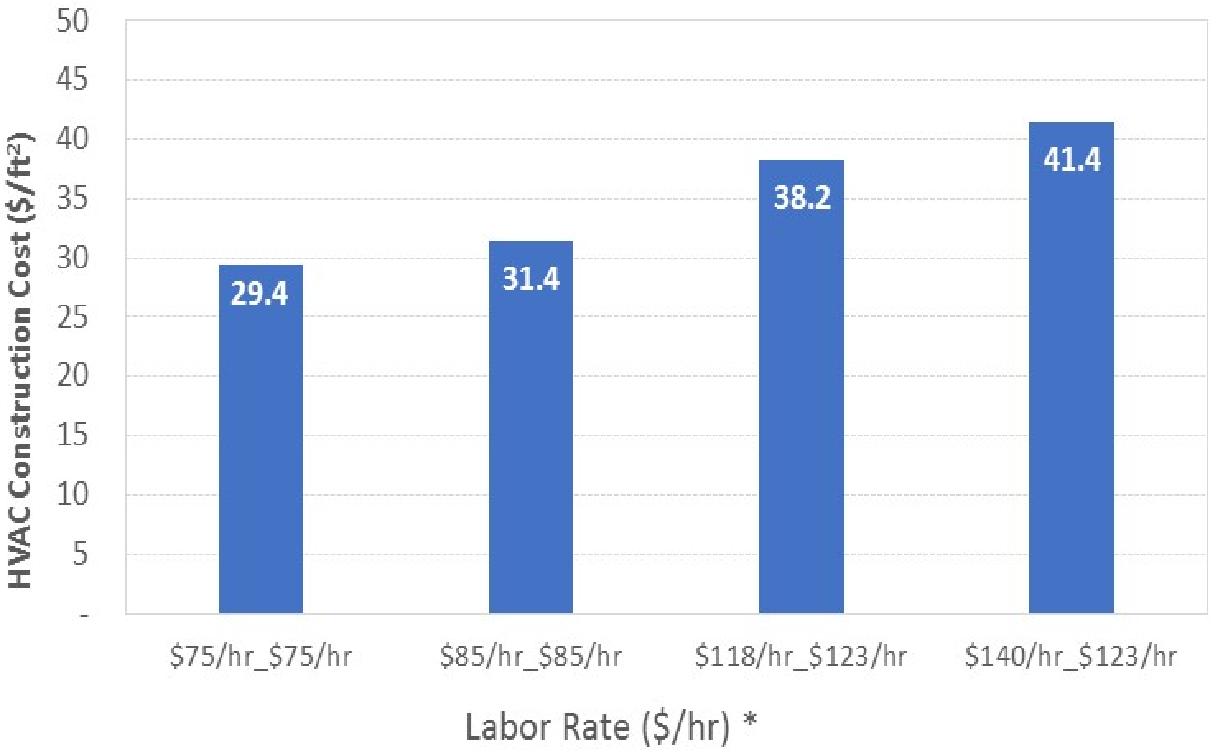
DOAS AHU : $0.79/ ft²

ASHP: $2.71/ ft²



Impact of labor rate

- National average labor rate: $85/hr



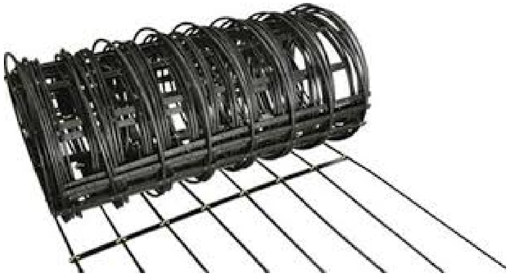
(*Piping Labor Rate _ Sheet Metal Labor Rate)

How to reduce radiant system cost?

Facilitate the use of radiant mat

Costs

- Mats :   ~$4 - 6 /ft^2
- Loops*: ~$6 - 8 /ft^2



Radiant roll-out mat

Limitations for mats

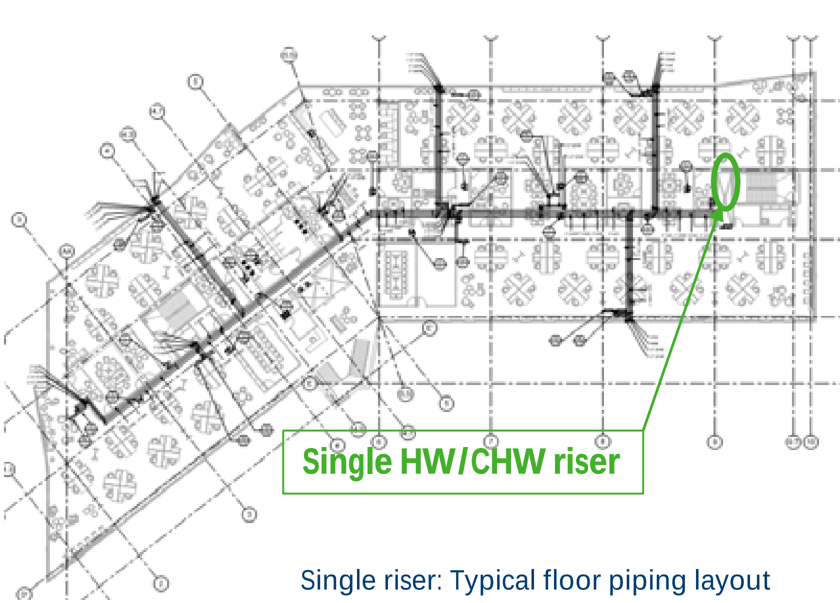
- Maybe limited by shape and size of radiant zones
- May not be cost effective for smaller jobs (assembled on a made-to-order basis)

Traditional loops

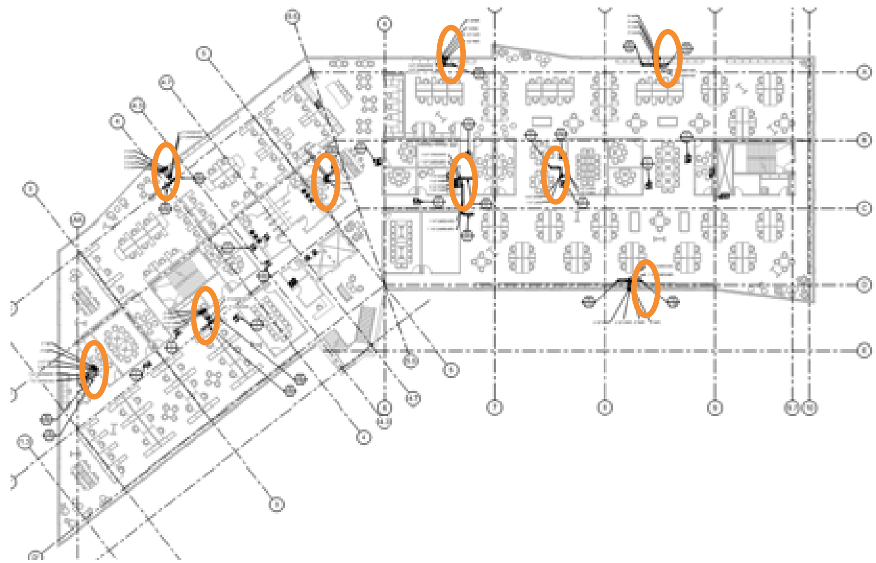
* For 6-inch tube spacing

Hydronic distribution layout: Multiple risers vs. single riser

- Strategically locate risers to minimize piping: 30% piping reduction
- Cost savings: $2.5/ft^2$



Single riser: Typical floor piping layout



Multiple risers: Typical floor piping layout

Use larger radiant tube spacing: 9” vs. 6 in”

- Loop design: ~$1.7/ft^2$ of labor cost savings
- Mat design : 5-15% cost savings and 5% labor savings
- Thermal capacity: initial evaluation shows similar dynamic performance

Other approaches to reduce radiant costs

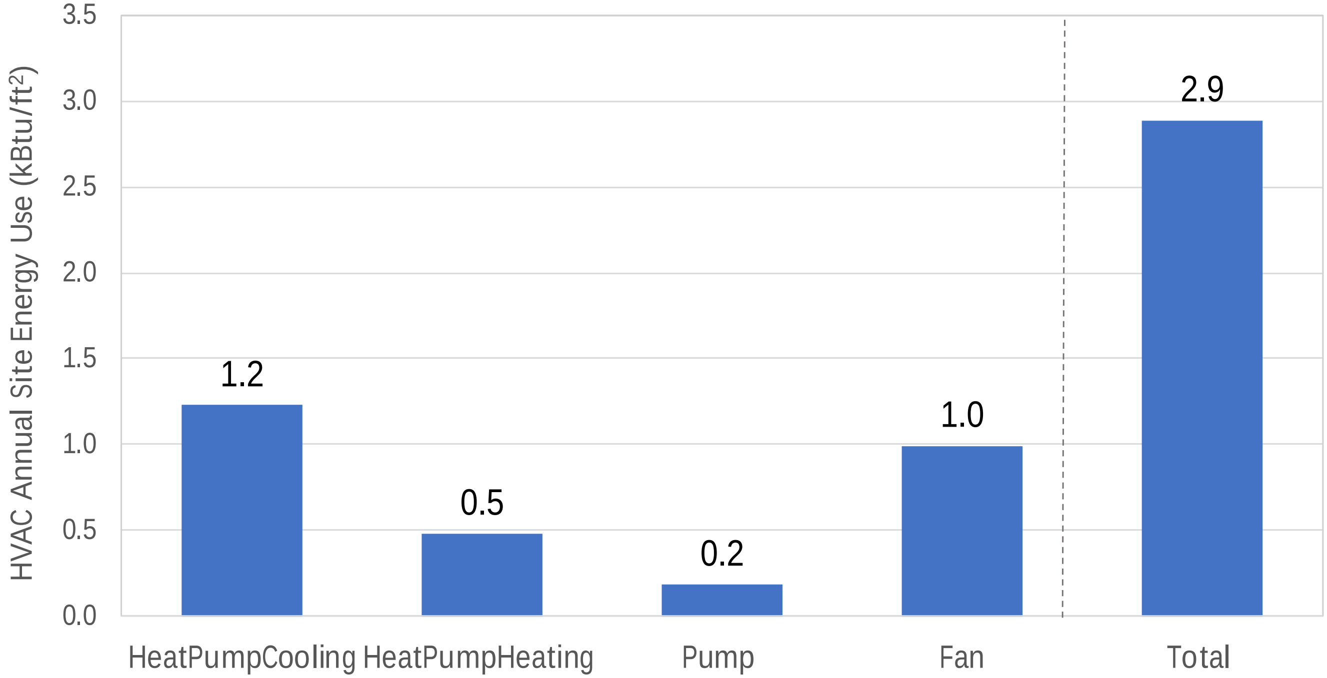
- Large vs. small radiant zones
- Consider no radiant tubes in ground or roof slab
- Use passive supplemental system strategically (For example, ceiling fans)
- Hydronic system type: 4-pipe vs. 2-pipe vs. mixed 4 and 2-pipes
- Reduce central plant equipment size with load shifting
- More details in the report*

*Feng, J., & Cheng, H. (2018). *Comparison of Construction and Energy Costs for Radiant vs. VAV Systems in the California Bay Area.* Deliverable for California Energy Commission Project EPIC -14-009, Taylor Engineering. Retrieved from https://escholarship.org/uc/item/13h9z4gg

HVAC annual site electricity

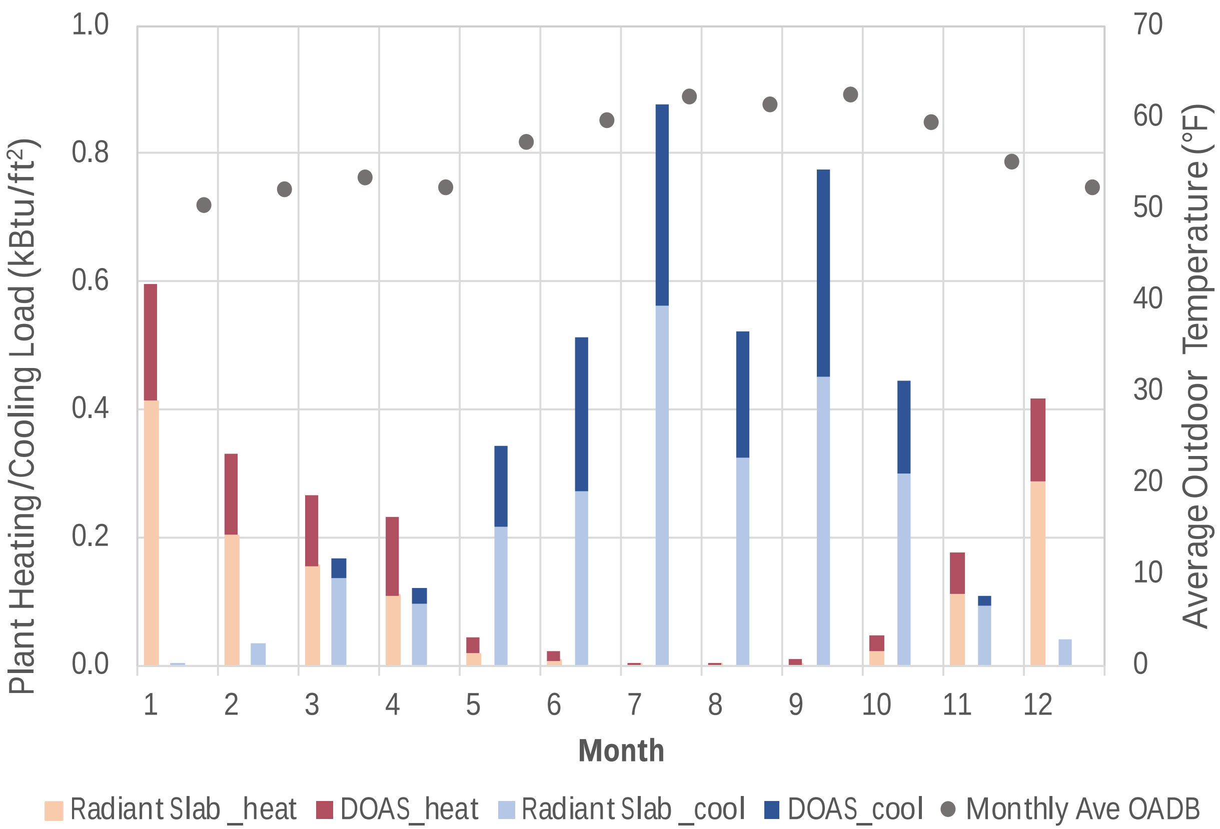
Total: 2.9 kBtu/ft²

- Cooling is 41% of total energy
- Fan energy is 34% of total energy



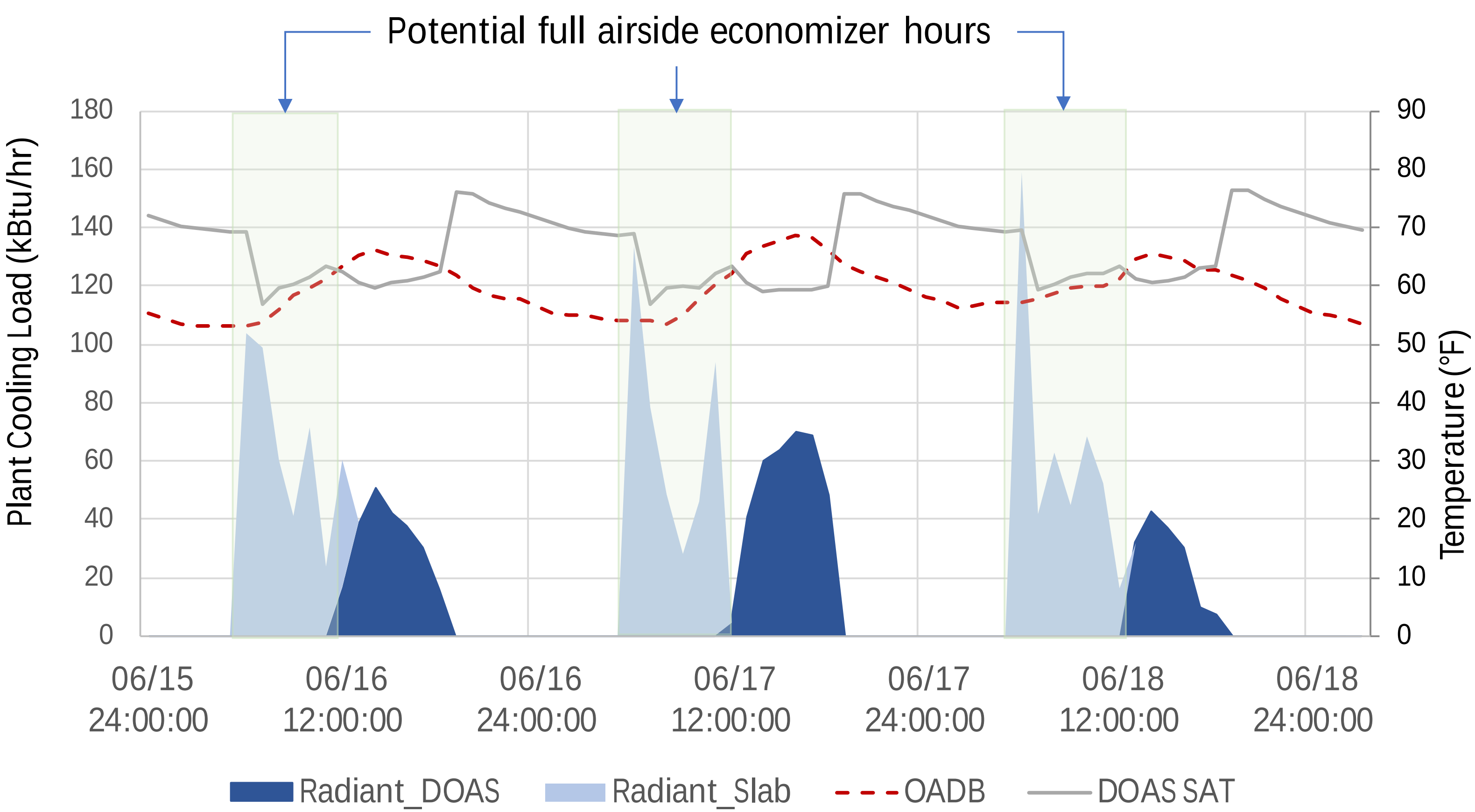
Central plant cooling and heating load

- Cooling energy use in winter months
- DOAS uses significant energy

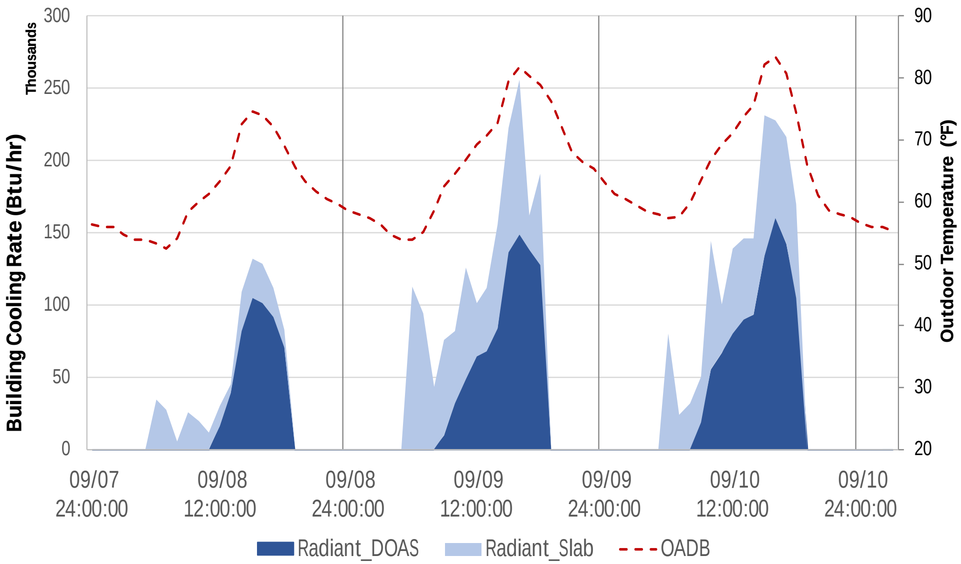


How to reduce radiant system energy cost?

Potential for economizer to reduce cooling energy

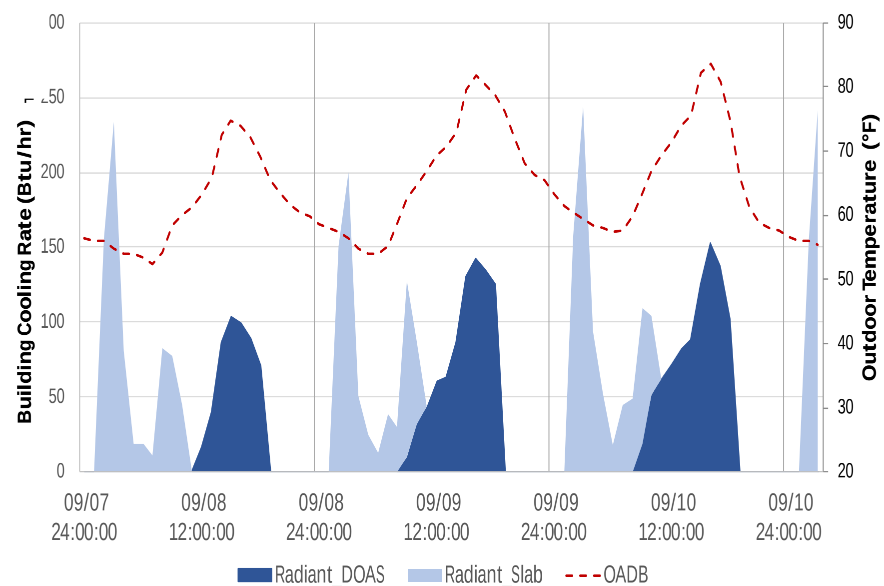


Implement load shifting strategy to reduce demand



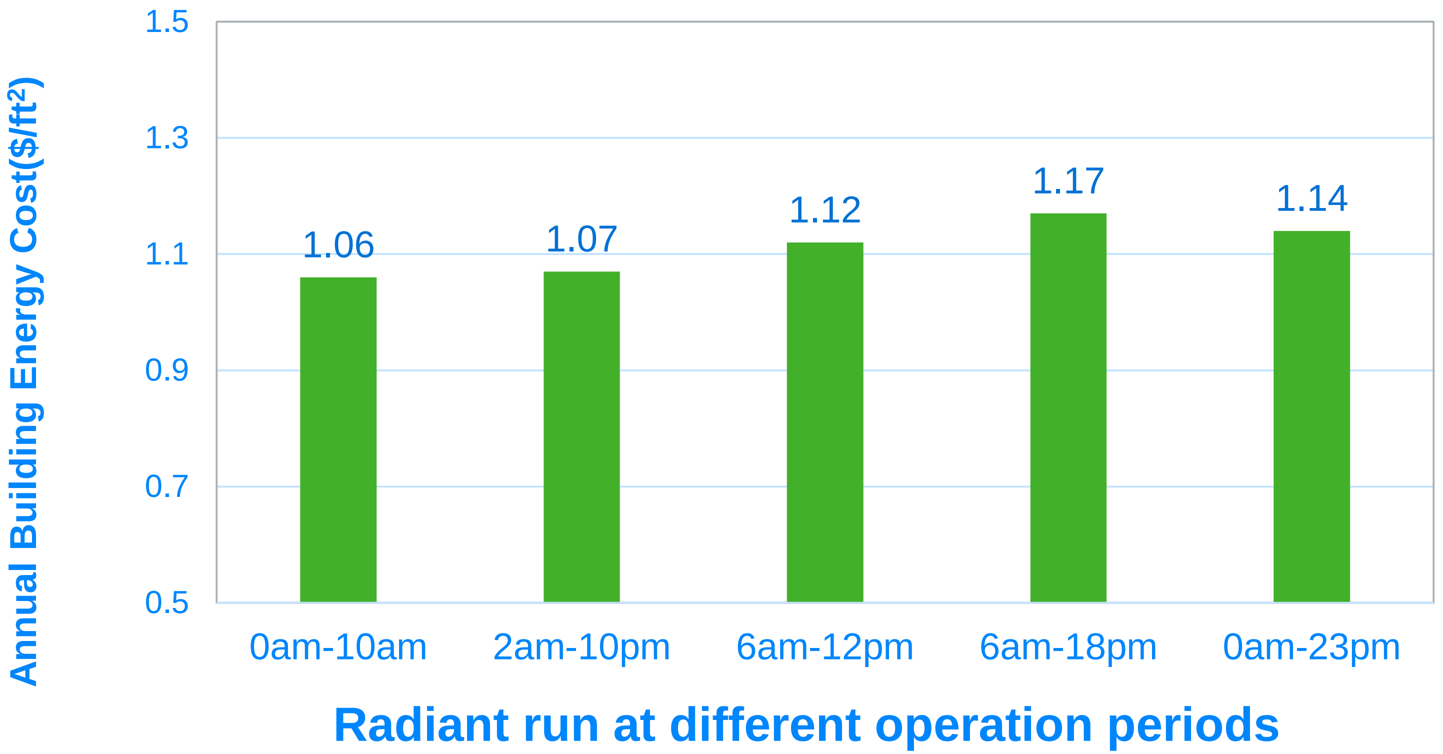
Radiant slab operates 6 am - 6 pm

Radiant slab operates 0 am-12 pm

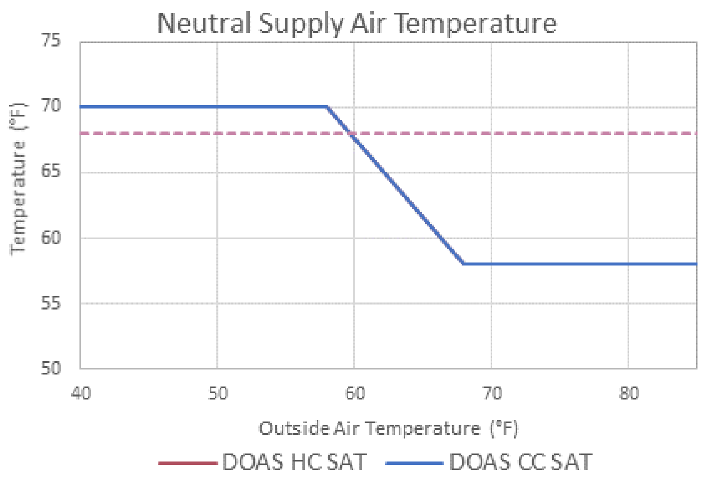


Implement load shifting strategy to reduce demand

- Whole building electricity cost
- High performance design to minimize heat gain is key



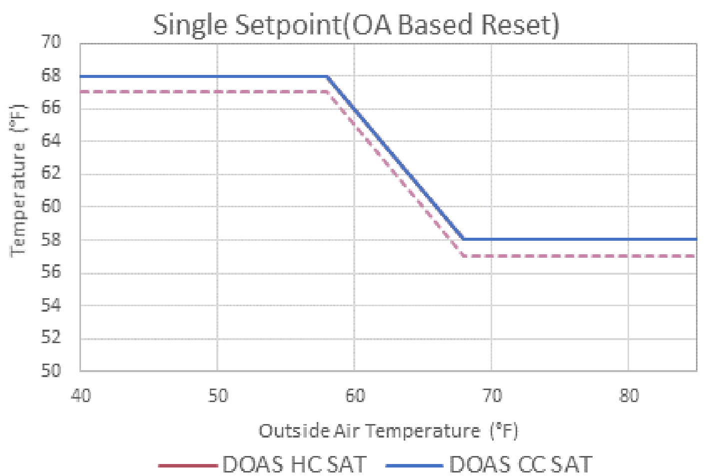
Optimize DOAS supply air temperature control

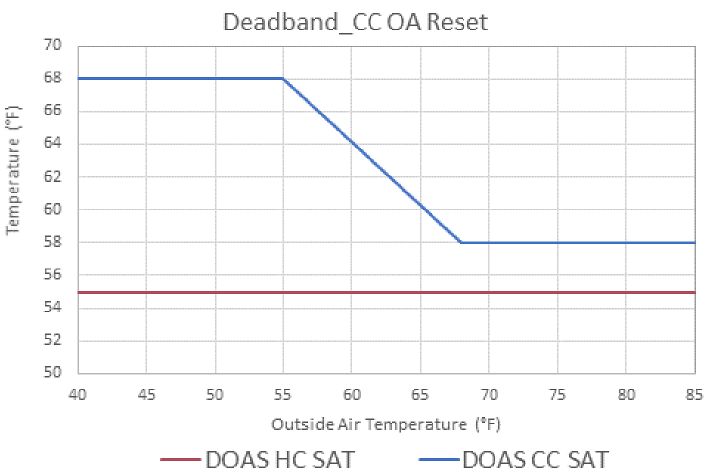


Neutral SAT

OA reset

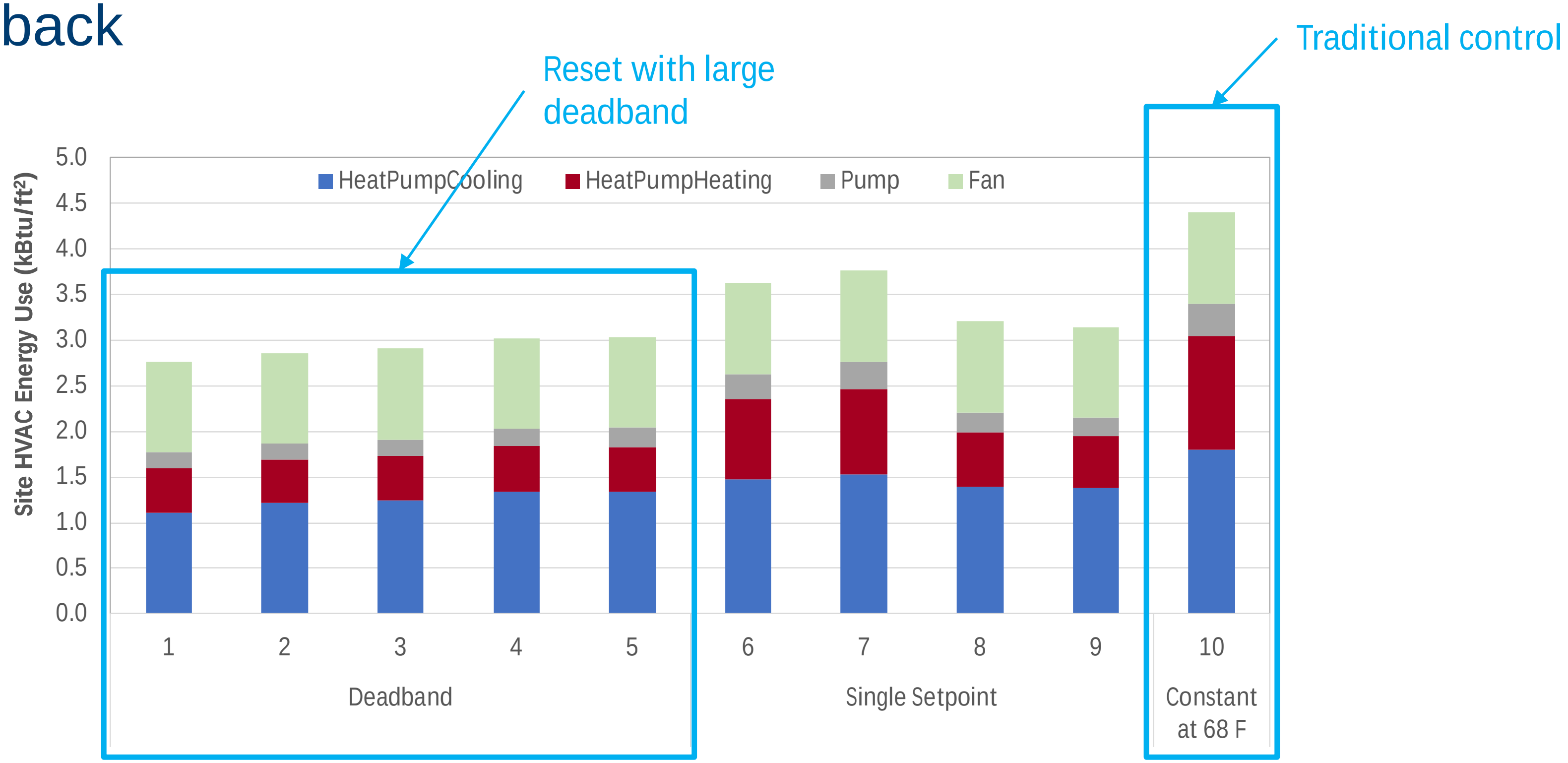
Large deadband





Optimize DOAS supply air temperature control

- Use large heating/cooling setpoint deadband
- Reset supply air temperature higher with space humidity feedback



Approaches to reduce energy cost

- Take advantage of free cooling with waterside economizer (mild weather in particular)
- Implement load shifting strategy to reduce demand charge and equipment size
- DOAS design and control are critical
  - DOAS supply air temperature control is IMPORTANT
  - Avoid unnecessary oversizing of DOAS by strategically distributing the ventilation air
  - Decouple cooling source for radiant slab and DOAS in humid climates
- More details in the report*

There are opportunities for improving current practice!

*Feng, J., & Cheng, H. (2018). *Comparison of Construction and Energy Costs for Radiant vs. VAV Systems in the California Bay Area.* Deliverable for California Energy Commission Project EPIC -14-009, Taylor Engineering. Retrieved from https://escholarship.org/uc/item/13h9z4gg

Questions?

Thank You

Jingjuan (Dove) Feng
jfeng@trccompanies.com