

The path to net-zero passive commercial building

The role of natural ventilation and thermal mass in a heating dominated climate

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Massachusetts
Institute of
Technology

Building Technology

Computation for Design and Optimization

Precedent



Cornell Green Building, New York, 2017
Tallest passive house building, 76 m high

Energy reduction: 70%
Carbon emission reduction: 882 tons/year



Orchards at Orenco, Oregon
Largest passive house multi-family building in the US

Without active heating and cooling

Can we build the next largest **Passive House**
commercial building?

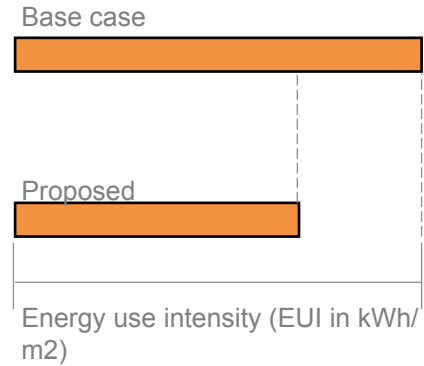
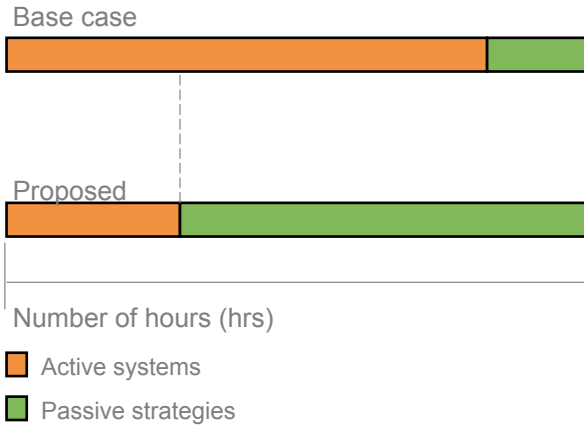
High performance envelope + passive building strategies

Volpe



Climate Zone 5A
volpe.mit.edu

Project goal



Indoor Air Quality



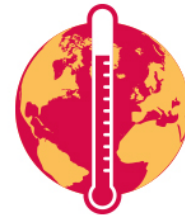
Thermal Comfort



Low Energy

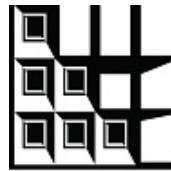


Climate Change

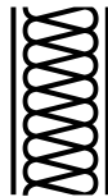


Strategies

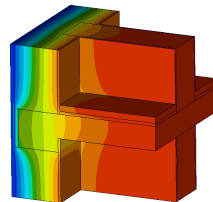
Passive house Beyond passive house



Glazing



Insulation



Thermal bridge



Thermal mass



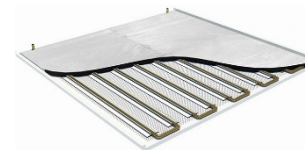
Natural ventilation



Low energy fresh air supply



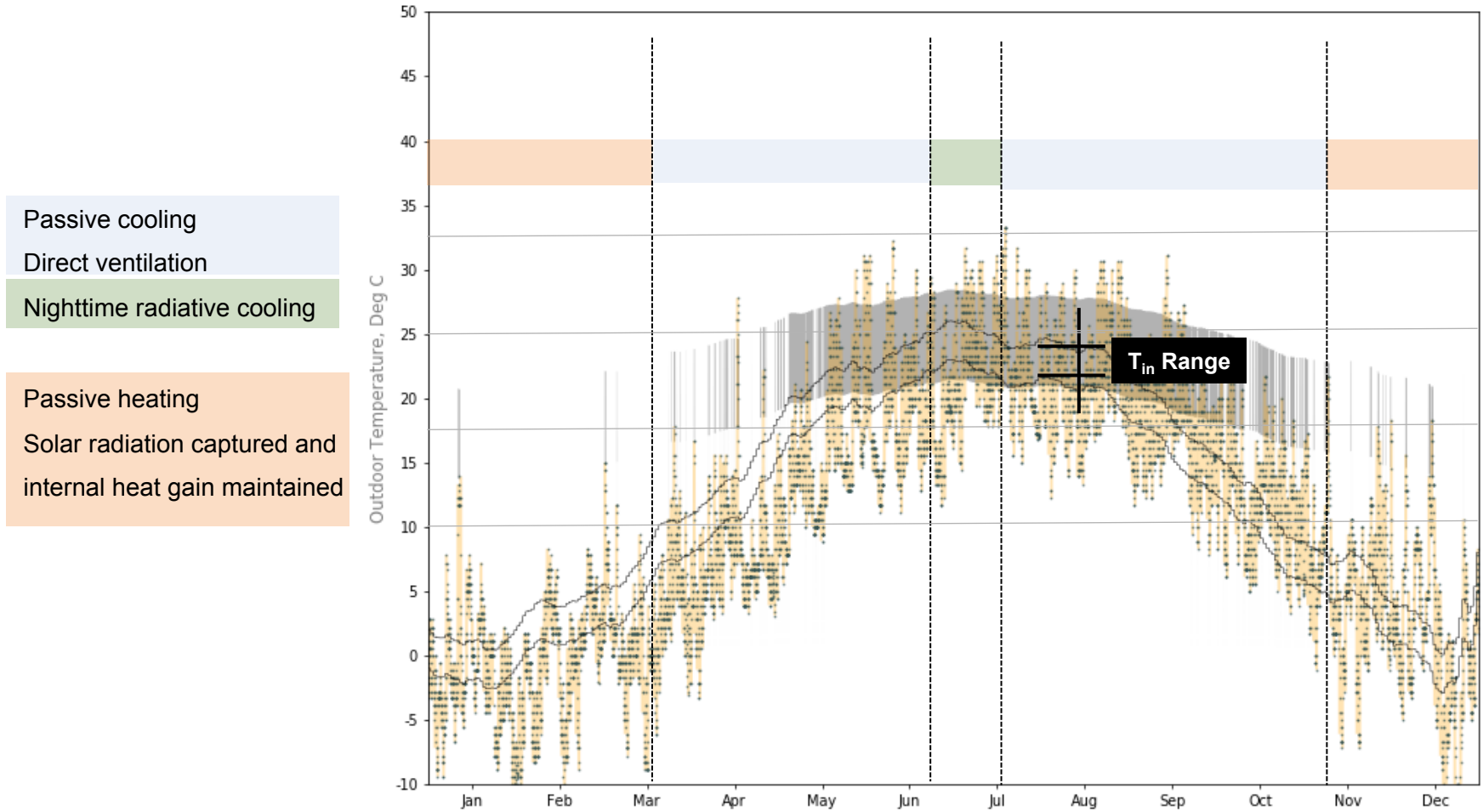
Solar gain/shade



Radiative cooling

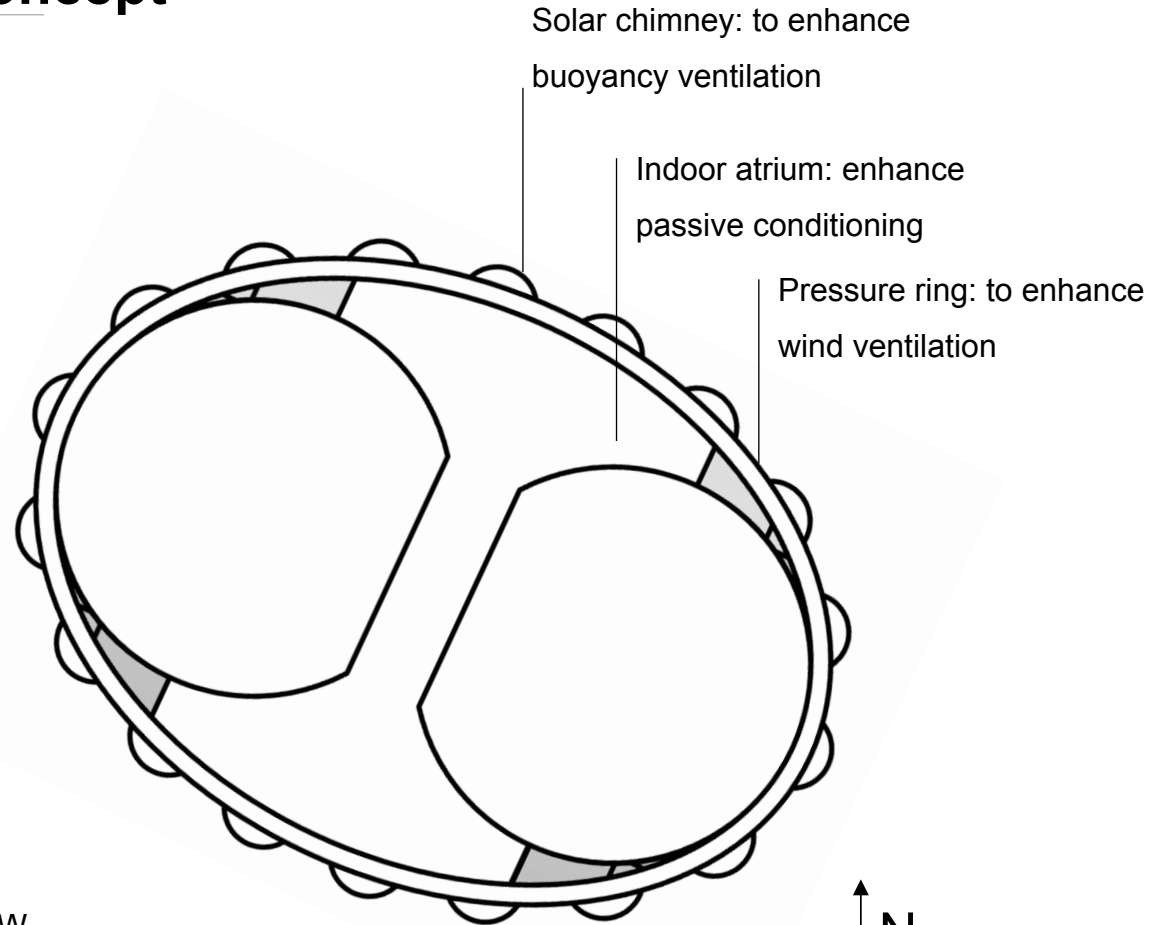
Integration of passive strategies

Current Climate



Volpe- design concept

Commercial / Office



Prevailing Wind: W, SW, NW

Average speed at weather station: 5 m/s

Wind speed on site: **2 m/s**



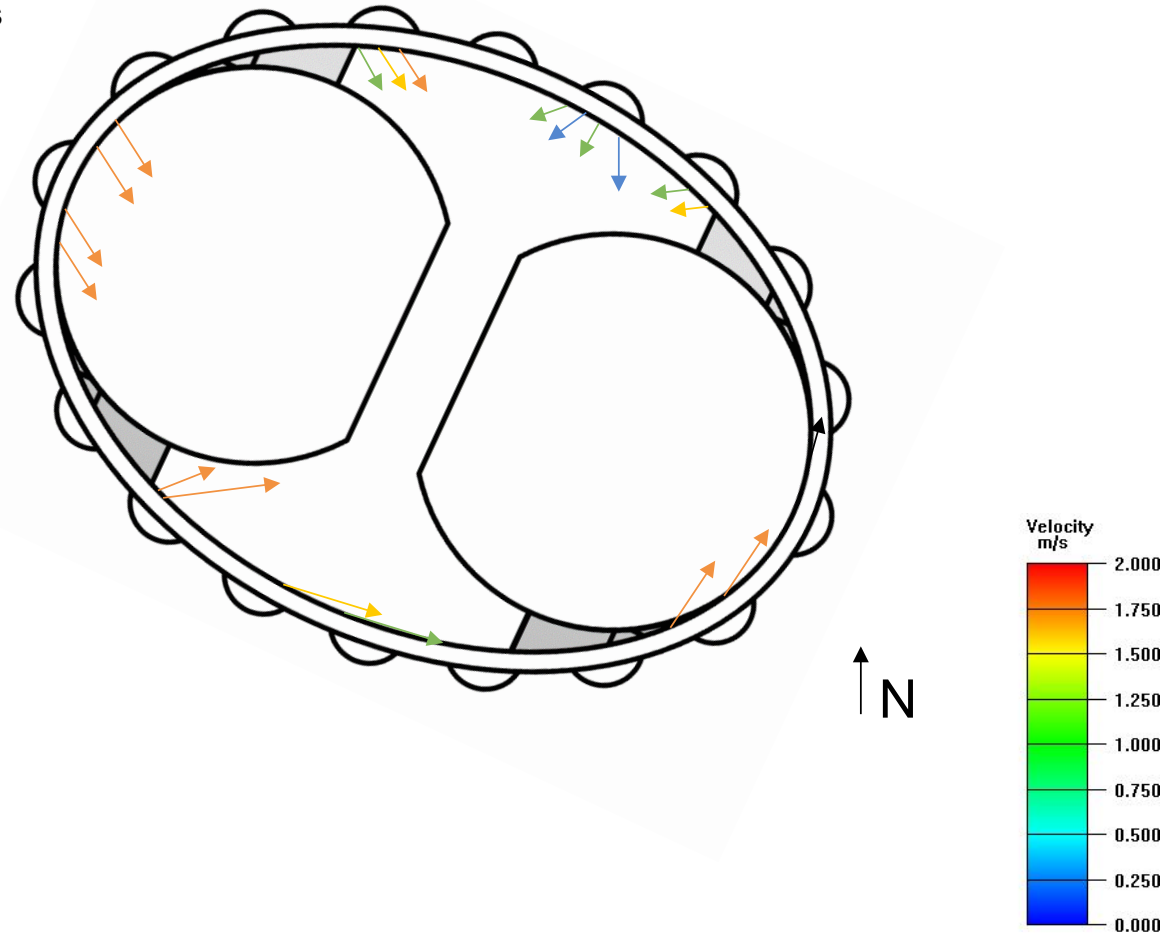
Pressure ring

ACH []

Programmatic arrangement

Regulating Window sizing

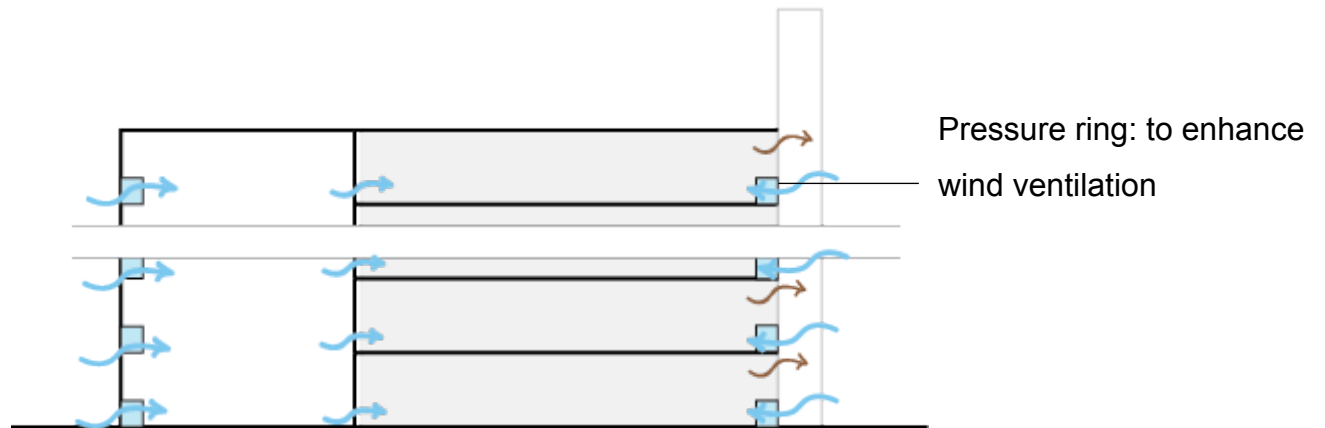
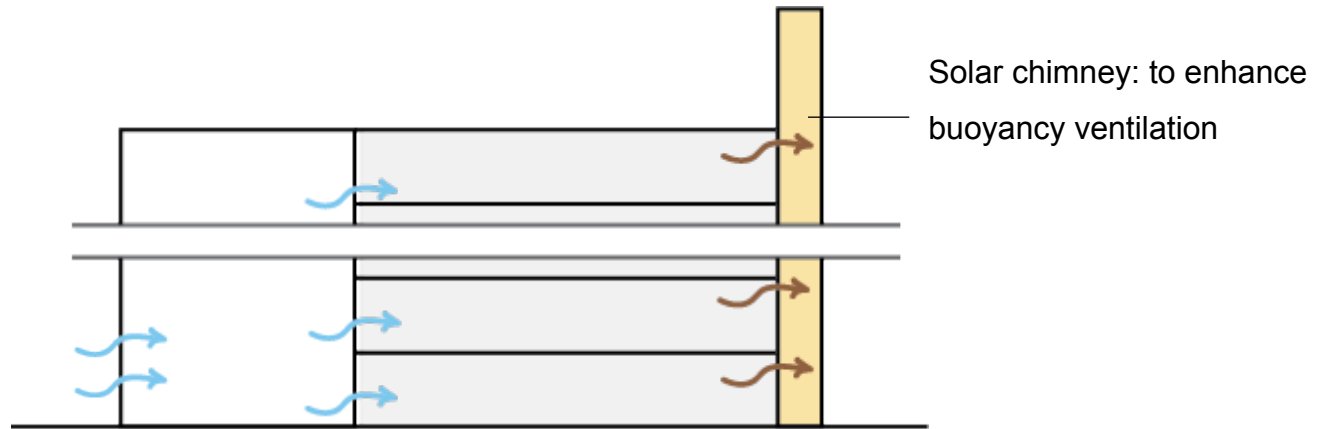
Window opening orientations



Volpe
Pressure ring

Passive cooling

Indoor air quality
Remove indoor heat gain
Physiological cooling

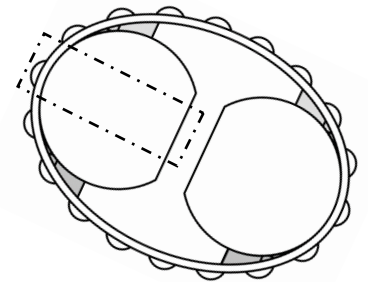
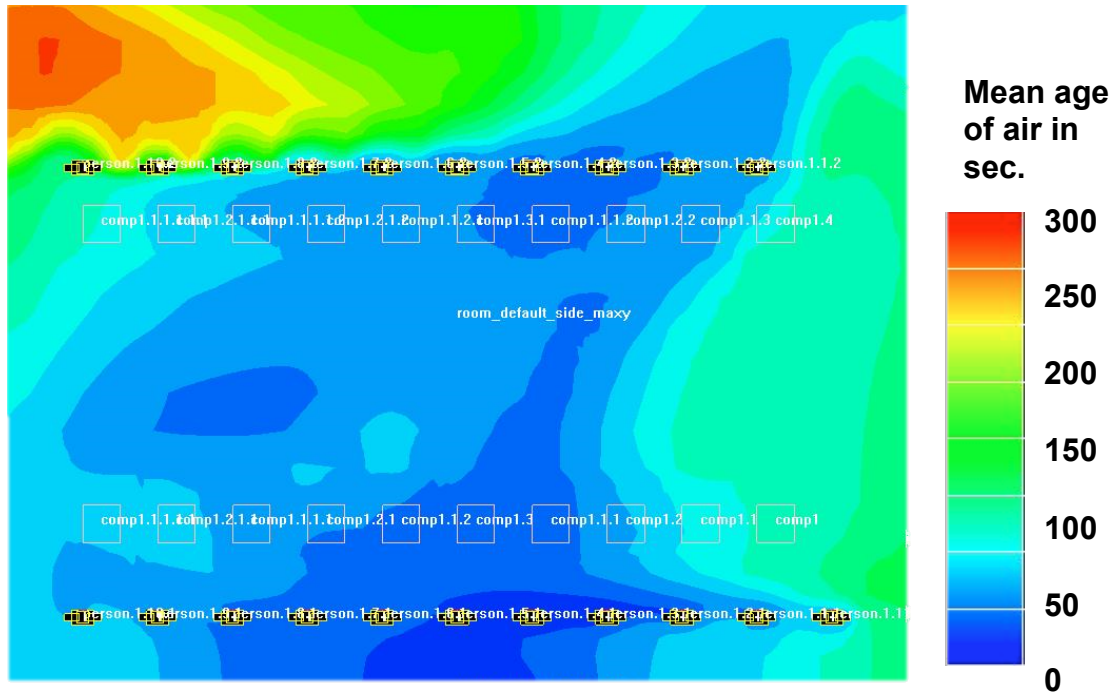


Indoor air quality

Mean age of air, simulation

Office at desk height.

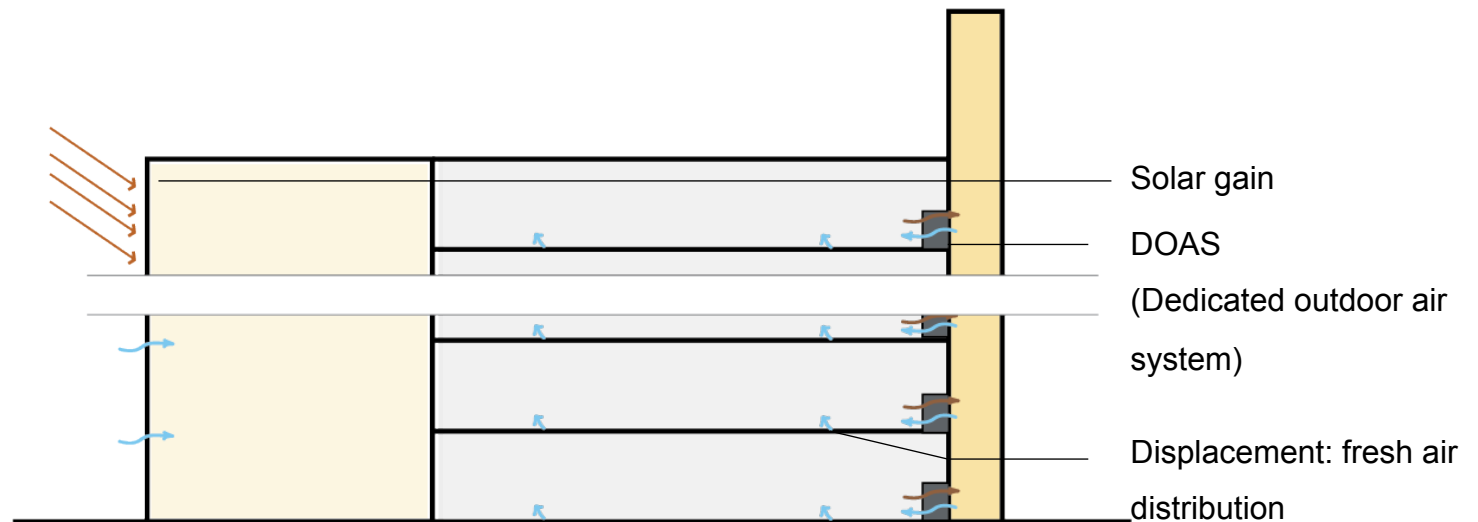
Opposite side fresh air inlet openings.



Winter

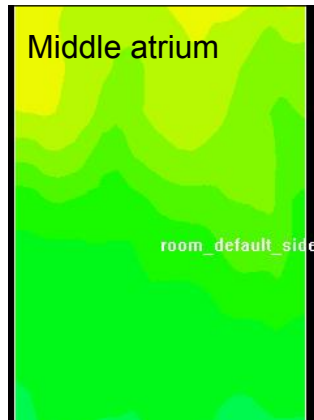
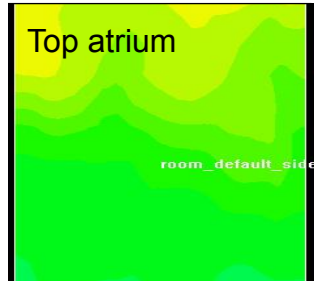
DOAS + Solar gain

Minimum ventilation for indoor air quality

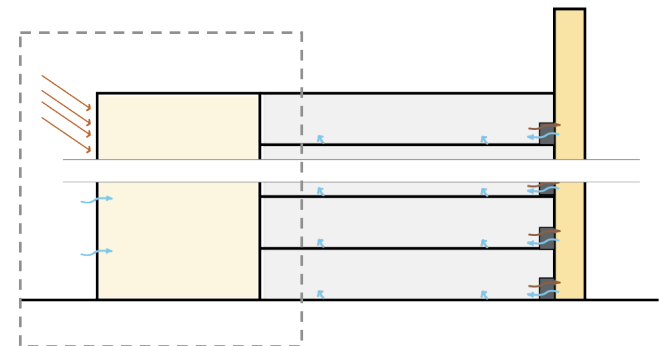
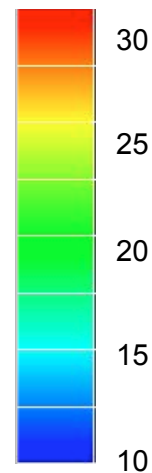


Winter

Passive conditioning of atrium



Temperature °C



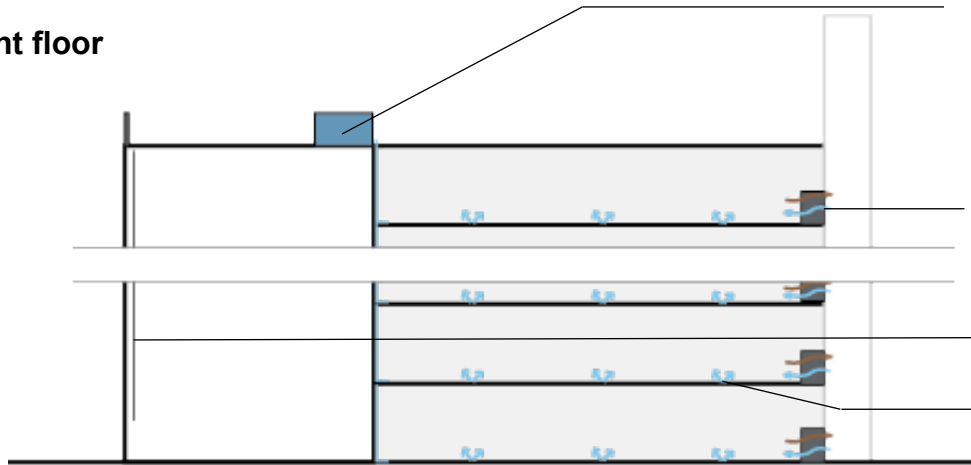
Atrium space temperature: close to office inlet.

Solar gain is maximized and minimum fresh air is supplied.

Peak Summer

Day: DOAS + Radiant floor

Minimum ventilation
for indoor air quality



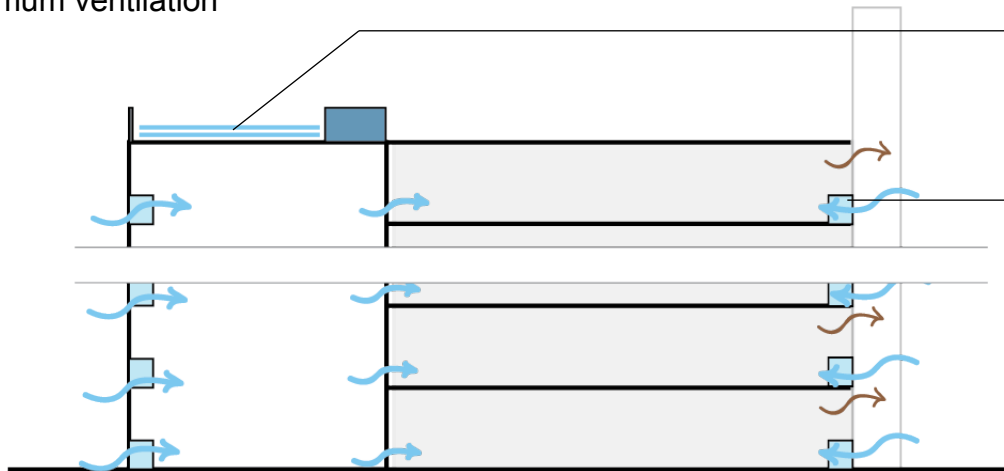
Water cooled at night.
(Radiative cooling to the sky)

DOAS
(Dedicated outdoor air system)

Solar shading

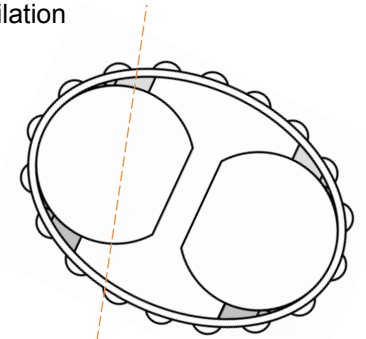
Radiative slab cooling

Nighttime: Night flushing + roof pond cooled to night sky, Maximum ventilation



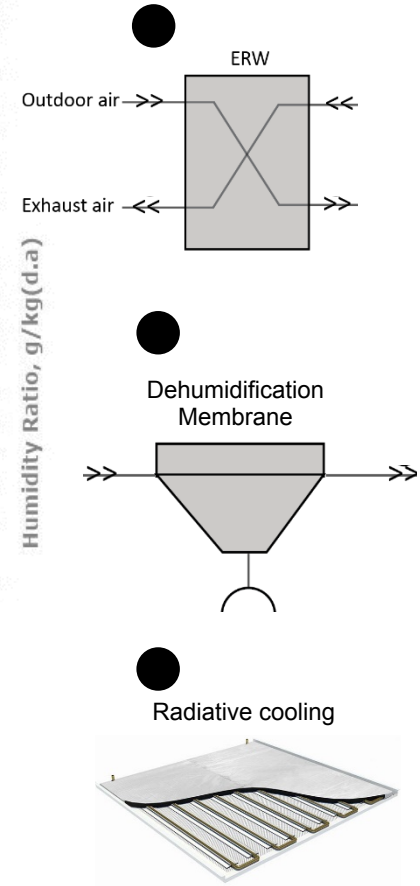
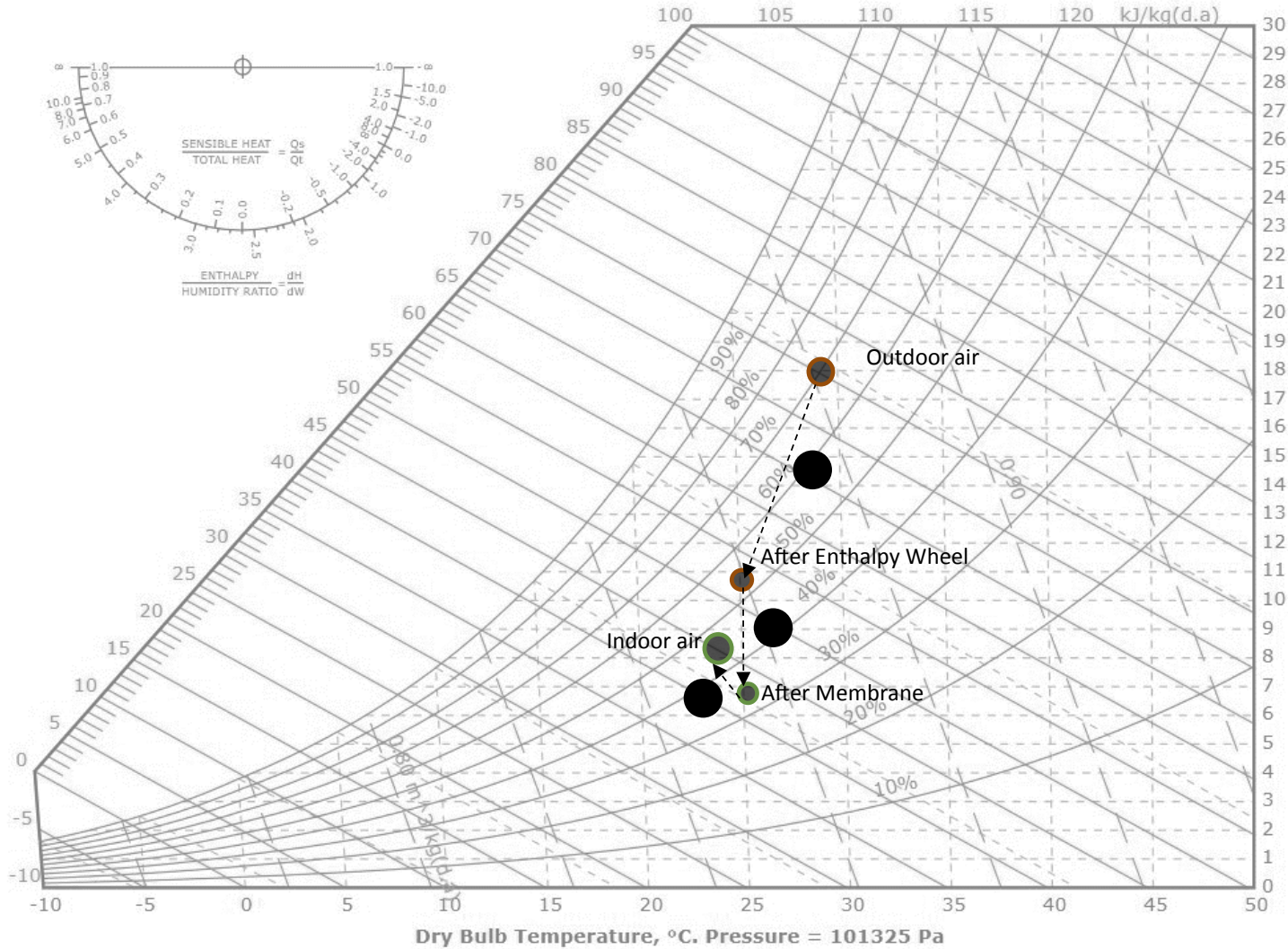
Water cooled at night.
(Radiative cooling to the night
sky)

Night ventilation.
Pressure ring for night wind
ventilation



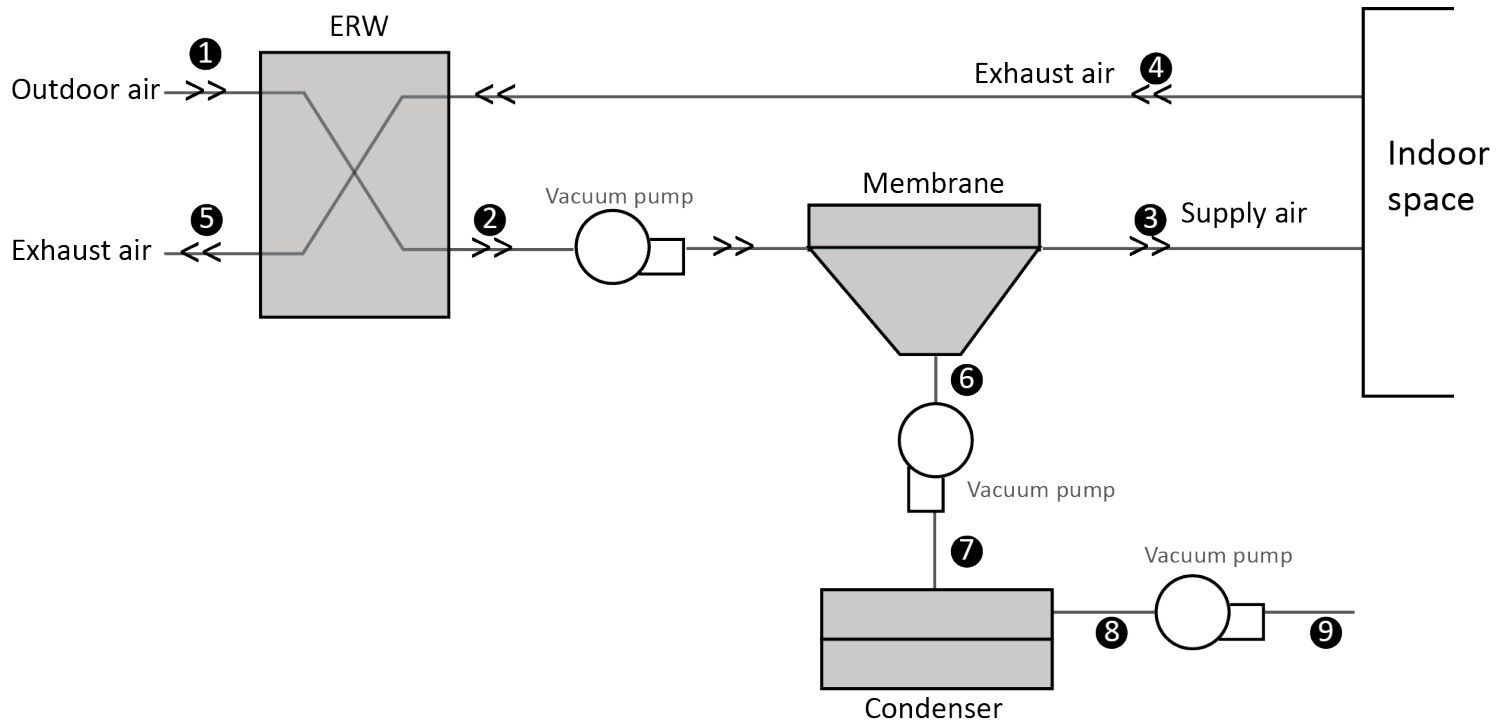
Customized DOAS (Dedicated Outdoor System)

Fresh air supply and dehumidification



Customized DOAS (Dedicated Outdoor System)

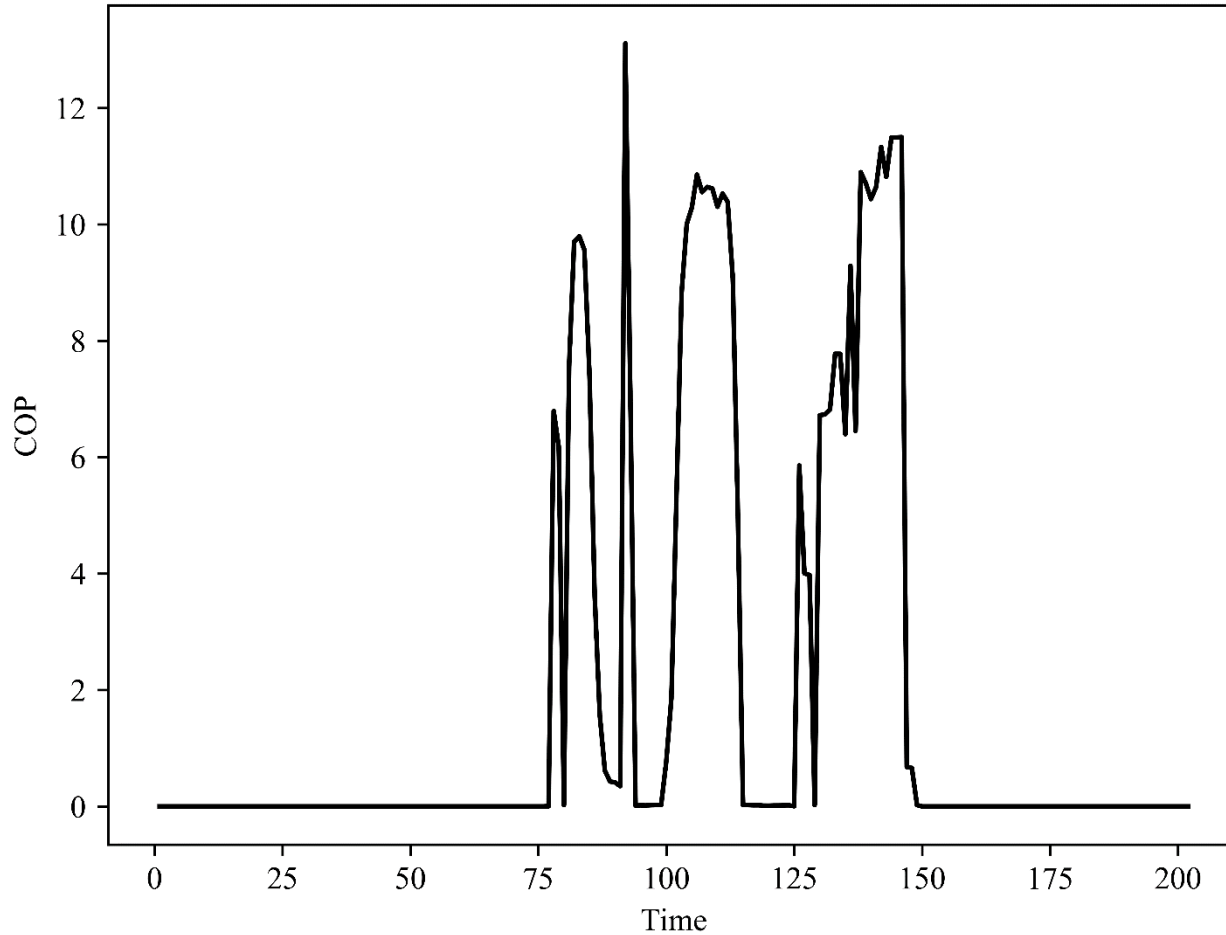
Fresh air supply and dehumidification



Customized DOAS (Dedicated Outdoor System)

Fresh air supply and dehumidification
[From August 5 -13]

ERW + Membrane (with condenser) COP Curve

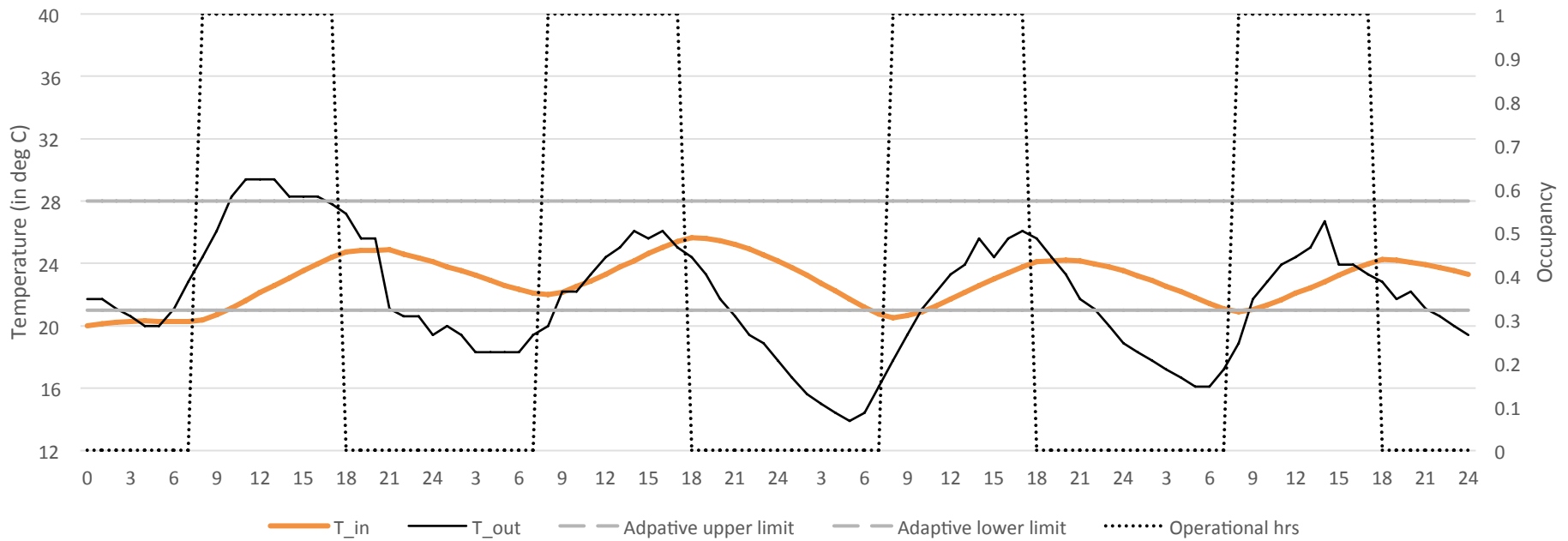


Thermal comfort evaluation

Summer week

Natural ventilation + Active thermal mass + solar shading

Current Climate (July 8-14): Interior temp with internal loads and reduced solar gain

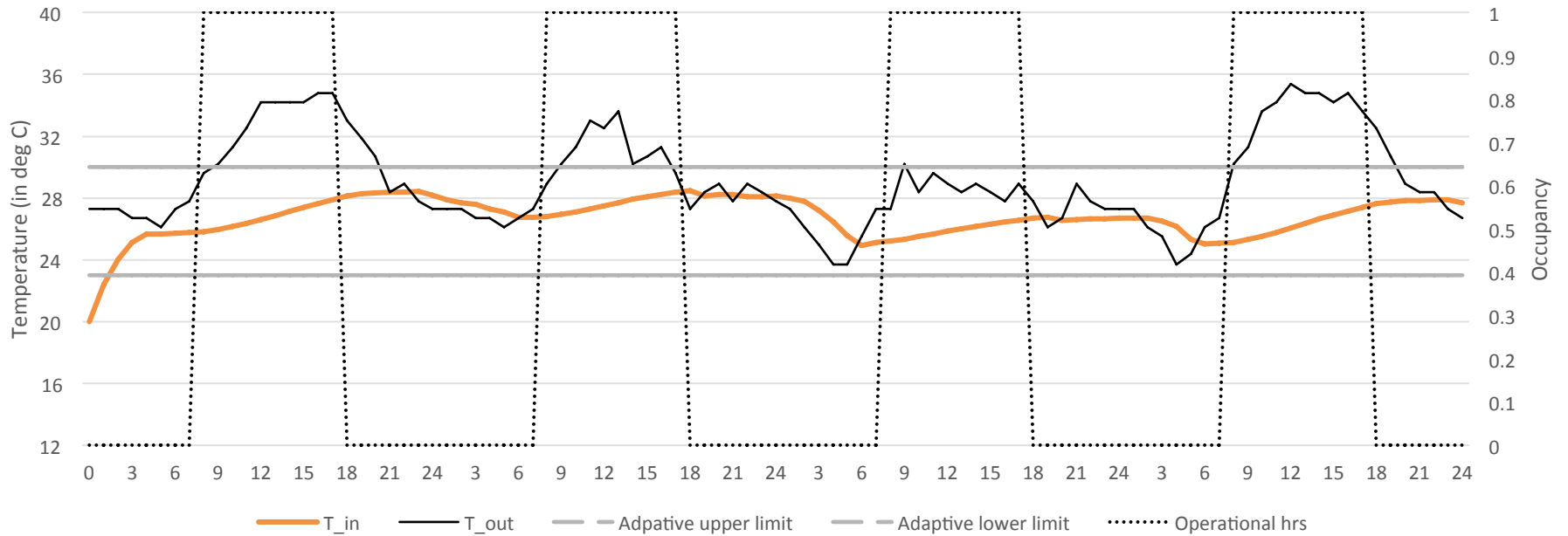


Thermal comfort evaluation-2080

Summer week

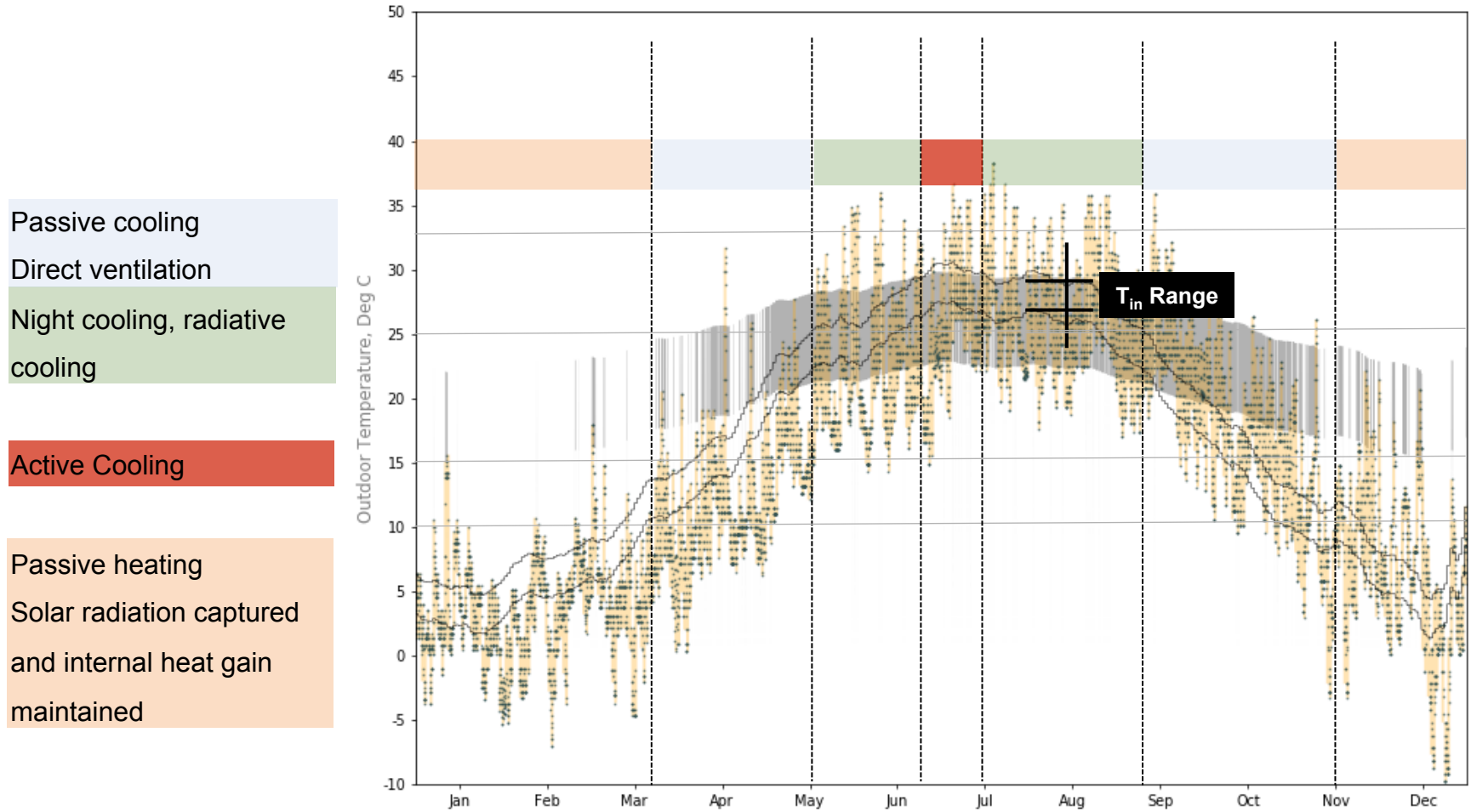
Natural ventilation + Active thermal mass + solar shading

2080 (July 8-14): Interior temp with internal loads and reduced solar gain



2080: Modes of operations

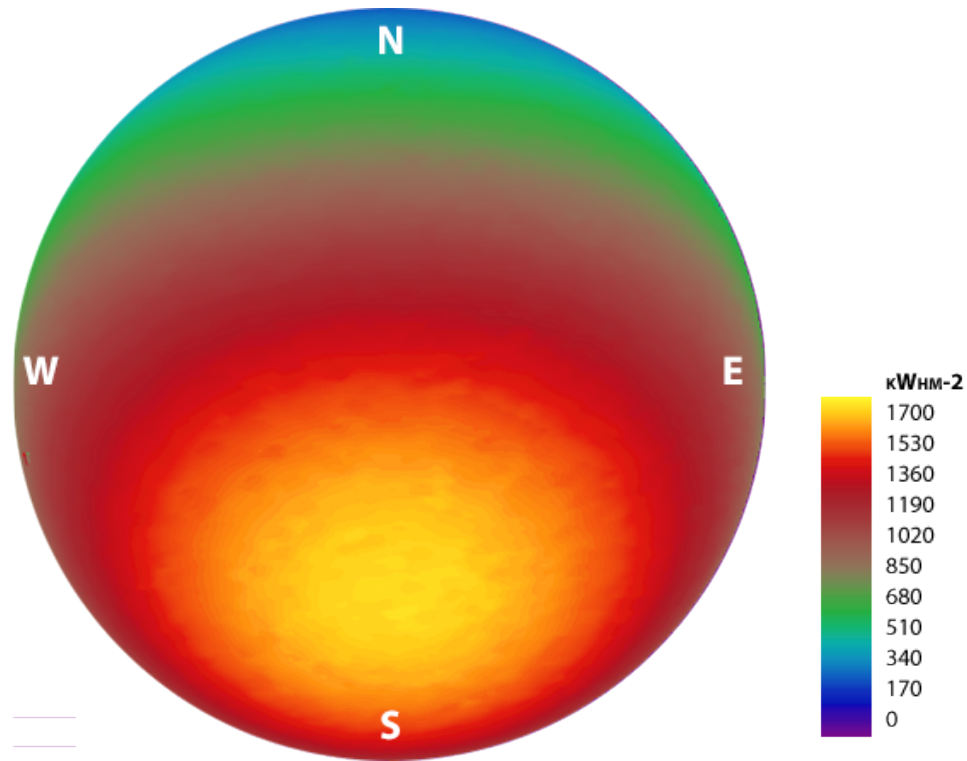
Passive strategies + Active cooling using proposed DOAS



Pathway to Net Zero

	[Heating] EUI (kWh/m2)	[Cooling] EUI (kWh/m2)
US Average for Commercial (US DOE)	19.5	21
Passive House, Zone 5 (PHIUS+ 2018 Space conditioning estimator)	27	27
HVAC + Passive Strategies (Proposal)	3	4
DOAS + Passive Strategies (Proposal)	0	0.5

Solar Thermal



Cumulative radiation annual
4.6 kWh/m² Average solar rad per
day.

Solar thermal for hot water
24 m³/day Commercial (DOE)
340 m² Area required for total water
supply (about 1/3rd of roof area).

Accommodating Labs

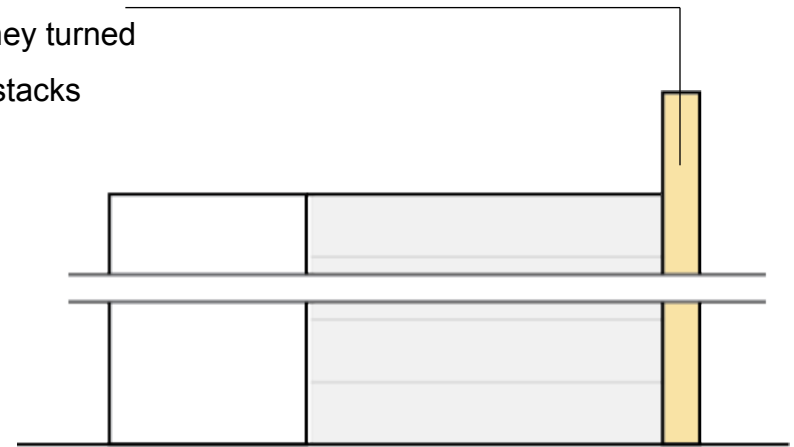
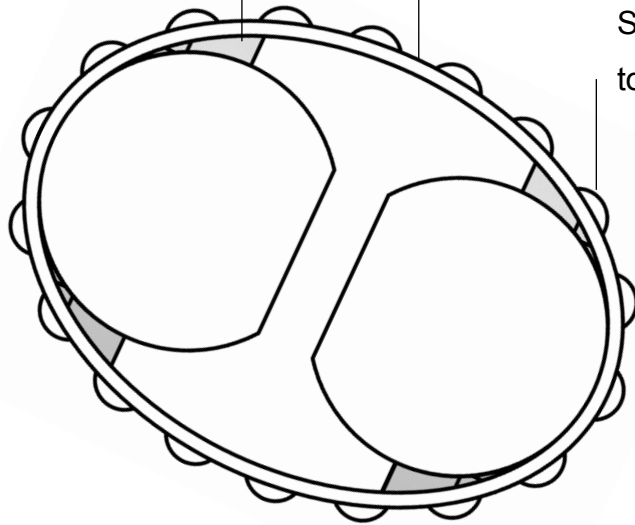
Enthalpy Wheels (DOAS)

Changed with Run-around Coil to
prevent air mixing

Pressure ring allows 30 ACH in average.

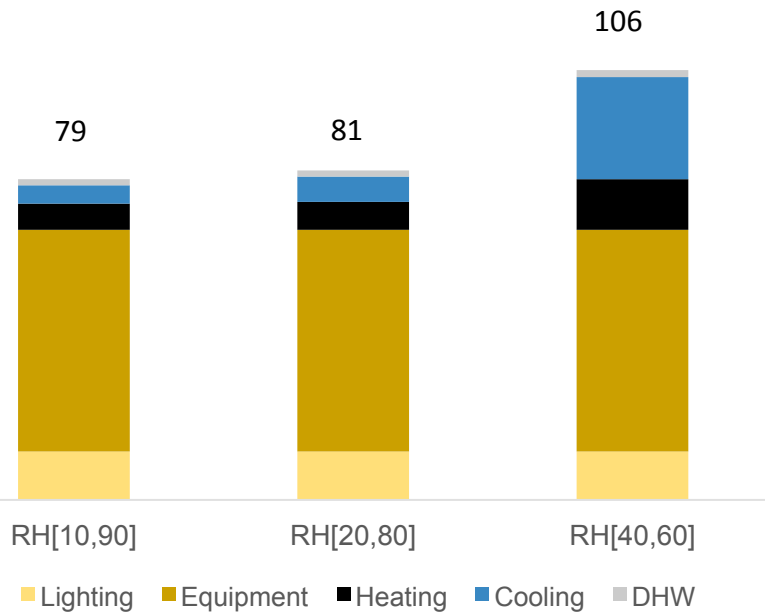
Labs require between 4-12 ACH (EPA DOE Ref)

Solar chimney turned
to exhaust stacks

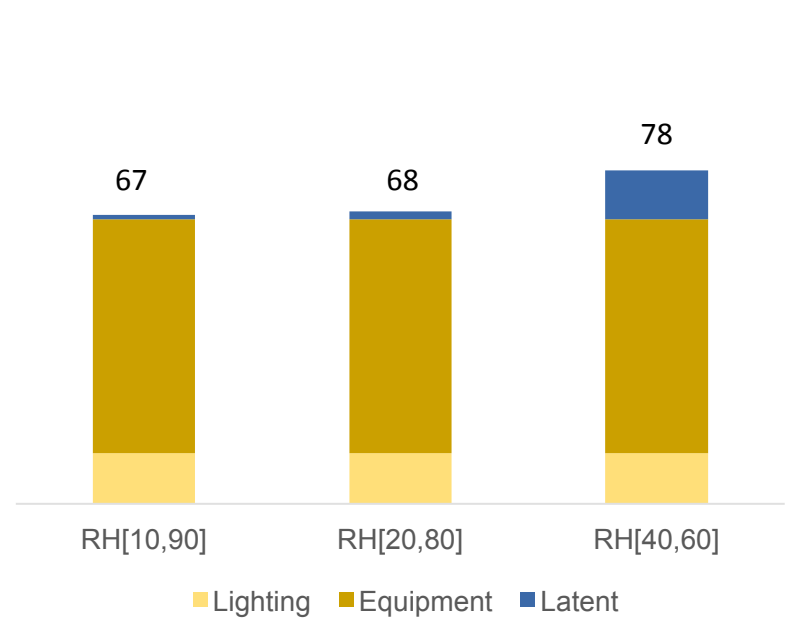


Programmatic Flexibility

Base Passive House
EUI (kWh/m2)



Optimized Passive House
EUI (kWh/m2)



RH[10,90]



RH[20,80]



RH[40,60]

Passive House at Volpe - Pathway to Net Zero

Key ideas

Great potential for passive strategies. Design solutions are used to maximize comfort without active systems.

Looking at future climate is critical. Current buildings will be challenged under global warming and this has to be part of the design process.