Third International Conference CONSOLFOOD2020

Advances in Solar Thermal Food Processing

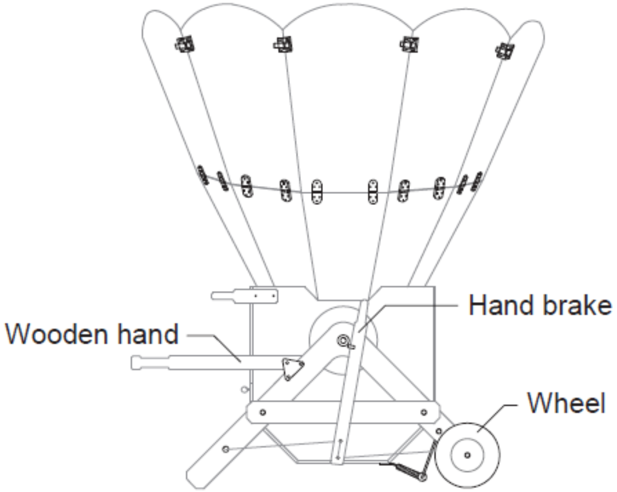
22-23-24 January 2020

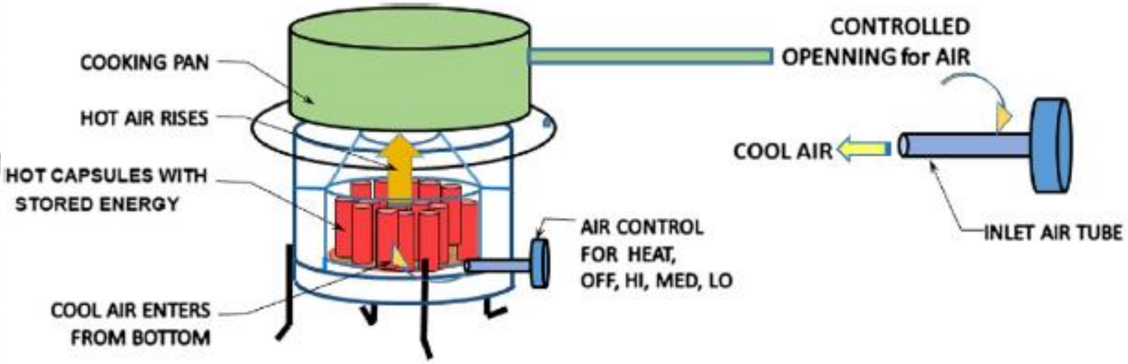
INSTITUTE OF ENGINEERING; UNIVERSITY OF ALGARVE; CAMPUS DA PENHA; FARO-PORTUGAL

HIGH TEMPERATURE SOLAR COOKING SYSTEM WITH A PCM ENERGY STORAGE UNIT

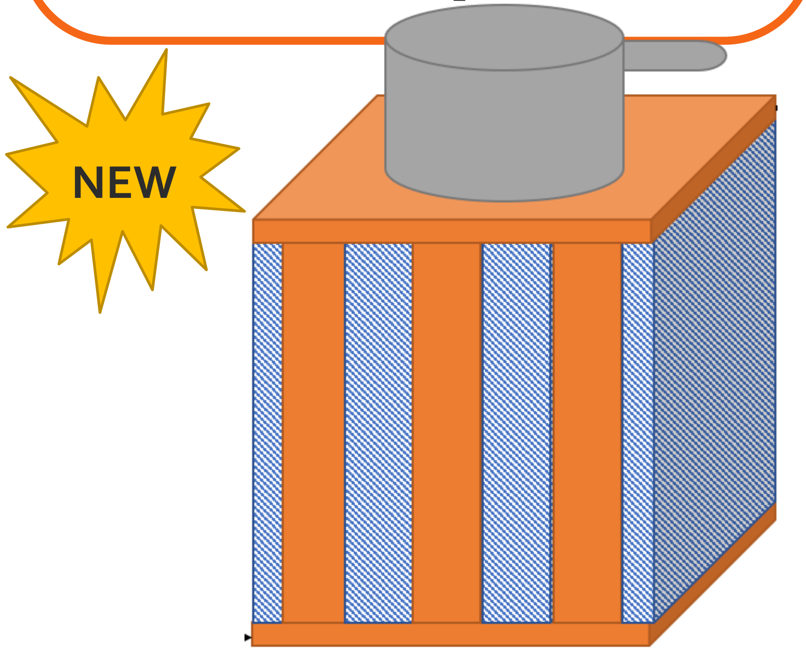
universidade de aveiro

Olivia Alves – Departamento de Engenharia Mecânica, Universidade de Aveiro (Portugal)
Vítor A. F. Costa – Departamento de Engenharia Mecânica, Universidade de Aveiro (Portugal)

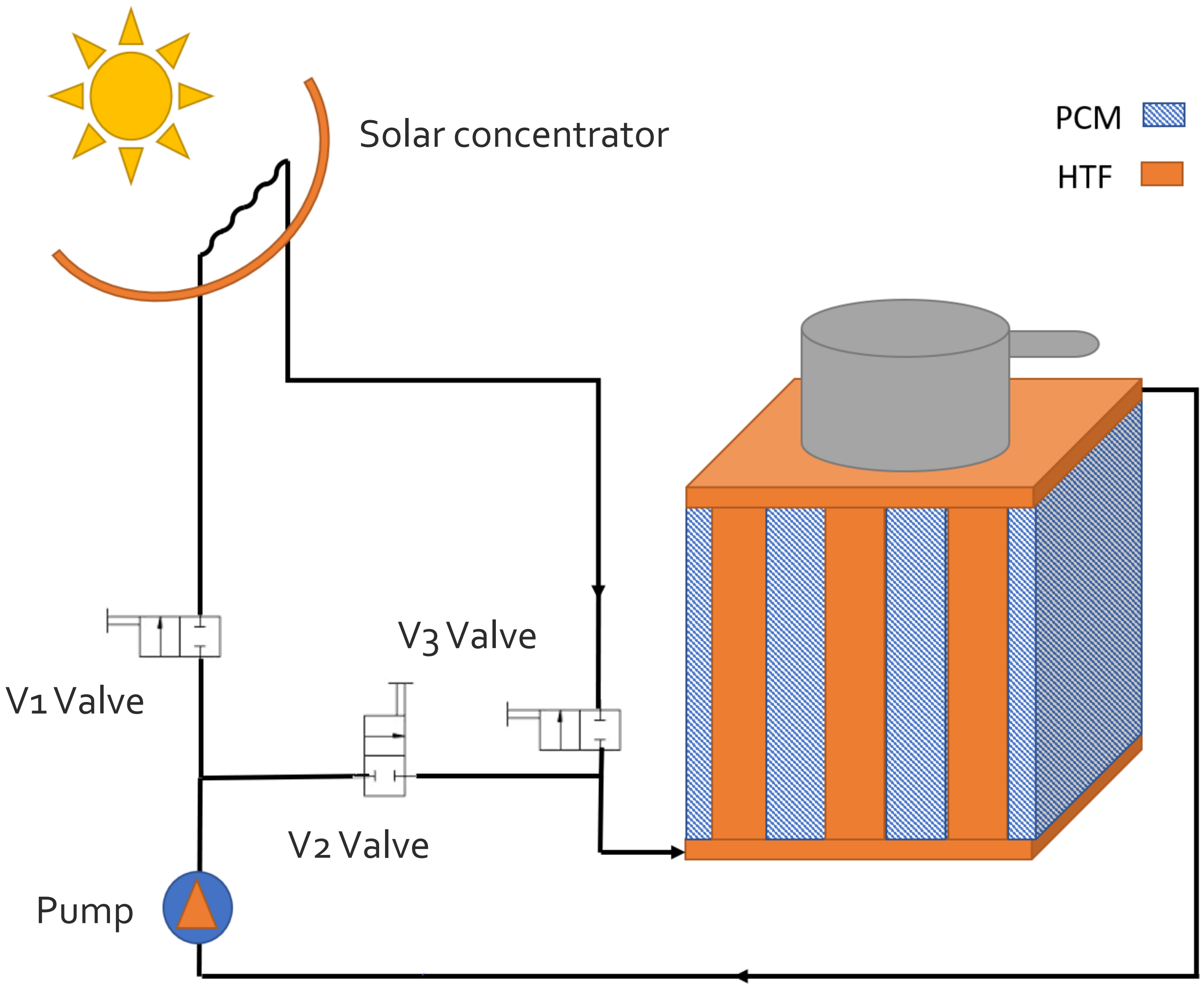




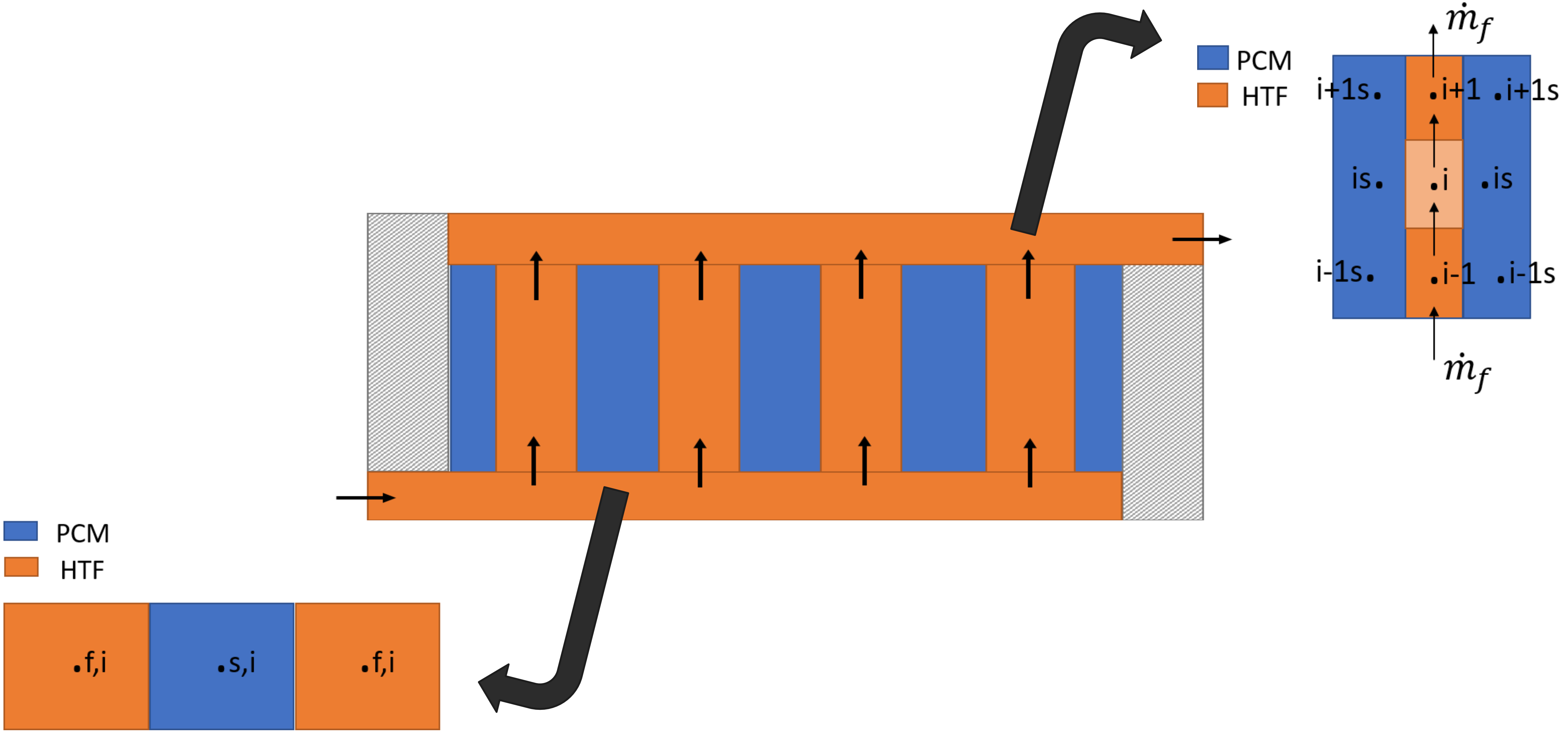
Usual indirect solar cooking systems require a specific cooking reservoir/pan, reducing their use and viability. Taking that in consideration, the proposed system allows the use of a conventional pan.



CONSOLFOOD2020



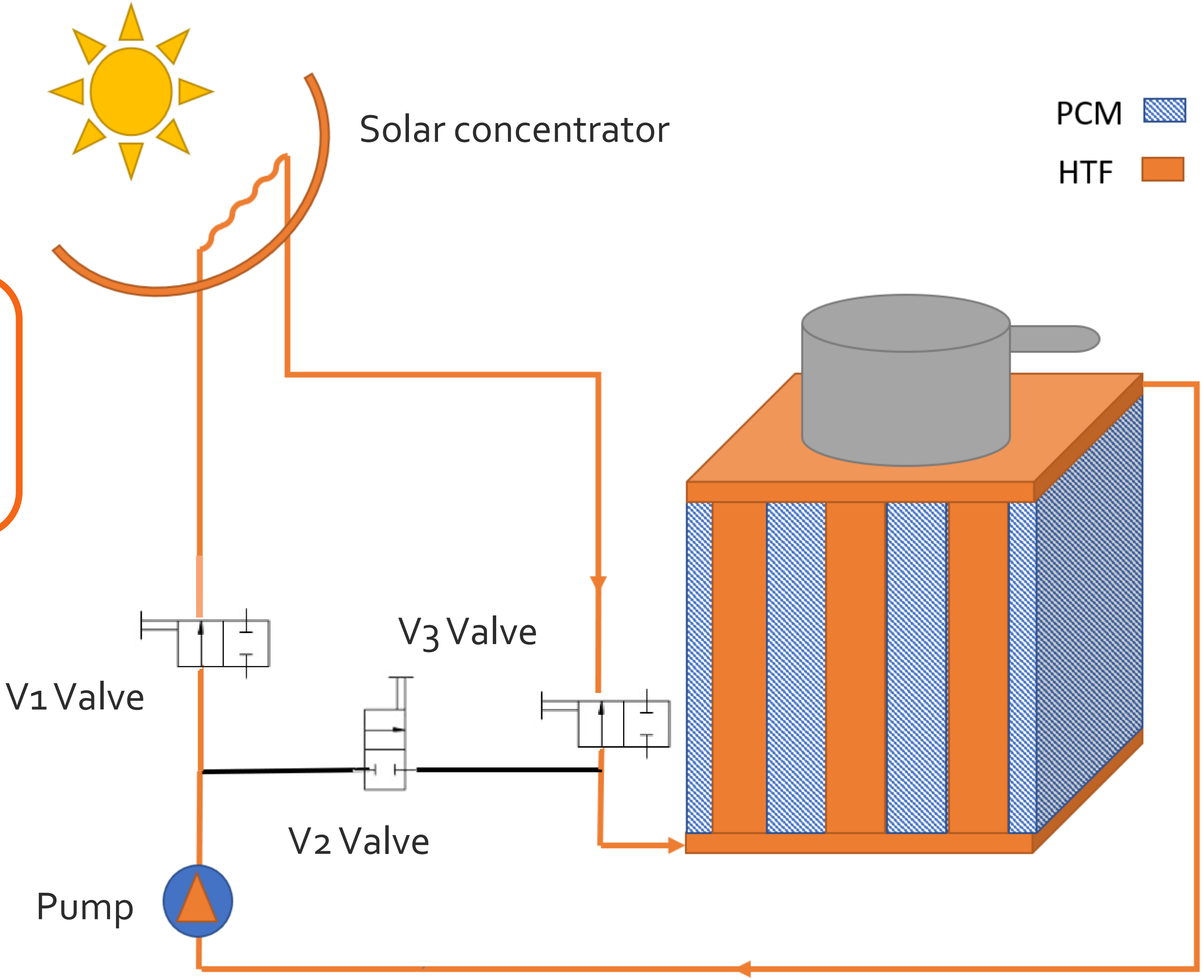
CONSOLFOOD2020



PCM
HTF
$\dot{m}_f$
i+1s
i+1
i+1s
is
i
is
i-1s
i-1
i-1s
$\dot{m}_f$
PCM
HTF
f,i
s,i
f,i

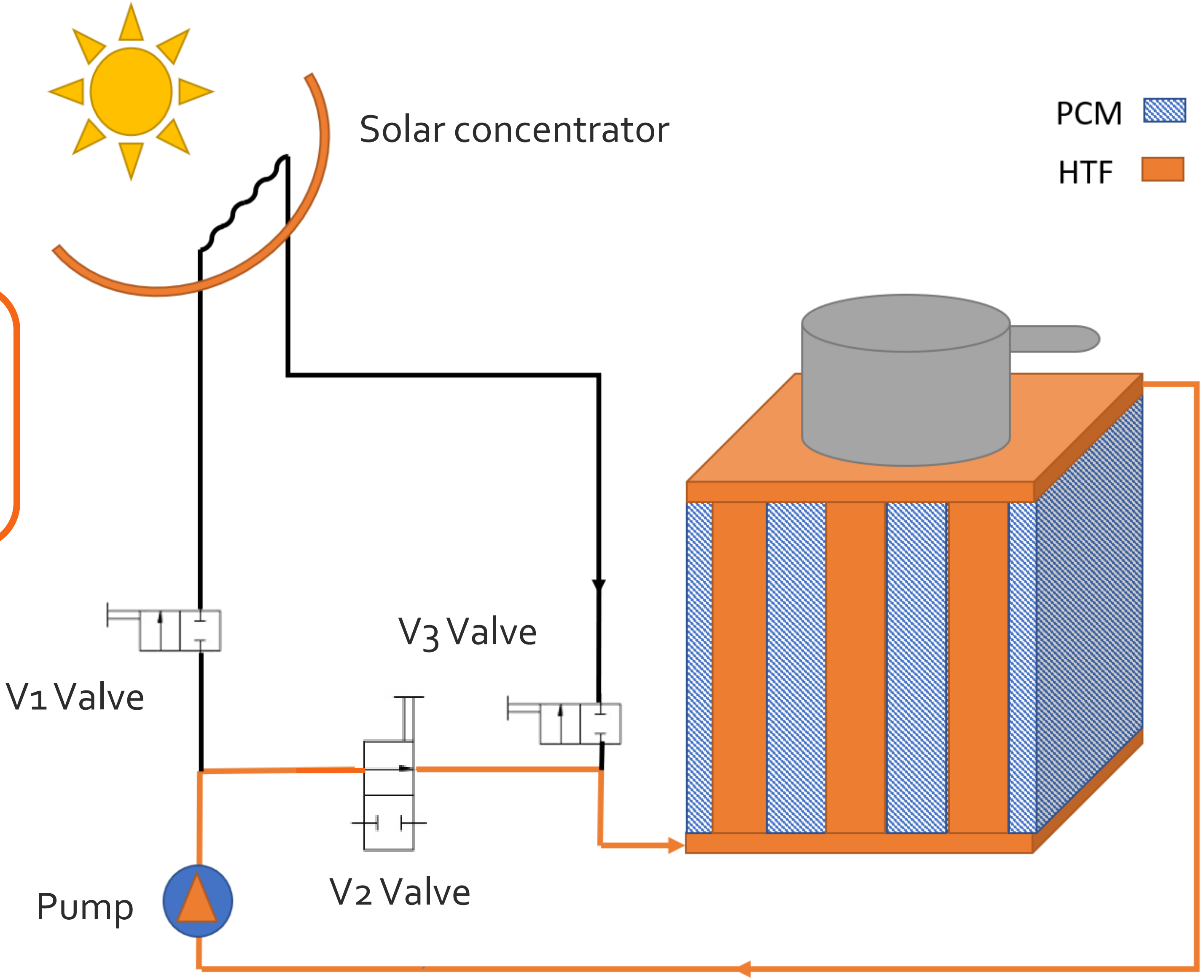
Primary circuit:

V1 and V2 : open
V3: closed

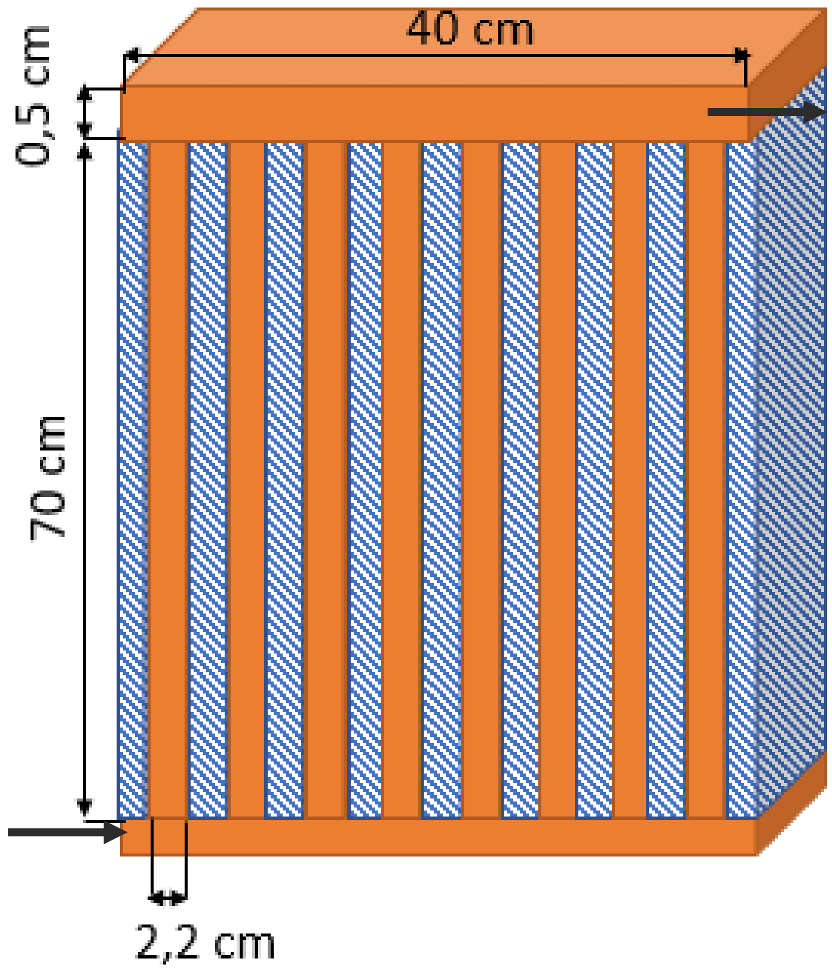


Secondary circuit:

V2 : open
V1 and V3: closed

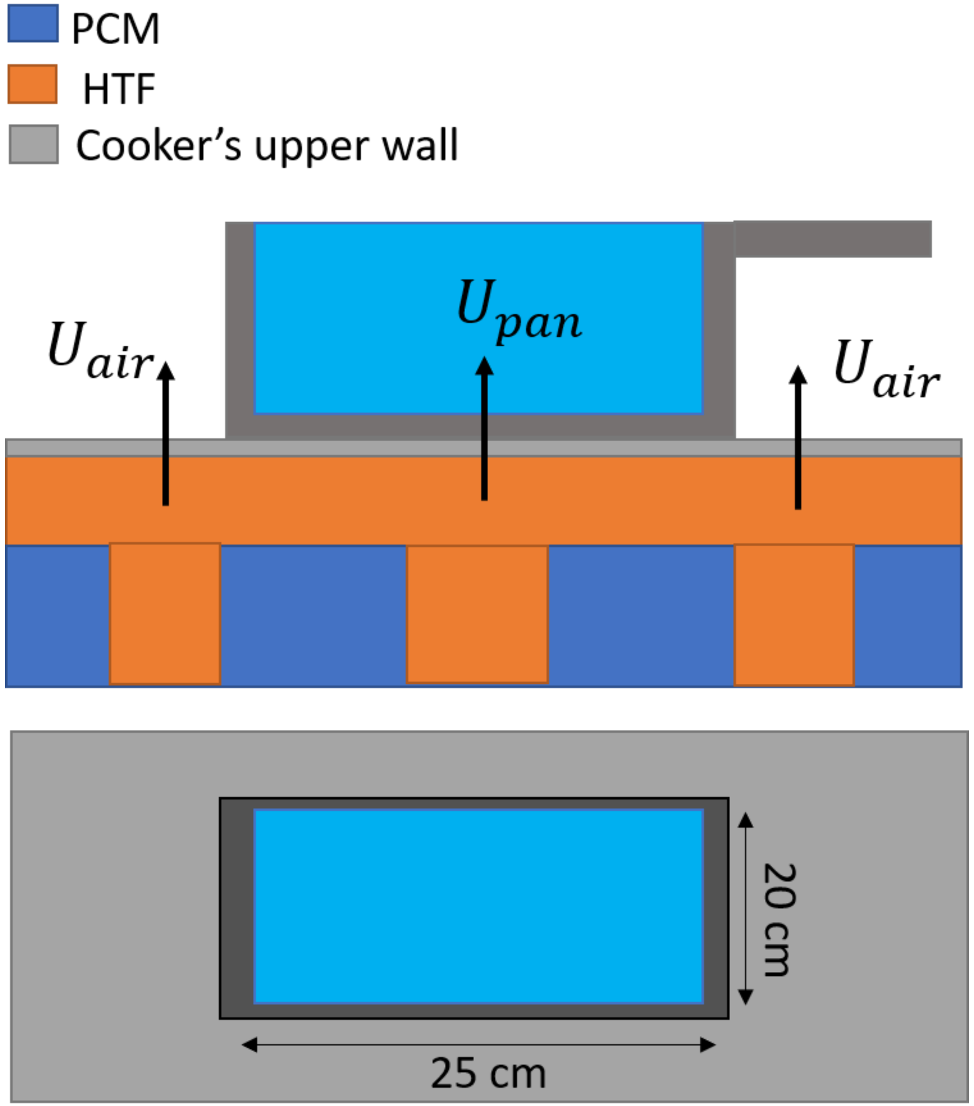


17 modules = 8 HTF passages and 9 PCM modules



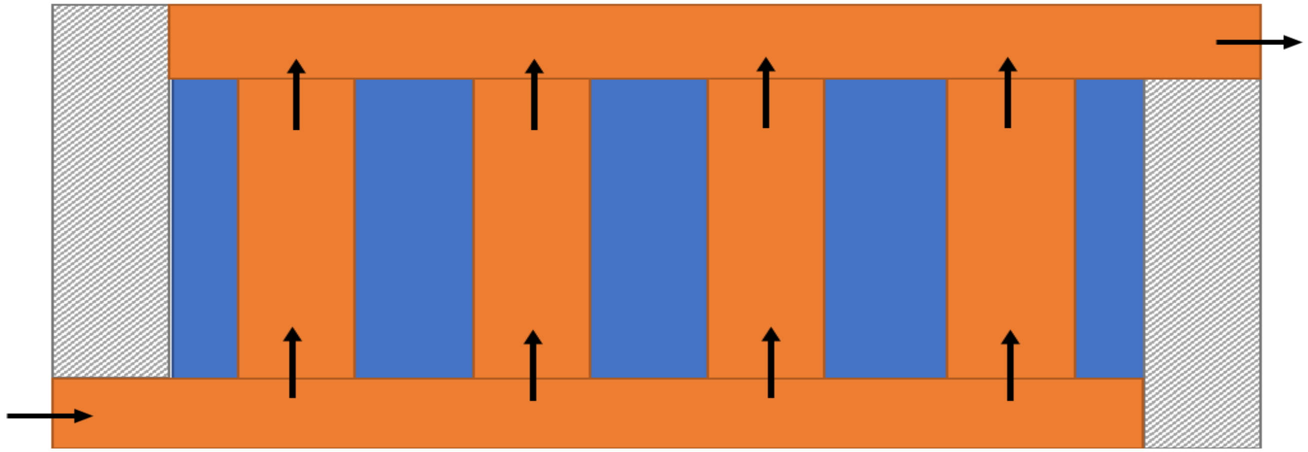
The chosen PCM is an eutectic mixture based on nitrite and nitrate salts (53 wt% KNO_3, 40 wt% $NaNO_2$, 7 wt% $NaNO_3$)

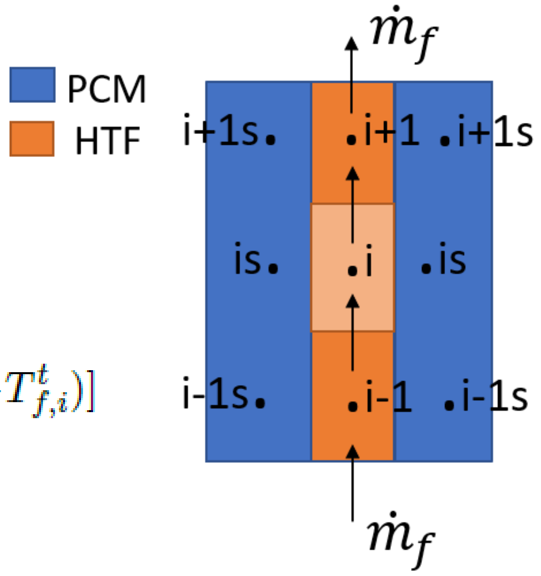
HITEC – Heat transfer Salt (PCM)	
T_{melt}	142 °C
Δh_{mf}	81.41 kJ/kg
$c_{p,s}$	1340 J/(kg.K)
$c_{p,l}$	1560 J/(kg.K)
k	0.57 W/(m.K)



The system is required to start boiling 1 L of water, and to cook 500 g rice during 20 min in the boiling water at 100 ºC.

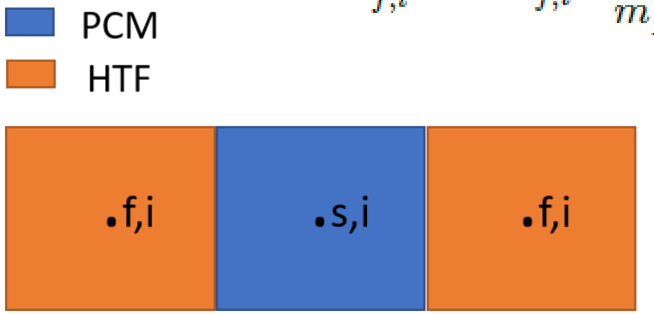
- Noon period: 12 pm
- Night period: 7 pm





Time evolution of the HTF temperature:

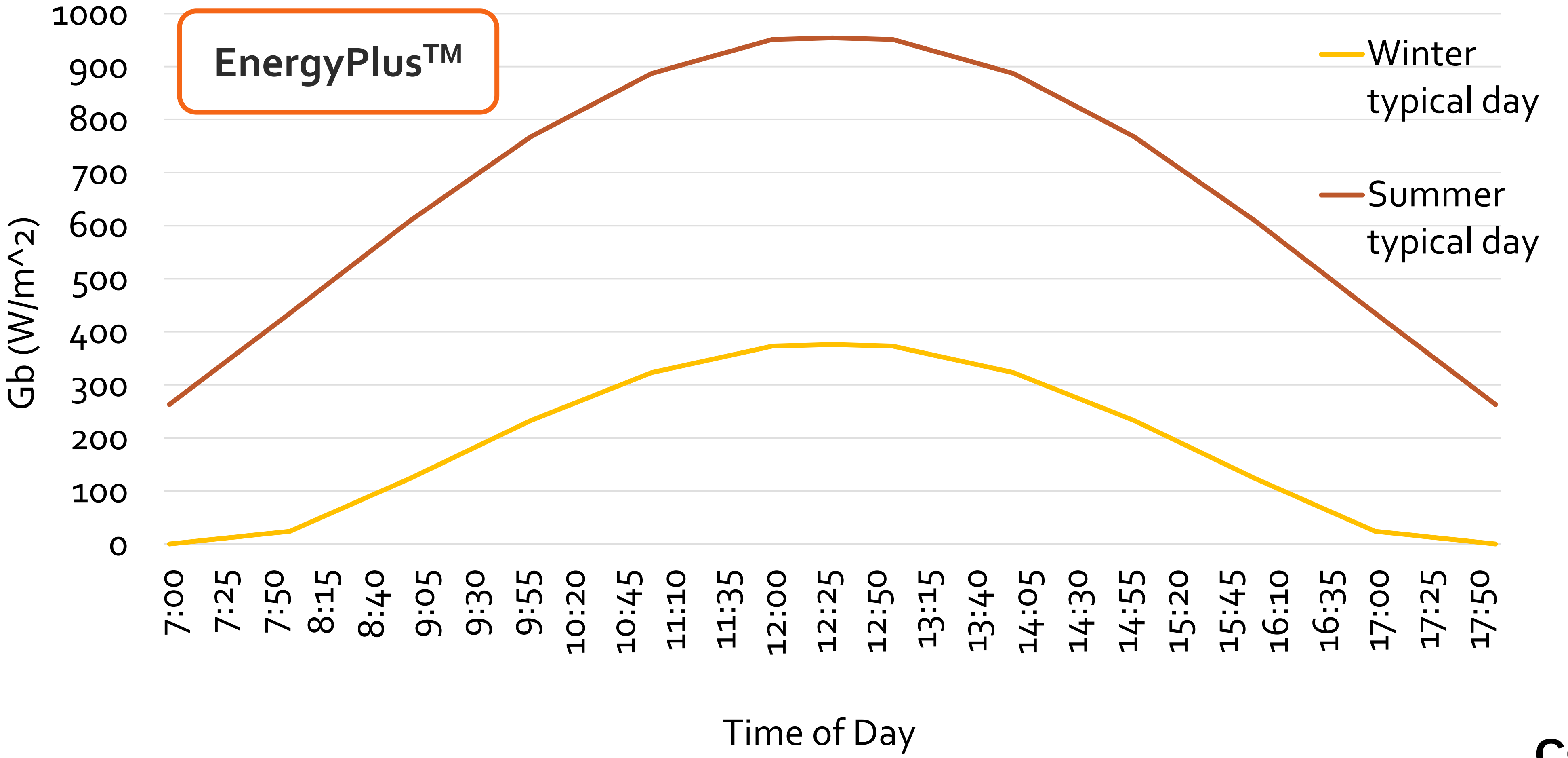
$$T_{f,i}^{t+\Delta t} = T_{f,i}^{t} + \frac{\Delta t}{m_{f,i}c_f}\left[U_iA_i(T_{s,i}^{t} - T_{f,i}^{t}) + \frac{k_fA_c}{\Delta y}(T_{f,i-1}^{t} - 2T_{f,i}^{t} + T_{f,i+1}^{t}) + \dot{m}_f c_f (T_{f,i-1}^{t} - T_{f,i}^{t})\right]$$



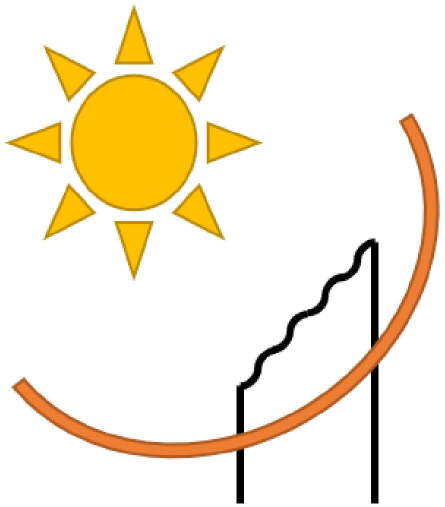
Time evolution of the PCM temperature:

$$T_{s,i}^{t+\Delta t} = T_{s,i}^{t} + \frac{\Delta t}{m_{s,i}c_s}\left[U_iA_i(T_{f,i}^{t} - T_{s,i}^{t}) + \frac{k_fA_c}{\Delta t}(T_{s,i-1}^{t} - 2T_{s,i}^{t} + T_{s,i+1}^{t})\right]$$

SOLAR DATA FOR AVEIRO



CONSOLFOOD2020



Solar concentrator

$$\eta_{total} = 0.35 - 0.4632\left(\frac{T_{in} - T_{amb}}{G_b}\right)$$

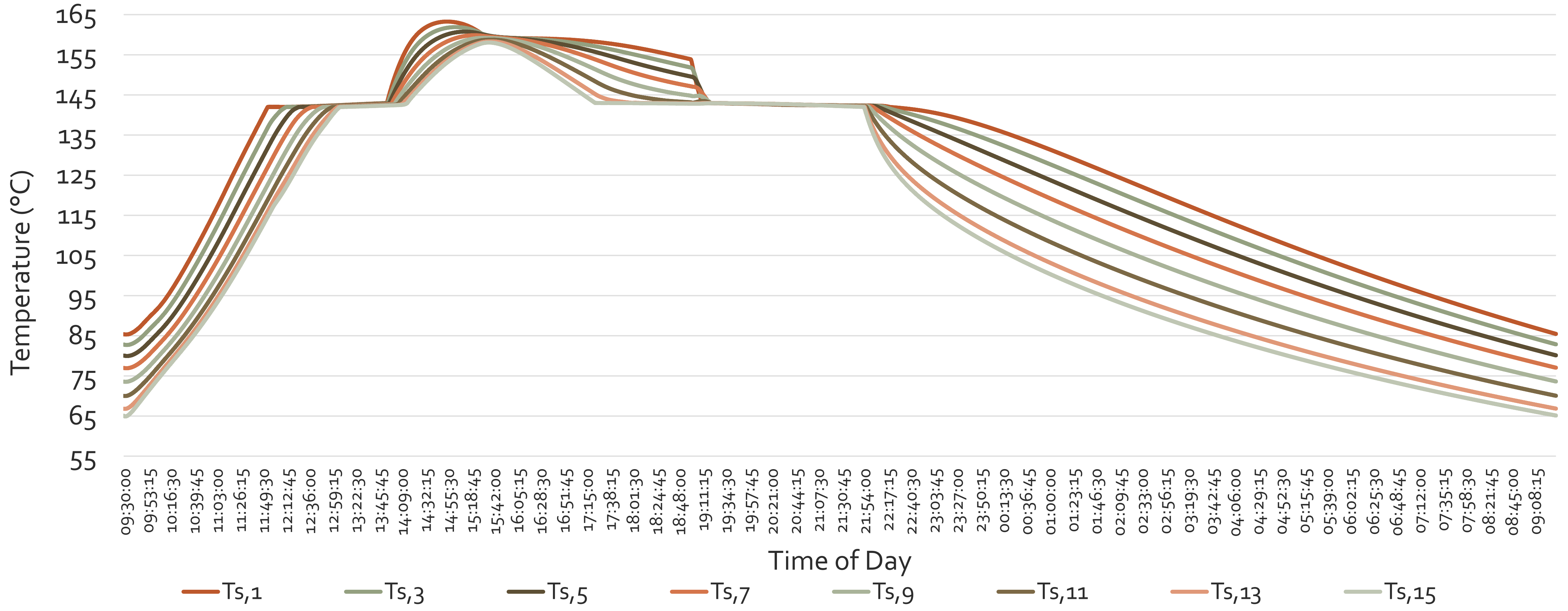
$$\downarrow$$

Area = 26.5 m^2

$$\downarrow$$

$$\dot{m}_f = 0.02\ \mathrm{kg/s}$$

PCM TEMPERATURE TIME EVOLUTION IN THE WINTER TYPICAL DAY



CONSOLFOOD2020

universidade de aveiro
theoria poiesis praxis

WINTER TYPICAL DAY

Noon period:

Time required to reach the water boiling point = **26 min**

+

Time required for the water + rice reach 100 ºC = **7 min**

+

20 min of additional cooking time

=

53 min

Night period:

Time required to reach the water boiling point = **23 min**

+

Time required for the water + rice reach 100 ºC = **7 min**

+

20 min of additional cooking time

=

50 min

SUMMER TYPICAL DAY

Noon period:

Time required to reach the water boiling point = **8 min**

+

Time required for the water + rice reach 100 ºC = **1 min**

+

20 min of additional cooking time

=

29 min

Night period:

Time required to reach the water boiling point = **8 min**

+

Time required for the water + rice reach 100 ºC = **1 min**

+

20 min of additional cooking time

=

29 min

CONCLUSIONS

- ✓ The proposed solar cooker proved to be feasible and viable for cooking at high temperatures, and could be an interesting solution to minimize current dependence on fossil fuels for cooking.
- ✓ It has been proved to be feasible to cook using previously stored solar energy as thermal energy, using a high melting temperature PCM (considering the thermal levels required for quickly cooking food) in both Winter and Summer seasons.
- ✓ Results show that the cooker's performance at the noon period depends mainly on the amount of PCM used, leading to a longer cooking time than at the night cooking period (as more thermal energy is stored in the PCM at the end of the day).
- ✓ More realistic simulations need to consider the thermal losses from energy storage system, and analysis of the temperature evolution of each single HTF and PCM modules.