PV-Battery Integrated Module

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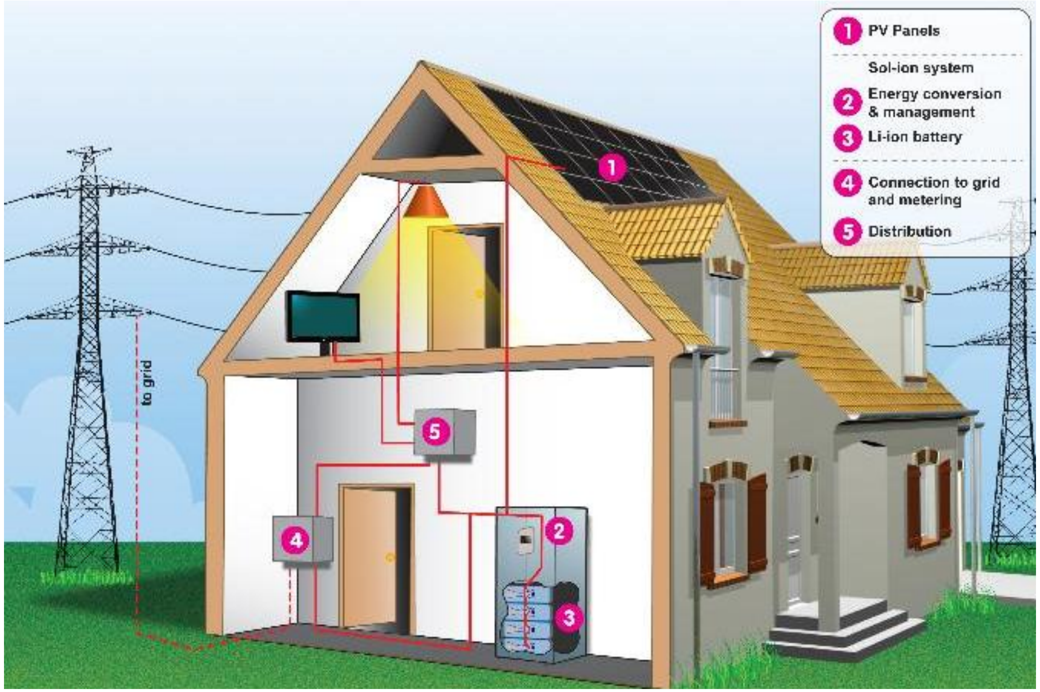
Motivation

- Current PV-battery systems are complex and costly.

Disadvantages



Source: Saft Batteries

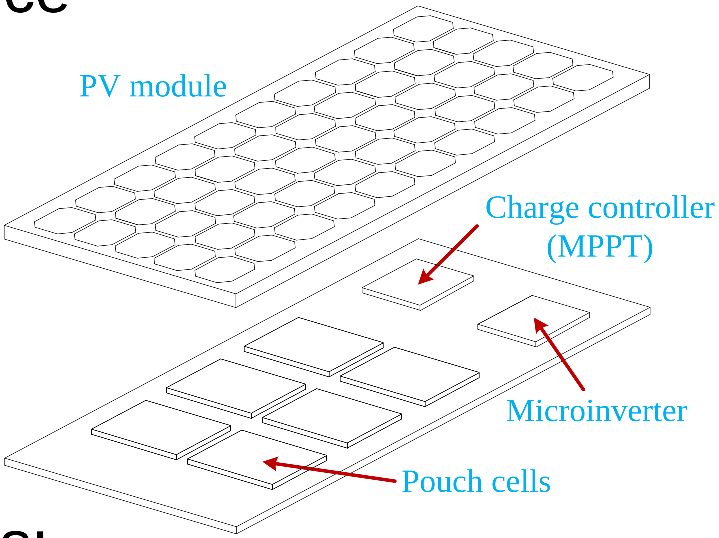
A lot of space used

Low integration degree

High installation cost

Our idea

- Integrate all components of a PV-battery system in one device



- Advantages:
  - Plug and play solution
  - Reduction of installation cost
  - Space saving solution
  - Modular approach
  - Portable solution

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Design considerations

- Thermal behavior
  - Aging, volume vs. weight, and safety
- Battery technology
  - C-rate and aging
- Optimum battery capacity
  - Storage motivations and cost
- PV-battery electrical architecture
  - Efficiency and cost

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Analysis of thermal behavior

- To determine operational conditions under severe cases
- To evaluate Phase Change Materials as a heat management solution

How to study the thermal behaviour?

- Thermal model using Finite Elements Method (FEM)
- Select an appropriate study case
- Test a lab prototype for validation purposes

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FEM Model

- Heat conduction in solids

$$\nabla \cdot (k\nabla T) + \dot{q} = \rho c_p \frac{\partial T}{\partial t} \qquad \textbf{(1)}$$

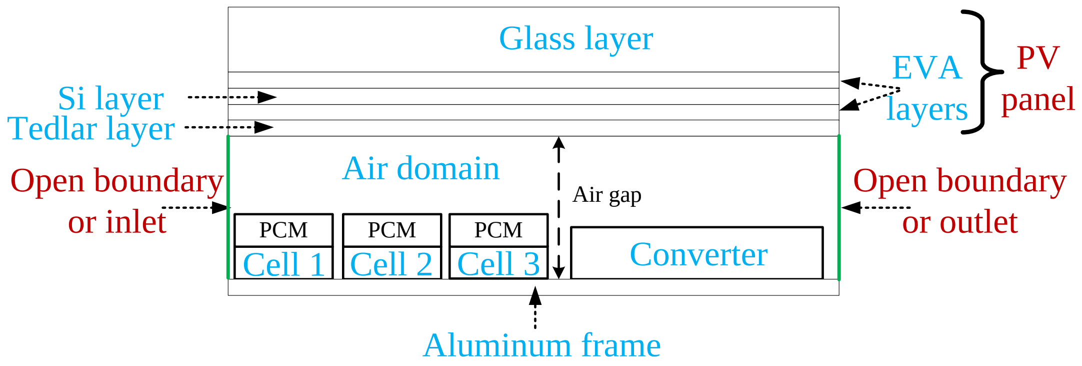
- Heat conduction in liquids

$$\nabla \cdot (k\nabla T) + \dot{q} = \rho c_p \frac{\partial T}{\partial t} + \rho c_p (u \cdot \nabla T) \qquad \textbf{(2)}$$

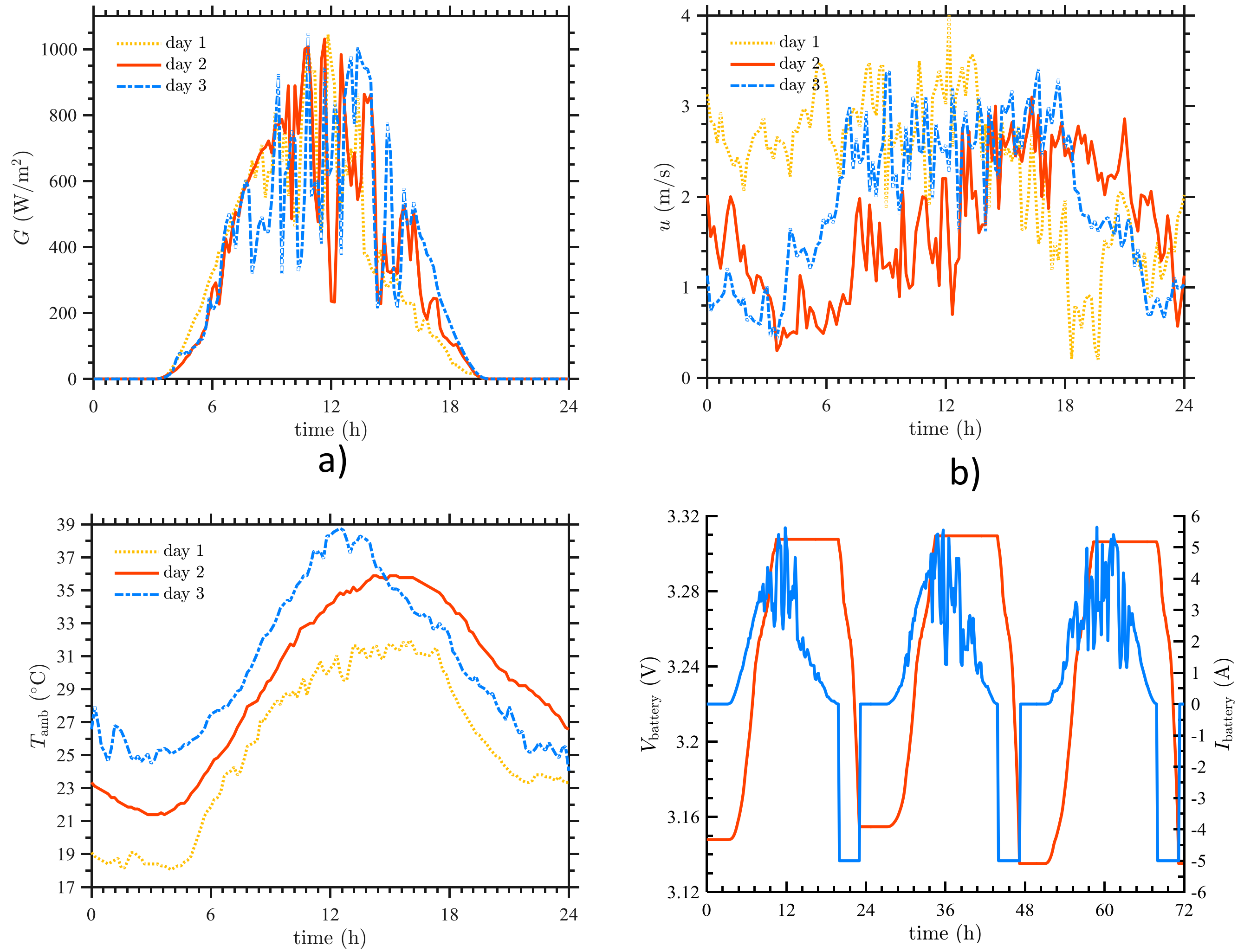
- Fluid dynamics

$$\mu \nabla^2 u - \nabla p + F = \rho(u \cdot \nabla u) + \rho \frac{\partial u}{\partial t} \qquad \textbf{(3)}$$

$$\nabla \cdot u = 0 \qquad \textbf{(4)}$$



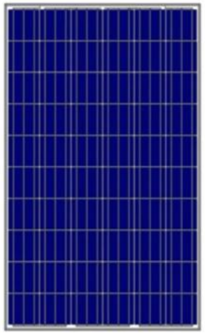
- Inputs
  - Three days with highest ambient temperature, highest solar irradiance, and lowest wind speed in a year for NL.



a)
b)
c)
d)

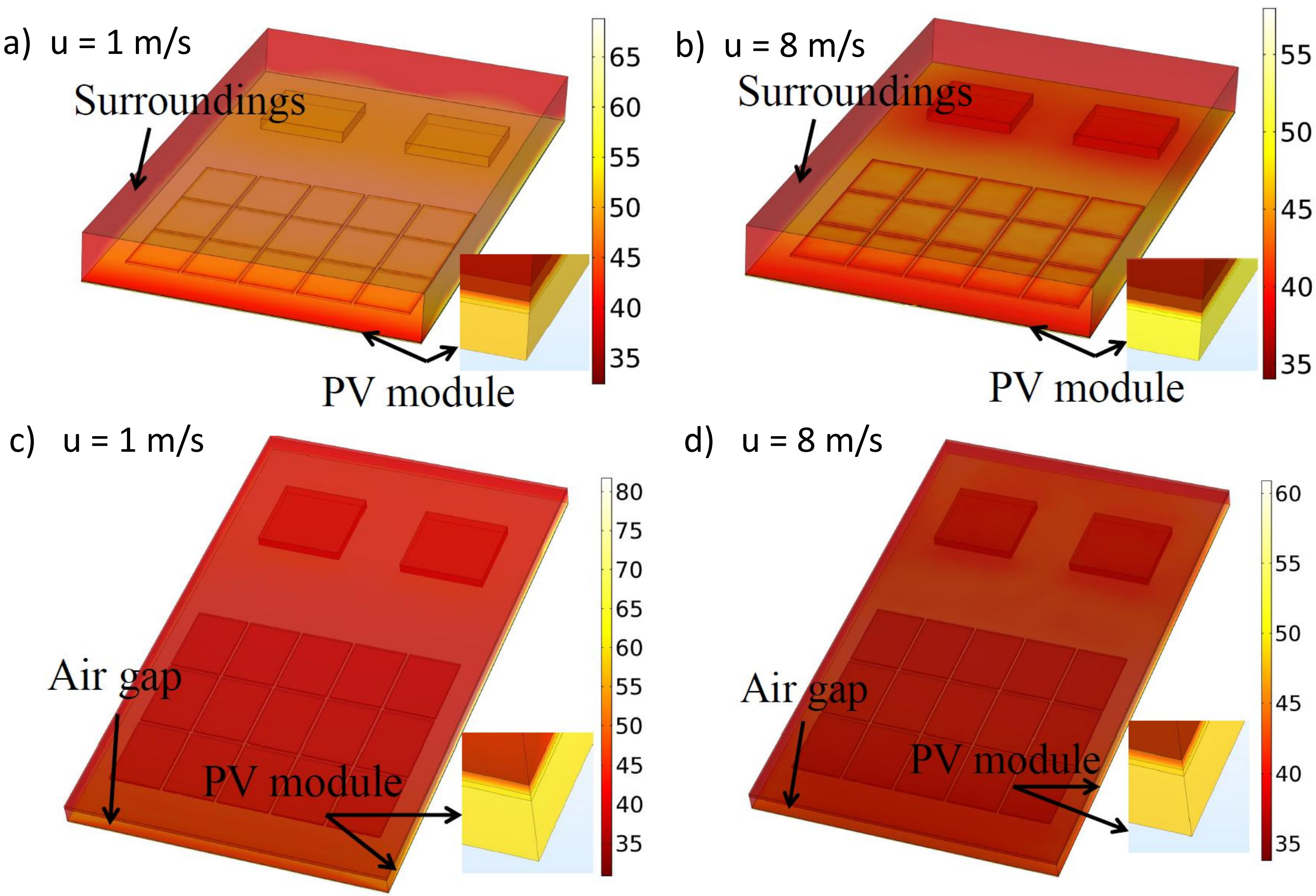
System specification

Solar panel	
Power	265 W_p
Open circuit voltage	38.6 V
Short circuit current	9.06 A
Efficiency	16.19 %
Power coefficient	-0.41 %/°C
Battery ($LiFePO_4$)	
Capacity	≈ 1 kWh
Battery nominal voltage	3,2 V
Maximum temperature	55 °C
Specific energy	131 Wh/kg



Results

- Directly attached or not?



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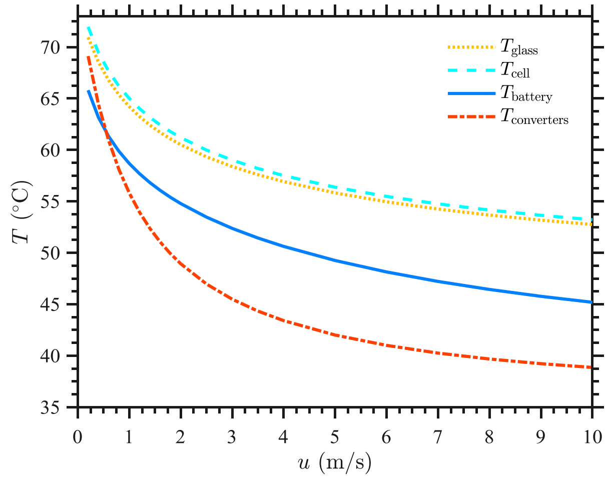
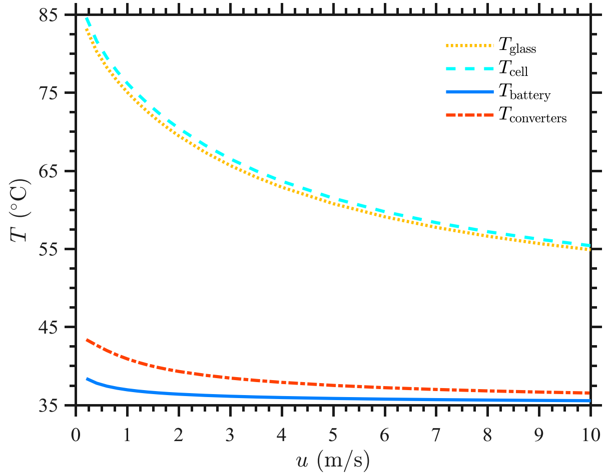
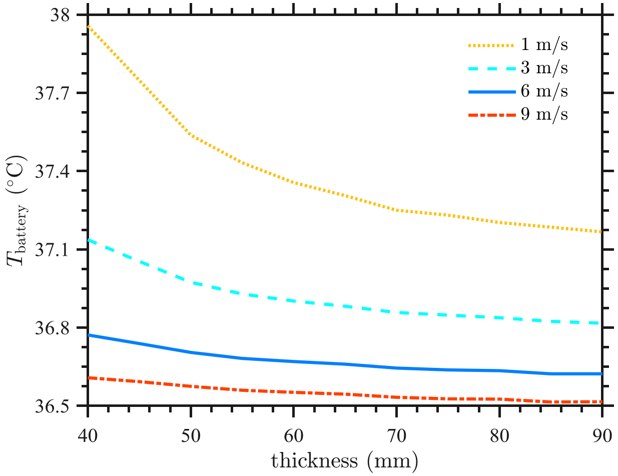


a)



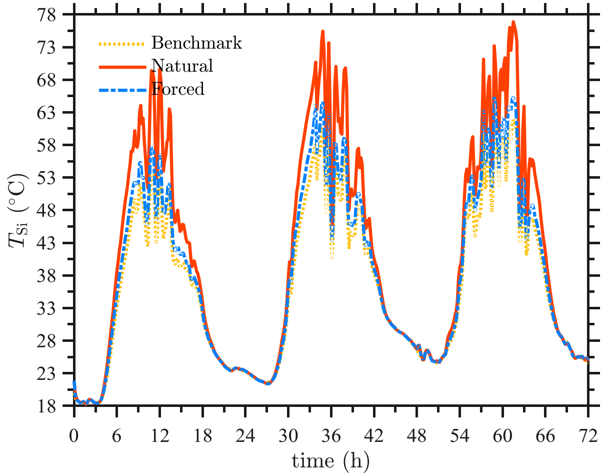
b)

- Optimal air gap



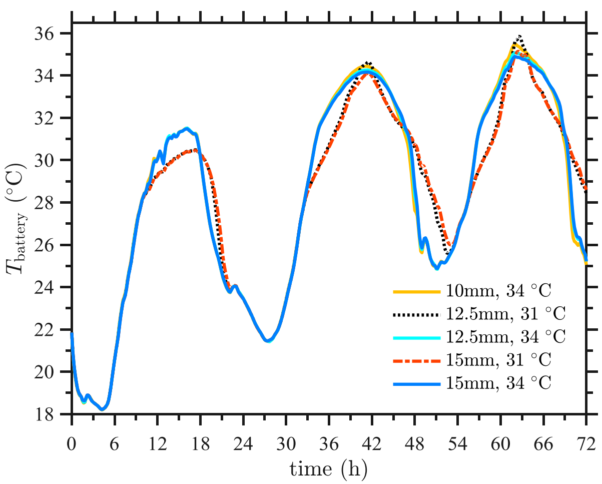
c)

- PV temperature

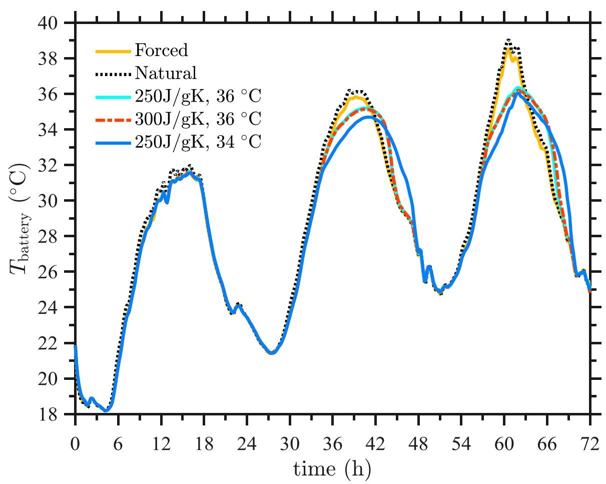


a)

- Battery pack temperature and PCM

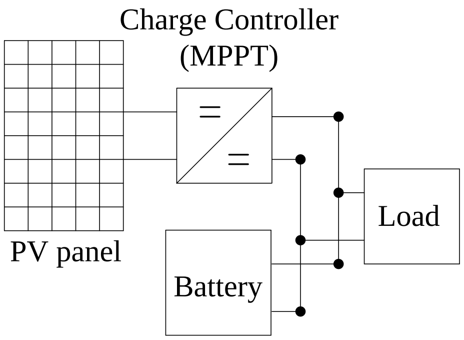


b)

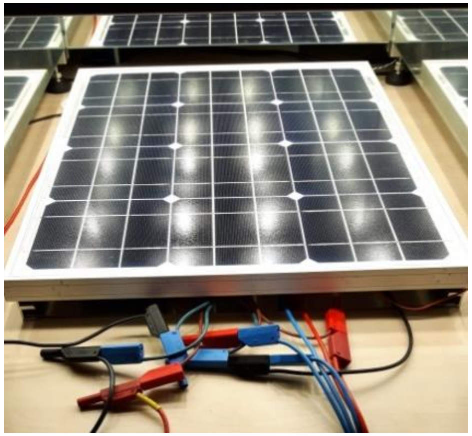


c)

Validation



a)



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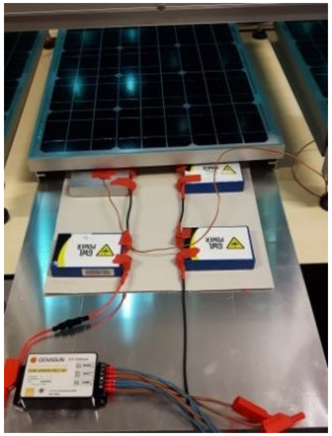
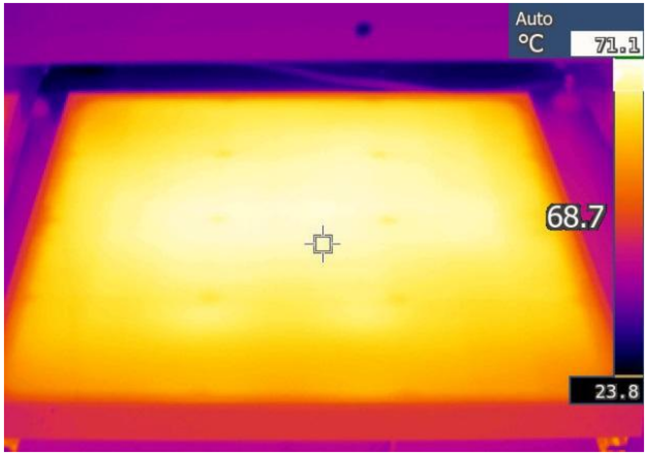
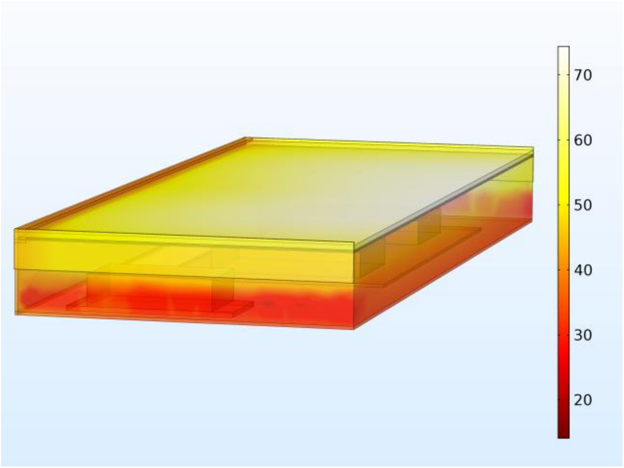


c)



d)



e)

Conclusion

- Air gap helps to reduce the temperature of the components.
- An air gap of 5-7 cm provides an appropriate packaging/cooling efficiency ratio.
- Batteries operate in safe a temperature range even under severe conditions.
- Phase change material is a useful heat management solution, it reduces by 5 °C the maximum battery temperature.

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Questions?