

Application of PCM-systems in Ventilative Cooling

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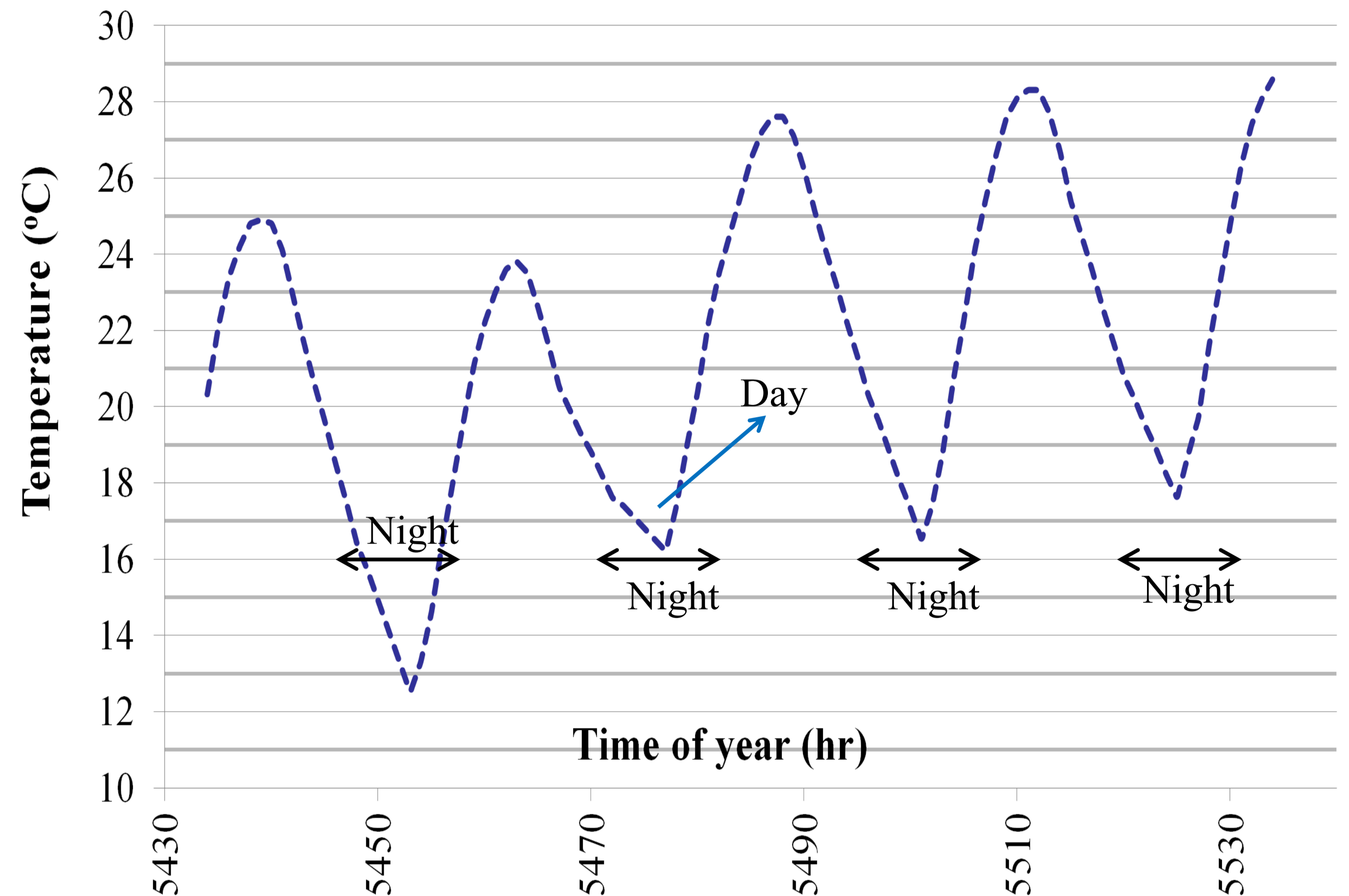
IEA Workshop Annex-62: Ventilative Cooling

Ventilative Cooling

- Use of low temperature outdoor air for cooling
- Very dependent on unpredictable ambient conditions
- Use of outdoor air does not always guarantee cooling during the day

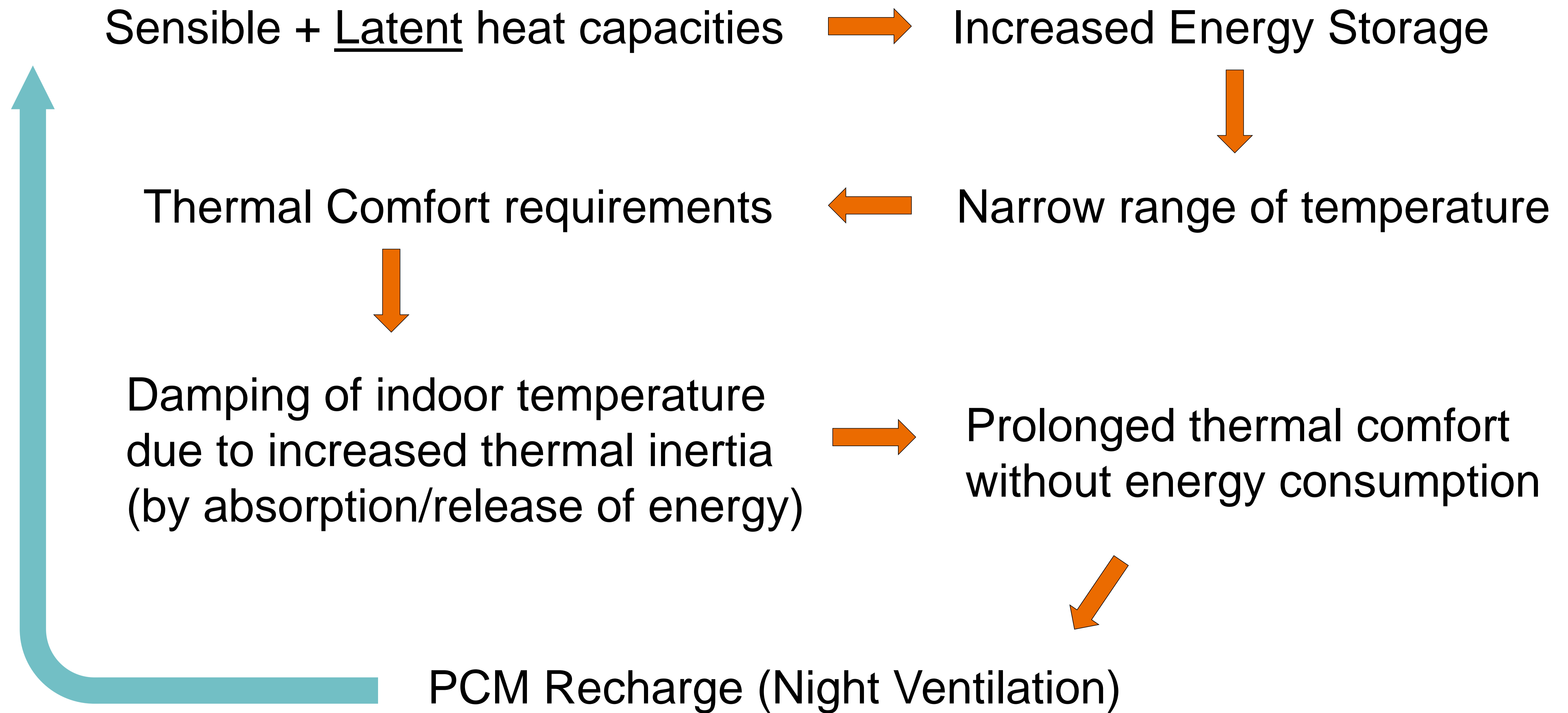
Proposed solution:

- Shift low night-time temperatures to occupied day-time
- Via Energy Storage – Phase Change Materials (PCM)



Ambient Air – UK Summer

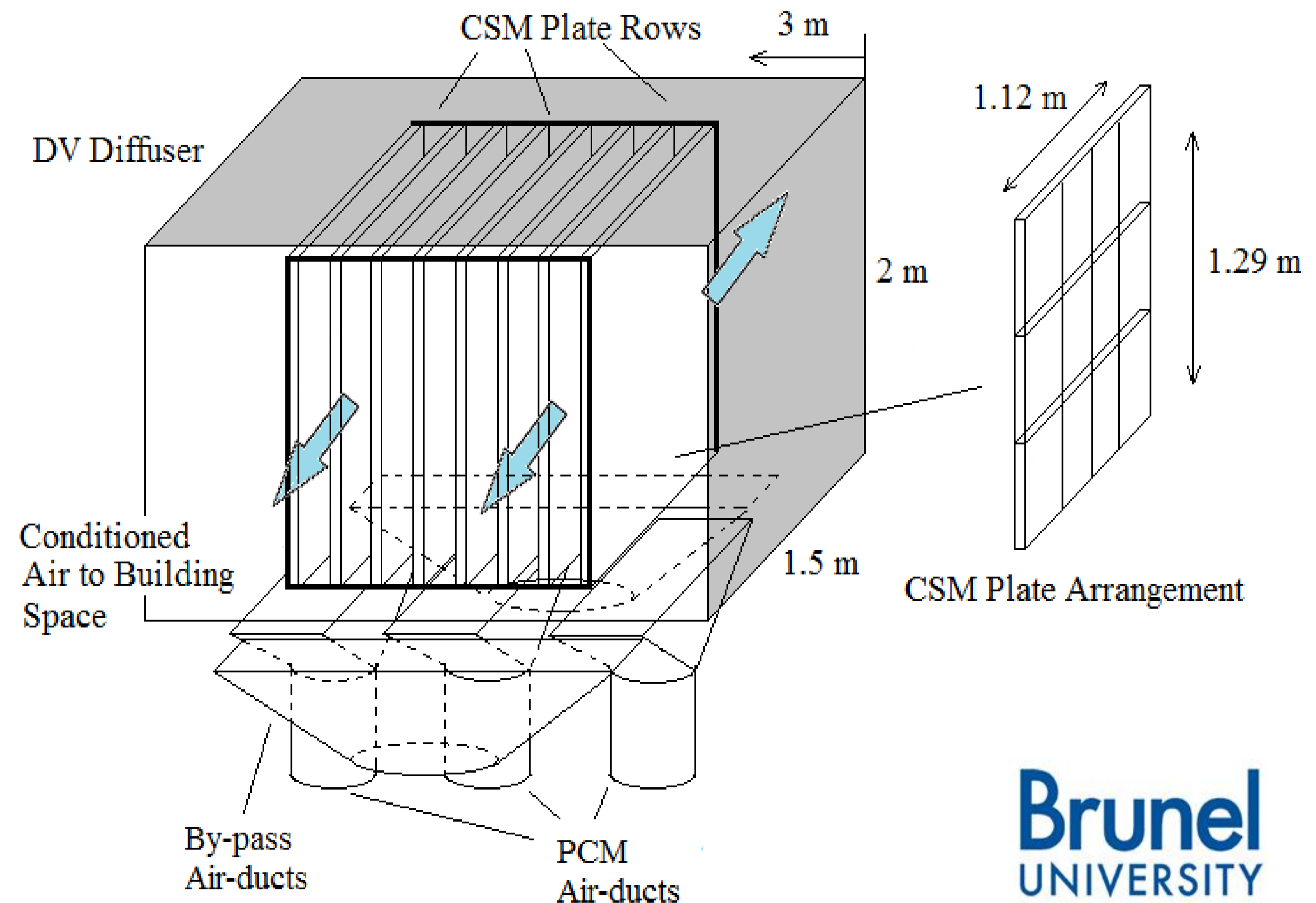
Phase Change Materials (PCM)



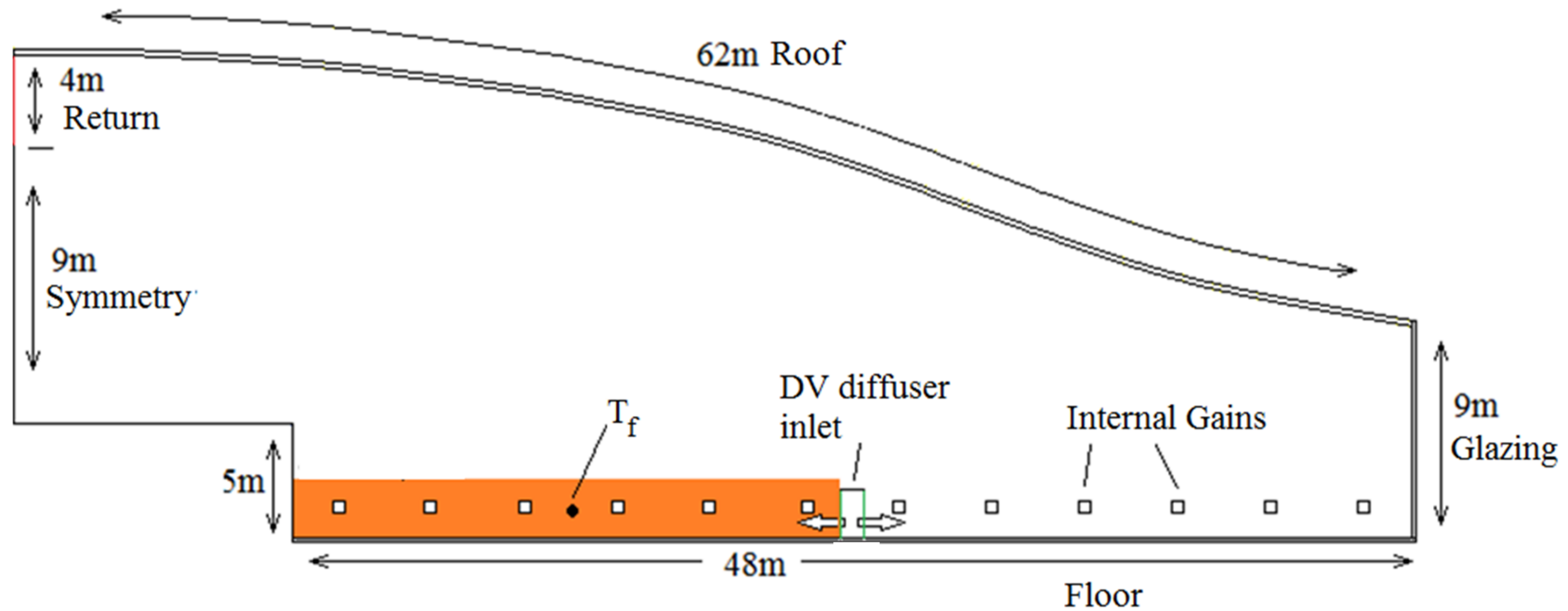
PCM + Ventilative Cooling

- Common PCM systems: PCM boards/envelopes, PCM -HX, PCM glazing
- Focus of PCM-HX in Airport Terminal Space (Heathrow T5)

- Displacement diffuser (DV)
- PCM plates retrofitted
- 2 configurations studied (8 /16 mm air gaps)
- PCM: 16-25°C & 180 kJ/kg
- Comfort temperature: 18-23°C
(CIBSE Guide A, 2006)



Case Study (1) – Airport Terminal



Airport supplied by Central CAV system – Airtight building

■ Conditioned Zone

T_f : Temperature sensor control system

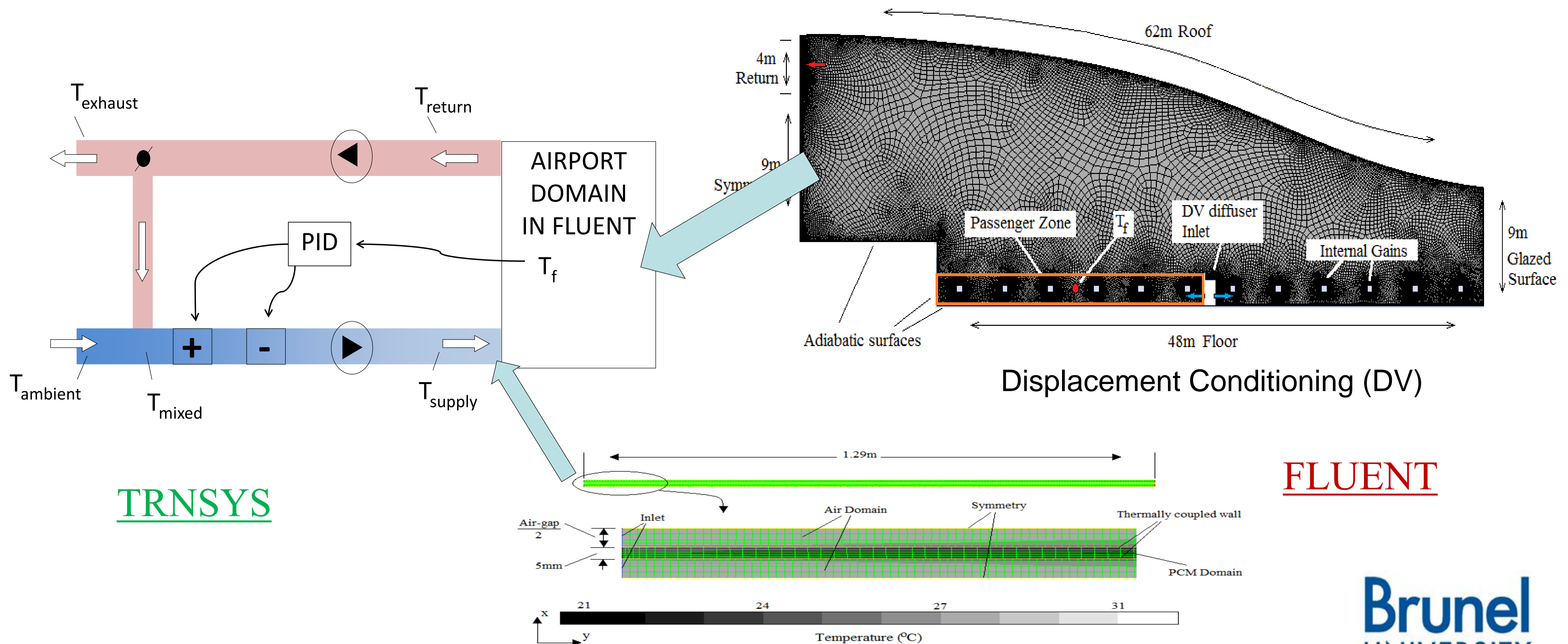
Case Study (2) – Modelling

Coupled TRNSYS-FLUENT model:

TRNSYS models HVAC + PID control

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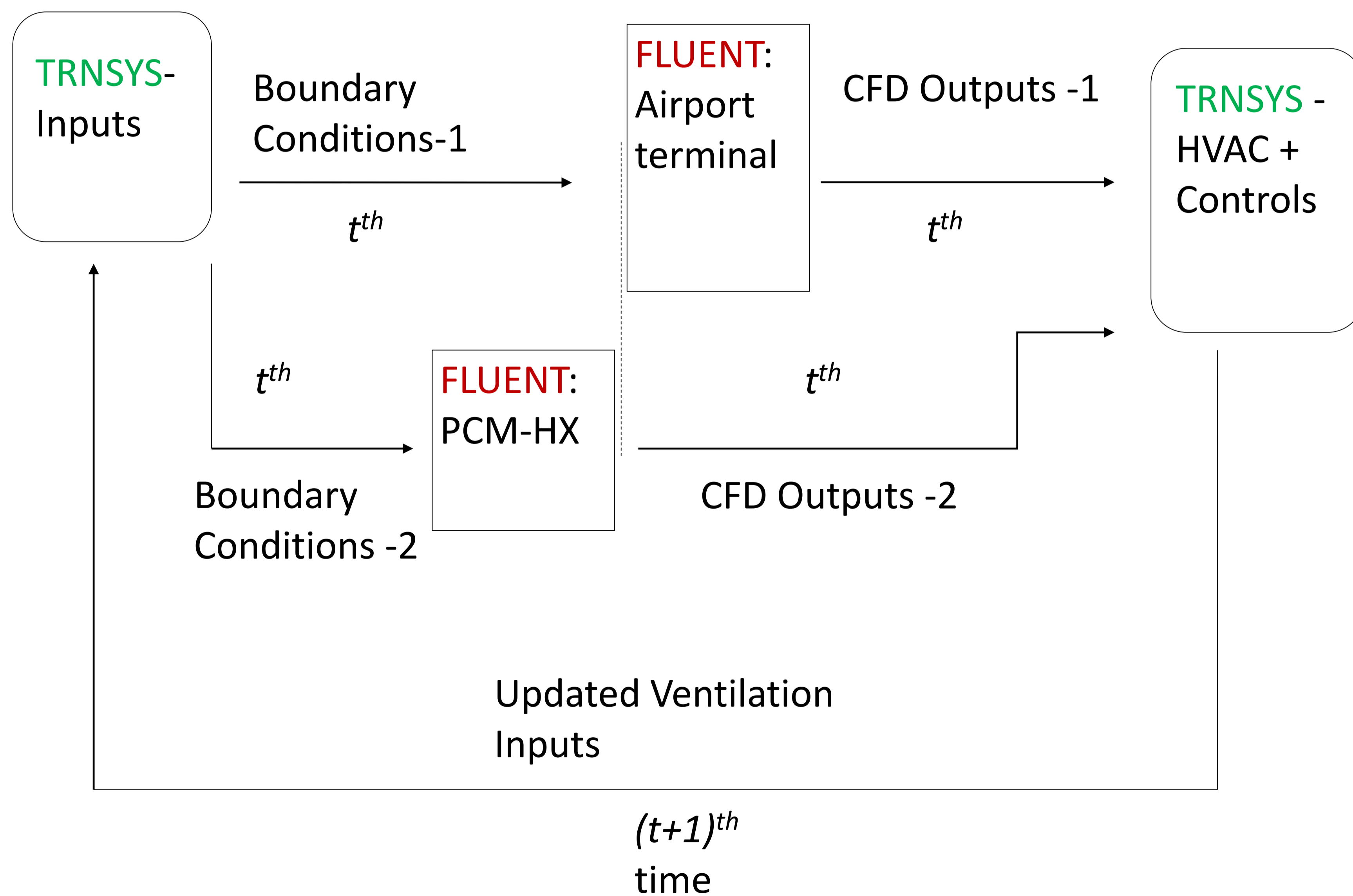
FLUENT models Airport airflow



FLUENT

Case Study (3) – Model Coupling

-Quasi-dynamic coupling, i.e. Only 1 coupled iteration between TRNSYS and FLUENT per timestep



Boundary conditions	CFD Outputs
Weather data (Ambient temperature, Solar gains)	Feedback temperature (T_f)
Internal heat gains	Return air temperature (T_r)
Ventilation conditions (Supply air temperature, air mass flow rate for both airport + PCM-HX)	PCM-HX - outlet air temperature

Case Study (4) - Control

PID Control (occupied hours 04:00-24:00):

If $18^{\circ}\text{C} \leq T_f \leq 23^{\circ}\text{C}$ \rightarrow T_m passes through PCM-HX and supplied to Airport
(Heating/Cooling units off) \rightarrow Free-Cooling

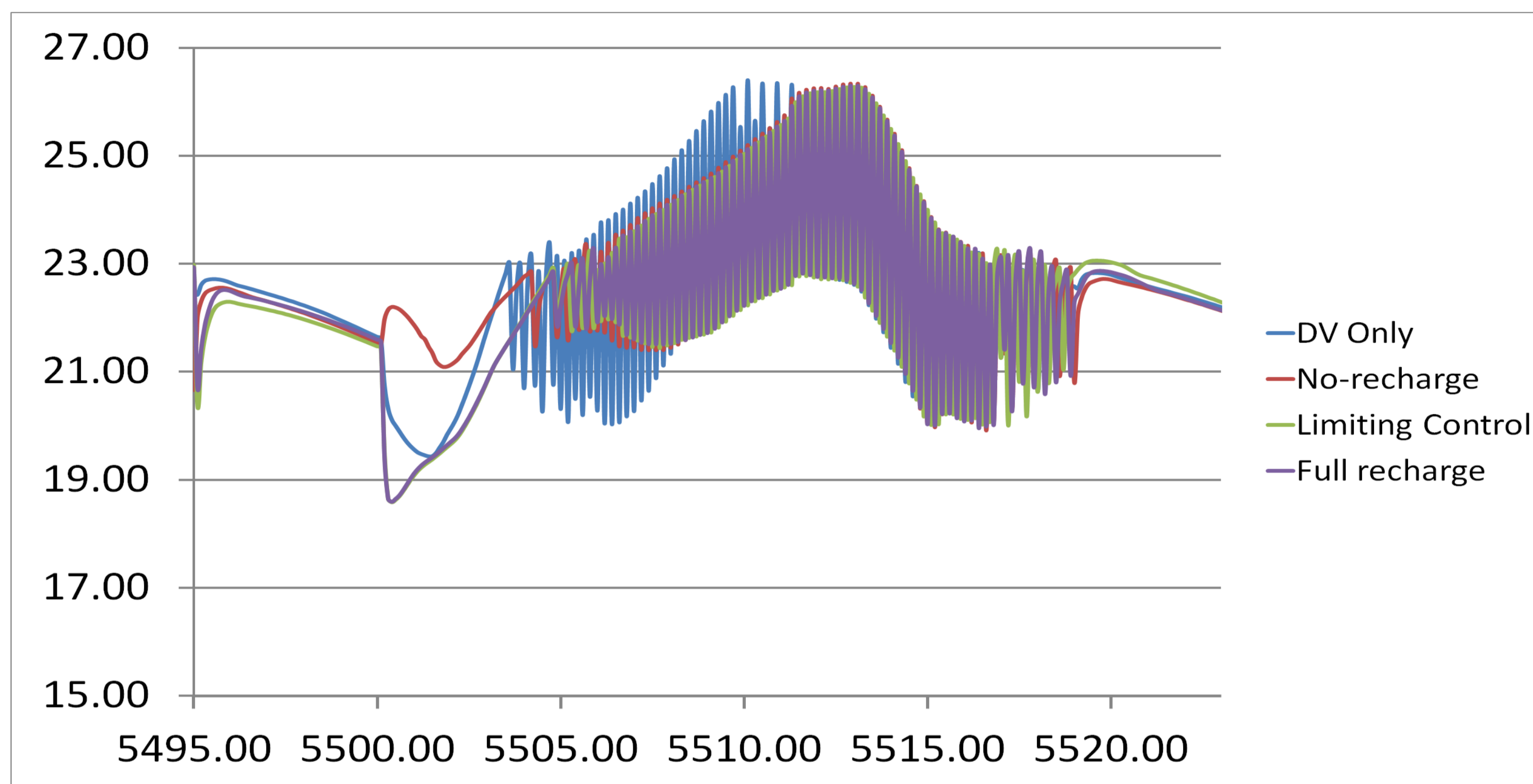
If $T_f > 23^{\circ}\text{C}$ \rightarrow PID calculates a low T_s to satisfy cooling load

If $T_f < 18^{\circ}\text{C}$ \rightarrow PID calculates a high T_s to satisfy heating load

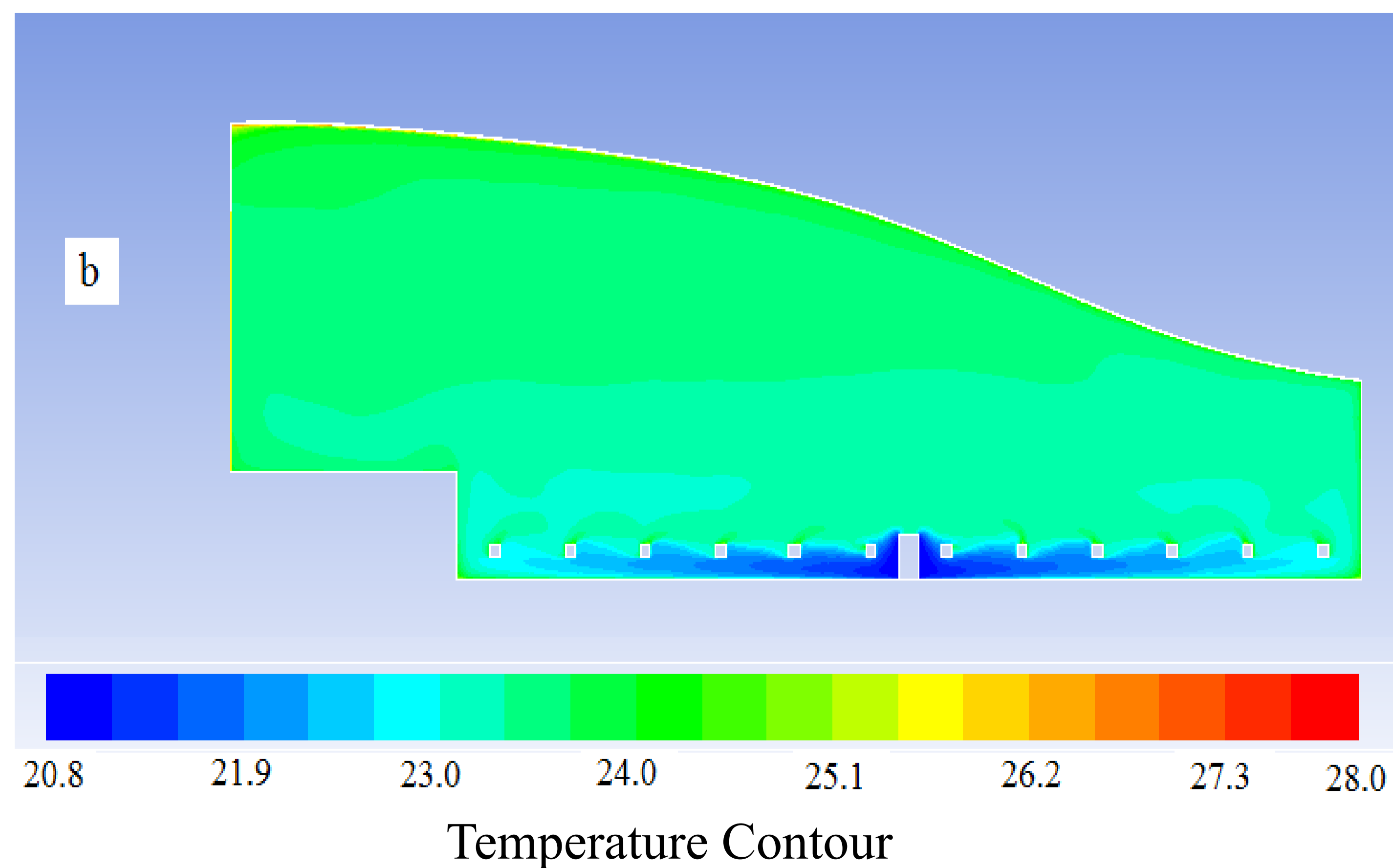
PCM Night Recharge Strategies (non-occupied hours 24:00-04:00): (Ambient air passed through PCM-HX)

1. No-night recharge
2. Full-night recharge
3. Recharge stopped when $T_{\text{pcm}} < 18^{\circ}\text{C}$ (limiting control)

Case Study (5) - Results



Indoor Airport Temperature – One day



-Air movements observed in CFD model

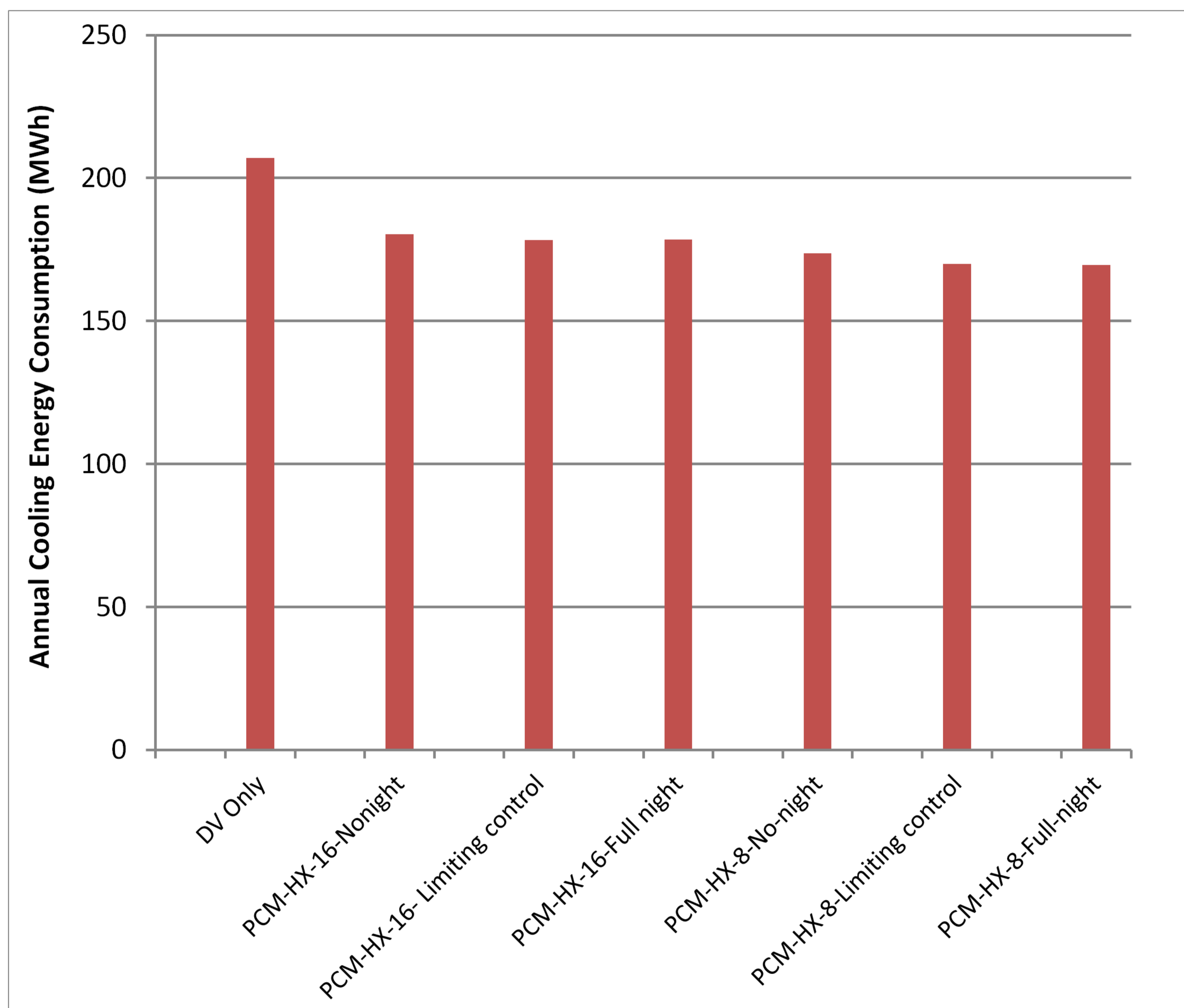
- PCM-HX reduces temperature swing in airport

- Similar temperature trends for 3 recharge strategies

	Summer overheat (>25°C)
DV-Only	6.3 %
PCM-HX No-night Recharge	3.9 %
PCM-HX Limiting-night control	3.5%
PCM-HX Full-night Recharge	3.1 %

Case Study (6) - Results

Annual Cooling Energies obtained through Cooling Degree Days



Systems	Cooling Energy Consumption
DV-Only	100 %
PCM-HX (16mm gap) No-night Recharge	- 12.9 %
PCM-HX (16mm gap) Limiting-night control	- 13.9 %
PCM-HX (16mm gap) Full-night Recharge	- 13.8 %
PCM-HX (8 mm gap) No-night Recharge	- 16.1 %
PCM-HX (8 mm gap) Limiting-night control	- 17.9 %
PCM-HX (8 mm gap) Full-night Recharge	- 18.0 %

Summary

- TRNSYS-CFD coupled simulation used for energy evaluations
- PCM-HX reduces summer overheating by $\approx 3\%$ of the time, compared to DV-only system
- Indoor temperature trends are similar for different night recharge strategies employed
- PCM-HX Cooling Energy requirements decrease in the range of 12 - 18%, compared to DV-only system

Conclusion

Retrofitted PCM-HX system provides similar indoor temperature trends, but employs less energy to do so, compared to a DV-only system.

Acknowledgements

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The logo for the Engineering and Physical Sciences Research Council (EPSRC). It features the acronym "EPSRC" in a bold, purple, sans-serif font. The letters are centered between two horizontal teal lines.

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? QUESTIONS ?