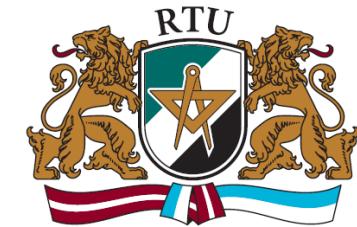




Rīgas Tehniskā universitāte  
Enerģētikas un elektrotehnikas fakultāte  
**Vides aizsardzības un siltuma sistēmu institūts**  
[www.videszinatne.lv](http://www.videszinatne.lv)



# Future Buildings as Prosumers Integrated into DH Systems



Prof.Andra Blumberga  
M.Sc.Arch.Ruta Vanaga

Prof.Dagnija Blumberga

3rd International Conference on Smart Energy Systems  
and 4th Generation District Heating

12.09.2017.



# Nearly zero-energy buildings

- Nearly zero-energy buildings have very high energy performance.
- The low amount of energy that these buildings require comes mostly from renewable sources.

## Challenge

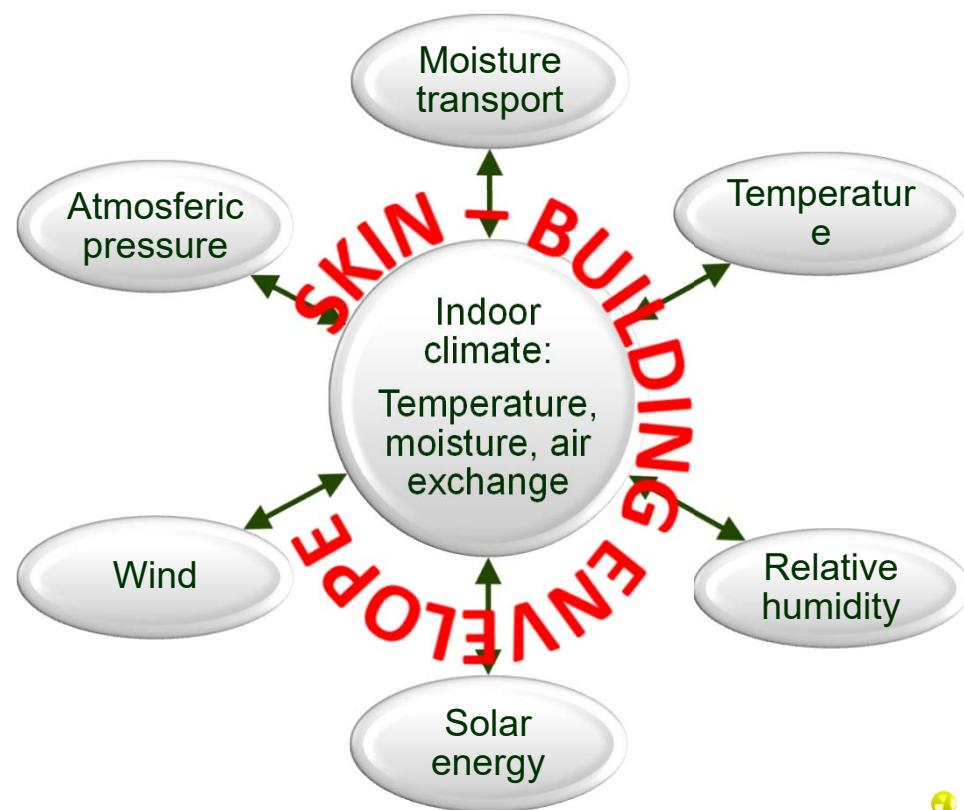
Existing energy efficiency technologies have limits to reach nearly zero energy building energy performance.



# CLIMATE ADAPTIVE BUILDING FAÇADE



# BIOMIMICRY

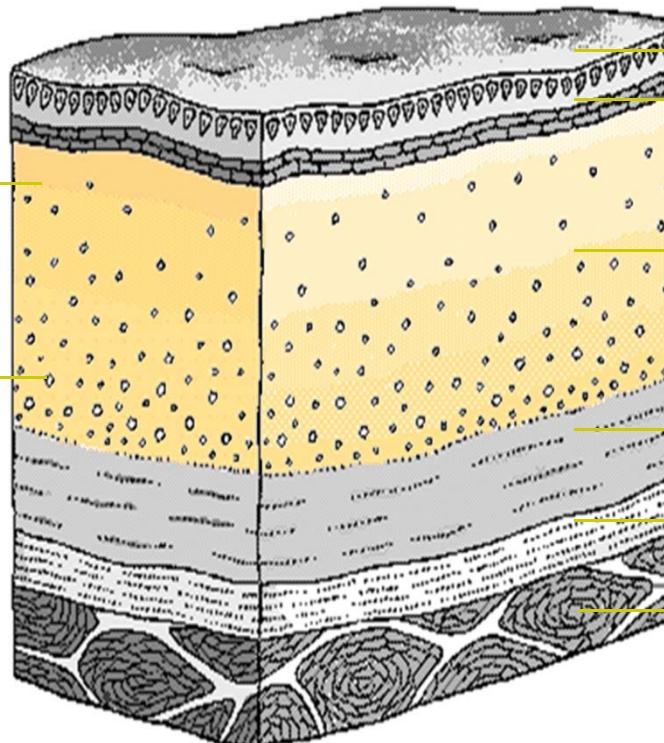


# BIOMIMICRY



Layer with lower heat conductivity value

Layer with higher heat conductivity value



Epiderm  
Derm

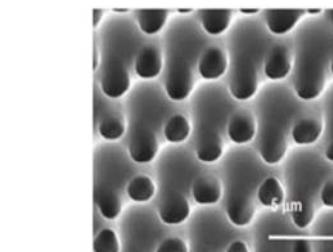
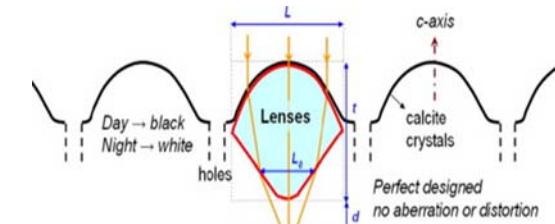
Layer of fat

Connective  
tissues

Fascia

Muscles

## Surface of brittle star

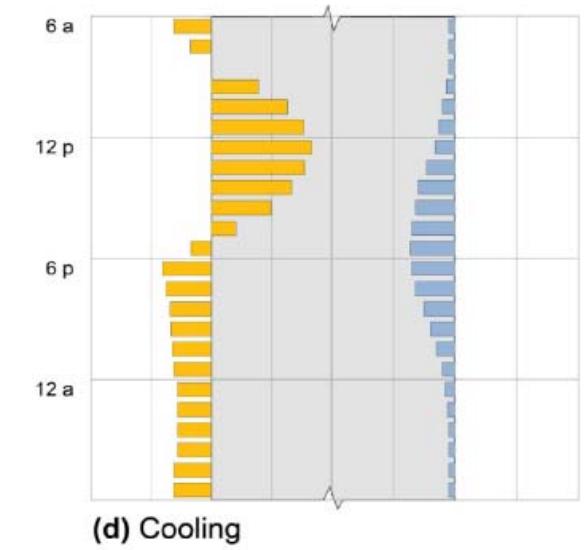
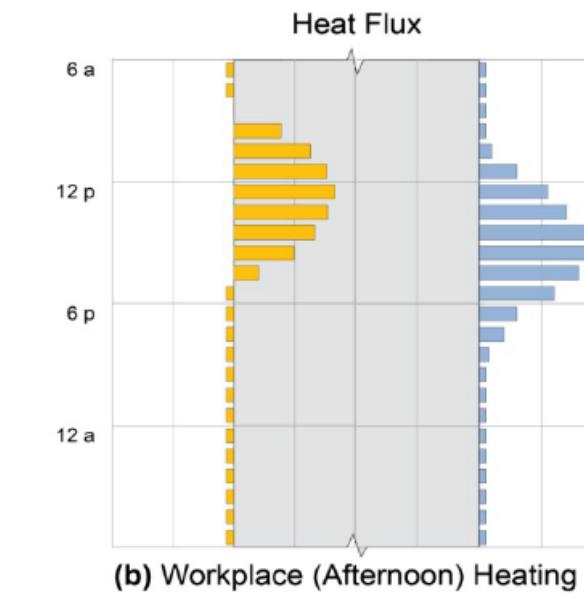
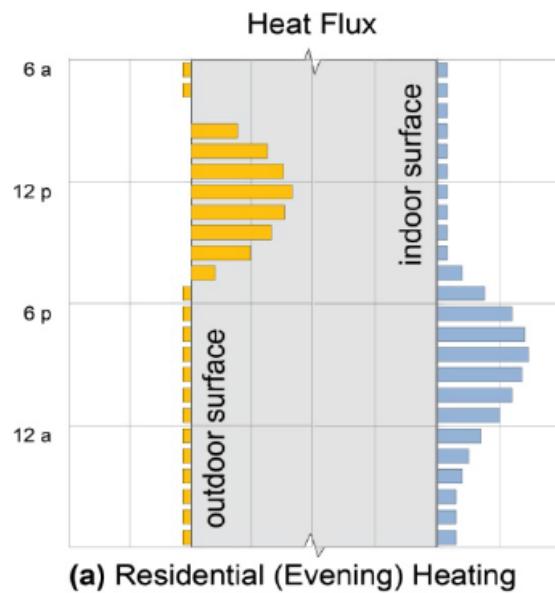


(b)

Chen P.-Y., McKittrick, Meyers M.A. Biological materials: Functional adaptations and bioinspired designs, Progress in Material Science 57, 2012, p.1492-1704



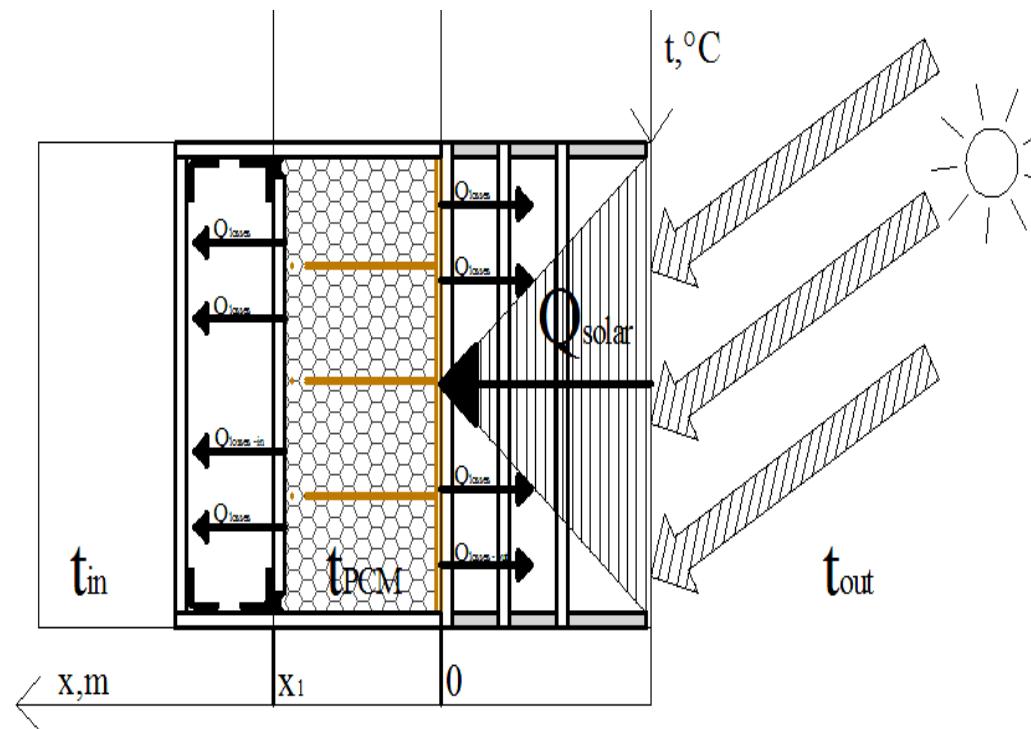
# Ideal heat flux profiles



Alexandra R. Rempel , Alan W. Rempel  
Rocks, Clays, Water, and Salts: Highly Durable, Infinitely  
Rechargeable, Eminently Controllable Thermal Batteries  
for Buildings, Geosciences 2013, 3, 63-101

# BIOMIMICRY

## Climate adaptive building facade

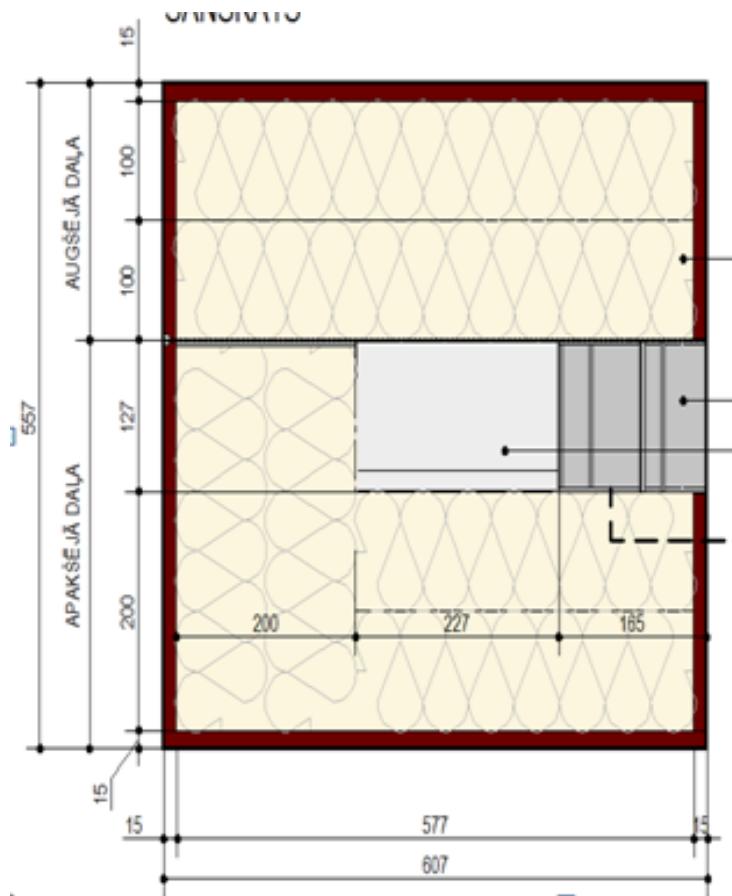


Copper enhancers + paraffin RT21 HC + granulated aerogel



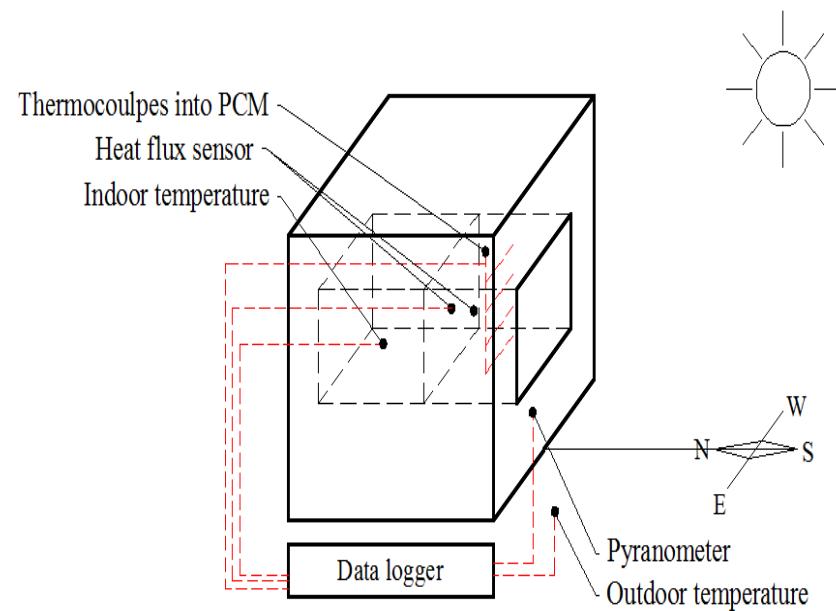
# Hypothesis

**Proposed climate adaptive facade element  
can accumulate energy to reduce heating and  
cooling loads in nearly zero energy building**



# Experimental setup

- Test box
- Reference box





# Experimental setup





Test rounds	PCM filling	Insulation of test and reference boxes	Focal point	Granulated aerogel
1	-	-	-	-
2	X	-	-	-
3	X	X	-	-
4	X	X	X	-
5	X	X	X	X



# RESULTS

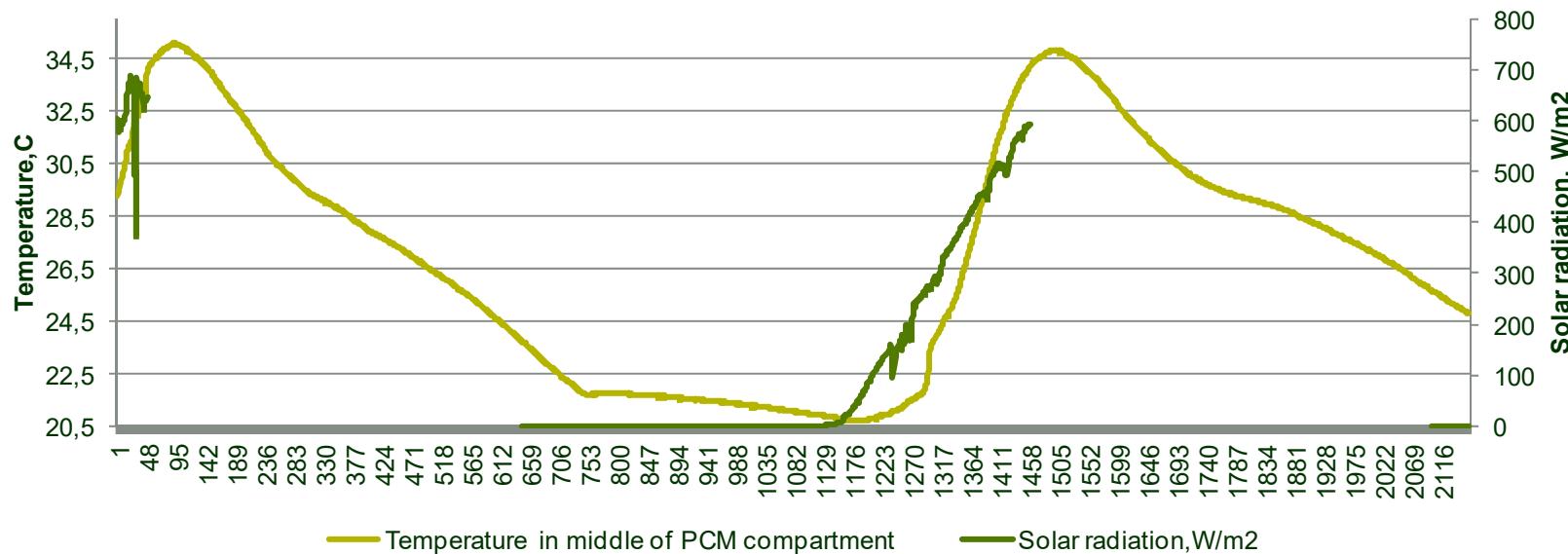


# Indoor temperatures: test box without PCM and insulation of boxes (round 1)





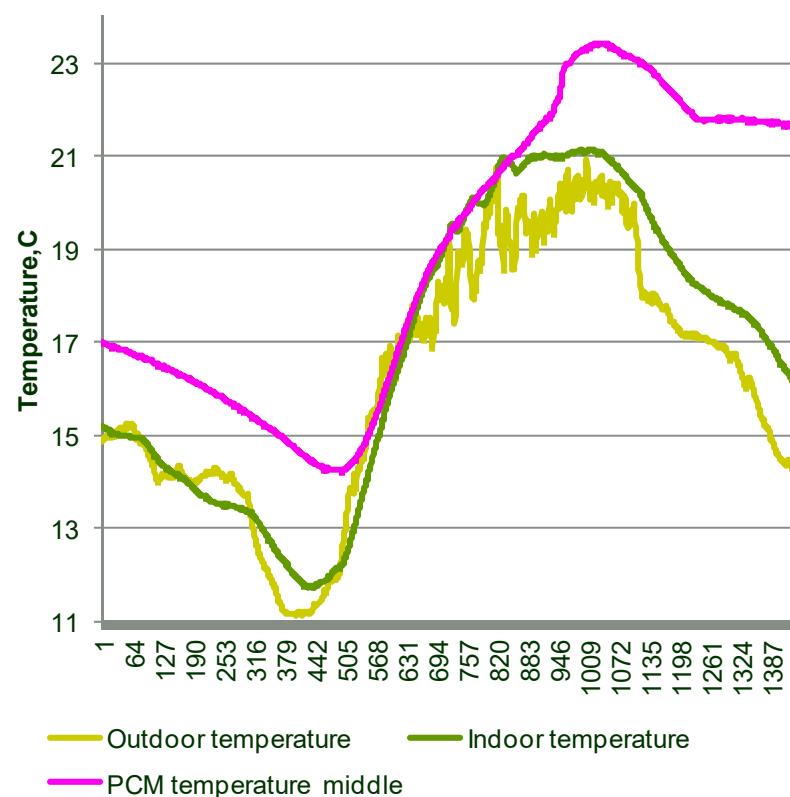
# Delay: test box without PCM filling and insulation of boxes (round 1)



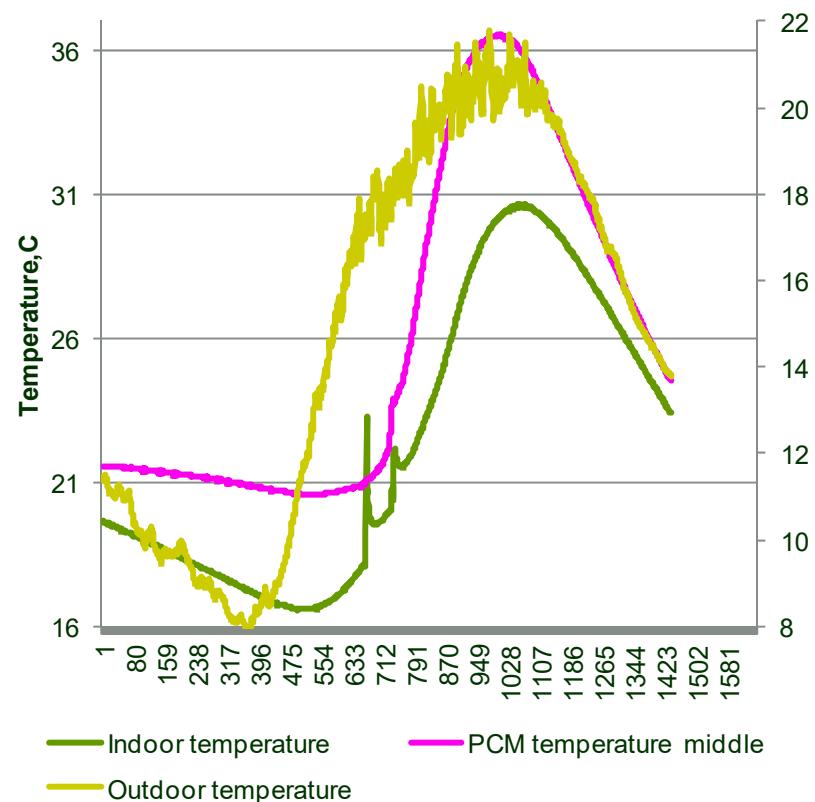


# Impact of insulation of the test box

**Without insulation (26.08.2017.)  
(round 2)**

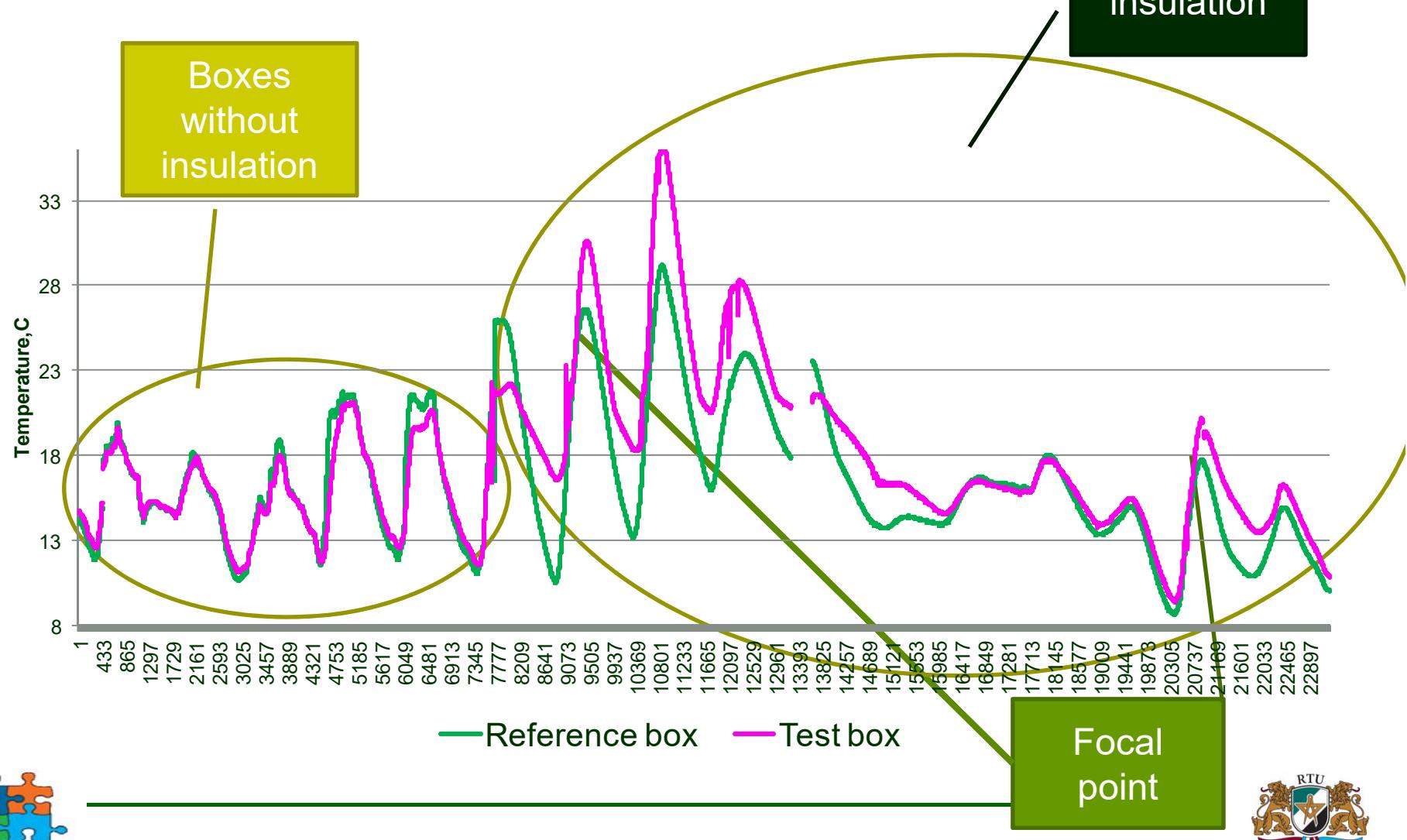


**With insulation (29.08.2017.)  
(round 3)**



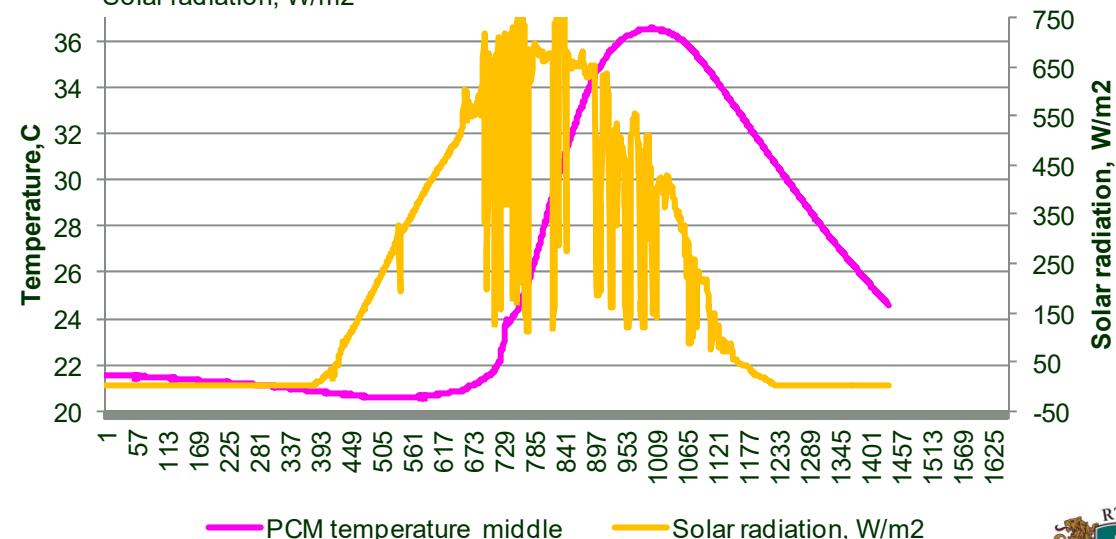
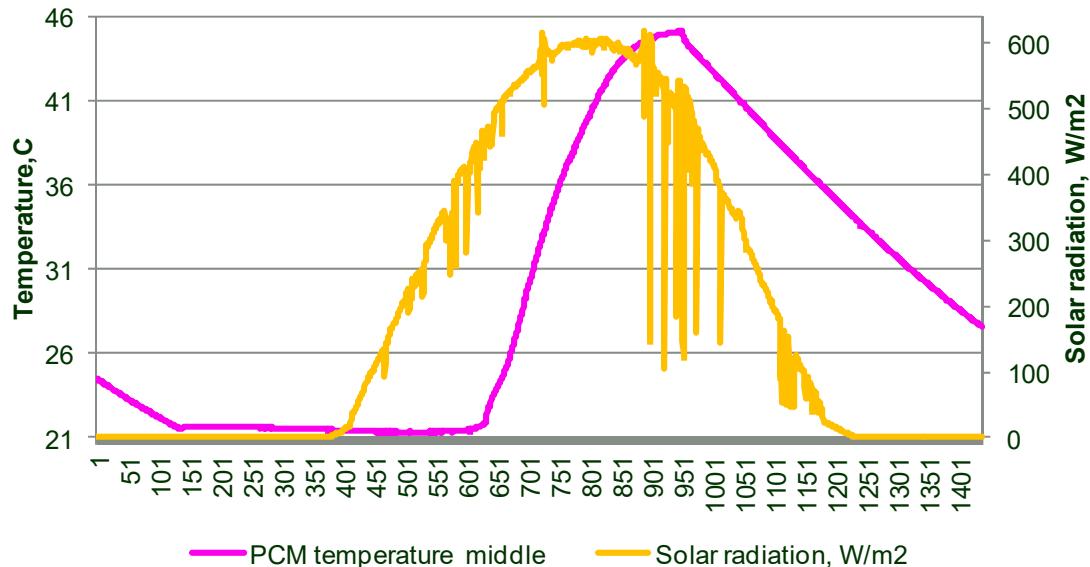


# Indoor temperatures with PCM filling (round 2 - 4)





## Delay: test box with PCM (round 2 - 4)



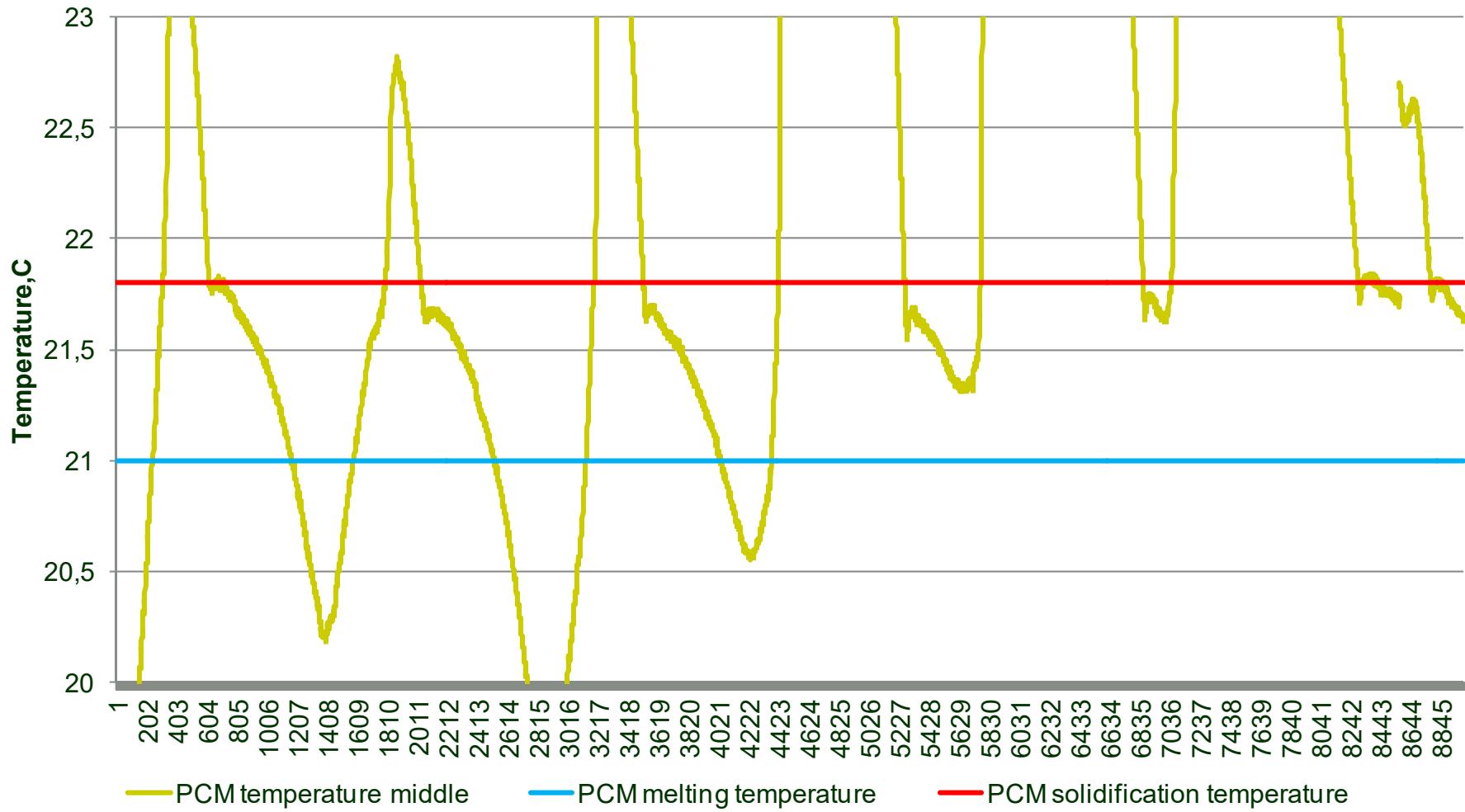


# PCM



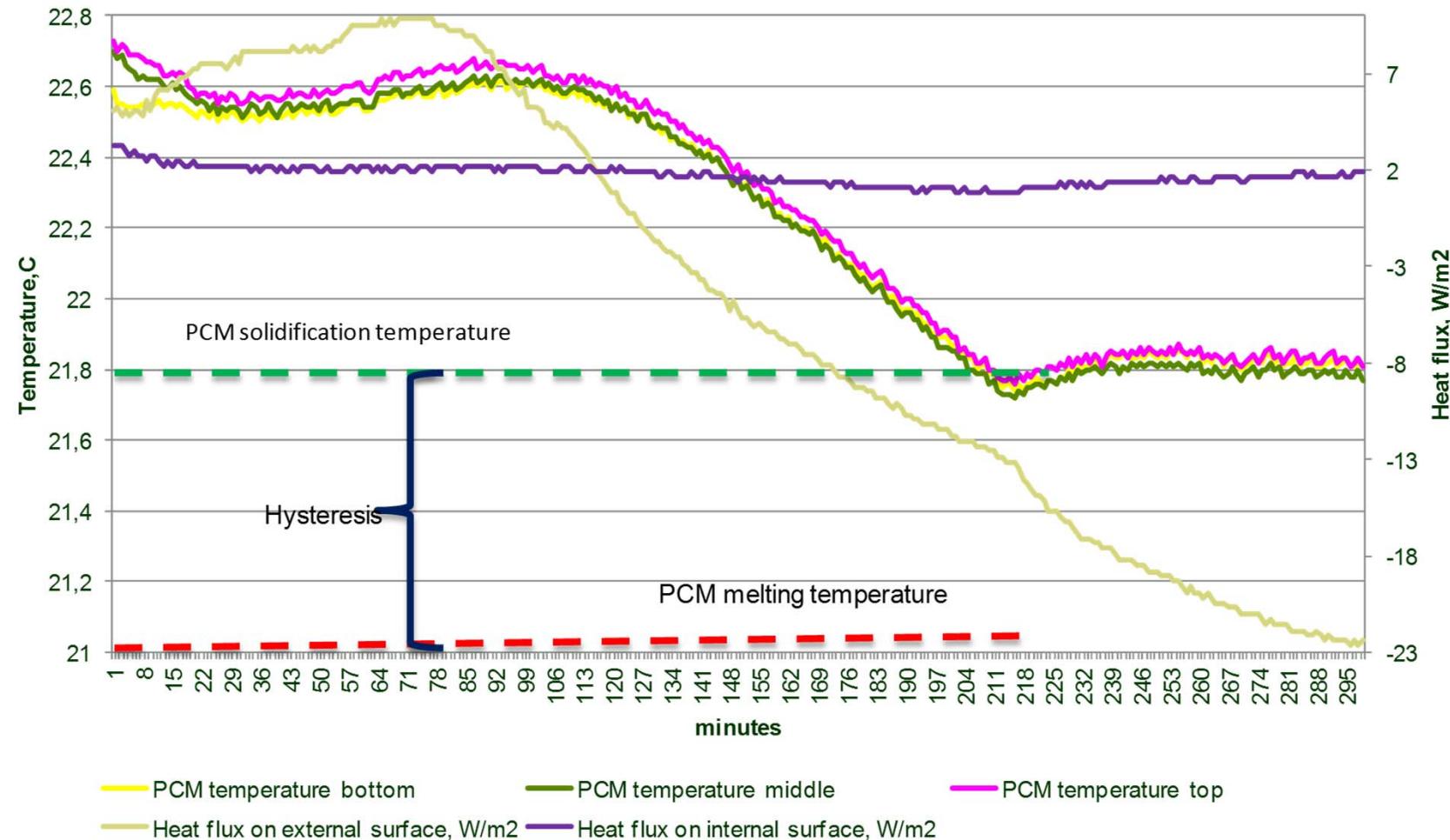


# Phase change processes



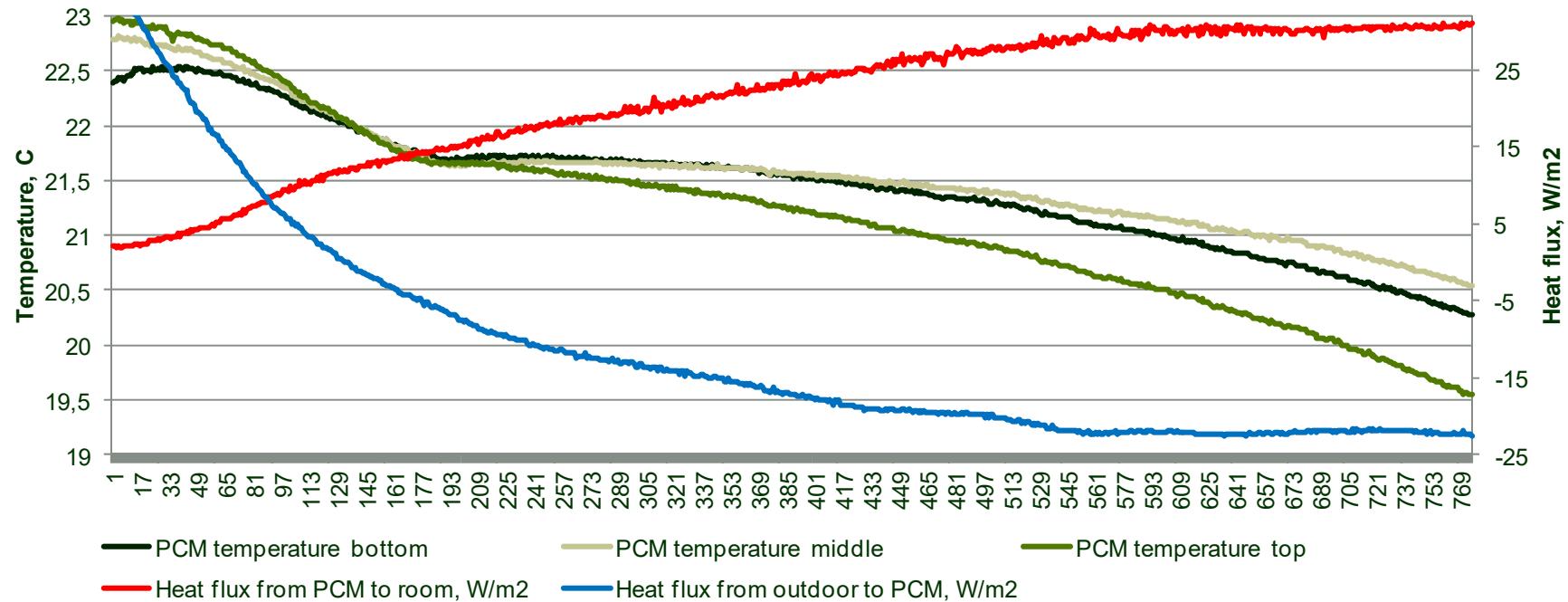


# Hysteresis





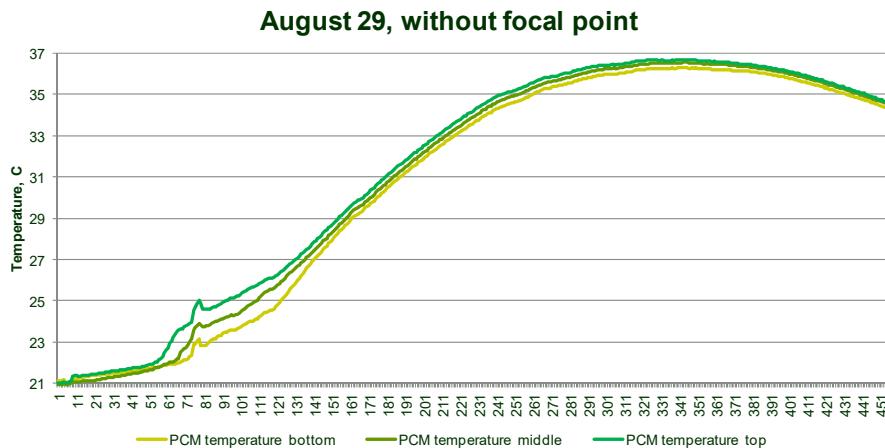
# PCM solidification process



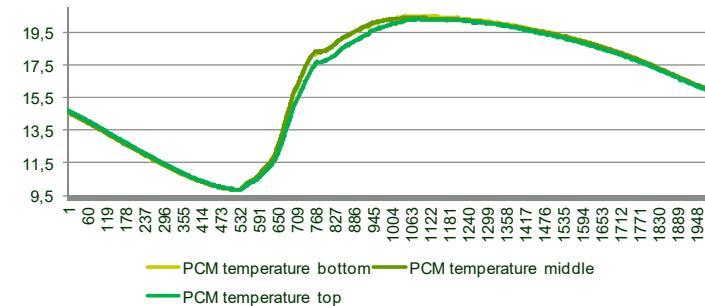


# Heating up process of solidified PCM

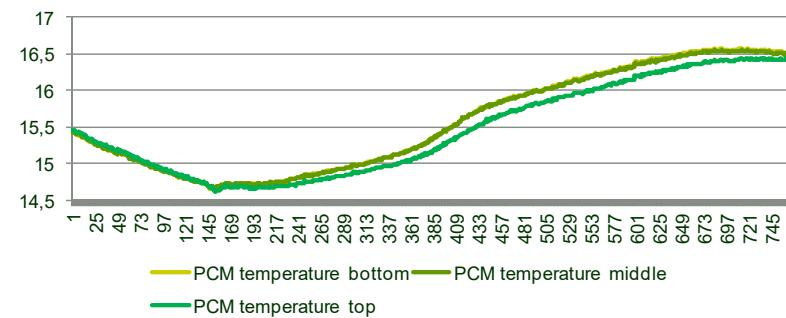
## PCM melting process



September 6, with focal point

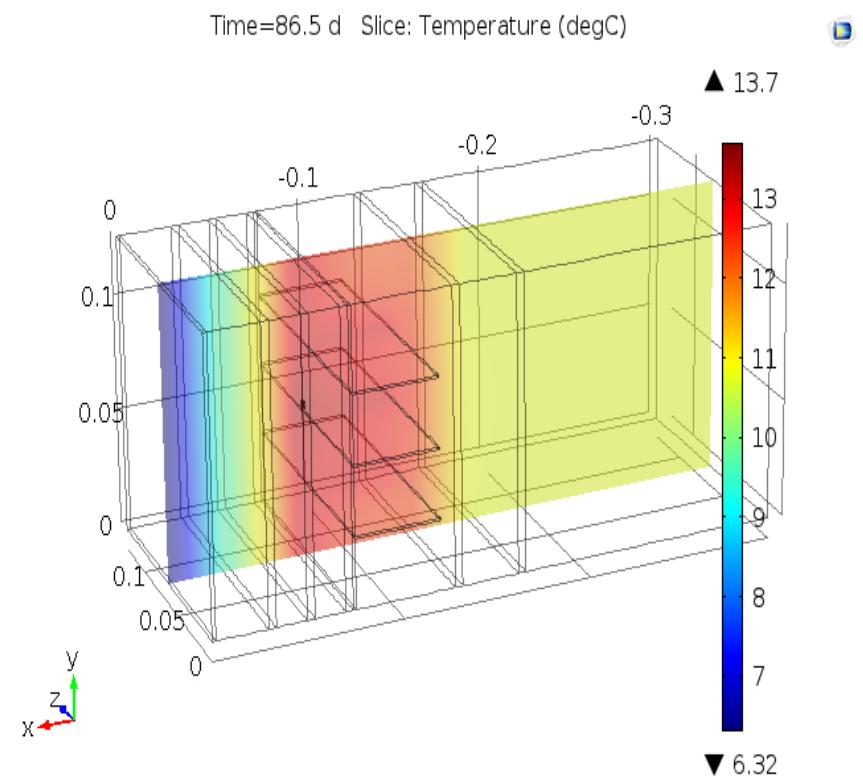
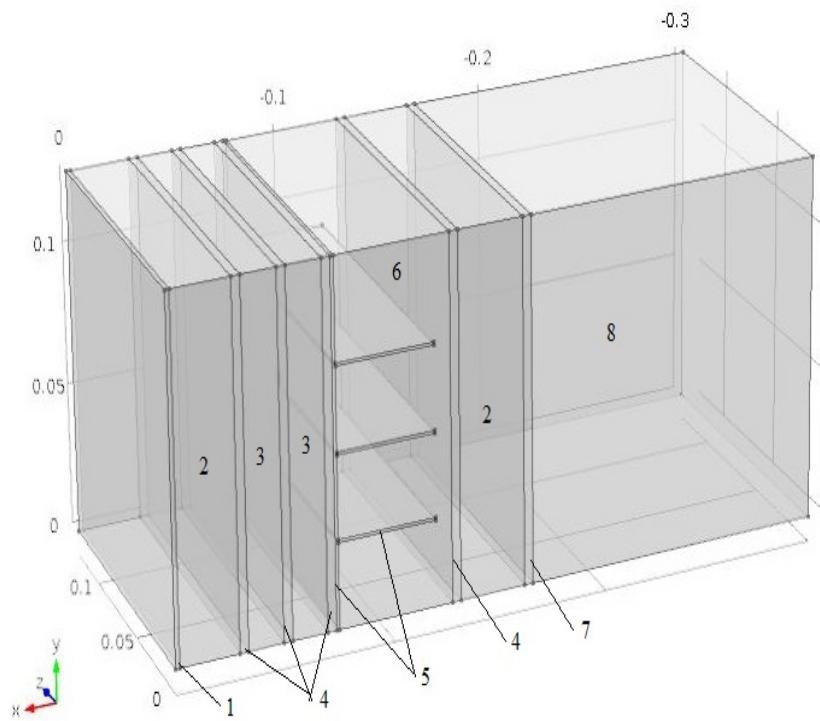


September 5, without focal point





# Modelling with COMSOL



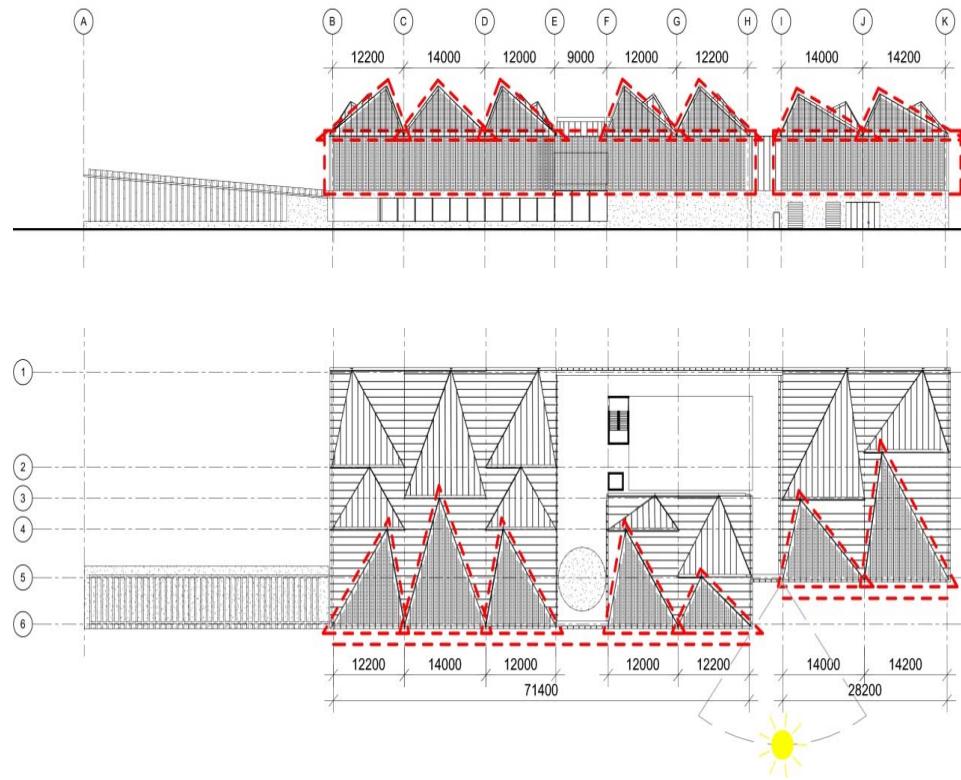
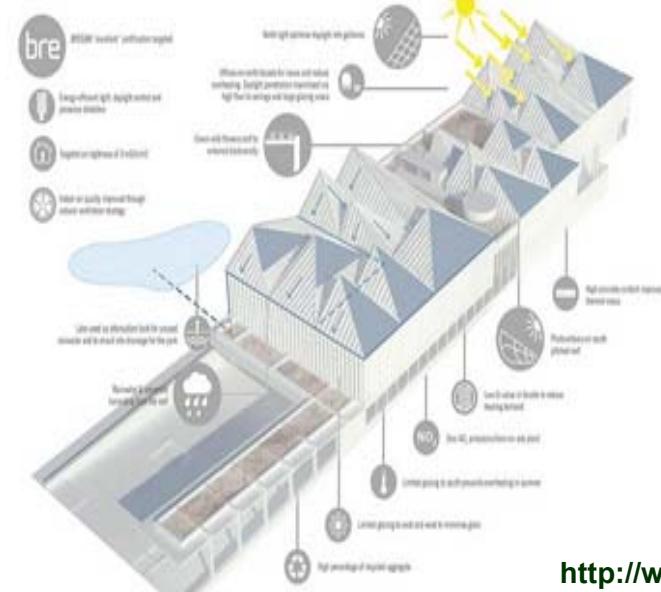
1 – acril glass, 2 – aerogel, 3/4 – three pane glass, 5 – copper with enhancers, 6 – PCM, 8 – acril glass, 8 – room



# Application



SUSTAINABILITY



<http://www.a4d.lv/lv/notikumi/muzeja-konkursa-uzvar-adjaye-associates-un-ab3d/>  
<https://competitions.malcolmreading.co.uk/lncca/adjaye-associates/>



# Conclusions (1)

- Multi-variable regression analysis of measured variables carried out for different parts of the day and different days explains 96-99% in variability of indoor temperature and heat flux inflow
- Round 1(no PCM and insulation):
  - no delay between ref.and test box indoor temperatures during days and delay during nights (Trombe wall)
  - delay between solar radiation and PCM compartment temperature



## Conclusions (2)

- Impact of insulation of boxes (round 1 vs round 2-4): time delay between outdoor temperature and indoor and PCM temperature
- PCM hysteresis: melting at +21°C and solidification at approx.+21.7°C
- PCM temperature:
  - When melted, PCM temperature is higher at the top;
  - When solid and is heating up, PCM temperature is higher at the bottom.
- Round 5: aerogel layer reduces heat losses from PCM to outdoor air



## Further research

- Continue with Comsol model
- Solar radiation adaptive element: moving granulated aerogel layer
- Solar tracking system for rotating test box
- Steady state tests in laboratory