A Side-by-Side Laboratory Comparison of Peak Space Cooling Loads and Daily Thermal Energy Use for Radiant and All-air Systems

Seminar 26: A Side-by-Side Laboratory Comparison of Peak Space Cooling Loads and Daily Thermal Energy Use for Radiant and All-air Systems

Jonathan Woolley
Center for the Built Environment, University of California Berkeley
jmwoolley@Berkeley.edu
(530) 204 7619

This investigation was part of a larger series of experiments at FLEXLAB

Objectives:

- Better understand the dynamics of cooling load for radiant systems as compared to all-air systems
- Investigate the impact of natural ventilation cooling on cooling load

Approach:

- LBNL FLEXLAB experiments
- Simultaneous parallel comparisons of radiant and air cooling systems

Funding:

- CA EPIC program, Price Laboratories, and CBE Industry Partners

Experimental arrangement at FLEXLAB

Envelope

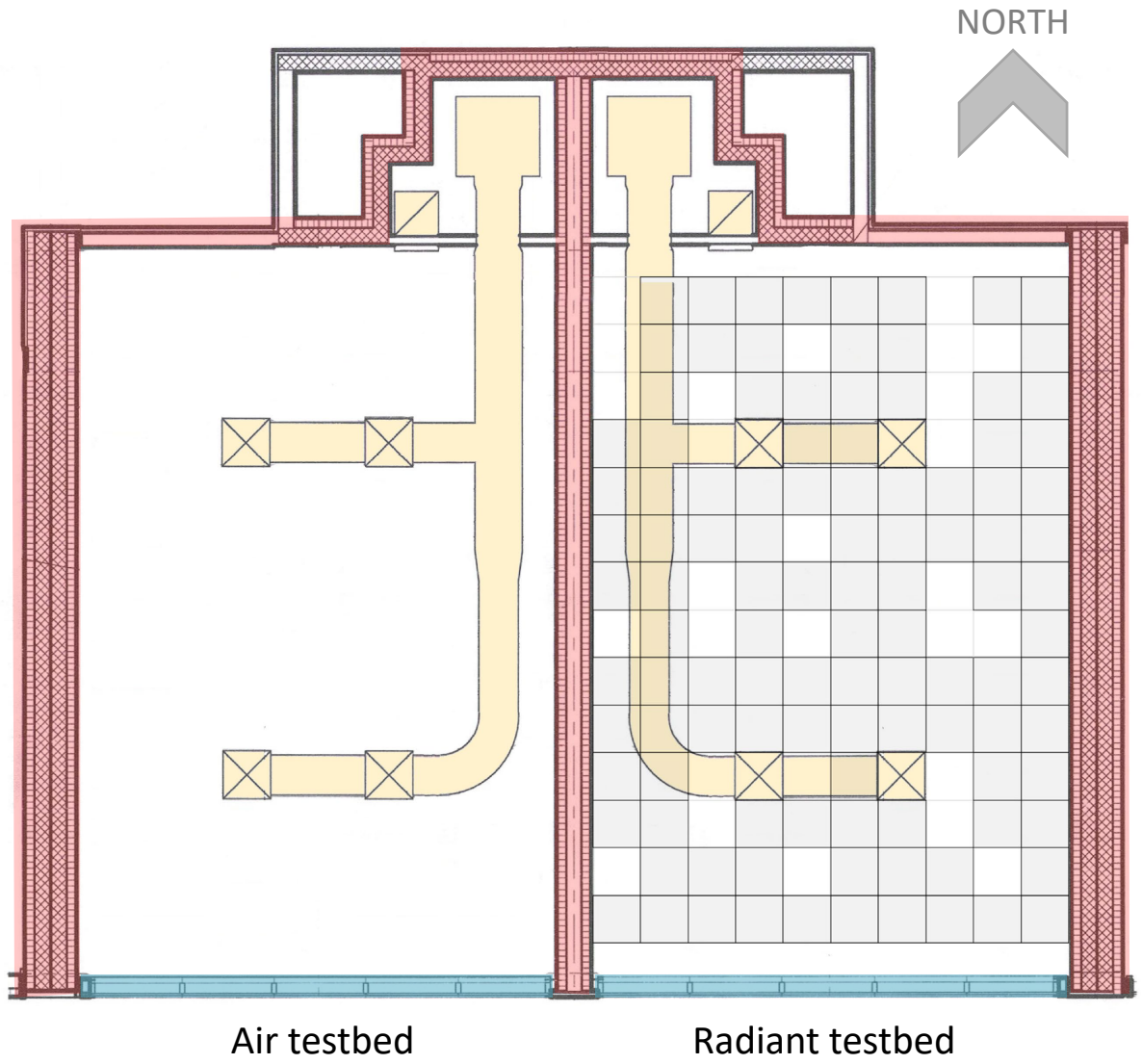
- 90% of envelope is very well insulated
- South wall constructed per standards
- ~30% window to wall ratio
- No exterior shading

Systems

- Overhead supply air distribution
- Air testbed – CVVT overhead mixing
- Radiant testbed – metal ceiling panels

Heat gains

- Controlled internal heat gain ~50 W/m^2 (~3,200 W total)
- Peak solar gain ~1,000–1,500 W
- Envelope gains ~(-10)–15 W/m^2



We compared space cooling rates to maintain equivalent thermal comfort

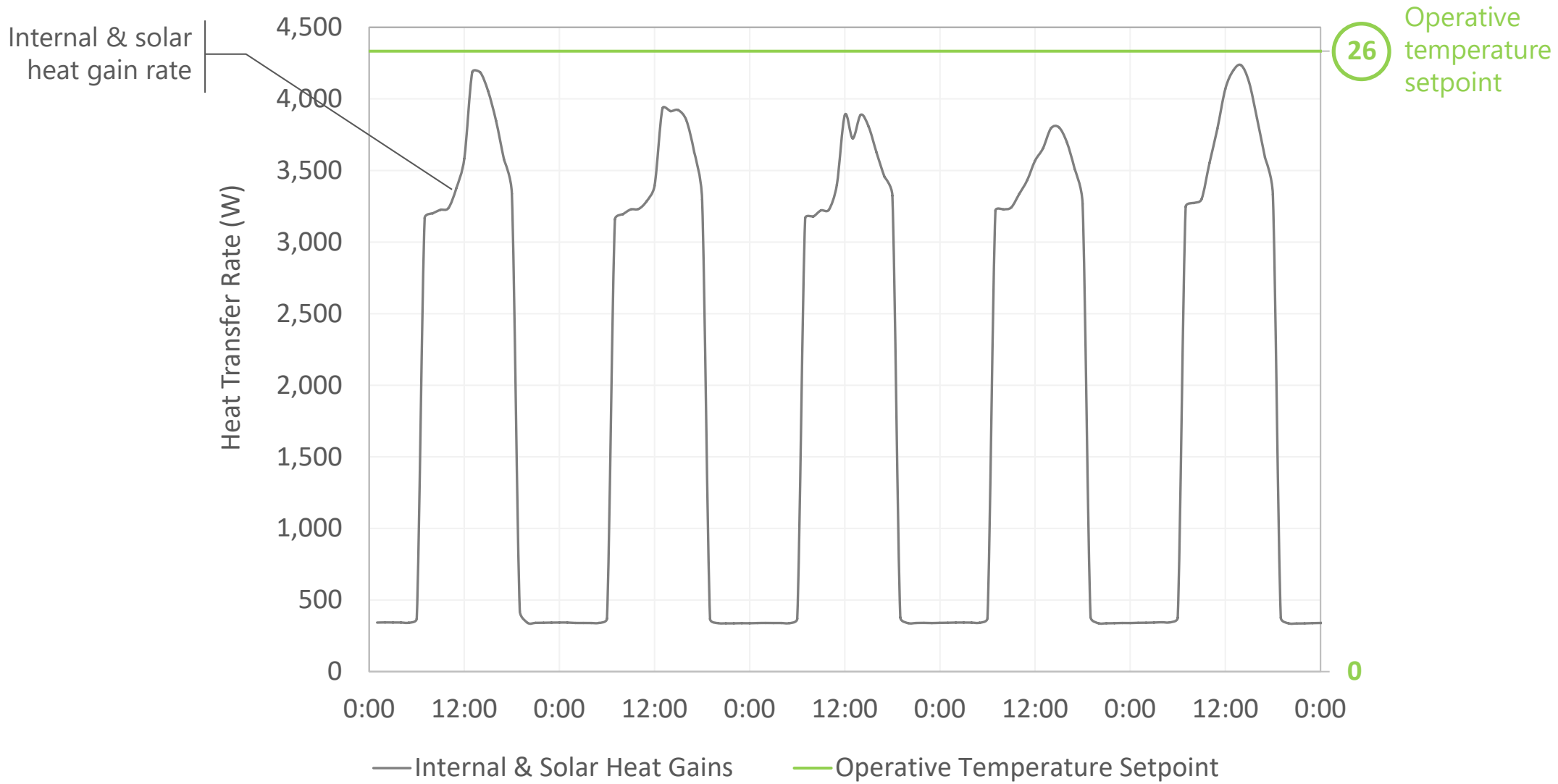
Key methods

- Equal operative temperature
- Equal heat gains
- Extended multiple day experiments

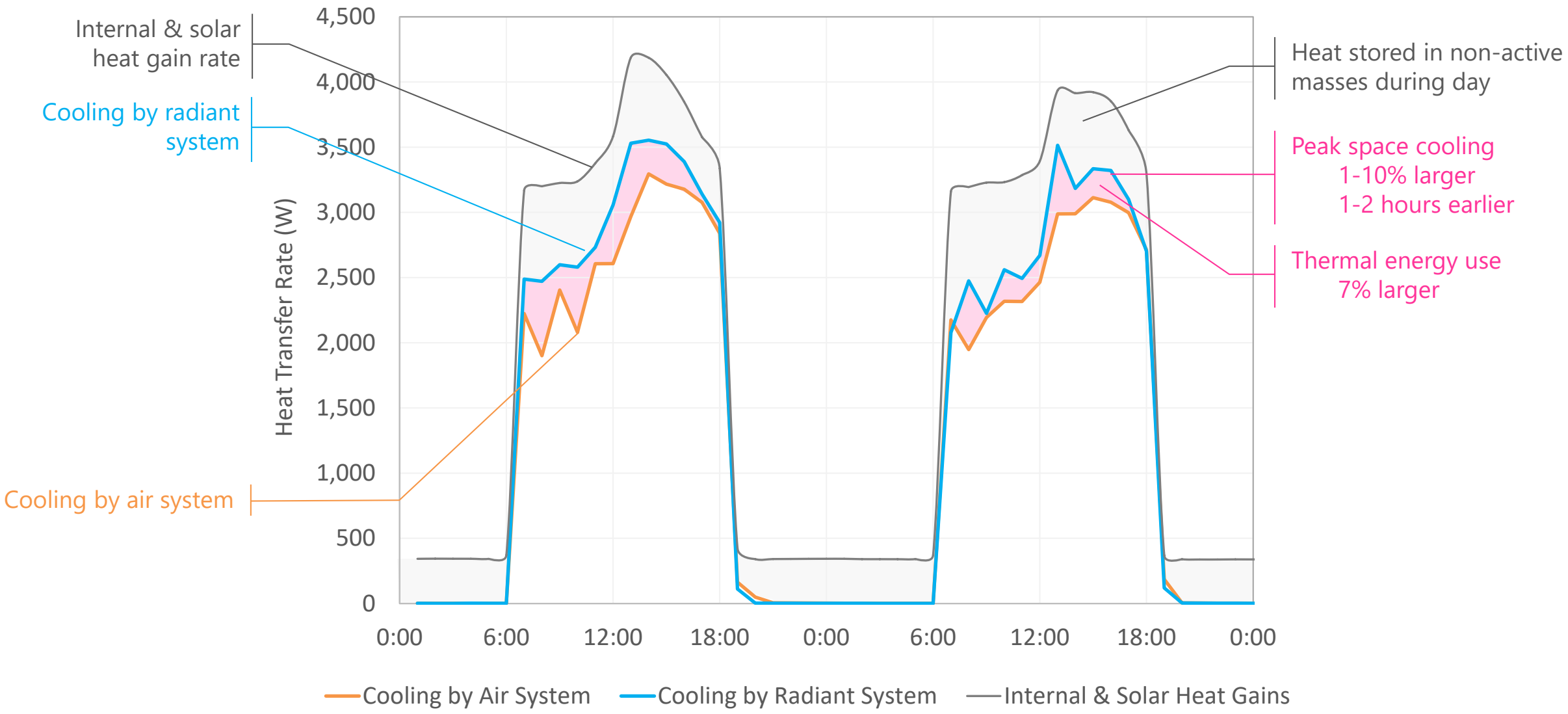
Key metric

- Space cooling rate required by each system.

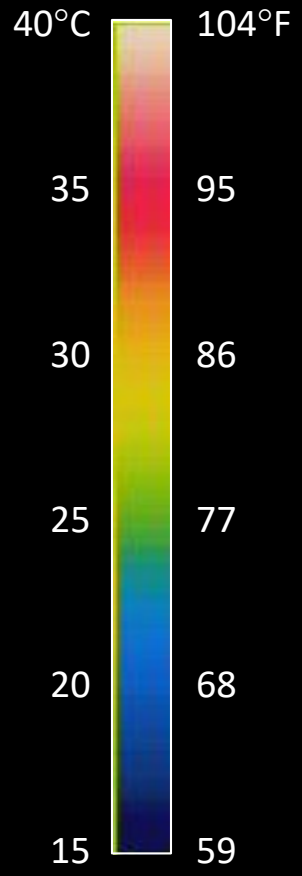
Heat gains and operative temperature set point



Radiant requires larger space cooling rate (load)



Envelope heat transfer is larger with radiant cooling and Less heat is stored in mass then released to the environment passively



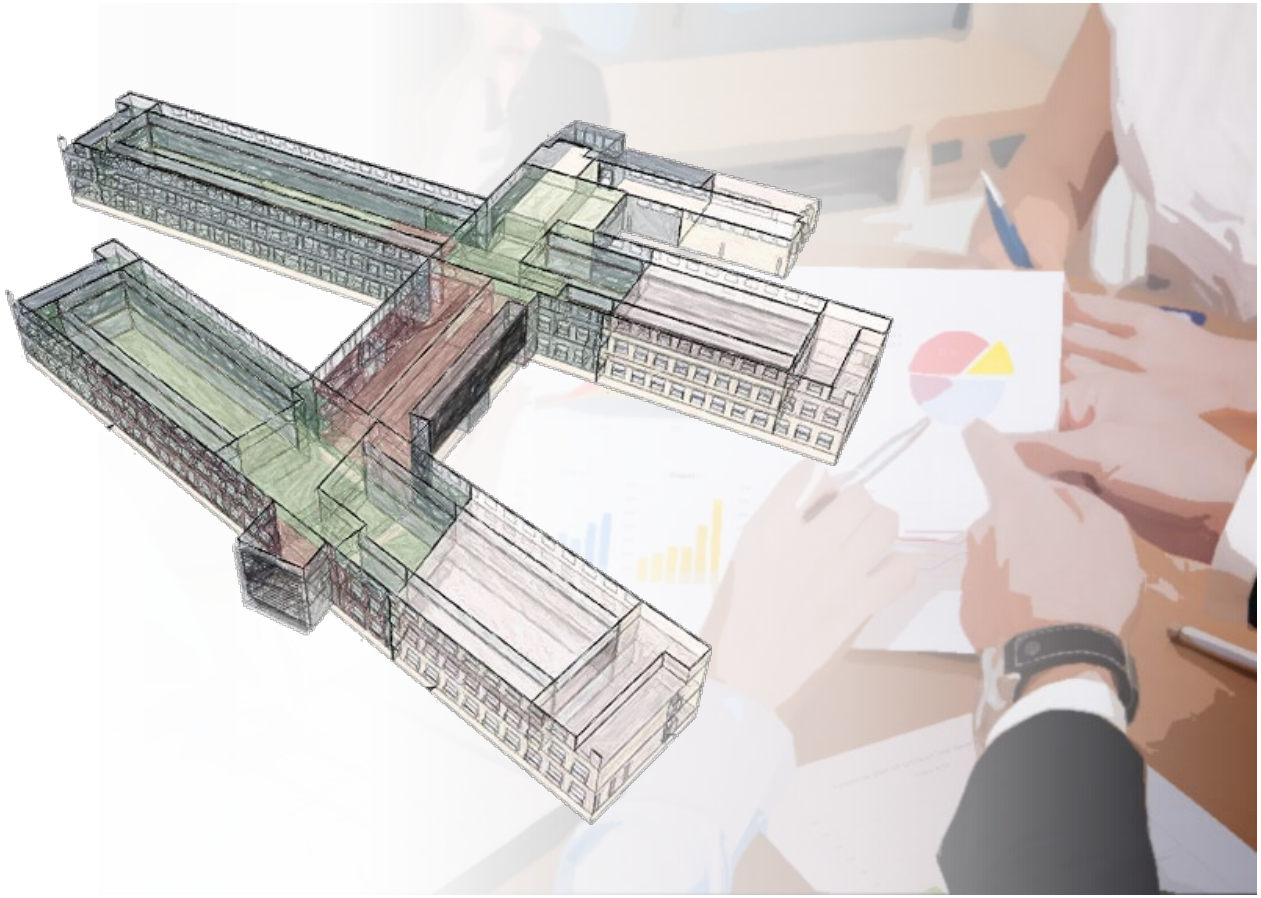
Cooling with radiant system (ceiling)
Operative Temperature = 26°C (78.8°F)
Air Temperature ~26.5°C (79.7°F)

Cooling with air system
Operative Temperature = 26°C (78.8°F)
Air Temperature = ~25.5°C (77.9°F)

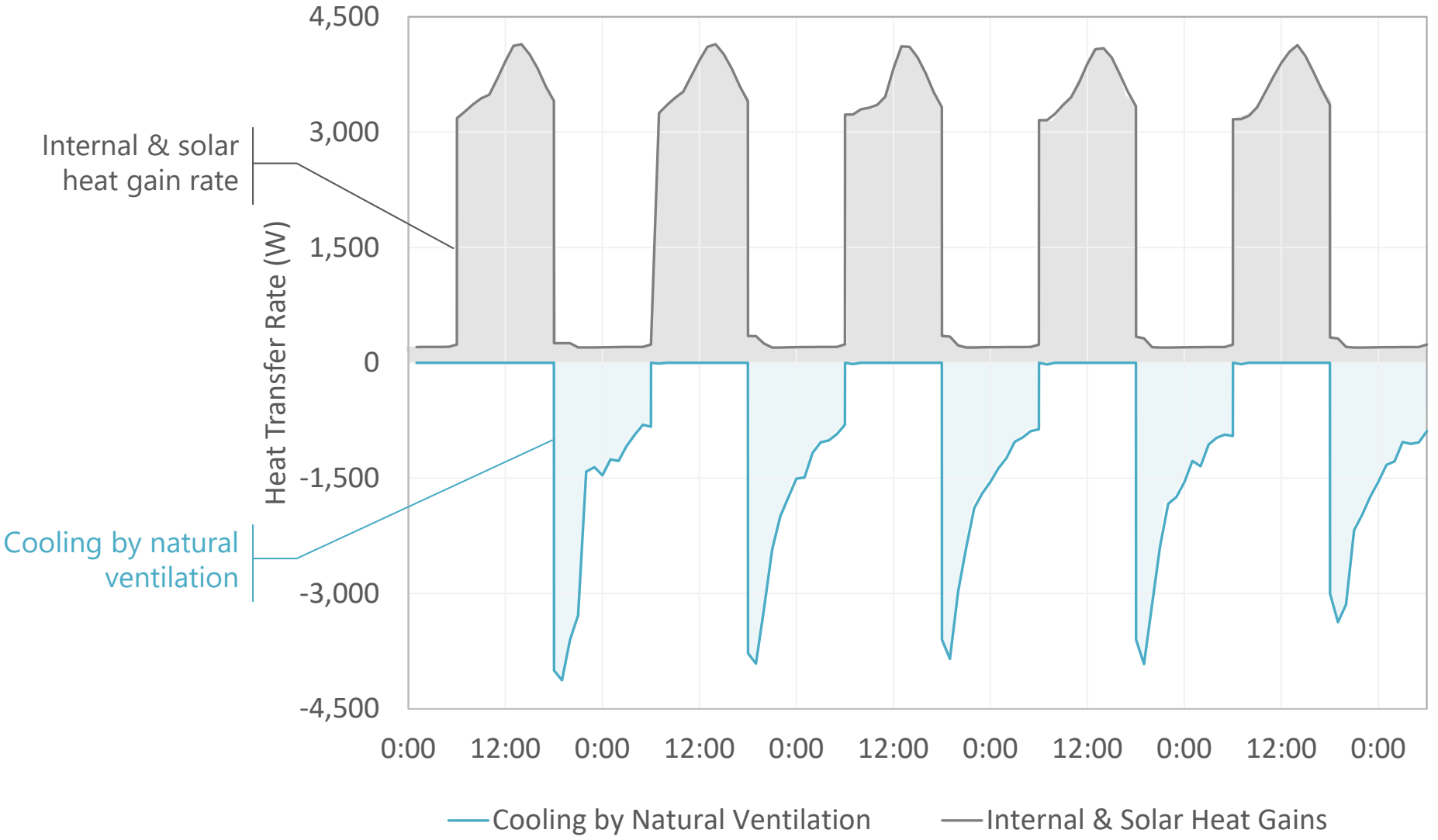
Visual image of chamber

Do the differences matter to design in practice?

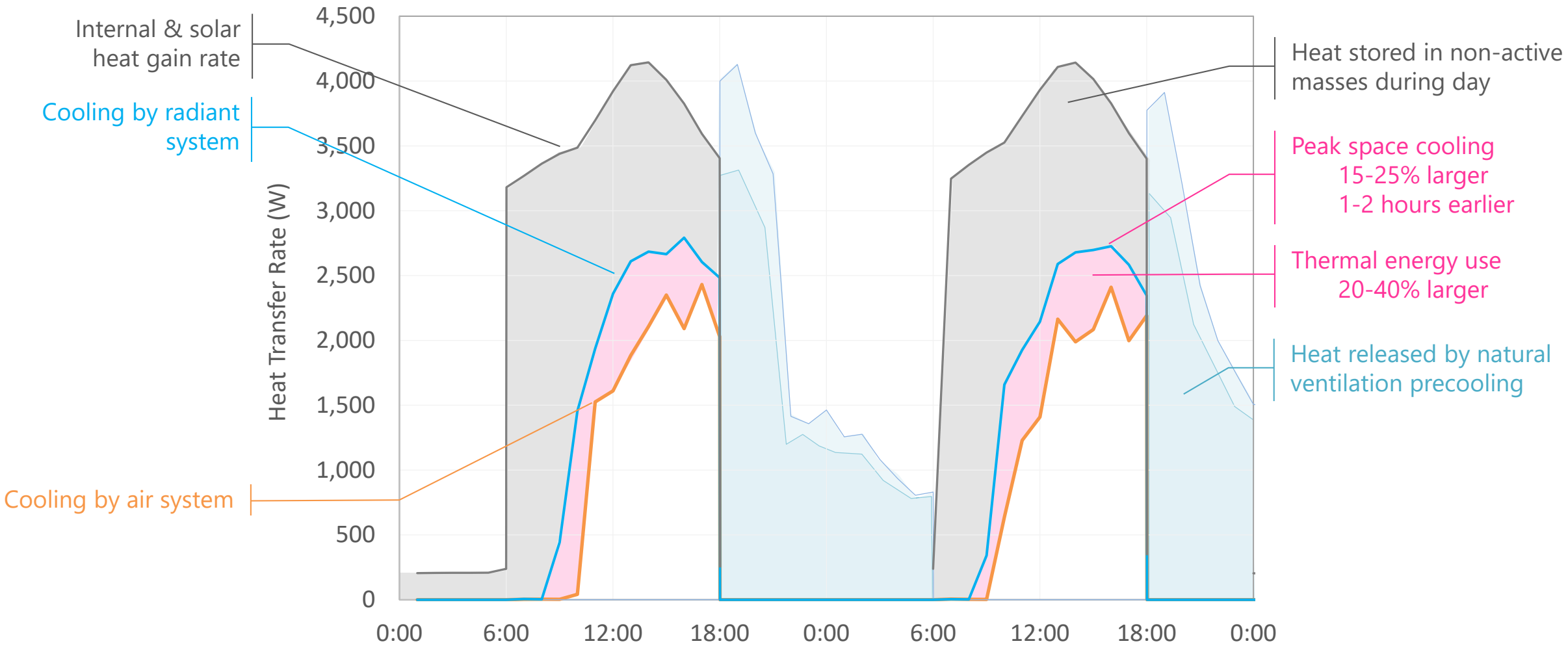
- Small differences may be outweighed by typical “oversizing” in mechanical design
- Differences impact energy use projections so are important for high performance design
- Simulations indicated that the differences are:
  - Larger in spaces with solar gains
  - Larger with more passive cooling
- We conducted a series of side by side experiments to investigate:
  - The impact of radiant-to-total ratio
  - The availability of passive cooling, such as natural ventilation precooling



Heat gains and natural ventilation precooling



Radiant cooling releases less heat to natural ventilation cooling



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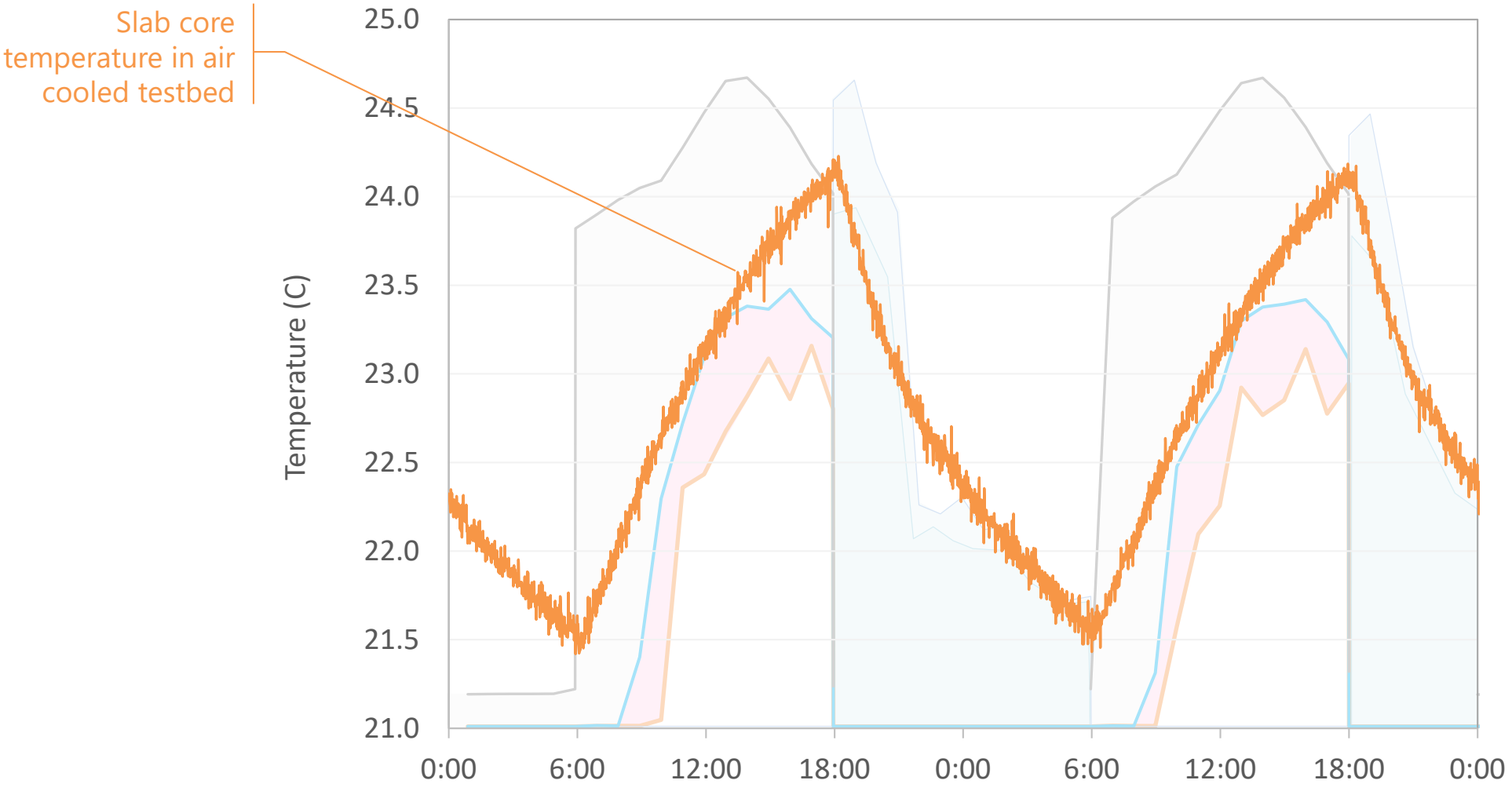

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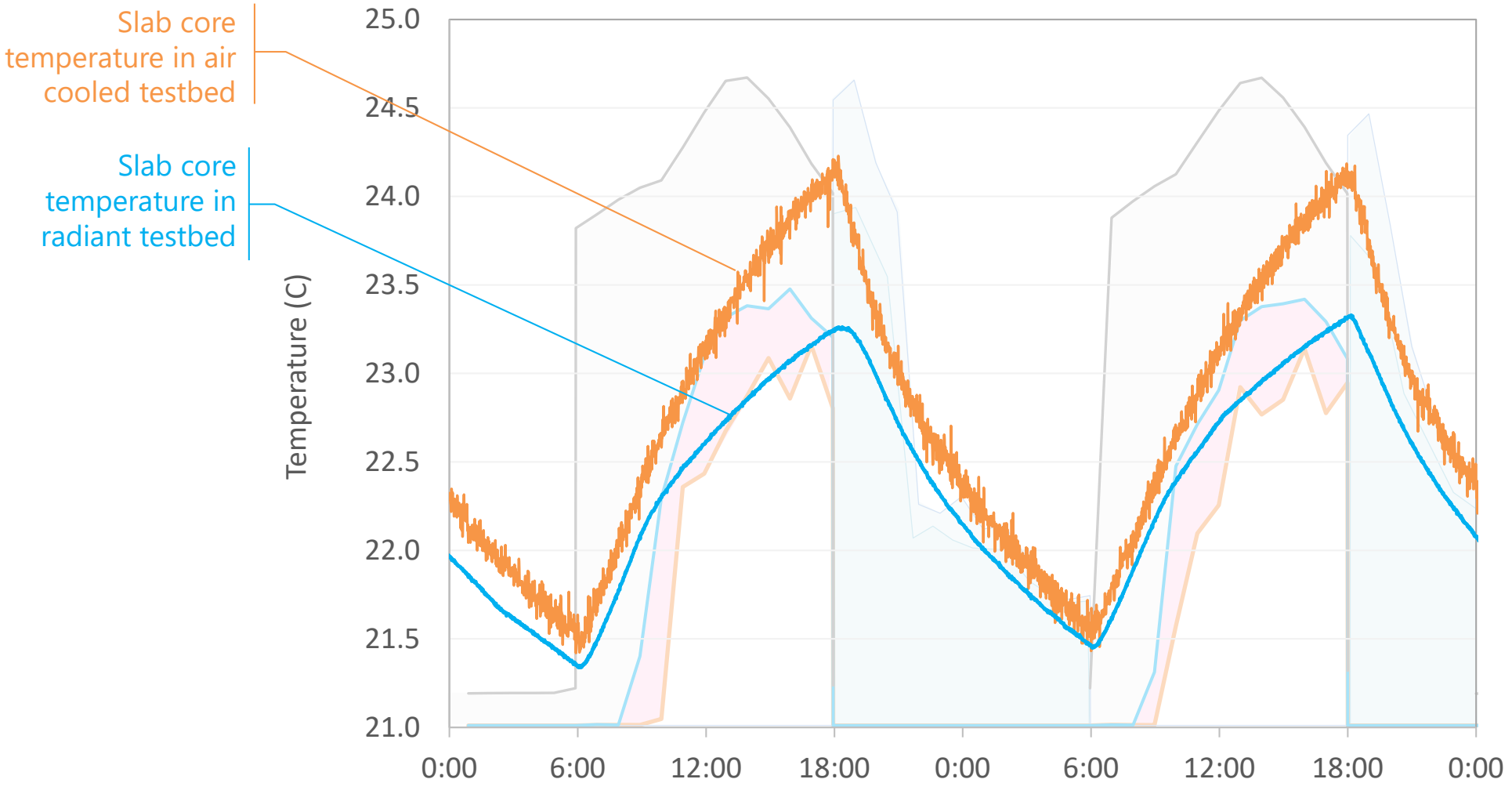
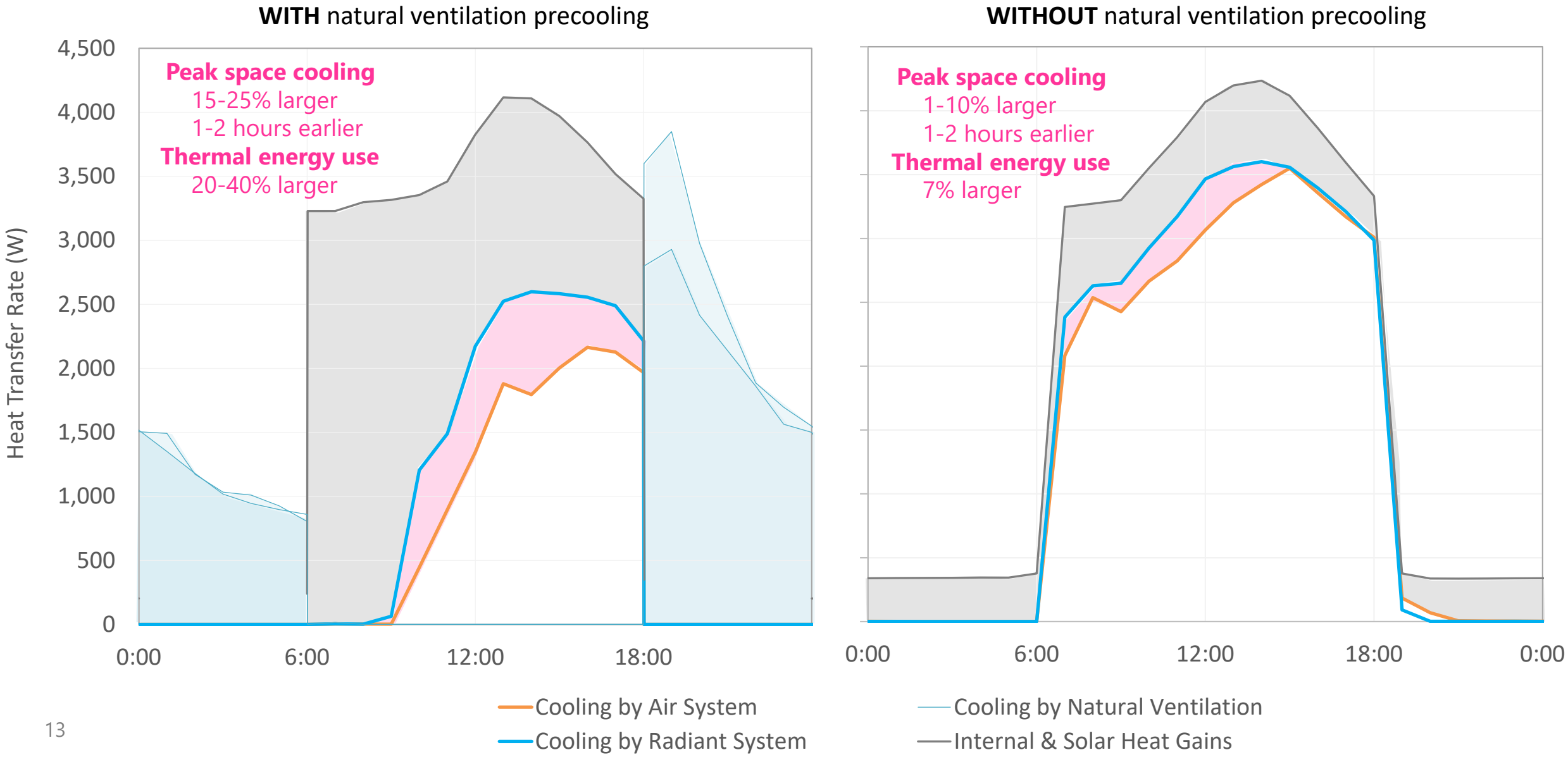


Comparison of differences with and without natural ventilation precooling



Natural ventilation cooling is beneficial for radiant, but could be more so

- Energy performance of radiant cooled buildings can suffer because they do not benefit from economizer cooling
- Many buildings with radiant cooling incorporate natural ventilation for night precooling
- Natural ventilation cooling is definitely beneficial, but with typical controls radiant must remove more more heat than all air cooling
- Advanced controls that strategically coordinate radiant and natural ventilation precooling could allow masses to absorb, store, and release more heat to natural ventilation

Nic Lehoux | The Bullitt Center

Although radiant uses more thermal energy, it can reduce electricity use

Radiant cooling may offer energy and demand advantages, but only where designed so as to:

- Improve cooling plant efficiency
- Improve distribution efficiency
- Effectively utilize passive cooling
- Shift electric demand

In common practice radiant cooling:

- Utilizes chilled water generated at low temperature
- Is not controlled to shift demand

http://asg-architects.com

Next steps

Papers on the results

J. Woolley, S. Schiavon, F. Bauman, P. Raftery, J. Pantelic, *Side-by-side laboratory comparison of space heat extraction rates and thermal energy use for radiant and all-air systems*, Energy and Buildings. 176 (2018) 139–150.

J. Woolley, S. Schiavon, F. Bauman, P. Raftery, J. Pantelic Side-by-side laboratory comparison of radiant and all-air cooling: the impact of passive cooling and heat gain characteristics on space heat extraction rates and daily thermal energy use. *(In review)*.

Future research plans

- Revise misconceptions in handbook, inform codes and standards
- Develop advanced controls to strategically coordinate radiant and ventilation cooling
- Simulate the energy use consequences of current practice radiant design, compared to advanced strategies

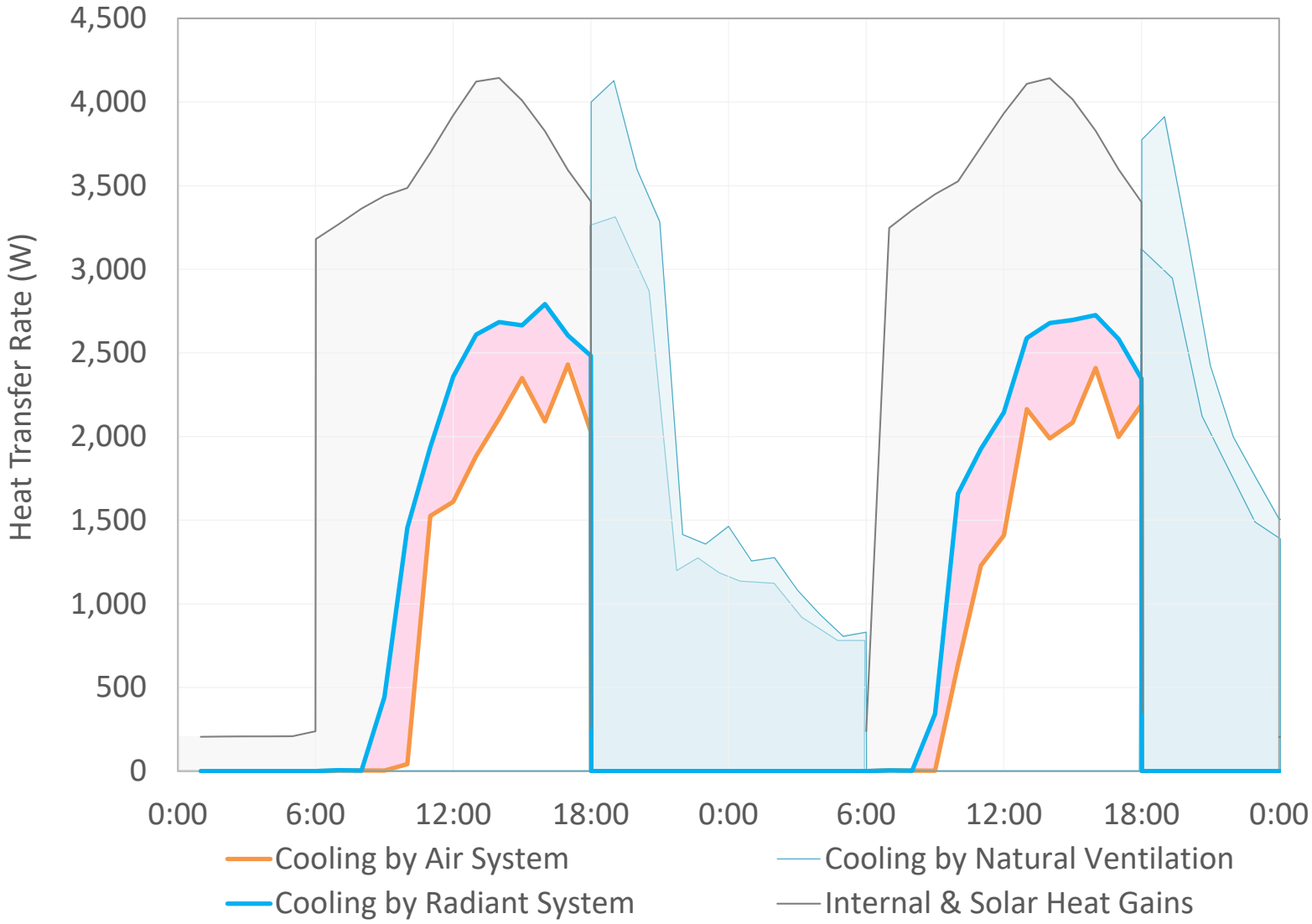
https://flexlab.lbl.gov/

Q&A

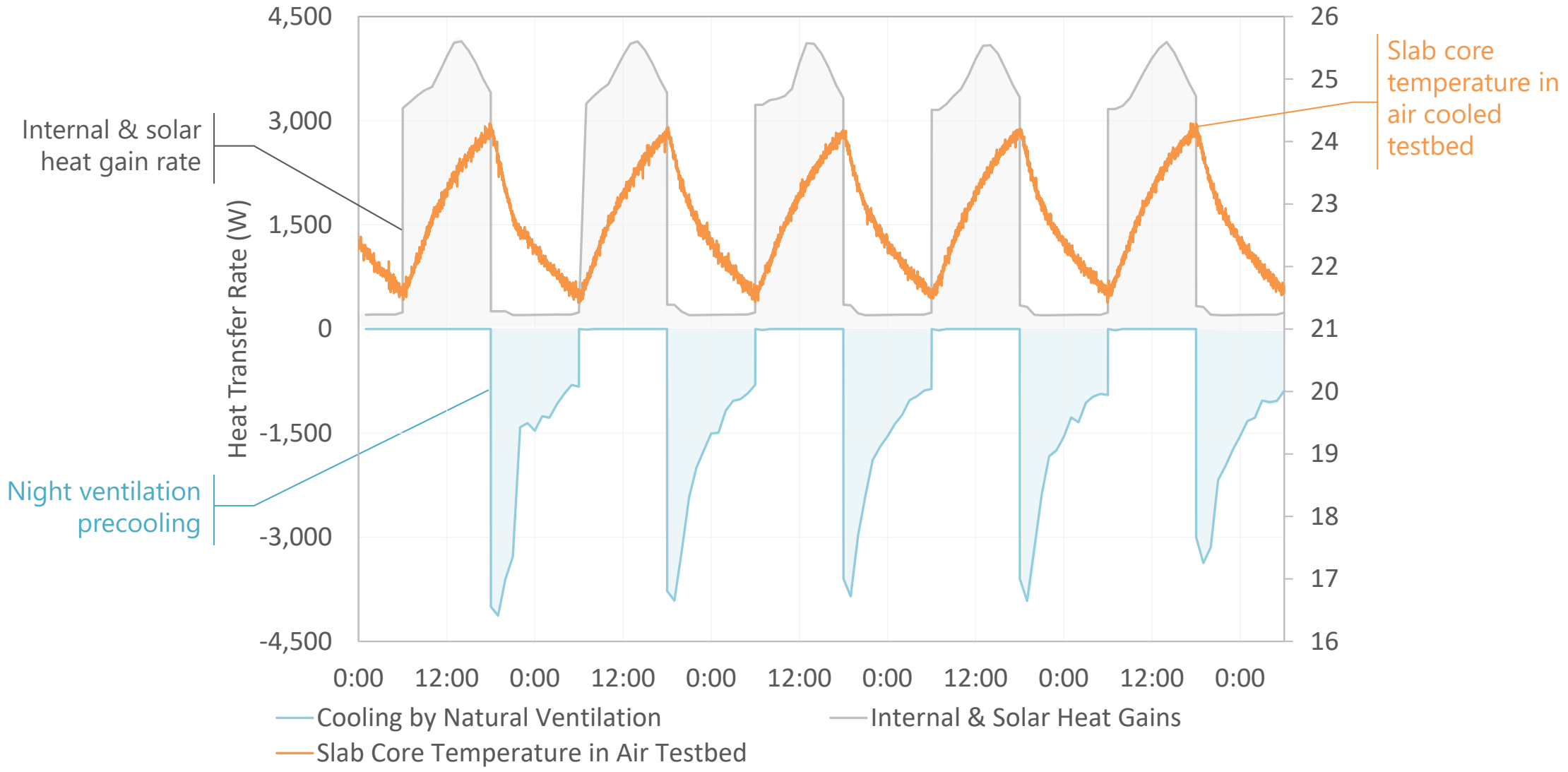
Jonathan Woolley
jmwoolley@berkeley.edu

Stefano Schiavon
schiavon@berkeley.edu

Please take a moment to fill out the feedback form.



Temperature of mass cycles as surfaces absorb, store, then release heat



Surfaces in radiant building absorb, store, and release less heat