New design tools and controls for load-shifting with radiant systems

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CENTER FOR THE BUILT ENVIRONMENT

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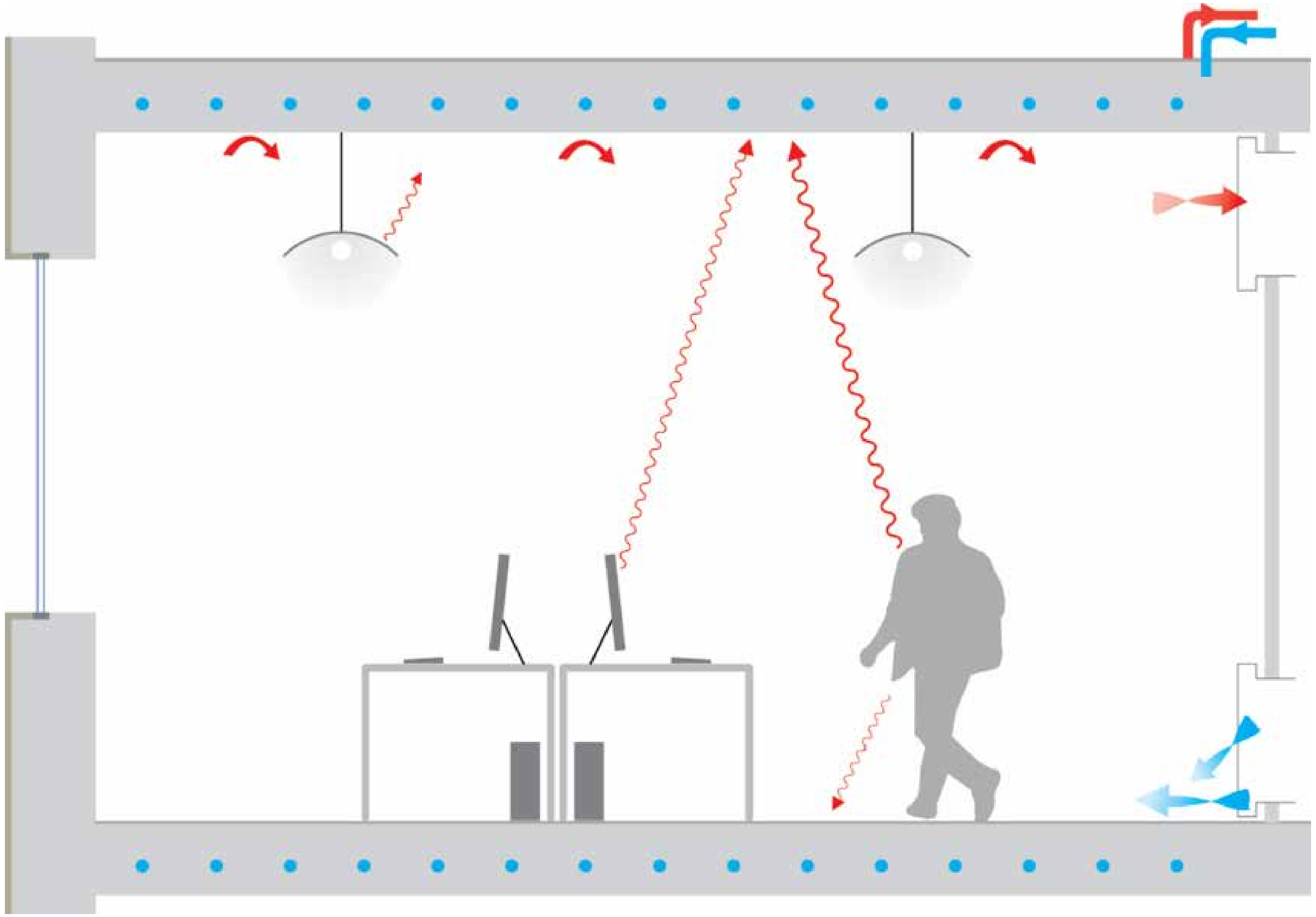
Overview

Objective

- Develop new controls for high thermal mass radiant systems

Approach

- Interview experts
- Review controls and trend data from existing buildings
- Develop new controls and iteratively test in simulation
- Demonstrate in two buildings



Interviews with designers

- Interviewed 11 prominent professionals who have designed over 330 radiant cooled buildings

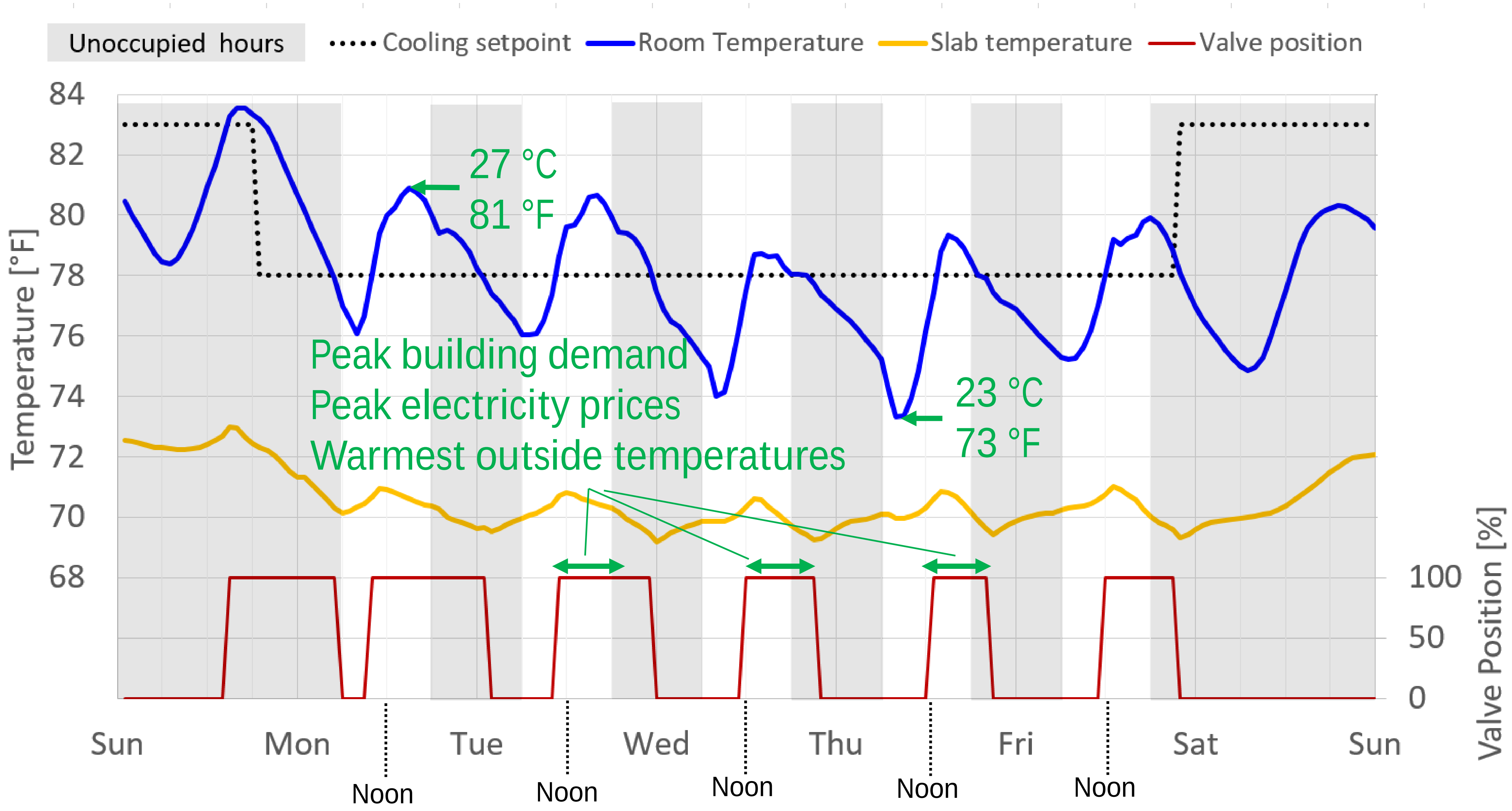
Findings

- Generally a wide diversity of design and control solutions - reveals opportunities for standardization and improvement
- Very rarely leverage thermal mass to shift load.

Example results: Radiant zone control device

How do you control radiant zones?	#
Two position zone valves	6
Modulating zone valves	4
Pumps with 3-way control valves at the zone	3
Constant speed pump	1
Variable speed pump	1

Trend data from a radiant building (in July)



Motivation

How can we help designers
benefit from the load shifting potential
of radiant systems?

Simulation results: Common control strategy

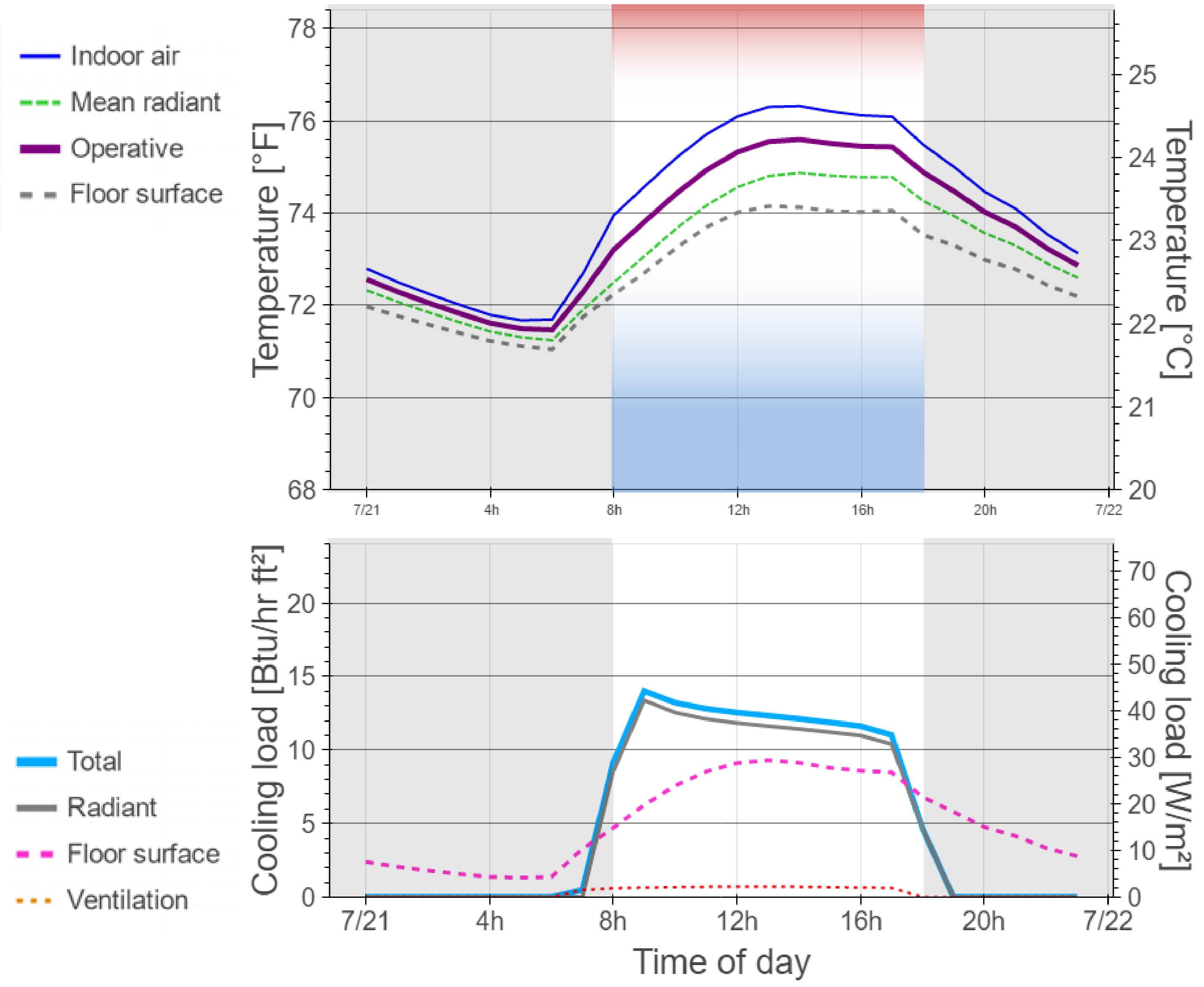
Results from a single zone energy simulation on the cooling design day.

Conditions

- Variable flow
- Constant temperature (18 °C | 64 °F)
- Modulating valves 0.5 °C (1 °F) band

Advantages

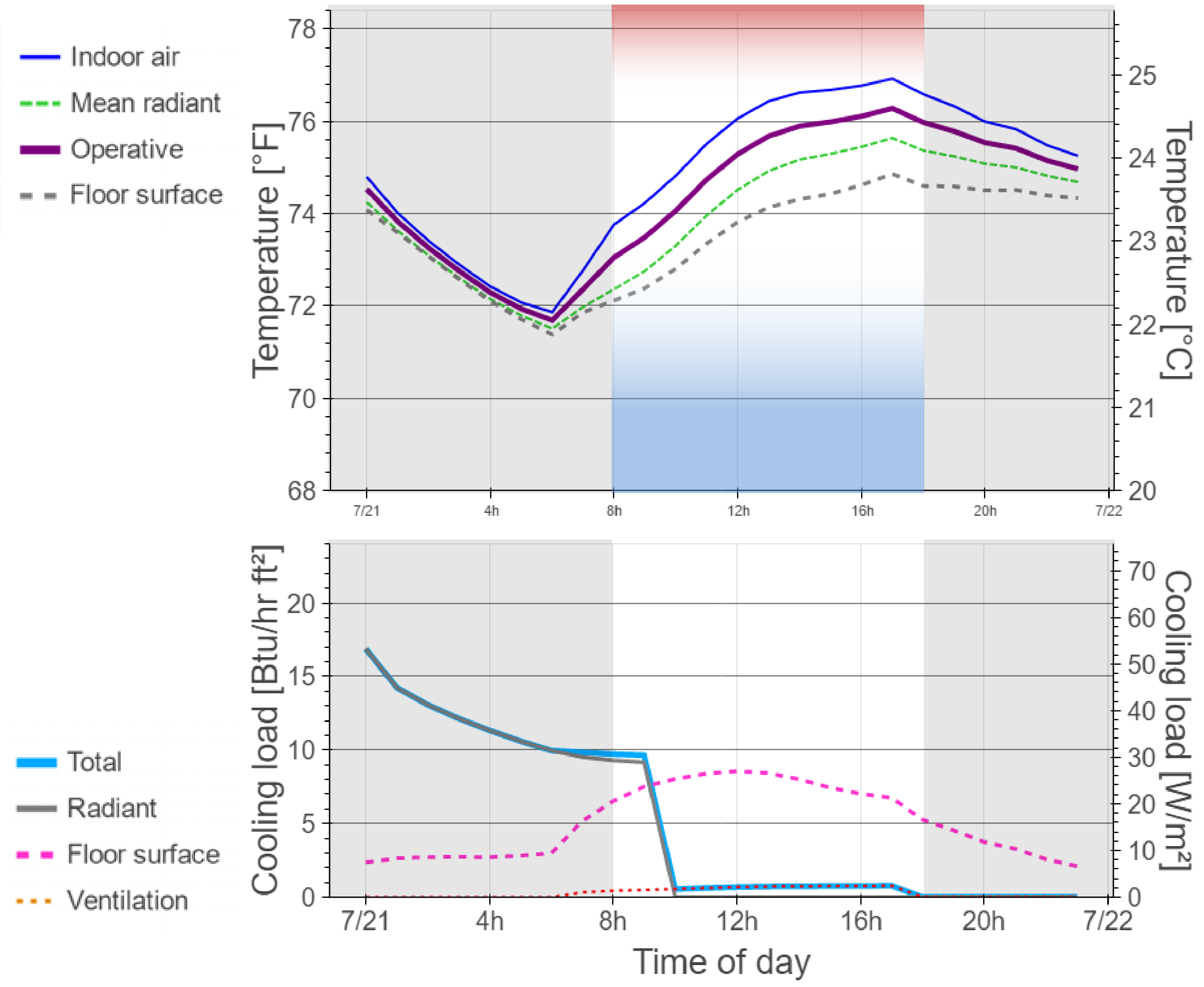
- Simple, familiar controls



Effect of different operating times

Conditions

- Constant temperature (18 °C | 64 °F)
- Constant flow (two position valves)
- Constant duration of operation (9 hours)
- Varying *time* of operation



Effect of different operating times

Conditions

- Constant temperature (18 °C | 64 °F)
- Constant flow (two position valves)
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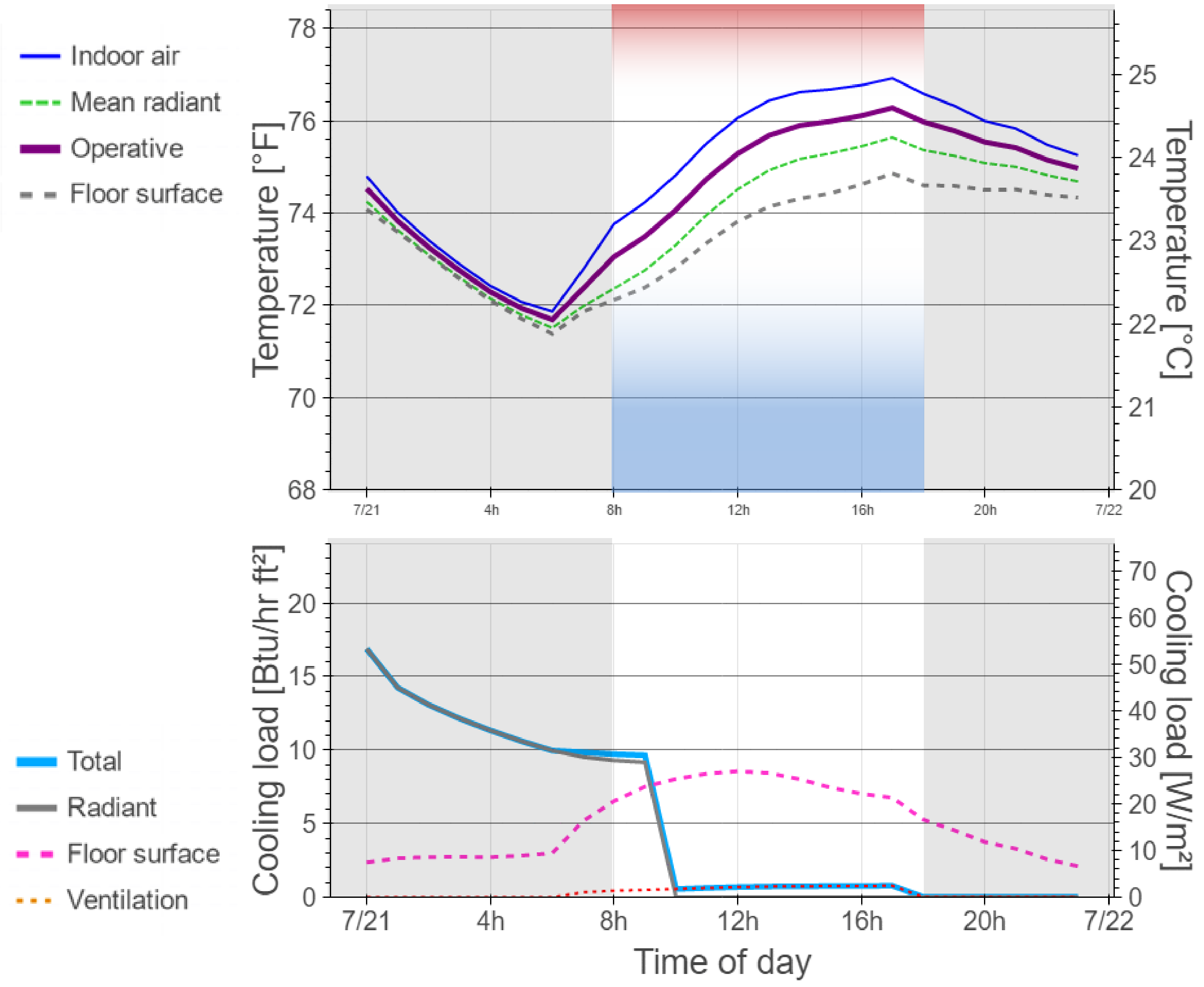
- Varying *time* of operation

Result

- Can maintain comfort regardless of time of operation



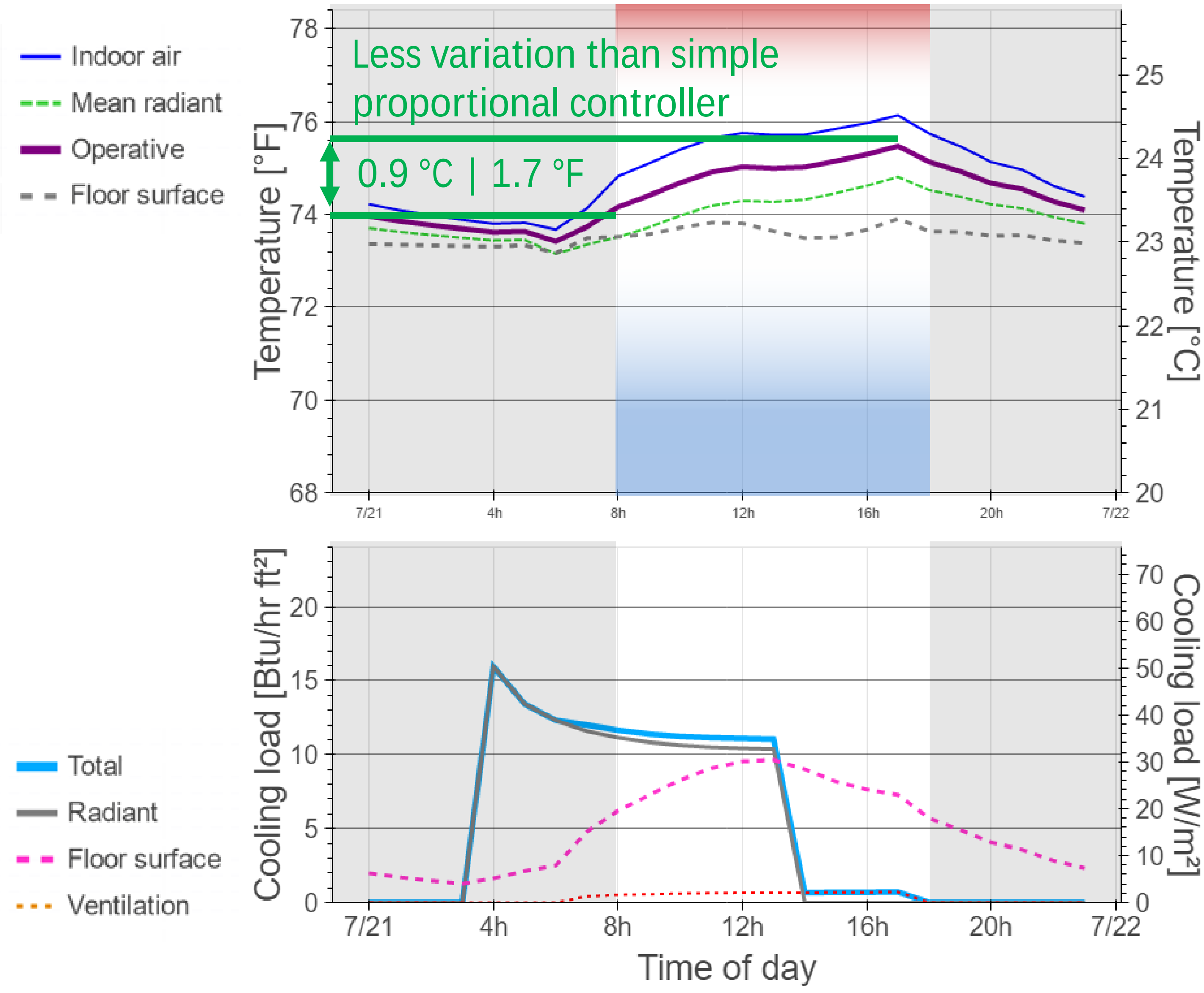
Design/operation possibilities: Afternoon shutoff

Conditions

- Constant temperature
- Constant flow (on/off valves)
- Operates during the morning and early afternoon

Advantages

- More uniform daily comfort conditions
- Reduces peak energy charges
- Avoids building peak demand charges



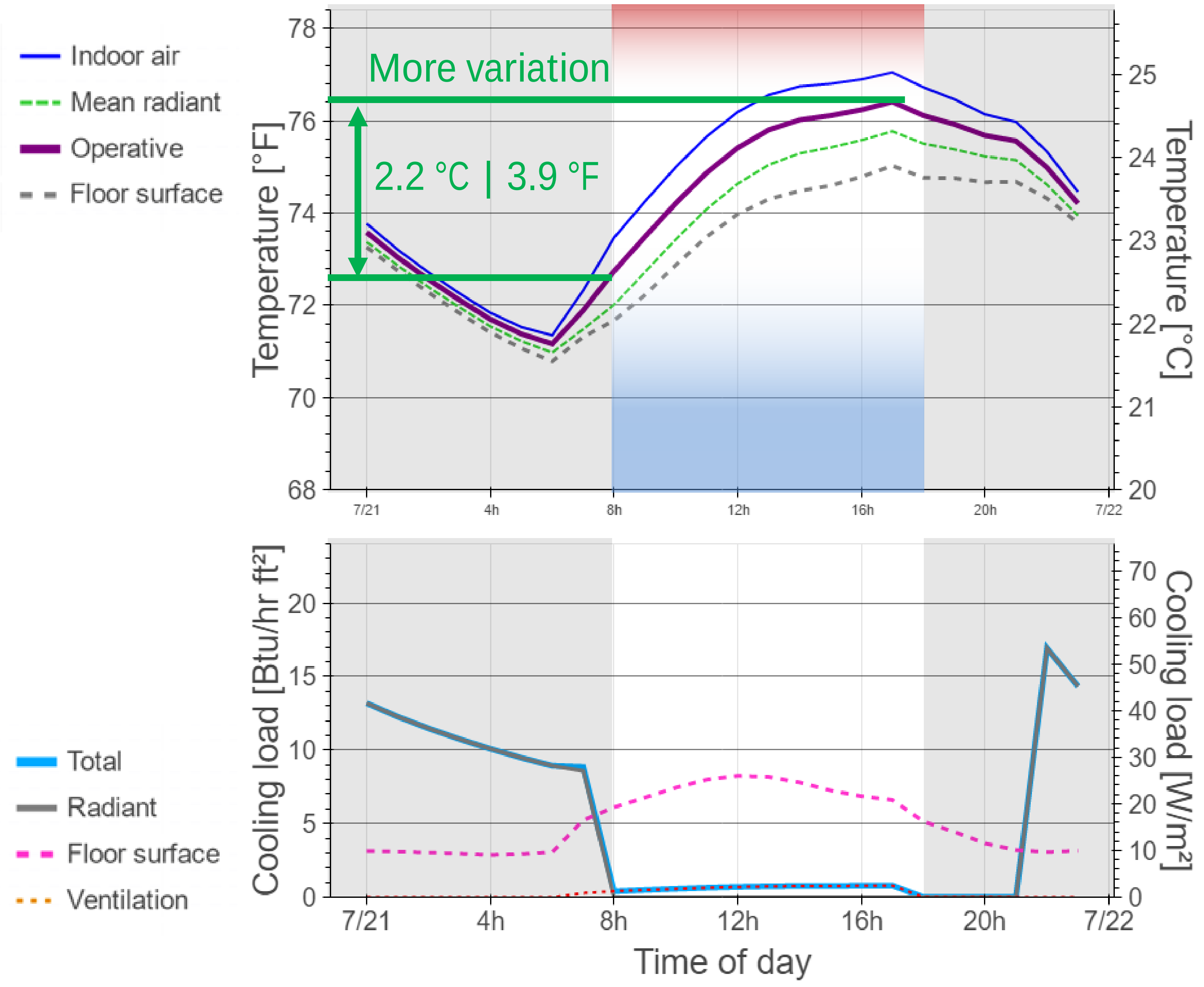
Design/operation possibilities: Daytime shutoff

Conditions

- Constant temperature
- Constant flow (on/off valves)
- Operates only during the night

Advantages

- Low energy charges
- No demand charges
- Chilled water plant operates at night, when dry- and wet-bulb temperatures are lowest



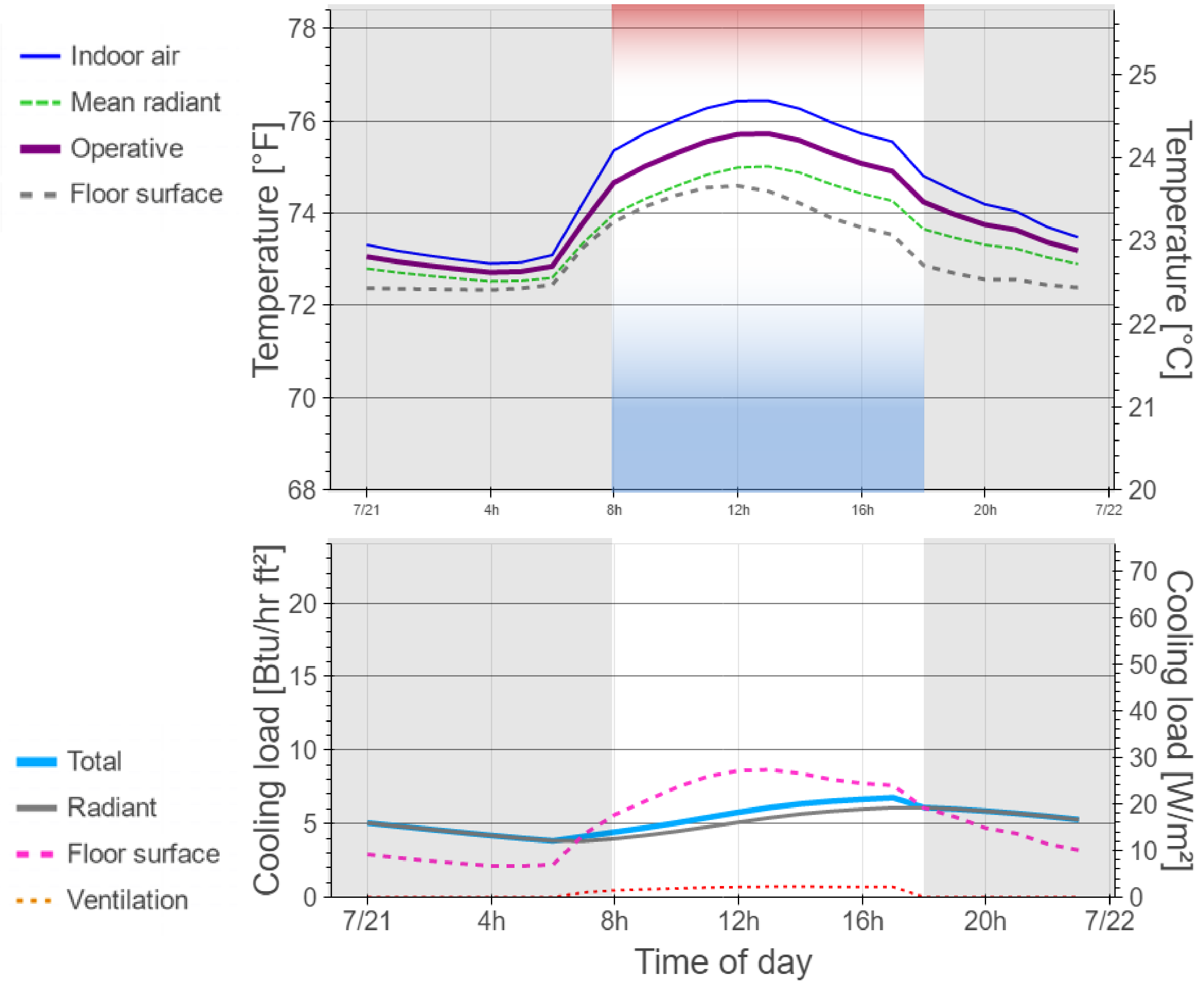
Design/operation possibilities: Constant flow

Conditions

- Constant supply temperature 4 °F higher than previous cases: 68 °F (20 °C)
- Operates 24 hours per day

Advantages

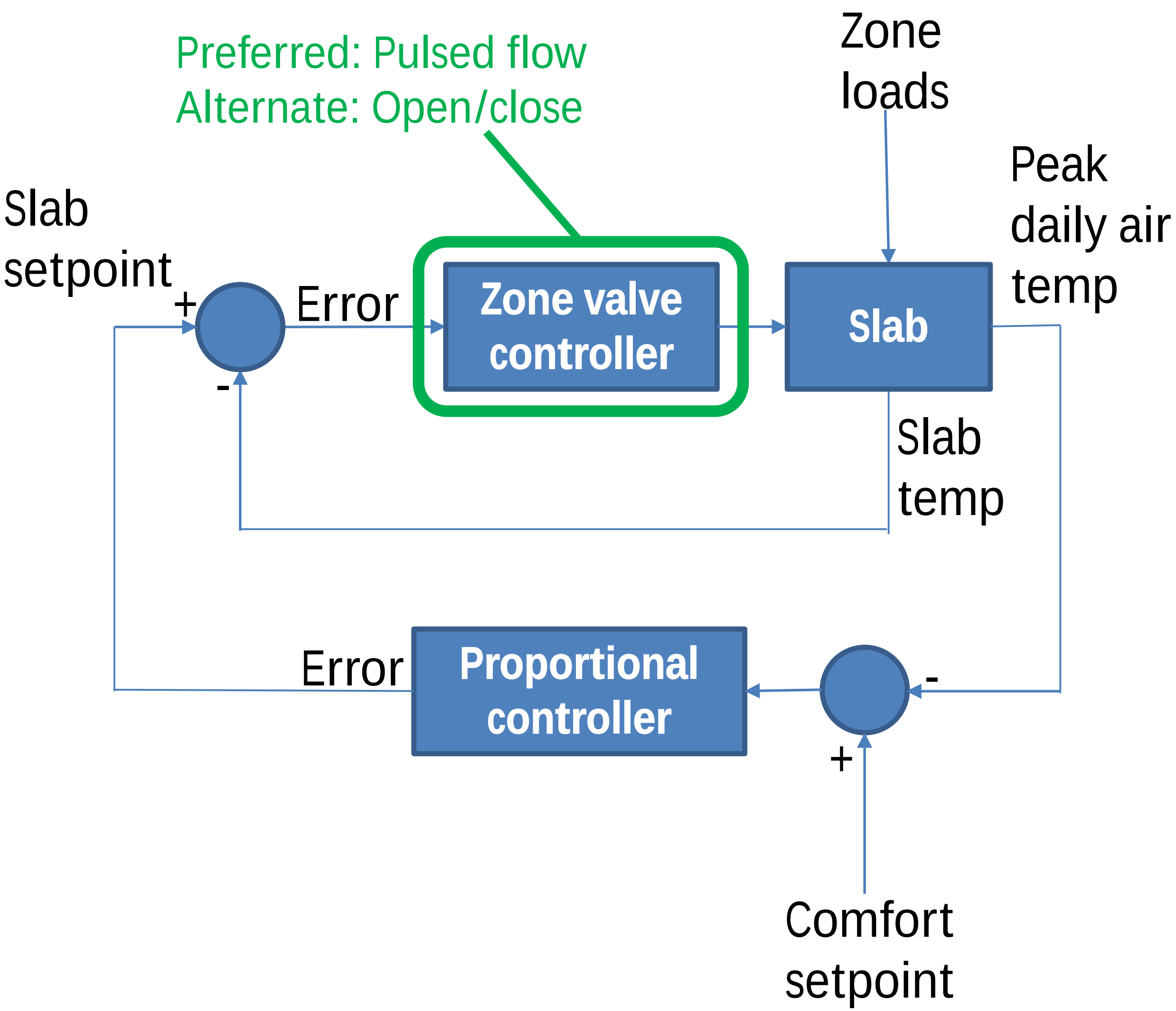
- Low peak plant load
- Small chiller, low initial cost
- High supply water temperatures



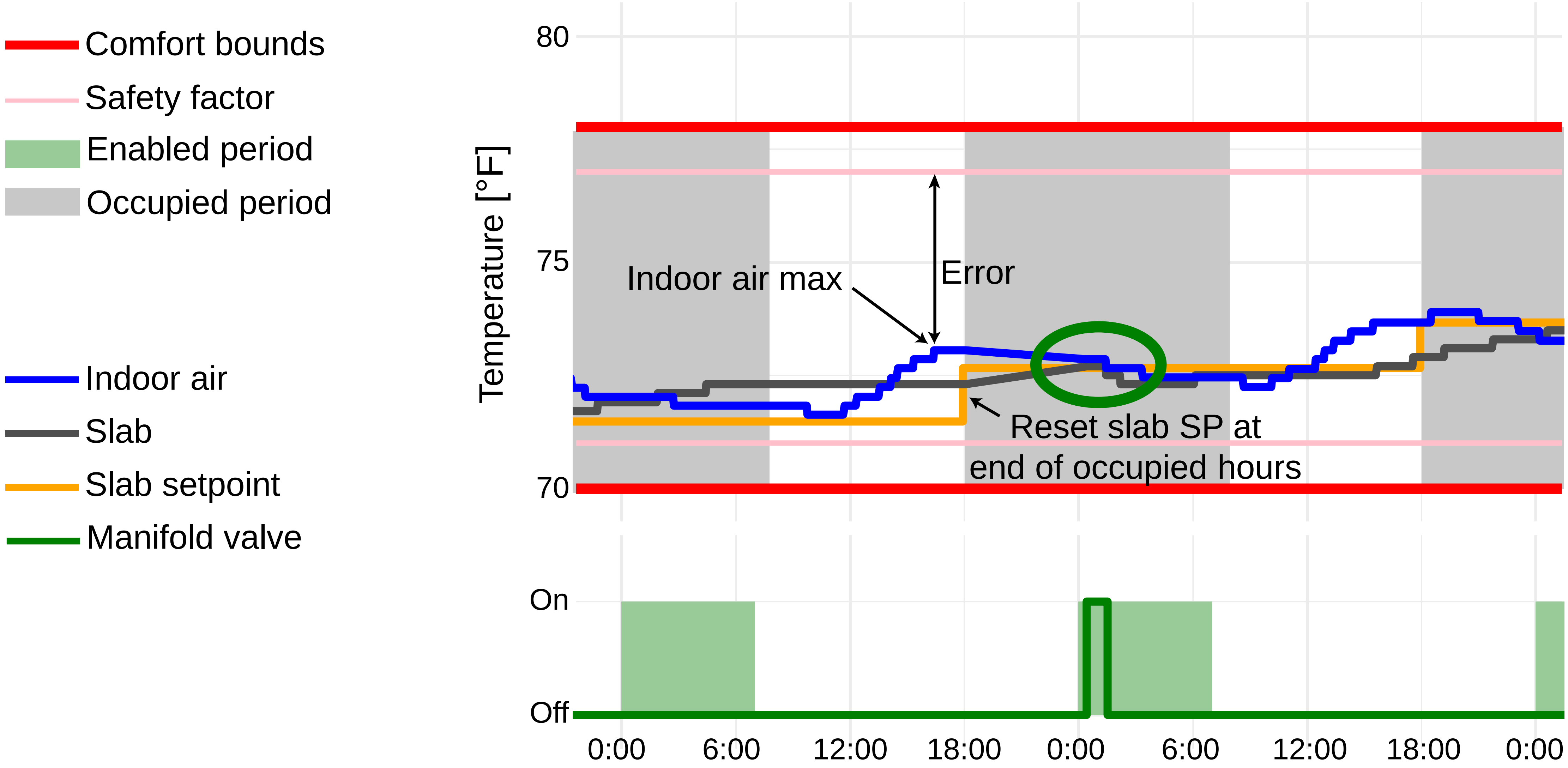
Controls for radiant systems

Overview of the controls (sequences publicly available)

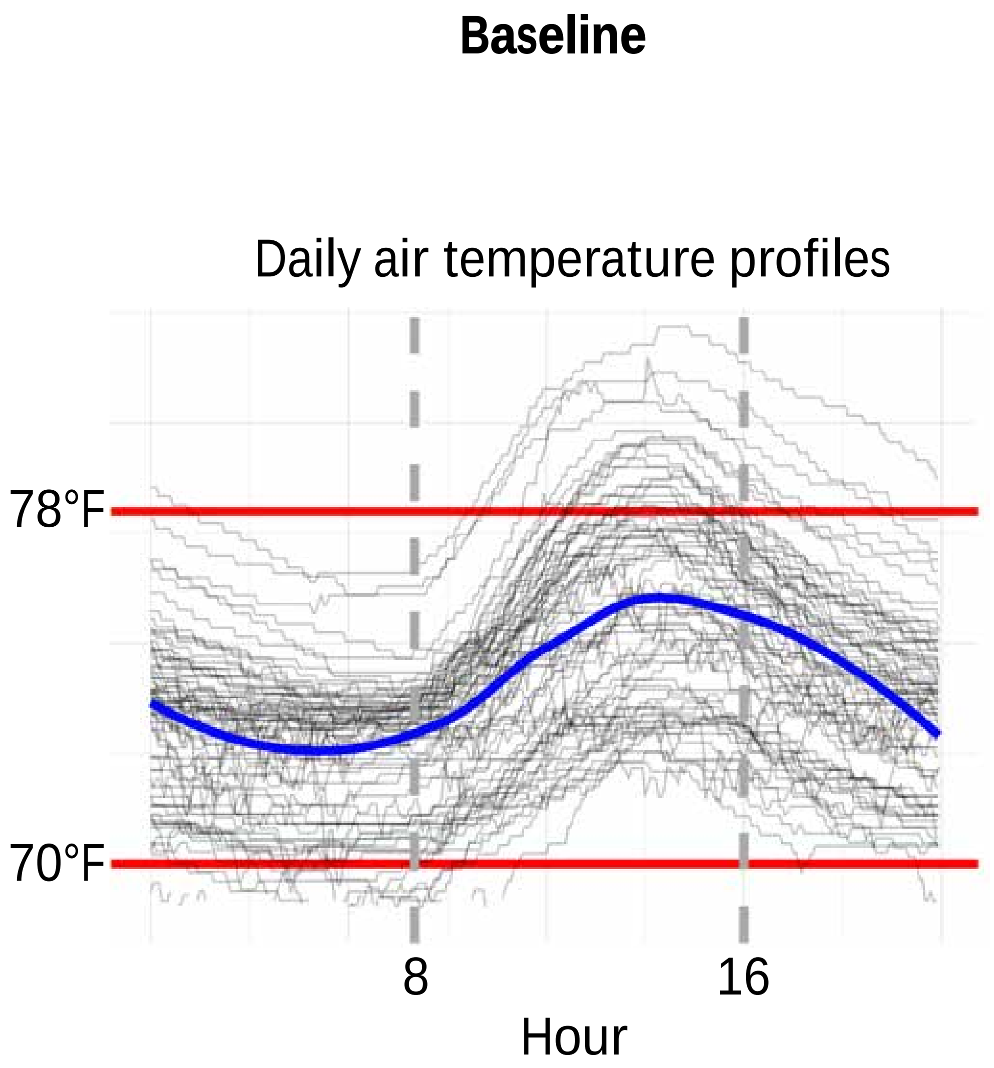
- First loop responds to slab temperature and controls the radiant zone valve
- Second control loop adjusts slab setpoint *once per day* based on previous day's zone conditions.
- Choose enabled time period each day. Radiant system is disabled at all other times.
- Heating or cooling mode separated by at least one day
- Supplemental zone cooling/heating systems:
  - Prioritizes radiant system
  - Limits systems operating in opposing heating/cooling modes on the same day

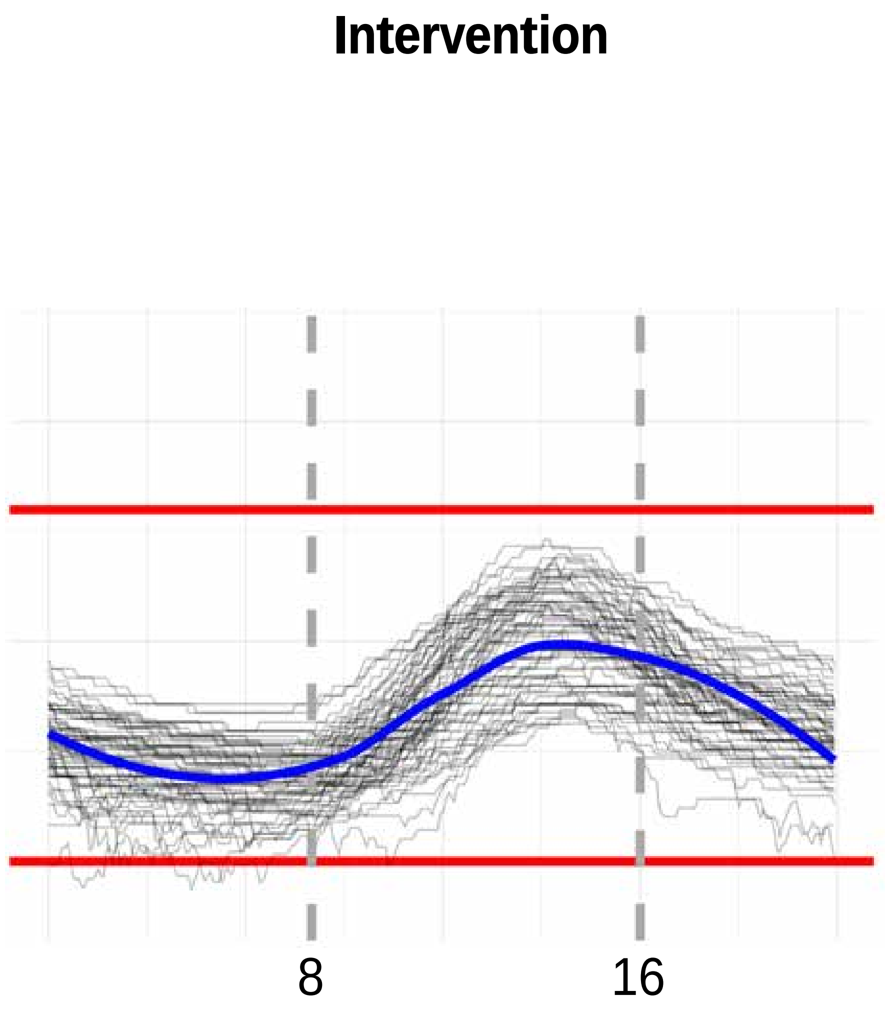


Example cooling day operation from field study demonstration

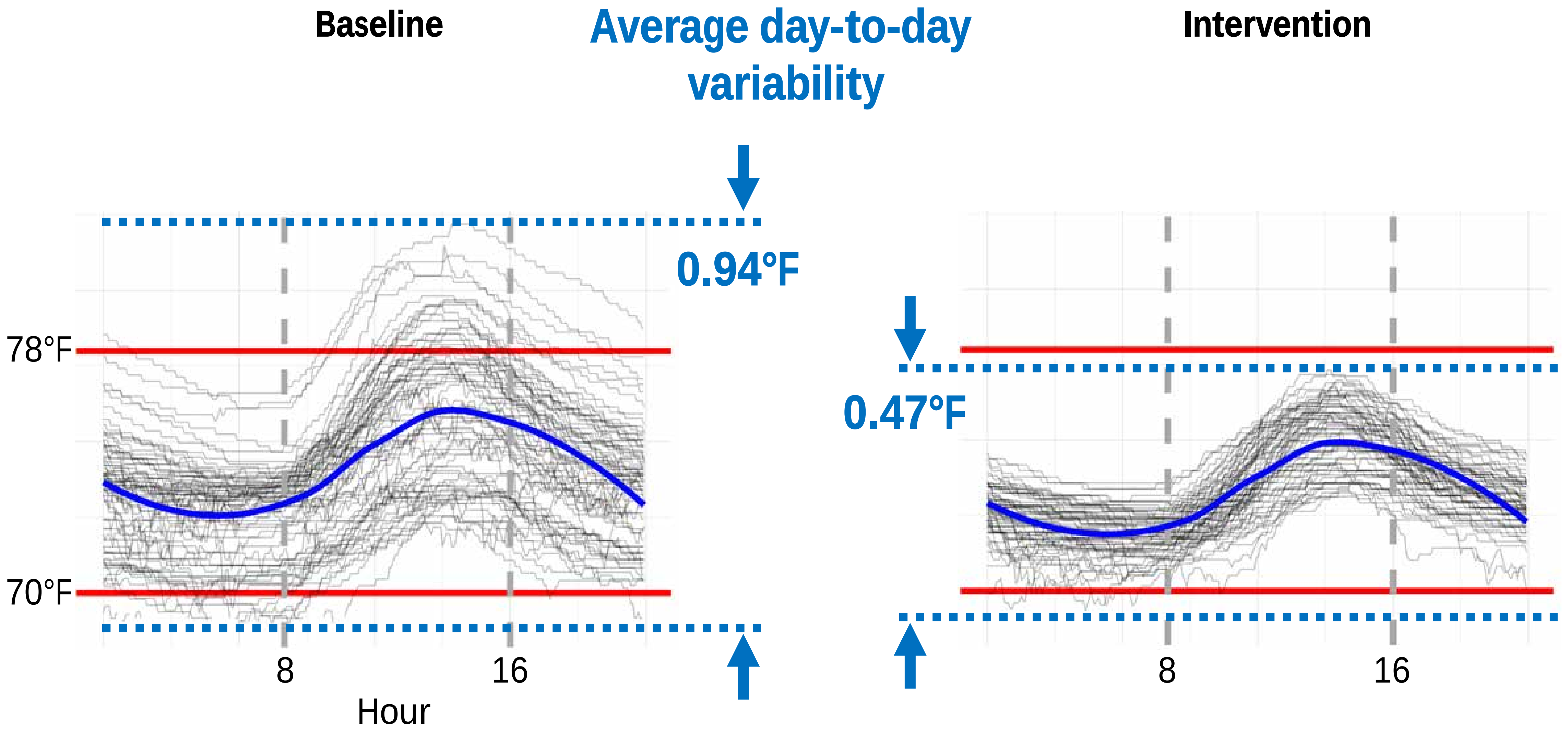


Example thermal comfort comparison in **one** zone





Example thermal comfort comparison in **one** zone

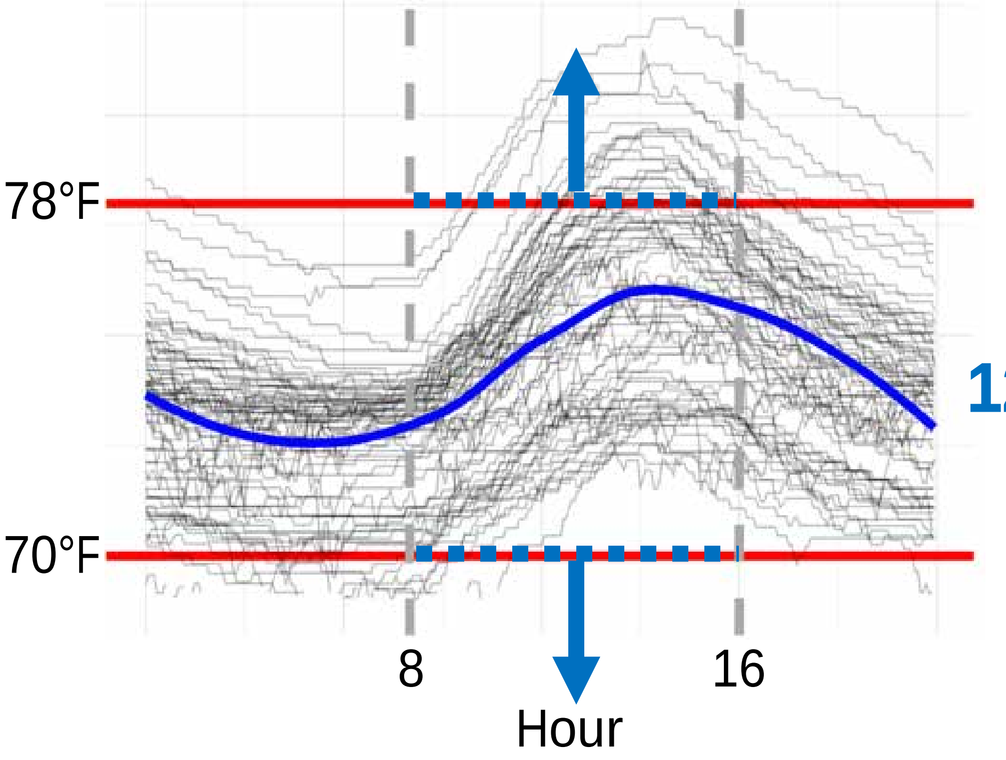


Example thermal comfort comparison in **one** zone

Baseline

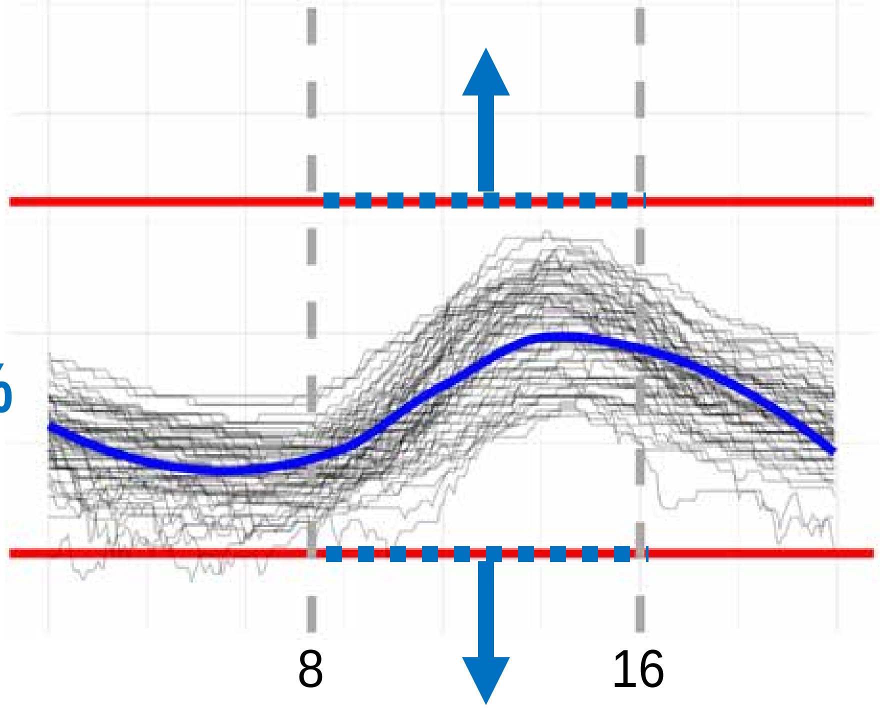
Exceedance percentage of total occupied hours

Intervention



12.3%

0.6%



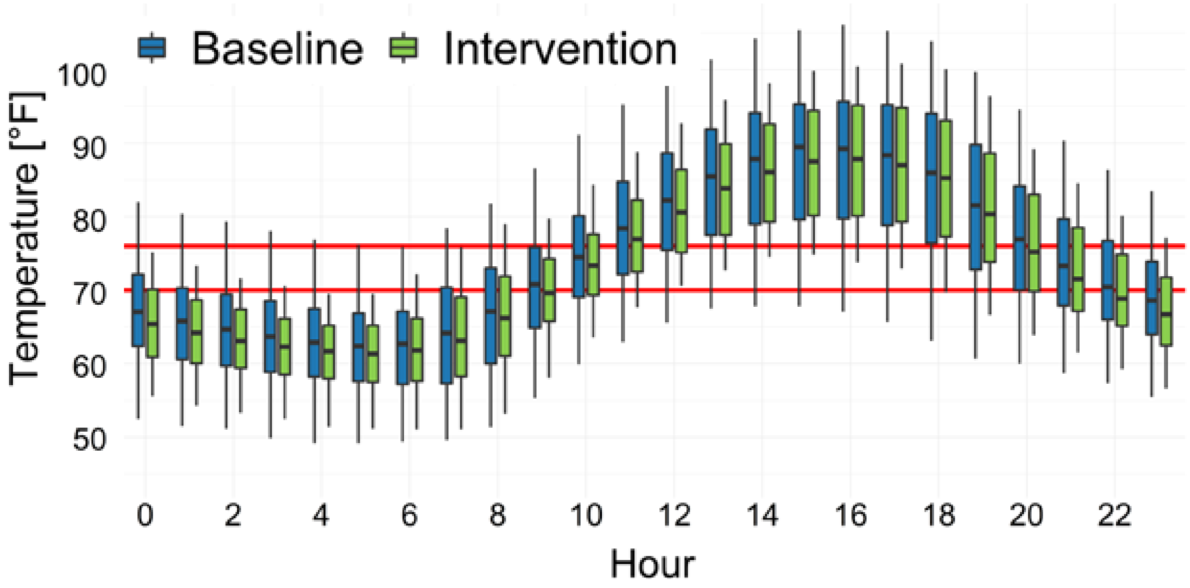
Sacramento Municipal Utility District East Campus Operations Center (SMUD)

- Five story, 200K ft^2
- LEED Platinum
- Low WWR and well shaded
- Single tenant; 900 occupants
- Sacramento, CA

- Cooling season weather summary 2017-2019
- Max: 111°F
- Daily averages
  - Mean: 74°F | Range: 30°F
  - Day-to-day variability: 2.7°F

Tested new control sequences

- Baseline: May – Nov 2017
- Controls implemented in Siemens Apogee system
- Split zones into two groups
- Intervention: May – Nov 2018
- Compared results



Baseline

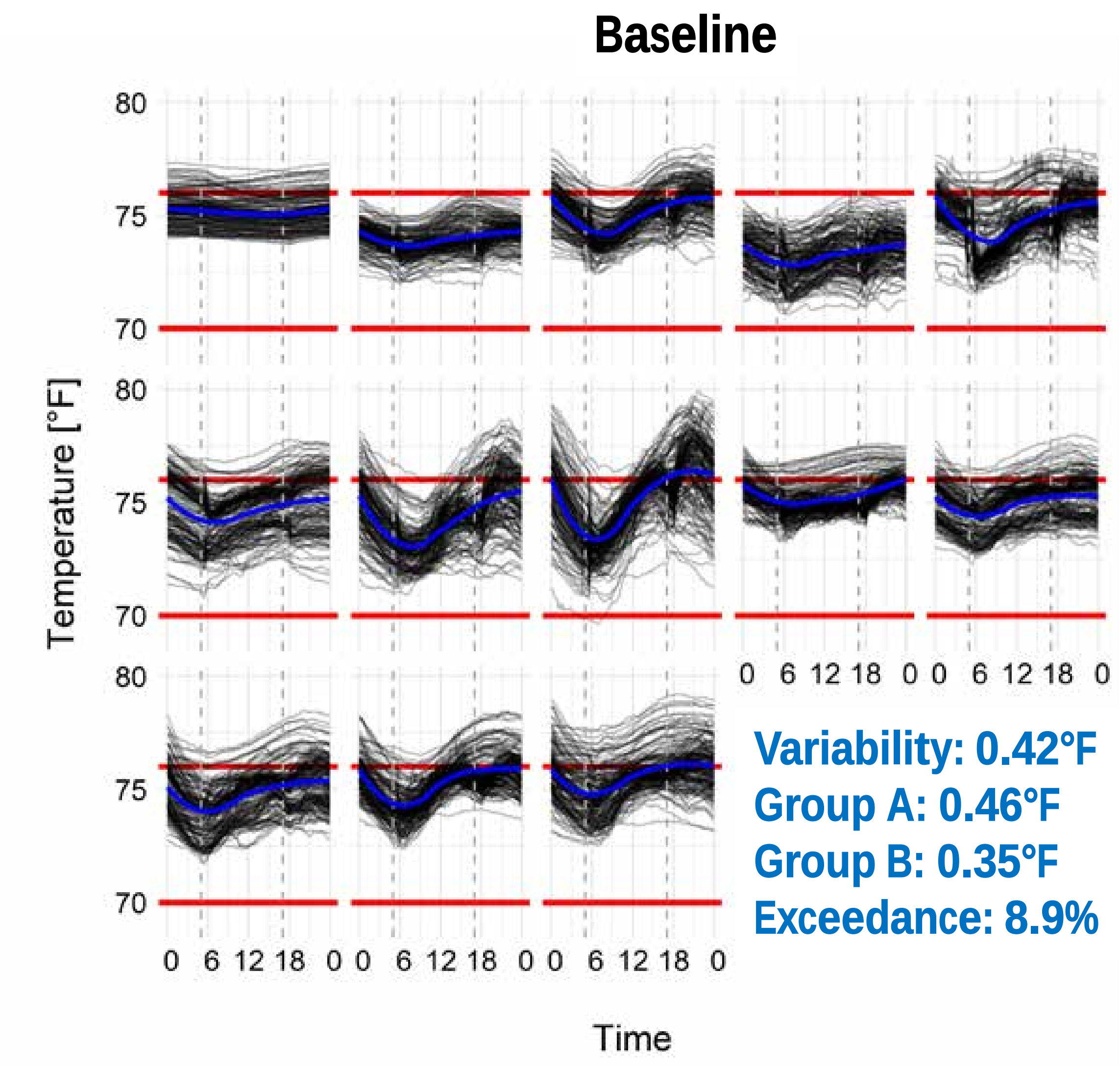
Group A and B zones cool whenever needed during the day or night

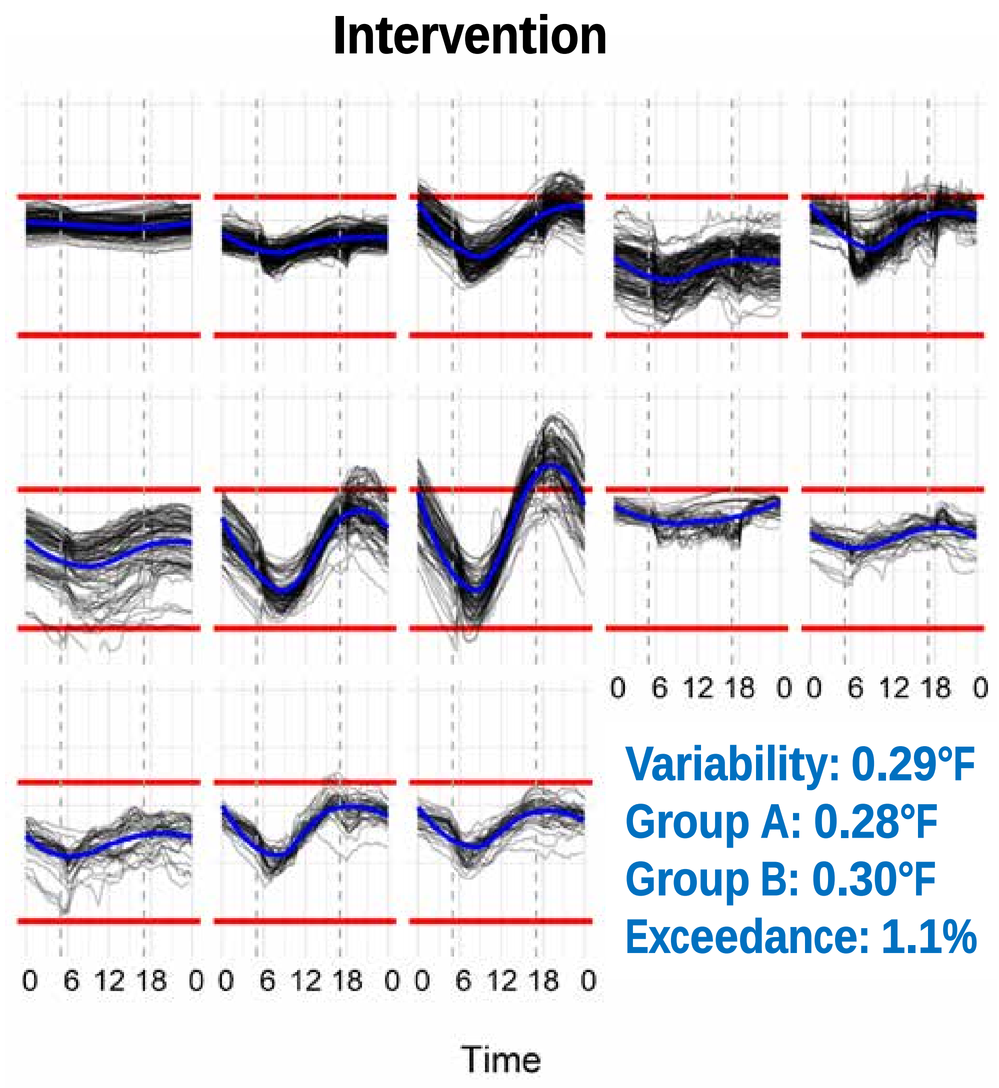
Intervention

Group A zones cool only from morning to early afternoon

Group B zones cool only during the night

SMUD radiant system thermal comfort performance in **all** zones

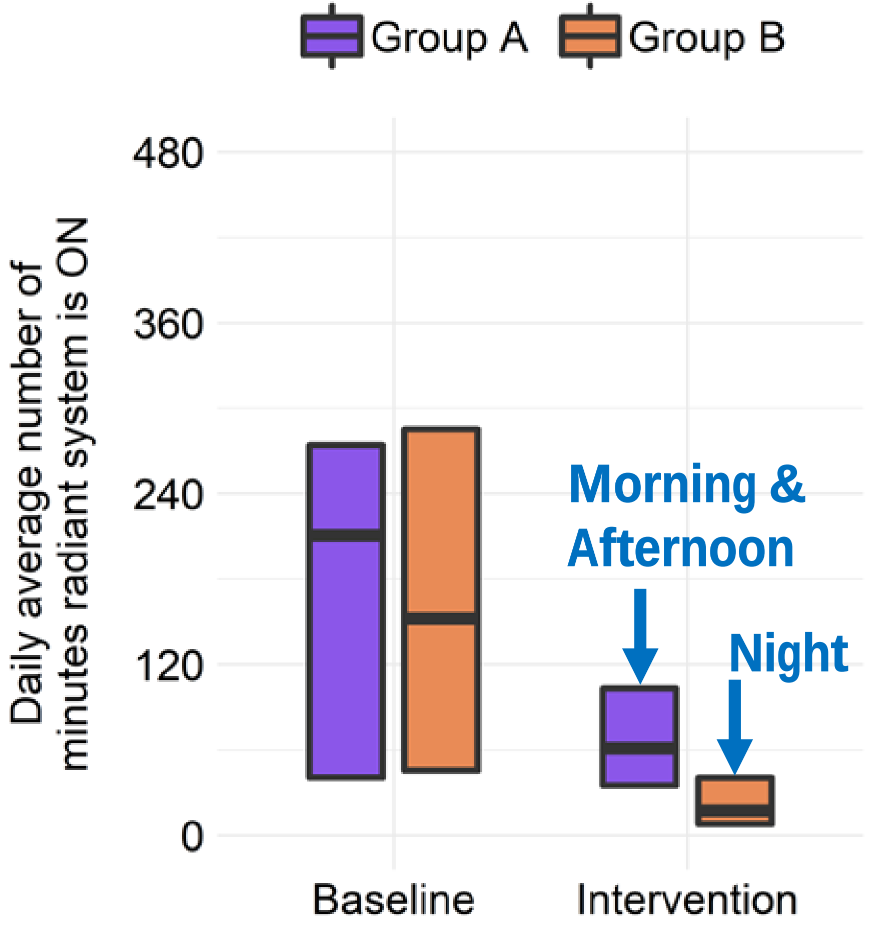




SMUD radiant system zone performance

Radiant system operation

- § Proxy for pump consumption
- § Actuated far less time
- § Daily average ON time
  - Baseline: 2-4 hours
  - Intervention: 0.5 - 1 hour
- § Some days does not turn on at all



Resources

Please share, use and give us feedback.

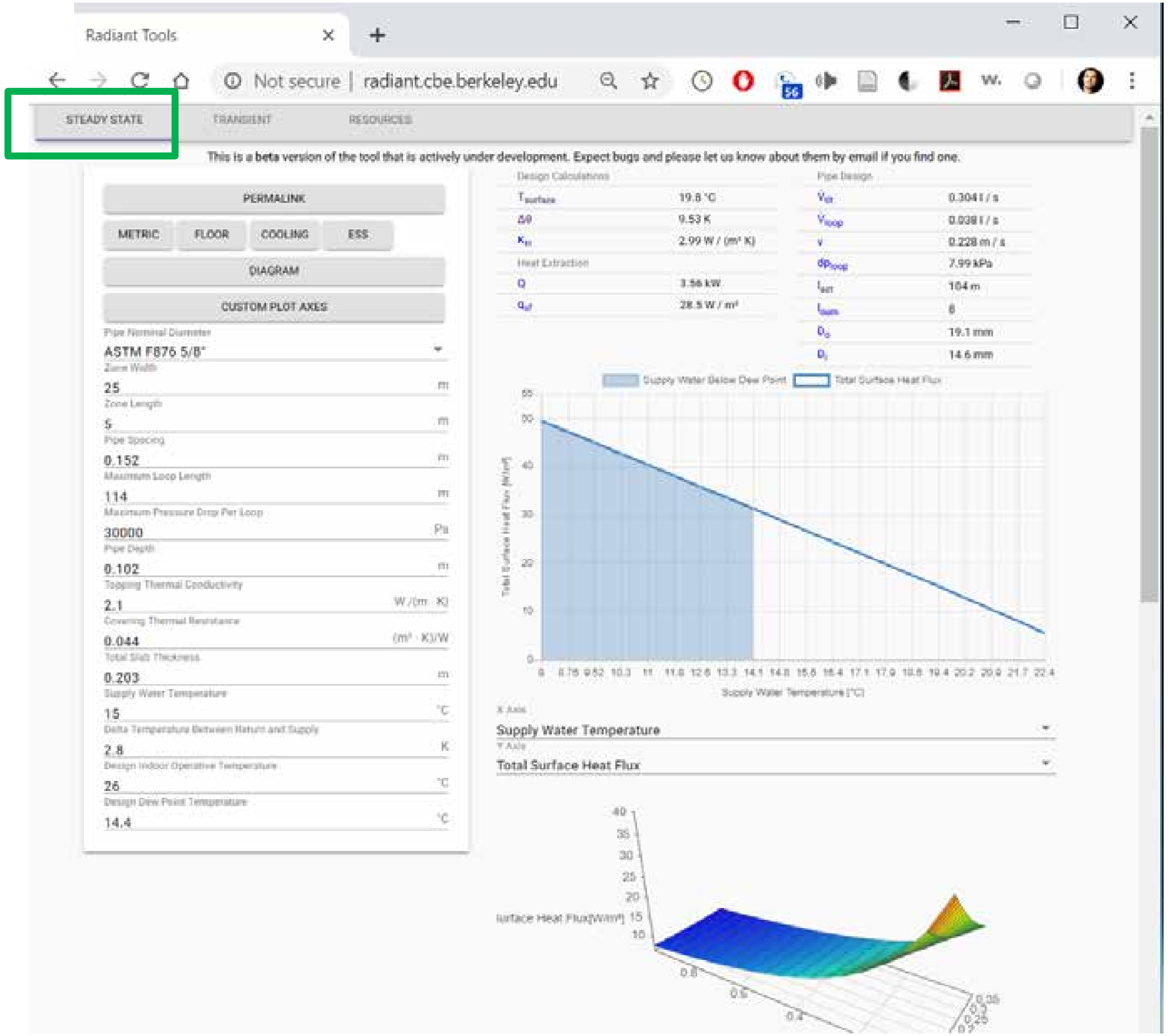
Free webtool (steady-state performance): radiant.cbe.berkeley.edu

Applications:

- Heating and cooling
- Floor and ceiling systems
- Radiant systems with and without insulation and/or surface coverings
- Metric and I-P units

Calculates:

- Steady-state capacity (ISO 11855)
- Number of circuits, pipe length and pressure drop



Free webtool (transient performance): radiant.cbe.berkeley.edu

§ Transient results from over 2.5 million simulations

§ 13 user selectable design parameters incl. time and duration of operation

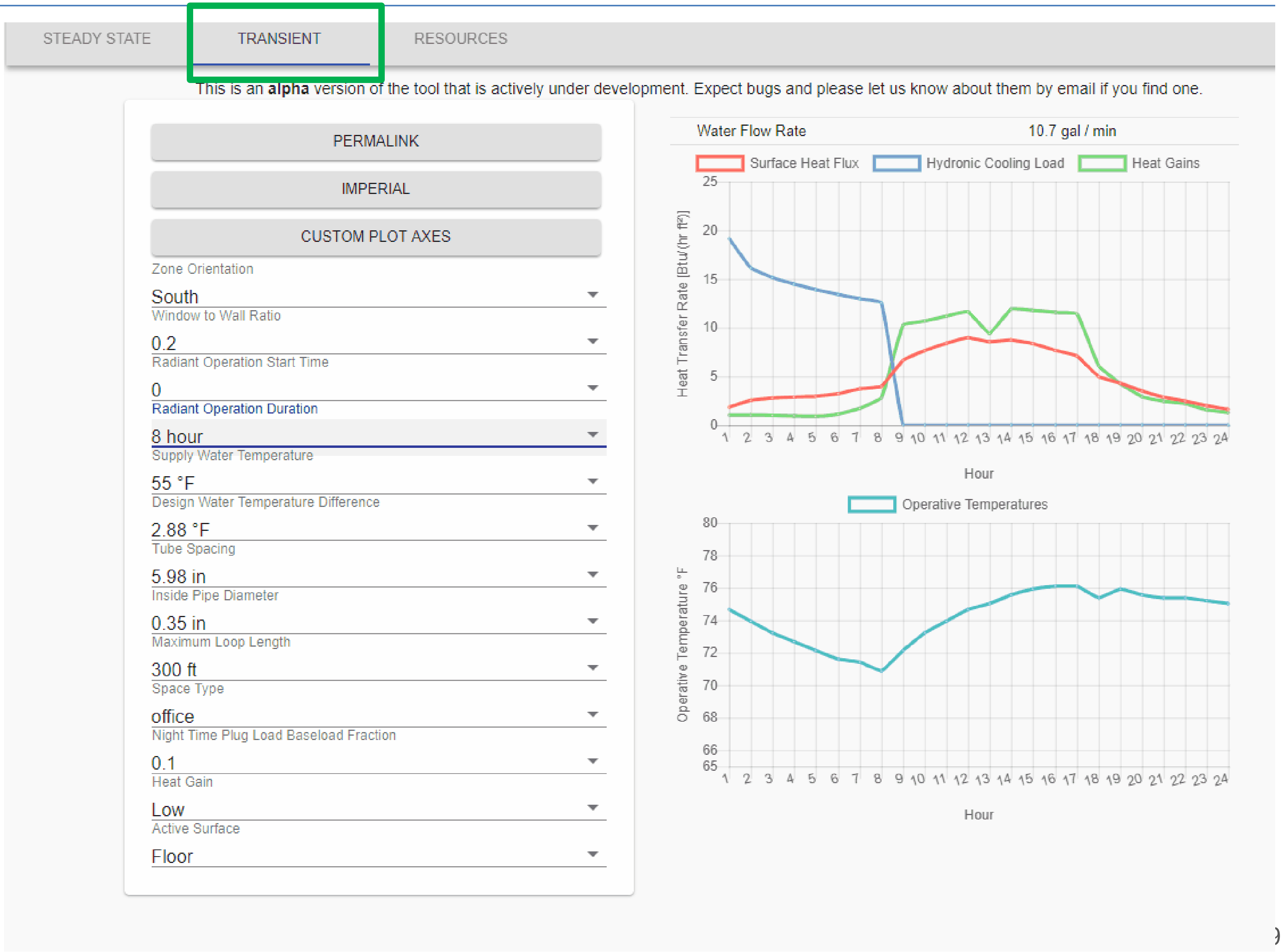
Outputs

§ 24-hour cooling day design values

§ Surface heat flux

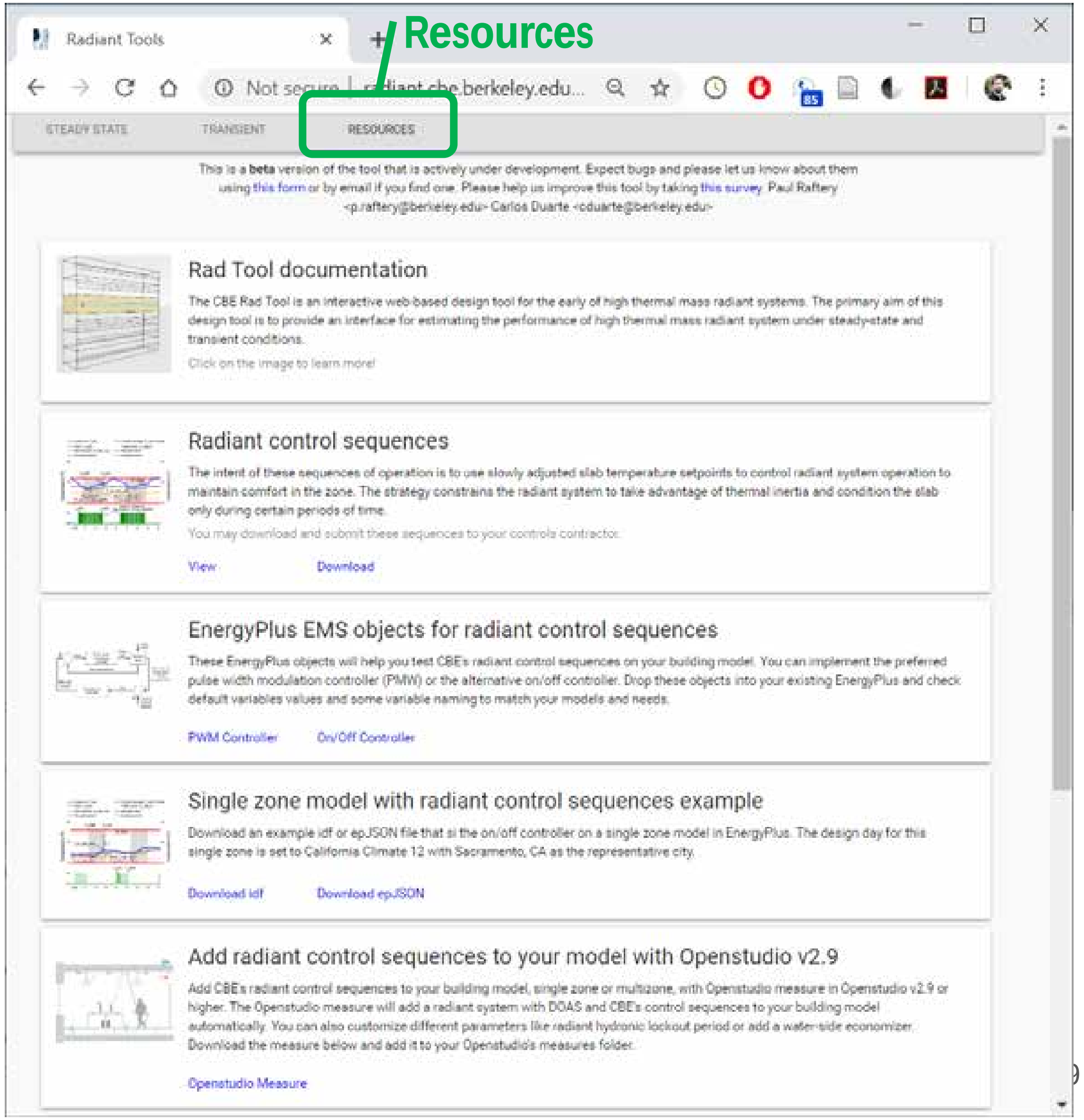
§ Hydronic heat capacity

§ Operative temperature



Controls publicly available in resources: radiant.cbe.berkeley.edu

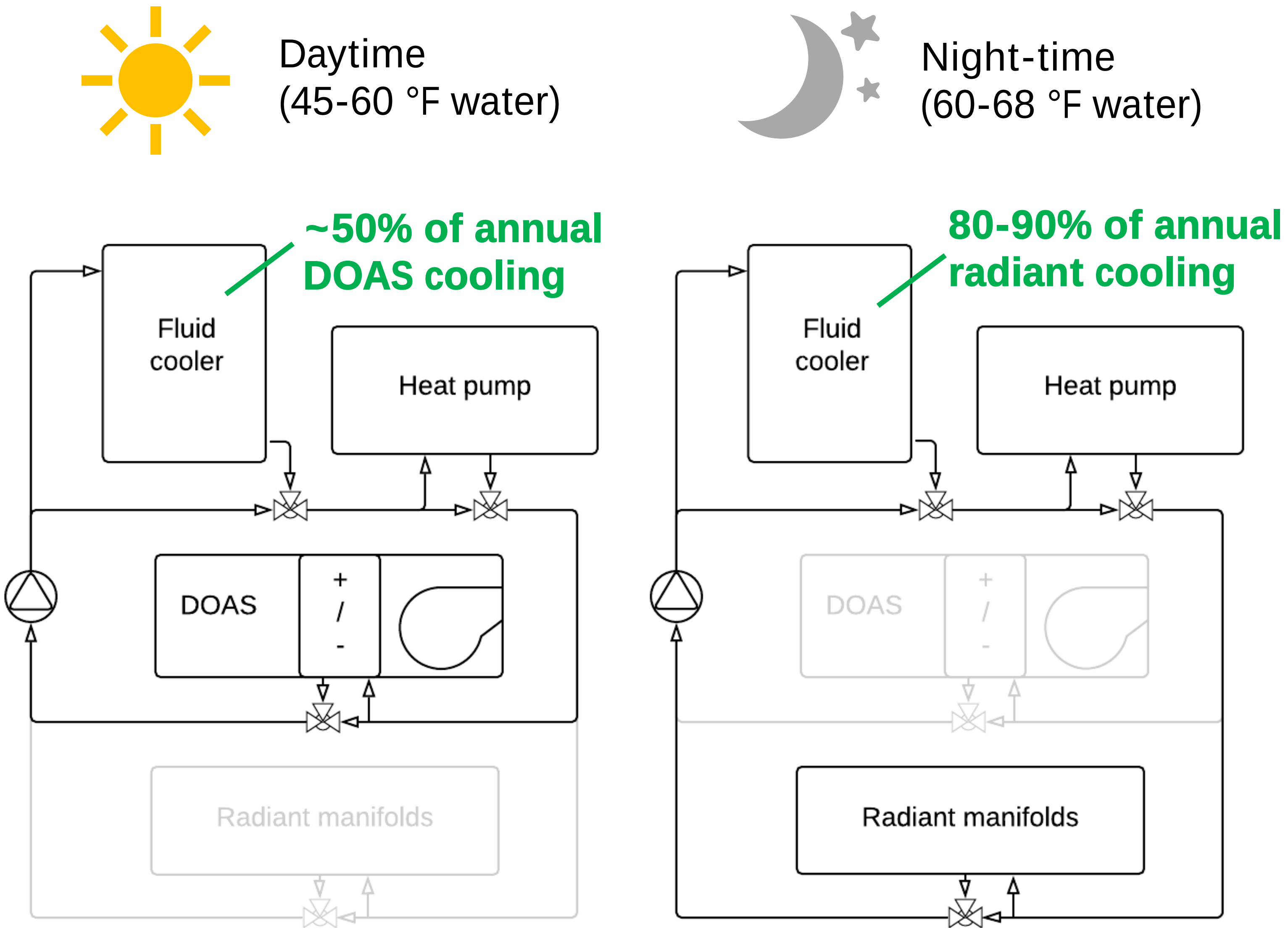
- Sequences of operation available
- English language, editable Word document
- Can be implemented in existing automation systems
- EnergyPlus examples available
- Available as a measure in OpenStudio



Design concept leveraging thermal storage

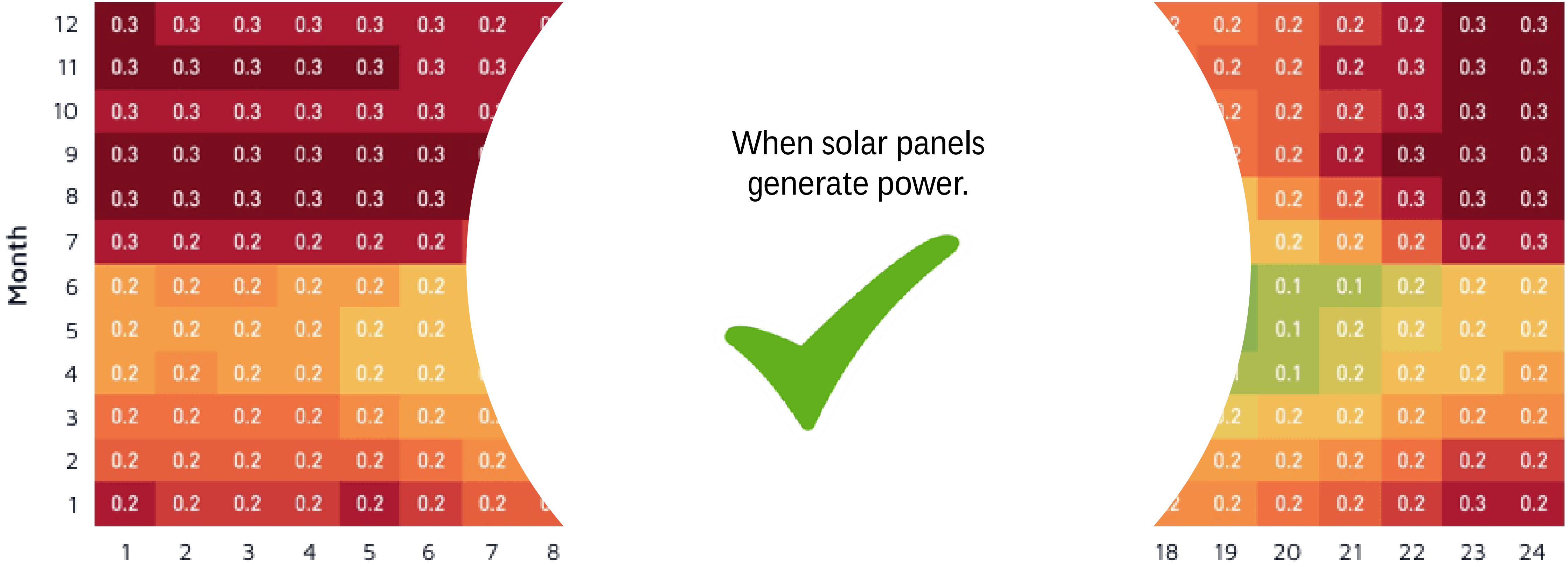
Example design concept leveraging thermal mass

- All-electric: Air (or ground) source heat pump for heating and cooling
- Dedicated outside air system (DOAS) and radiant can operate at different *times* and different *temperatures*, using the same heat pump
- Reduced design capacity
- Closed circuit cooling tower (fluid cooler) for economizer operation



Closing remarks

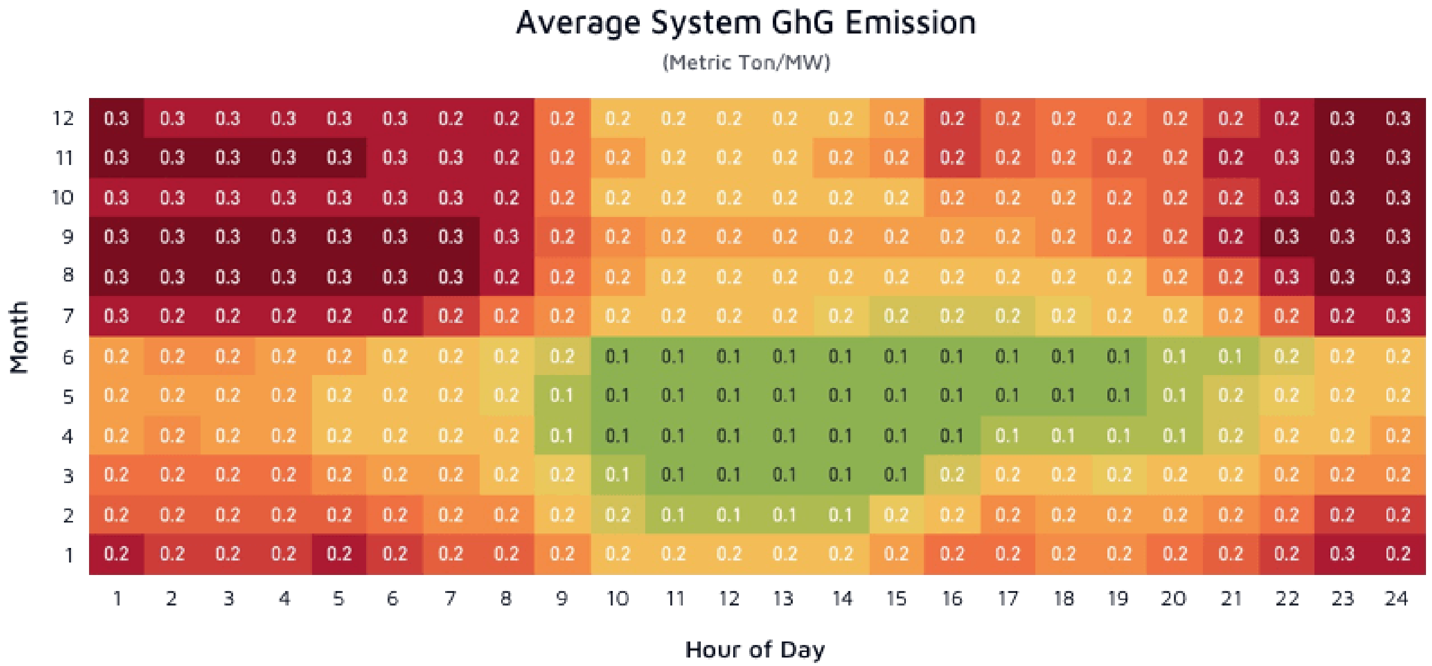
Annual grid greenhouse gas emissions



Source: Recurve.

Need for energy storage

- Getting the storage we need to make the grid renewable is a huge challenge.
- Storing energy in concrete is as cheap and easy as it’s going to get.



Source: Recurve.

New HVAC designs should leverage ***inherent*** thermal storage in buildings.

Questions?

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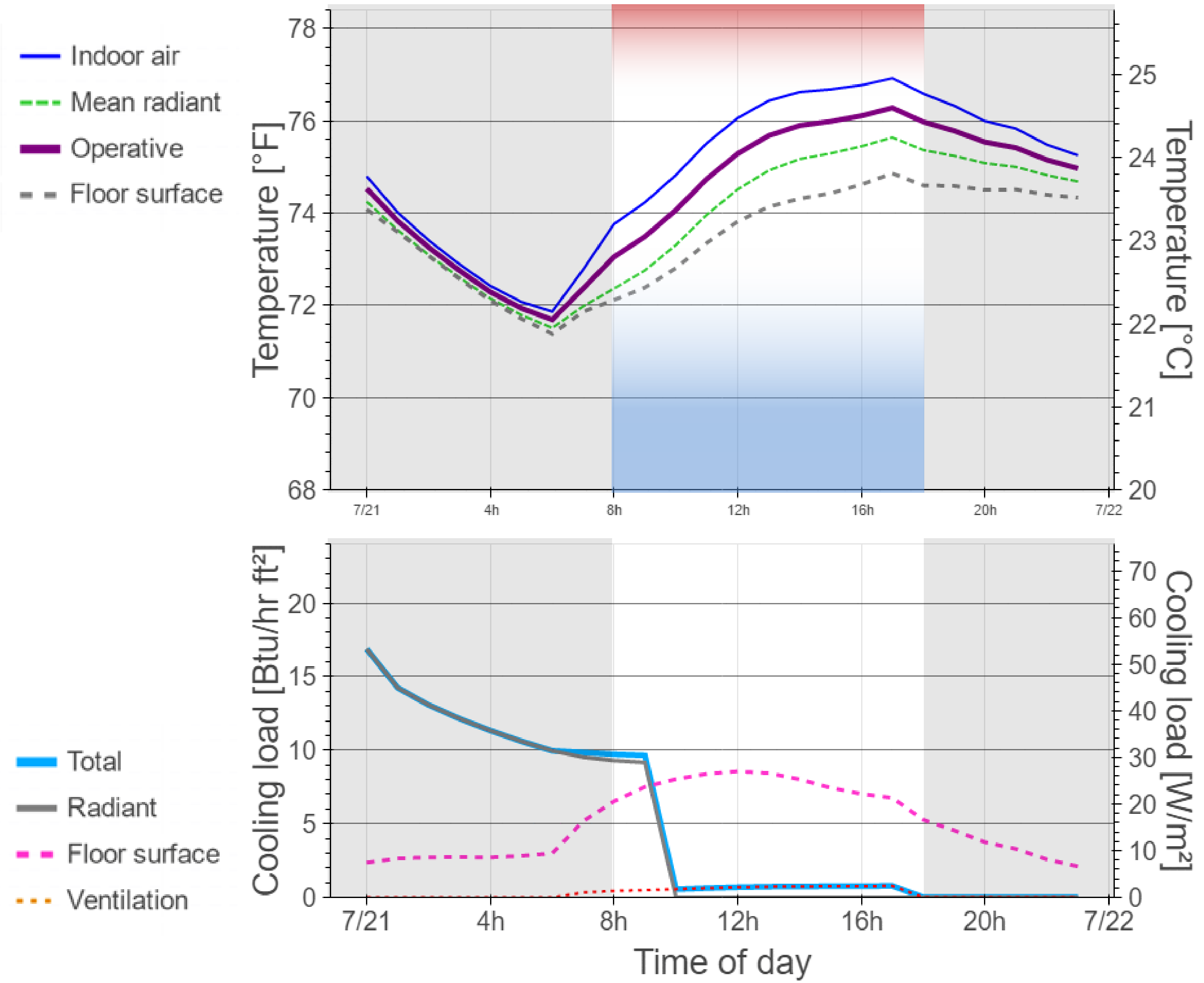

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