Air or water to PCM batteries and water storage in buildings

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- Acapulco-project

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Research facility 1
Co Creation Centre

- Very high glass to floor percentage 121 %
- Air to PCM-battery in climate tower
- Water to PCM-battery in crawl space
- Energy storage in the ground
- Energy storage in the surface water
- PV on tower and roof
- Research financed via Converge- and Acapulco-project grants

PRIVA

VAN DORP VOOR MORGEN

Research Facility 2 Office Lab

- Light weight wood construction
- Lower glass to floor percentage 35 %
- Air to PCM-battery

Follow-up aim of research

- Peak reduction by design energetic favourable, sustainable, economic and easy to integrate PCM-batteries for buildings.

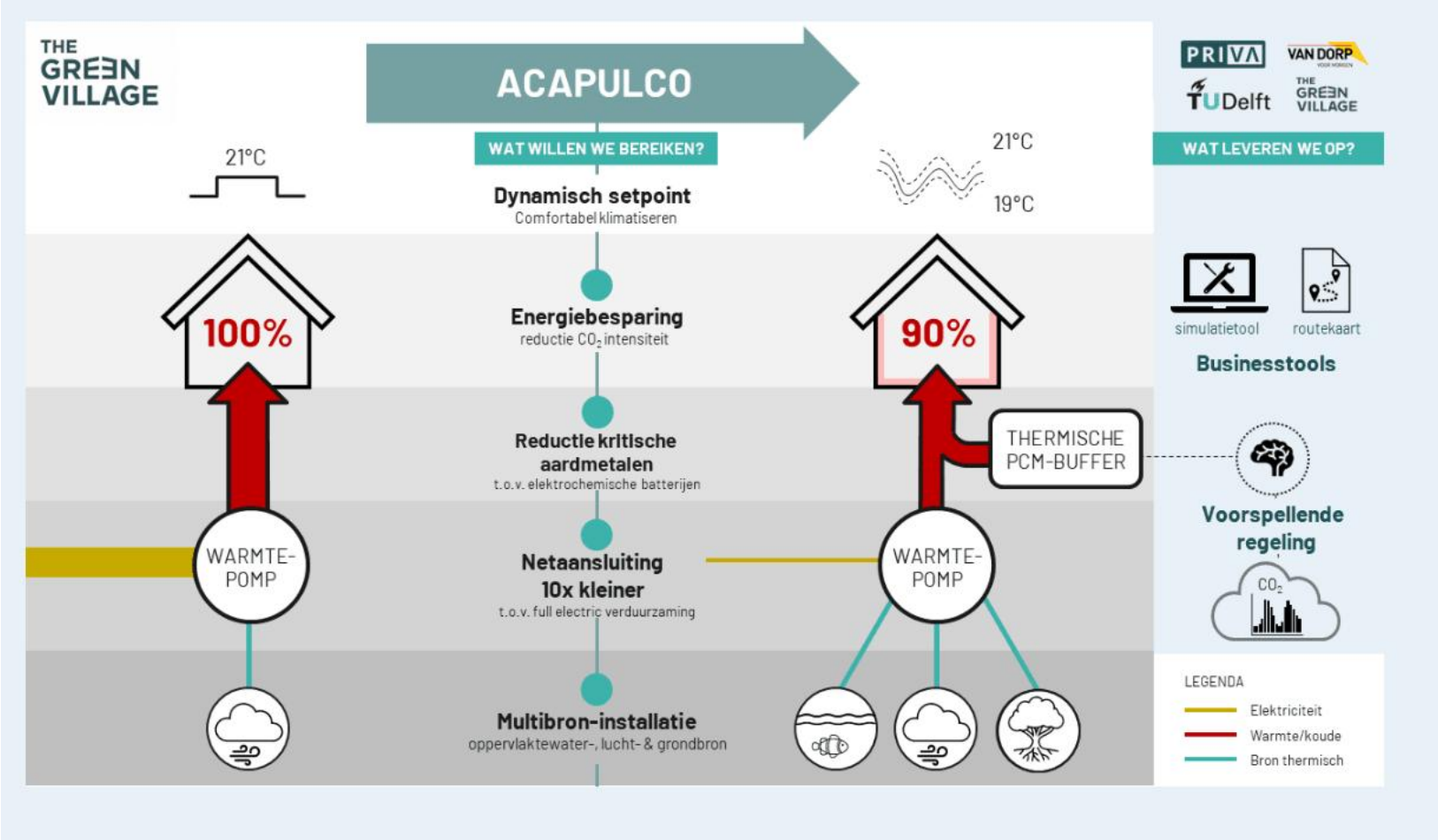
By:

- Storage of free thermal energy from inside or outside
- Optimizing COP of a heat pump
- Optimizing usage of PV and grid characteristics (peakshaving)
- Sufficient storage capacity
- Air or water as transport medium

Co Creation Centre: grid peak reduction

- Reduction heating energy peaks with 90 % due to smart storage and control

- Storage PCM (48 °C)
- Storage ground (35 °C)
- Usage of surface water
- < 20 kWh/m^2 for heating (electrical)



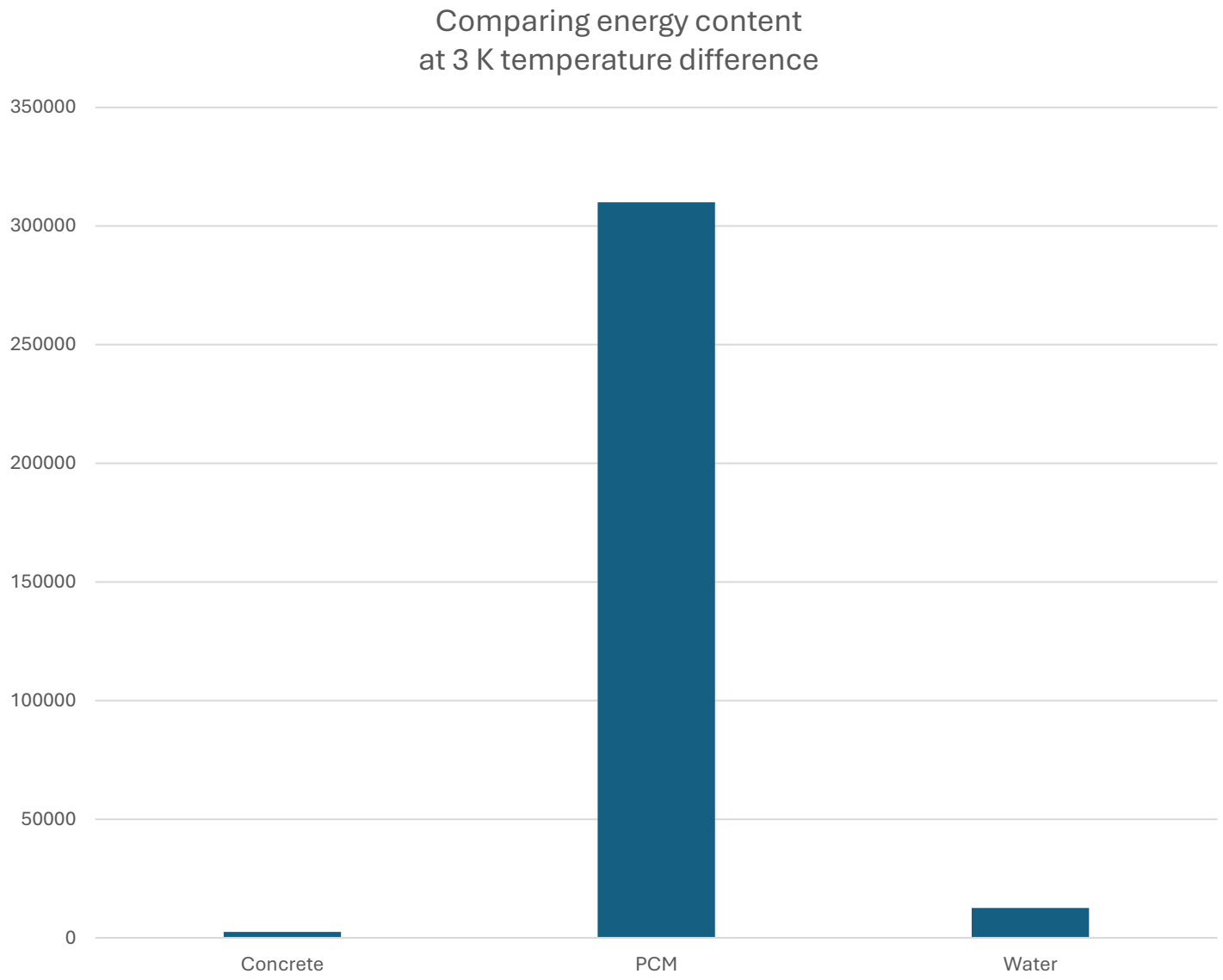
Air to PCM buffers

PCM-panels

- Example of Calcium Chloride Hexahydrate in a high-density polyethylene panel

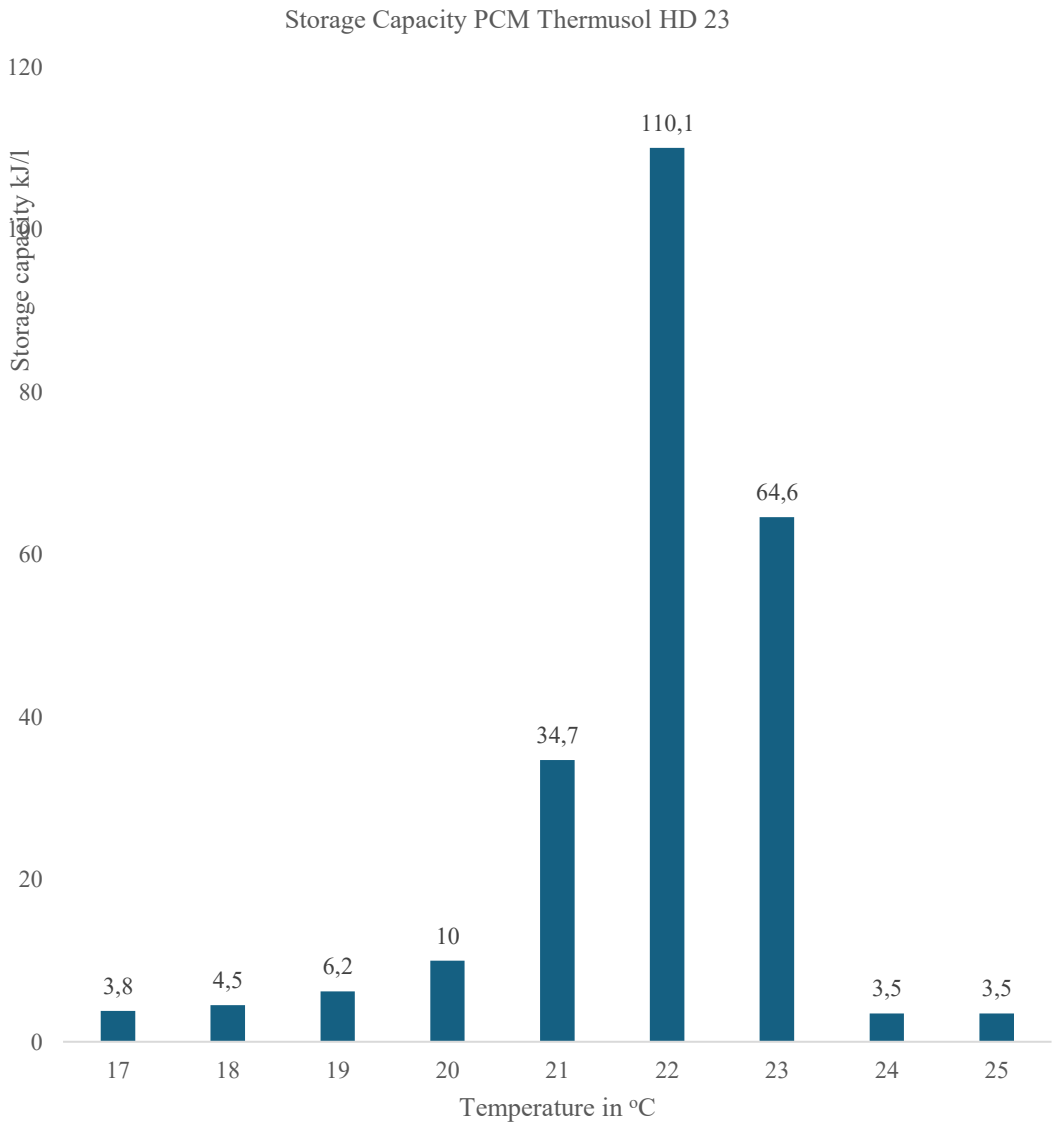
Energy content PCM type CSP 275 at 3 K

PCM has 123 times more energy content than concrete and 25 times more than water



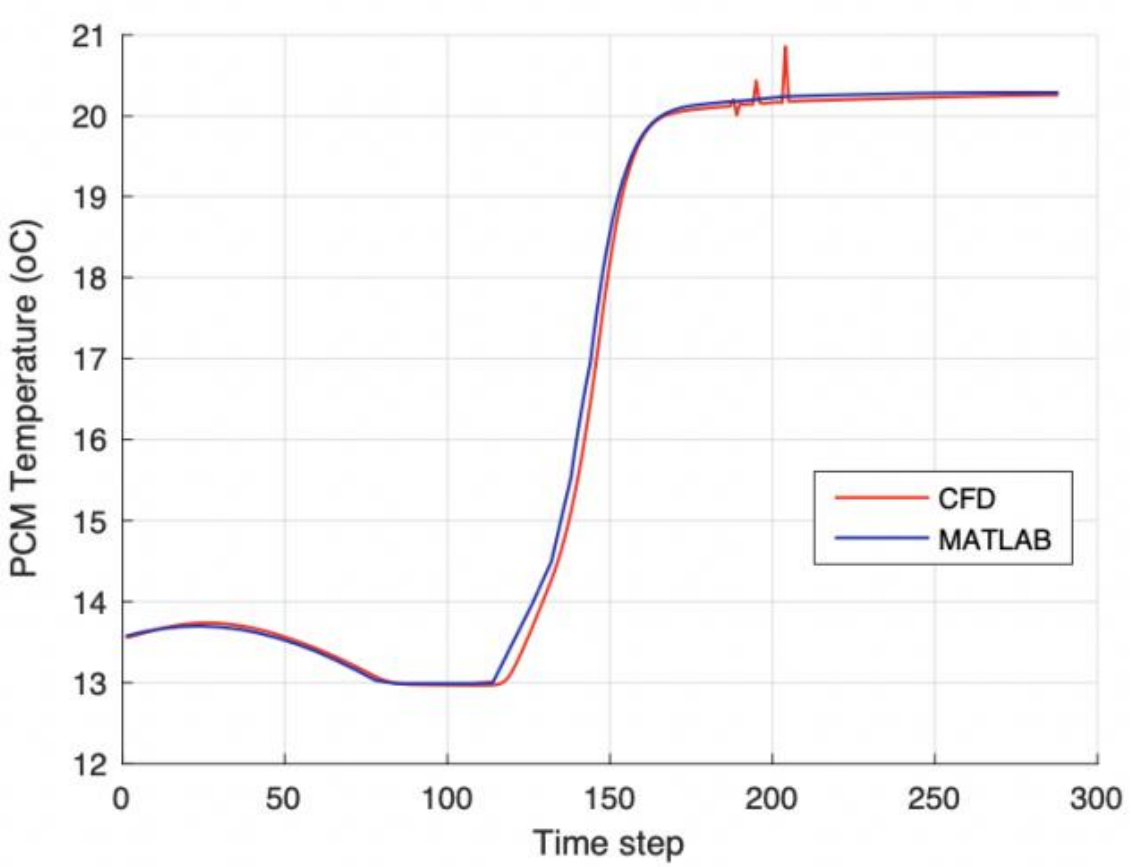
Hysteresis PCM Thermosol HD 23

- Solidification and melting between 20 and 23 °C, peak at 22 °C
- At the moment 17 – 23 °C by combining different panels



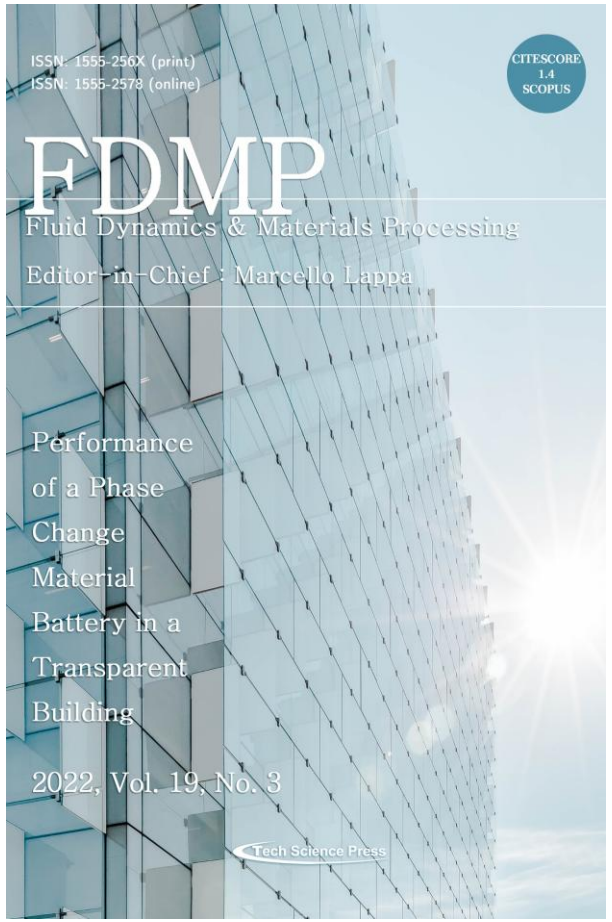
Comparing CFD with MATLAB

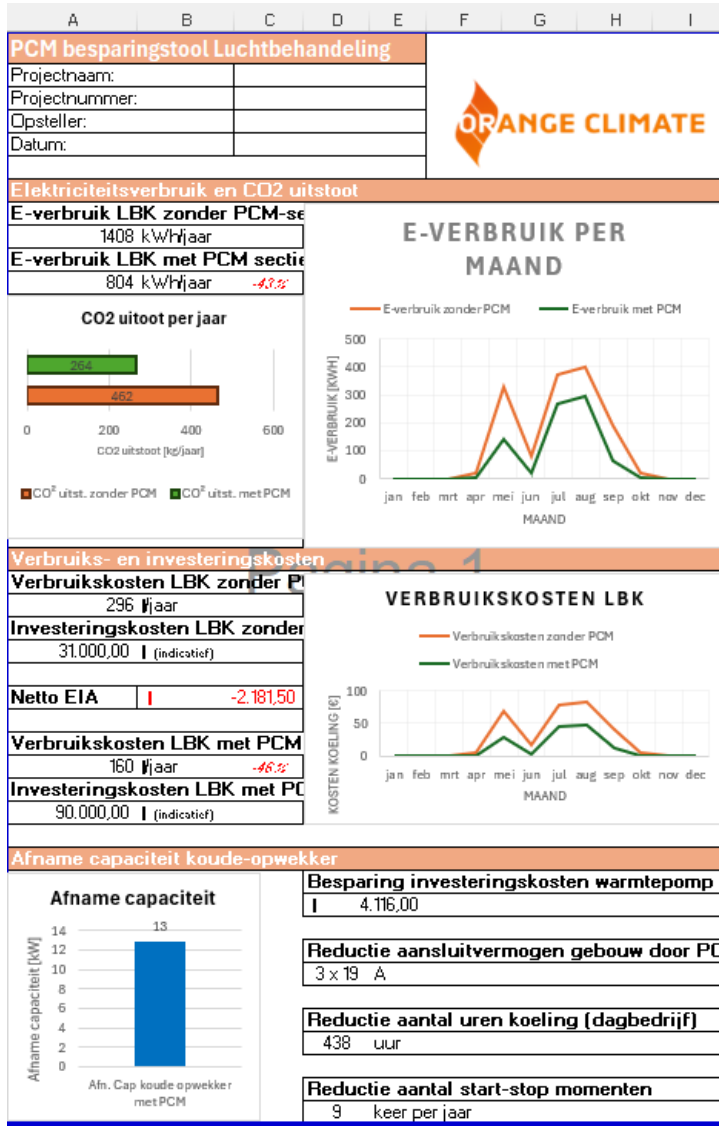
Close relation between simulations, PCM is simulated with only one high specific heat value (J/kgK) during the phase change, like conduction in a solid.



Accurate CFD + Excel-models under development

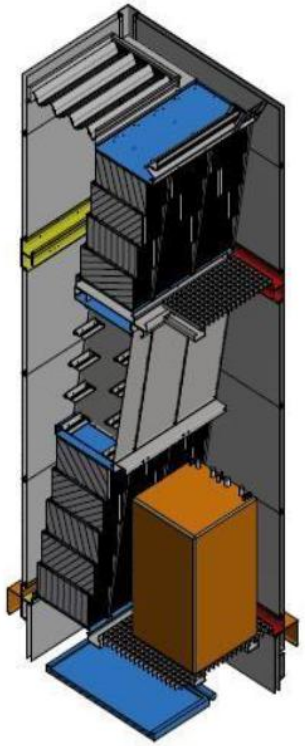
- Actual simulated or measured data are necessary for better insight
- Journal publication in Fluid Dynamics & Material Processing
- Journal of Material Sciences & Manufacturing Research

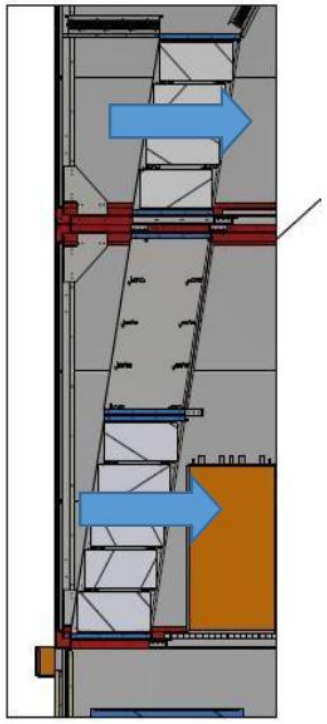


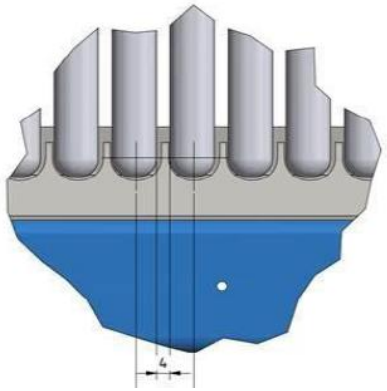


Air to PCM battery Co Creation Centre

- Climate tower, making use of the diurnal swing inside and outside (10 – 30 °C), 121 kWh, 4 mm distance elements





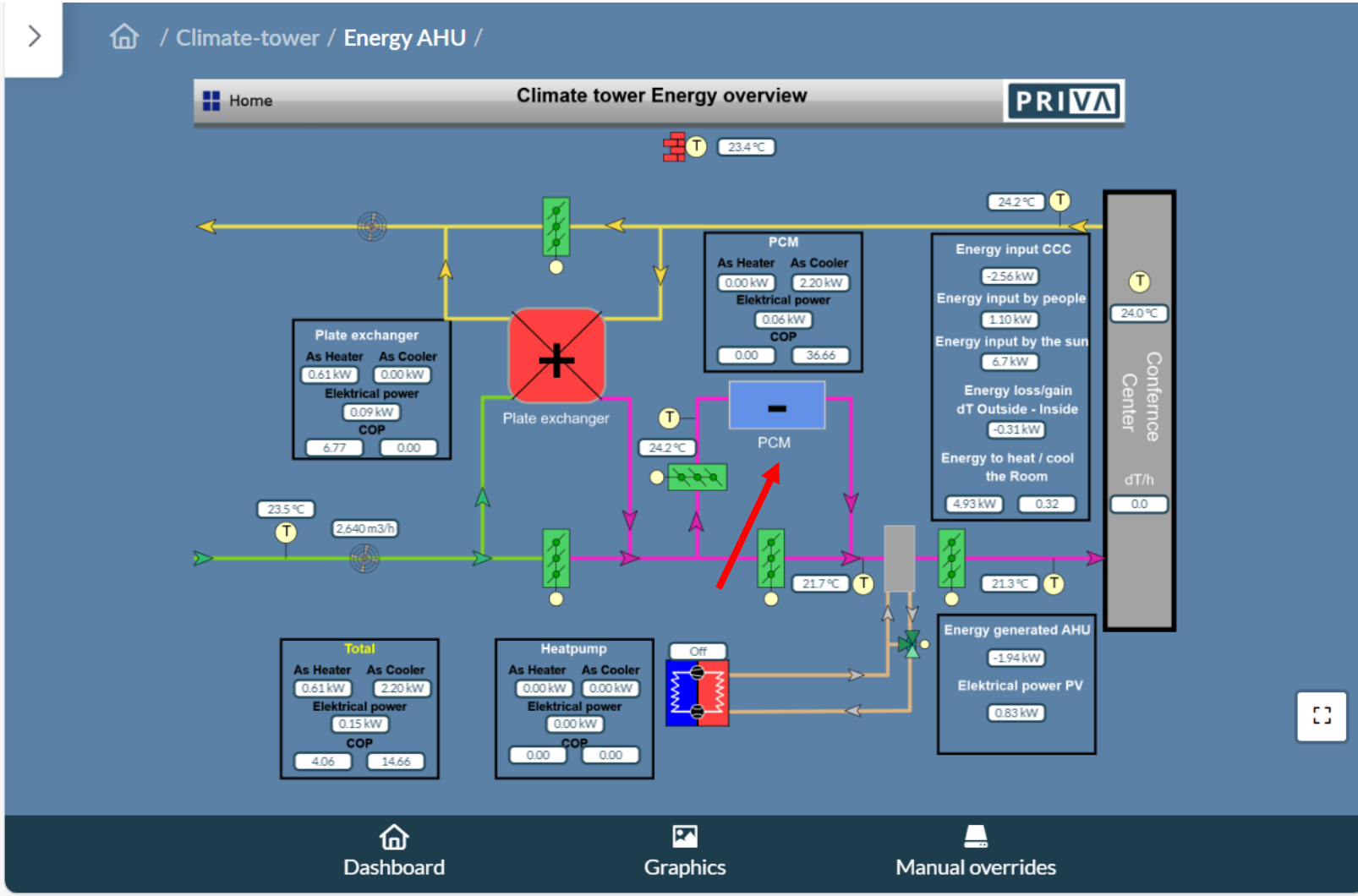


Building Management System

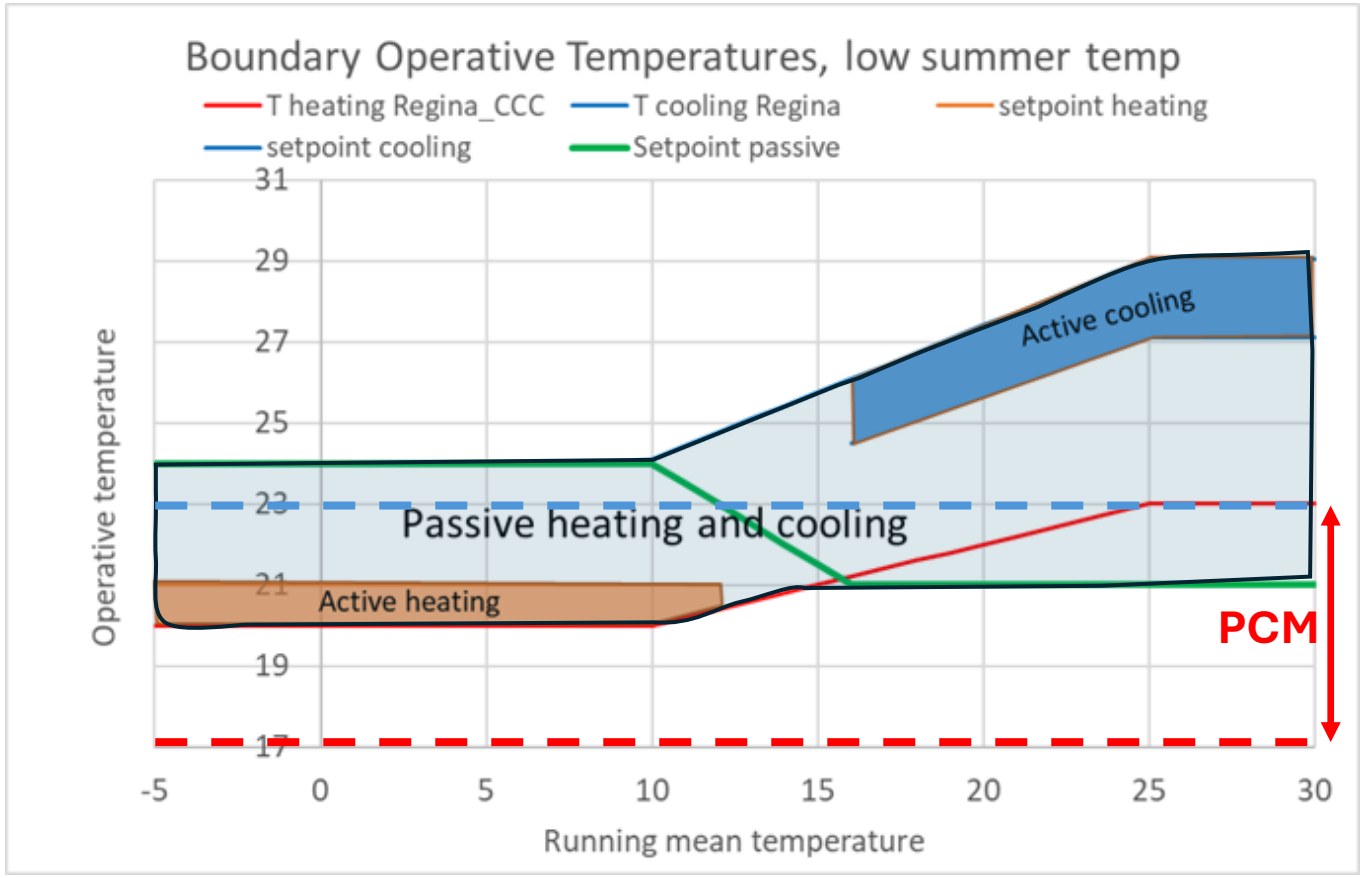
- COP PCM = 37
- COP heat exch. = 7

- 33 kWh/m^2
  heat pump, fans,
  lighting

- Goal 50 kWh/m^2<



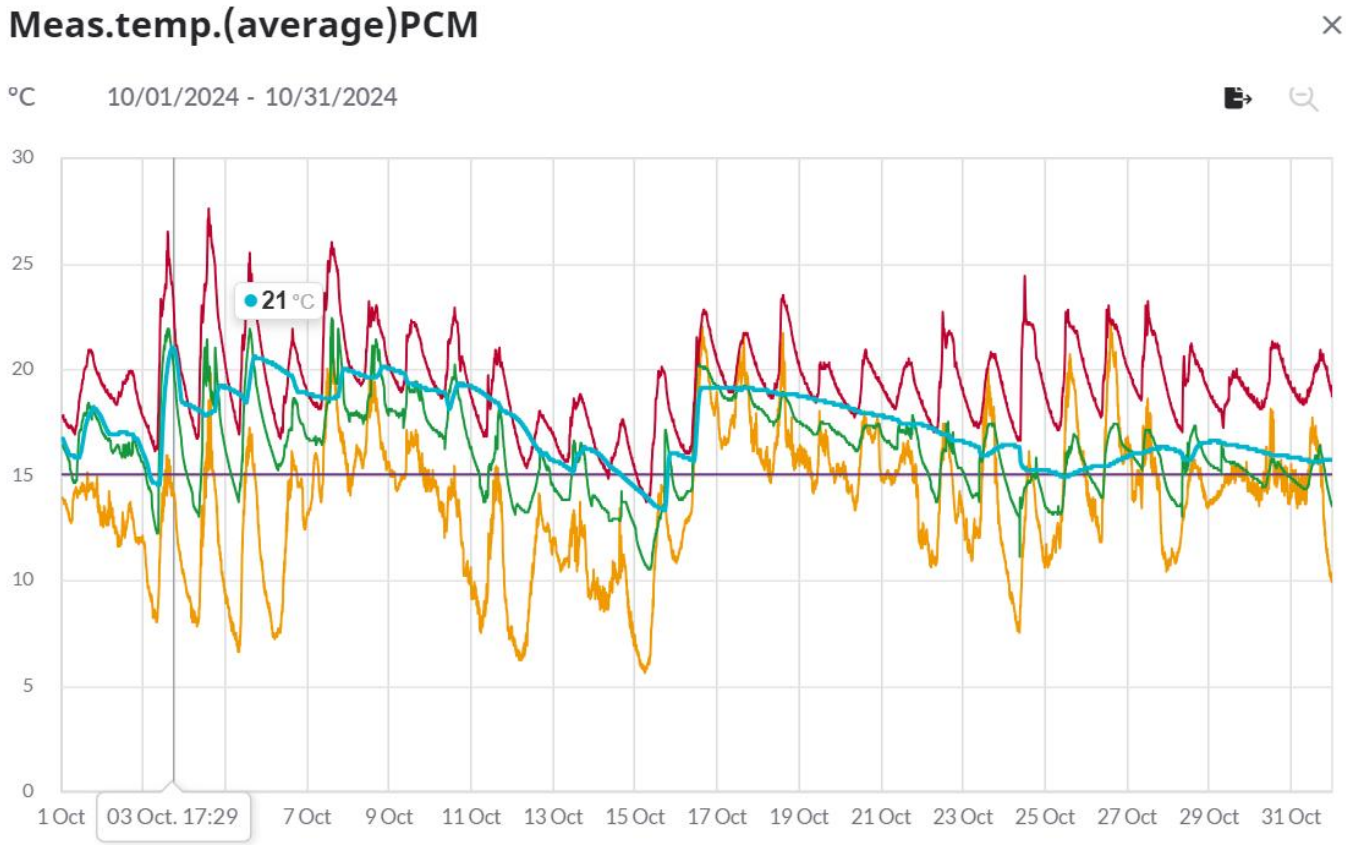
Smart adaptive comfort boundaries



- Starting point Category C NEN-EN-ISO 7730.
- In winter and summer heating and cooling is not always necessary.
- PCM can fill in gap between 17 and 23 °C. Most savings in Spring and Autumn.
- Limited thermal mass also reduces peaks.
- Limits of comfort boundaries are subject of research.

Stored energy PCM-buffer

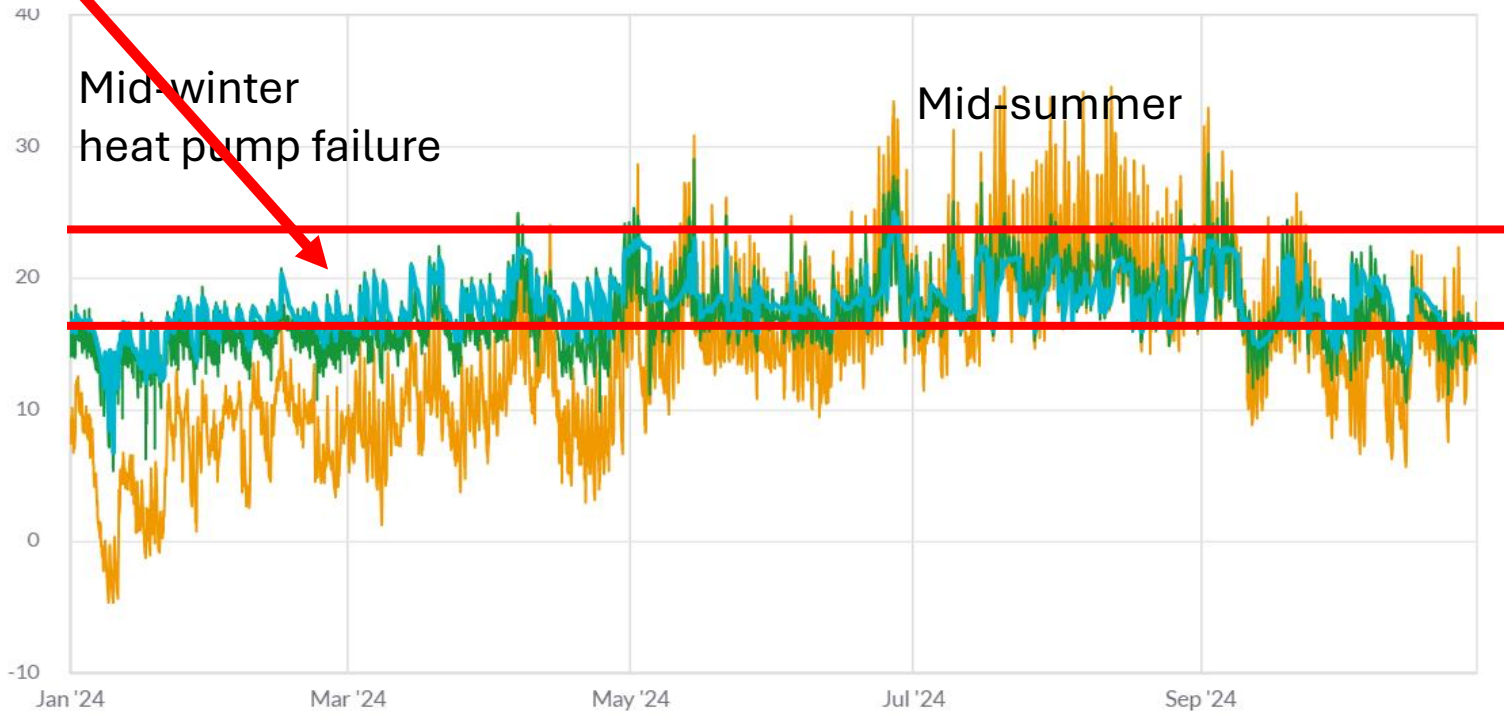
- Overview in October 2024, variety of indoor temperatures (purple)
- Space heats up to comfort-level via sun, people and - on demand – a local heater
- Heat pump off
- Large temperature fluctuations, with limited thermal mass



- Purple = T_{indoor}
- Blue = PCM
- Green = heat exchanger
- Yellow = $T_{outdoor}$

Stored energy air-PCM buffer

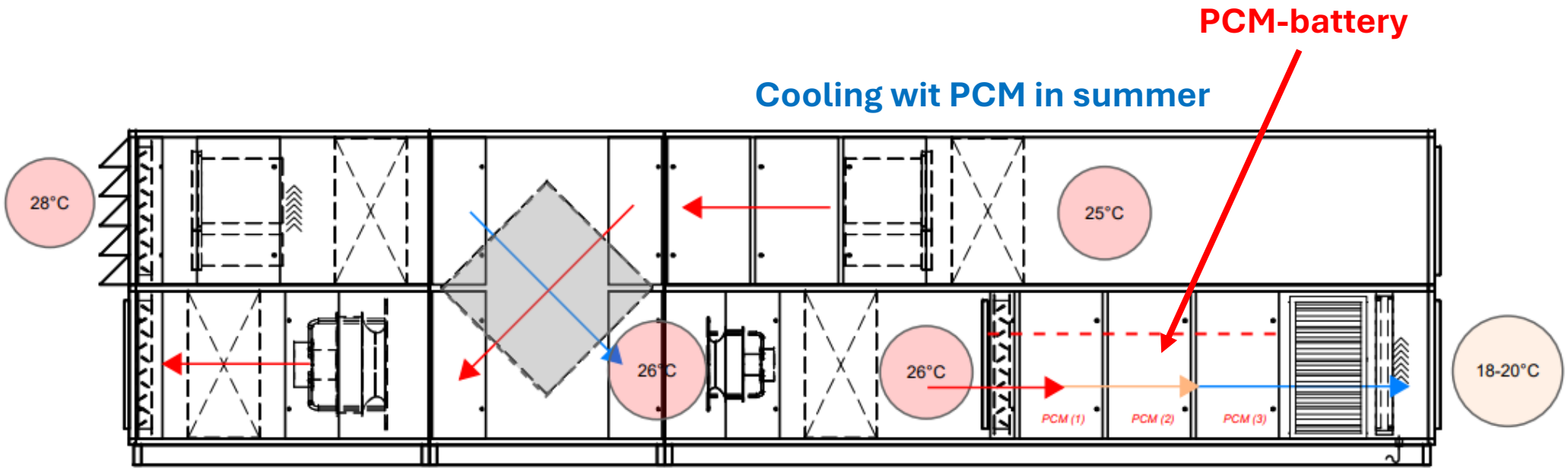
- Phase change between 17 and 23 °C.
- One year overview, stored thermal energy. In mid-winter low savings. Warm water-PCM battery will help to fill the gap.



- Blue = PCM
- Green = heat exchanger
- Yellow = $T_{outdoor}$

Air to PCM-buffer Office Lab

- Example PCM section in an air handling unit with 60 kWh.
- Buffer can be loaded by outdoor or indoor air and the heat pump.
- Passive level of the building is dominant: heat storage capacity.



Results air to PCM batteries

Storage capacities

- Co Creation Centre 121 kWh

2025		
December		
November		
October	494	kWh
September	582	kWh
August	325	kWh
July	660	kWh
June	751	kWh
May	578	kWh
April	1329	kWh
March	1573	kWh
February	500	kWh
January	262	kWh
2024		
December	363	kWh
November	213	kWh +
Total	**7630**	kWh

Office lab 60 kWh

2025		
December		
November		
October	1023	kWh
September	1487	kWh
August	1825	kWh
July	1686	kWh
June	1819	kWh
May	1066	kWh
April	1314	kWh
March	1321	kWh
February	973	kWh
January	756	kWh
2024		
December	381	kWh
November	456	kWh +
Total	**14107**	kWh

Conclusions air-PCM measurements Office Lab

- The storage effectiveness of PCM in the Office Lab is 4 times better than in the Co Creation Centre.
- 80 - 90 % heating and cooling energy is “passive” energy in the Office Lab: sun, people, equipment, lighting, outdoor air.
- Simulations in Design Builder without PCM: cooling and heating 5.000 - 7.000 kWh = 11 – 15 kWh/m^2.
- PCM energy in the Office Lab almost 2 times more than calculated with DesignBuilder, but this includes free running temperatures.
- In Co Creation Centre limited passive energy due to heat losses.

Discussion air-PCM buffer 15 kW

- Substantial savings in spring, summer and autumn.
- Inside or outside temperatures (free energy) between 10 to 30 ^{o}C can be used to (un)load PCM for an air-PCM buffer.
- Pay-back time still unclear, difficult to measure and assess PCM-savings and prices PCM-batteries.
- Air-PCM buffer € 415,- per kWh (17 - 23 ^{o}C)
- DX-unit connected to AHU COP = 3 € 17,000,-
- Air-PCM buffer COP = 30 € 25,000,-

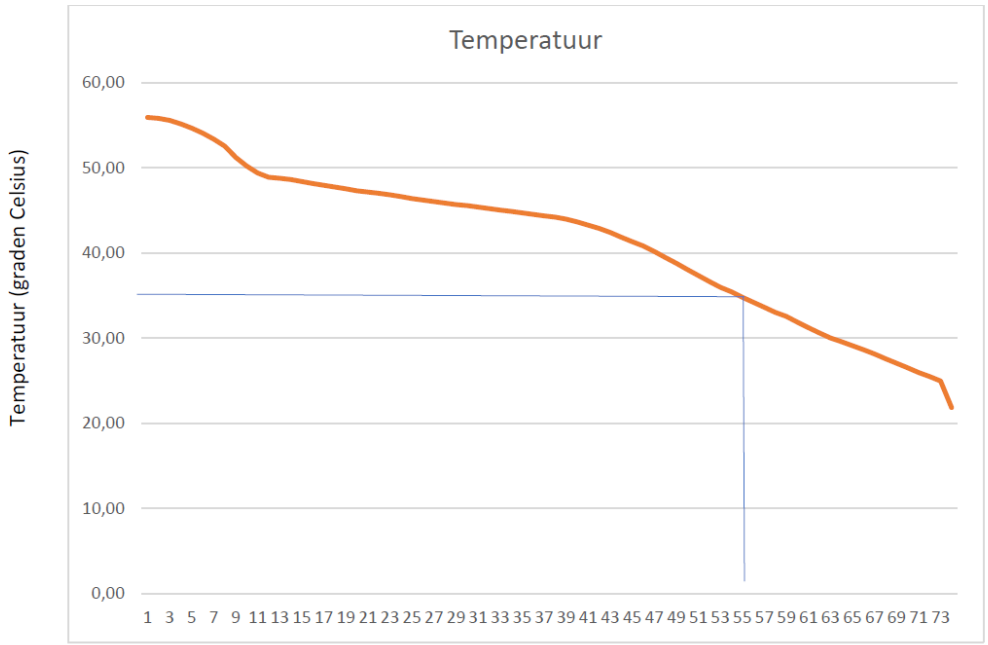
Water and water to PCM buffers

Future promising solutions: water buffers

- Borg, long term hot water buffer, in the ground
- 7 m^3 water 200 kWh, 65 ^oC, 30 cm isolation, large size
- Too vulnerable for damage from above
- Integration not always possible
- Usage of rainwater buffers?

Water to PCM buffer, first prototype

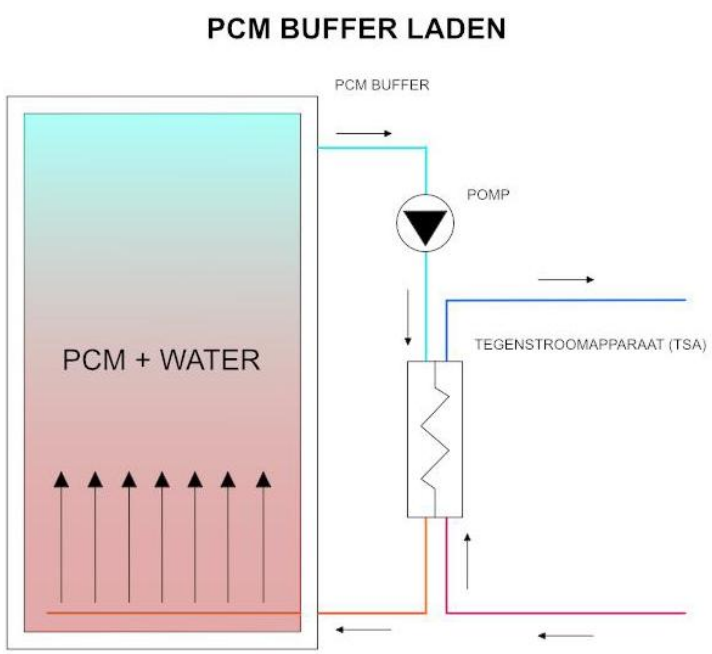
- 30 mm isolated buffer, 24 kWh per buffer with PCM52,
- 0,75 x 0,75 x 1,50, 10 l/min, 55 °C/ 9 °C, minimum 32 °C, unloading time 55 min
- delta T max. 46 K.

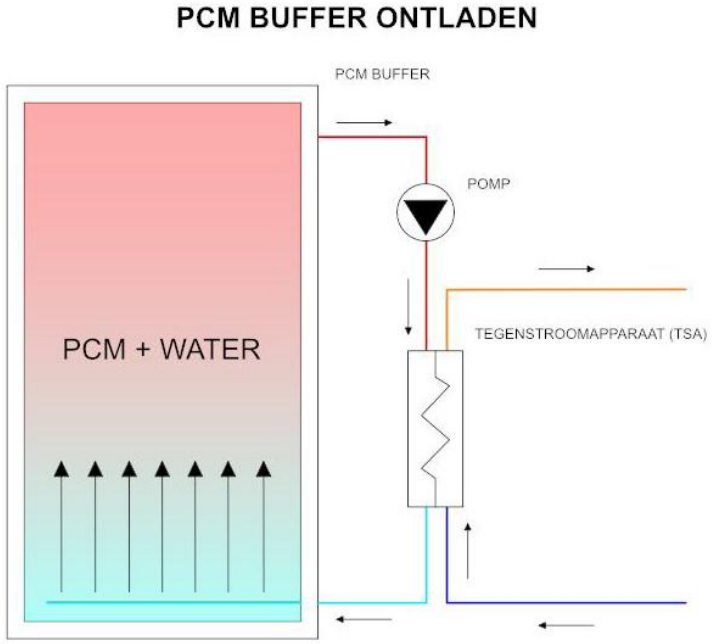


Grafiek 1: Afgiftetemperatuur 55 minuten tot 32 graden bij 10 liter per minuut en 9 graden water in TSA-zijde

Position buffers

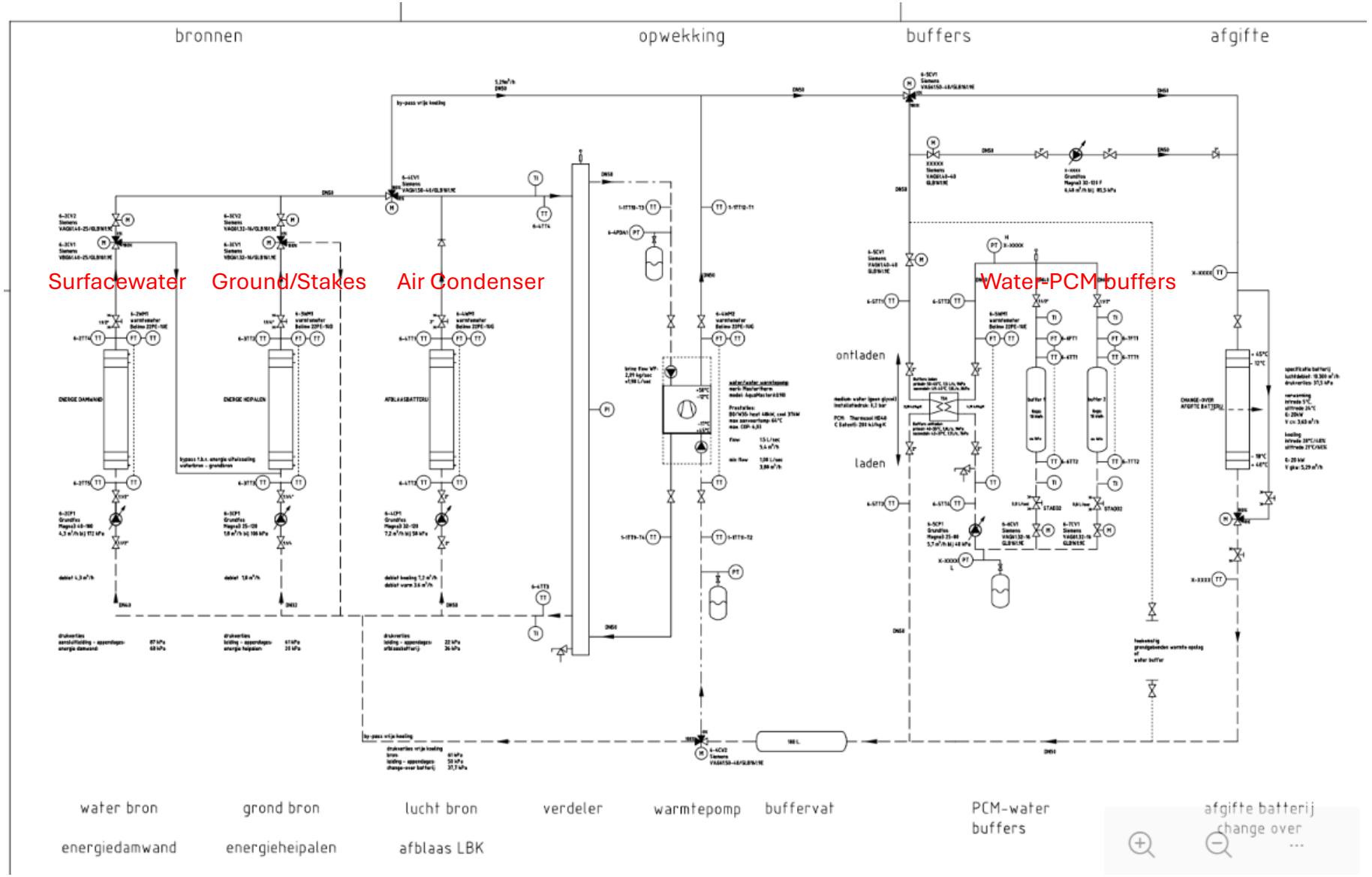
- Parallel system, like the air to PCM buffer. Each buffer can be (un)loaded separately. Buffer 24 kWh.





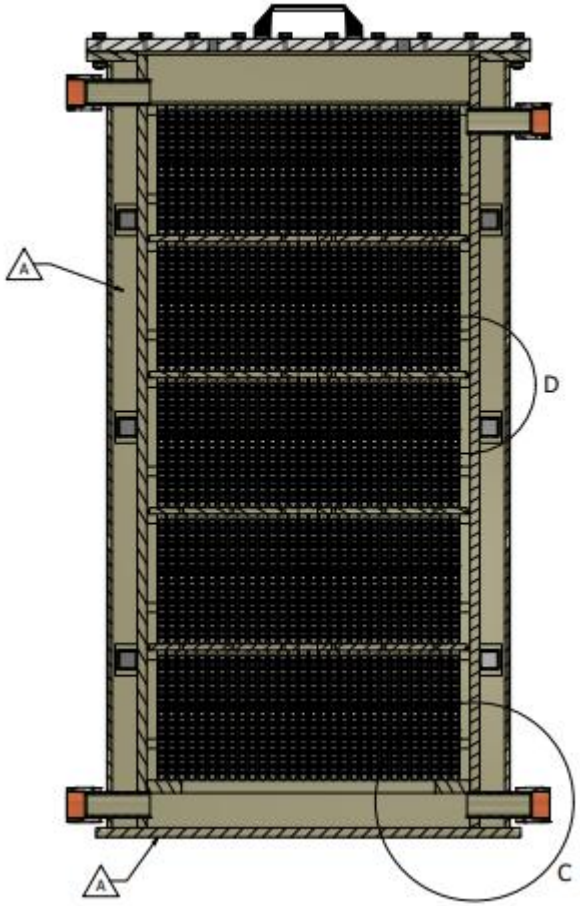
Hydraulic scheme buffers Co Creation Centre

Options without the Air to PCM buffer



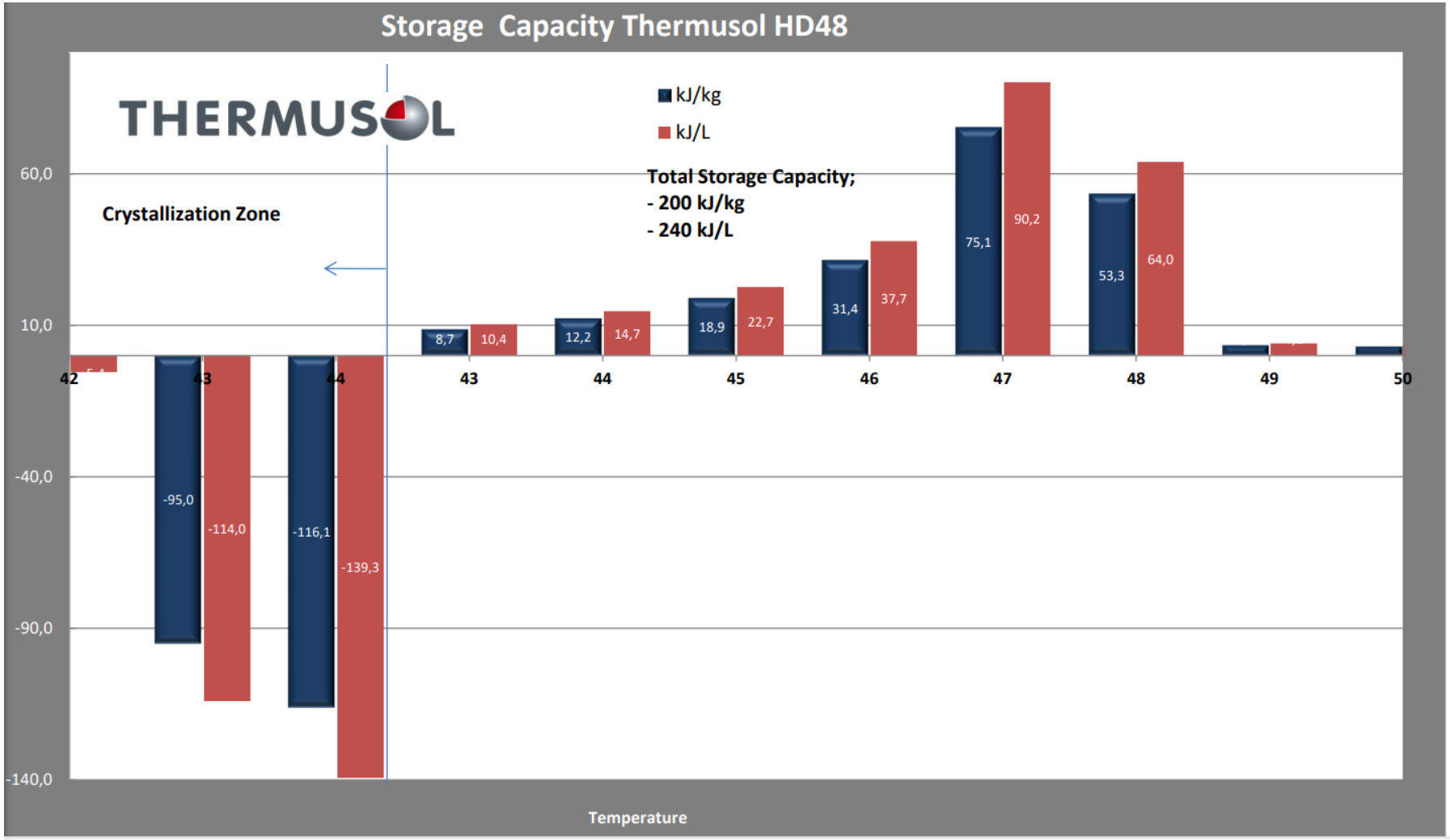
Second prototype

- 2 x 10 kWh buffer, under the floor



Phase change between 43 and 48 °C

- Phase change over 6 K



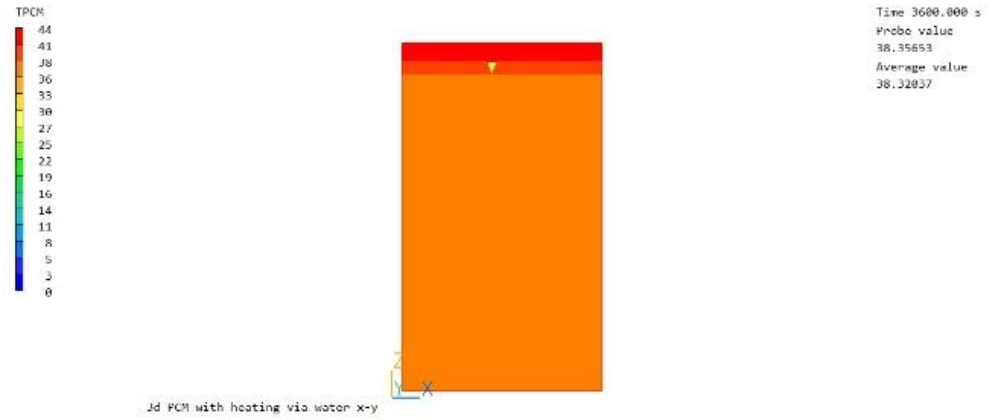
CFD-simulations air and water to PCM buffers

- Typical values 10 kWh

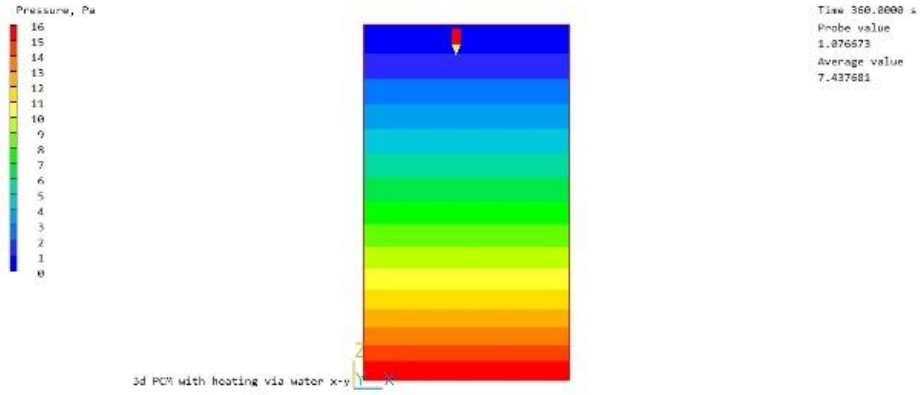
- Air to PCM
- 1.5 m/s 16 Pa, 10 hours (un)loading time

- Water to PCM (horizontal)
- 0.01 m/s, 15 Pa, 1 hour (un)loading time

Water-pcm simulation



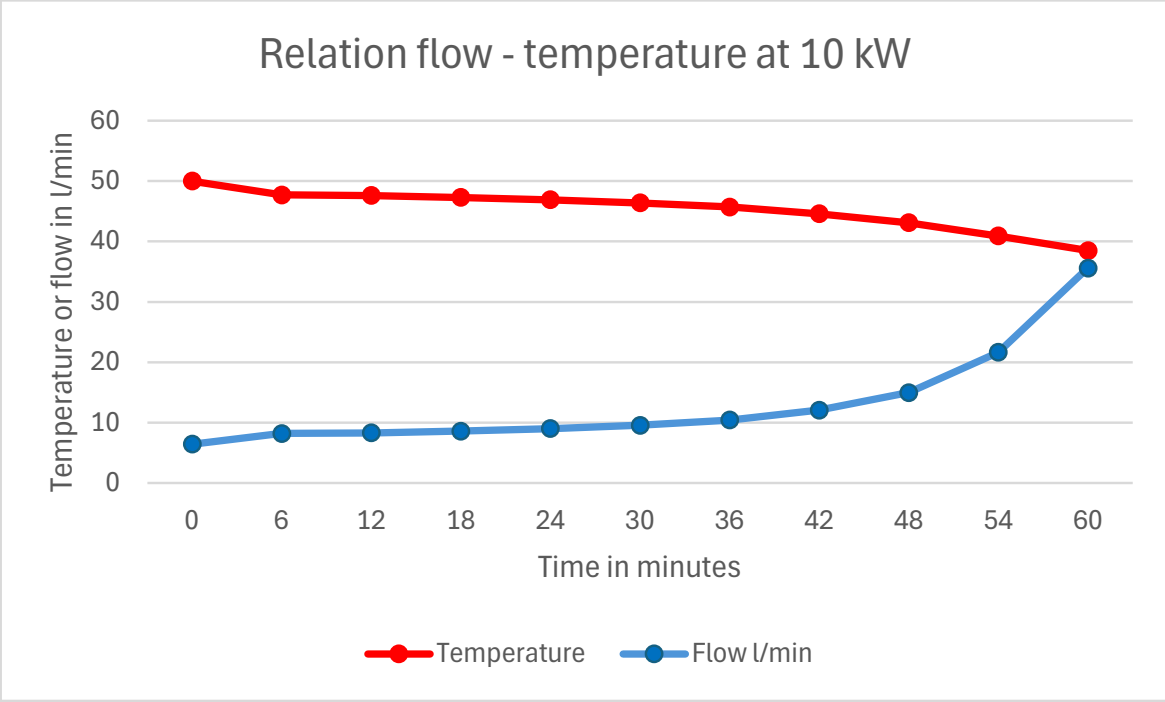
temperature after 60 min and pressures



Control characteristics

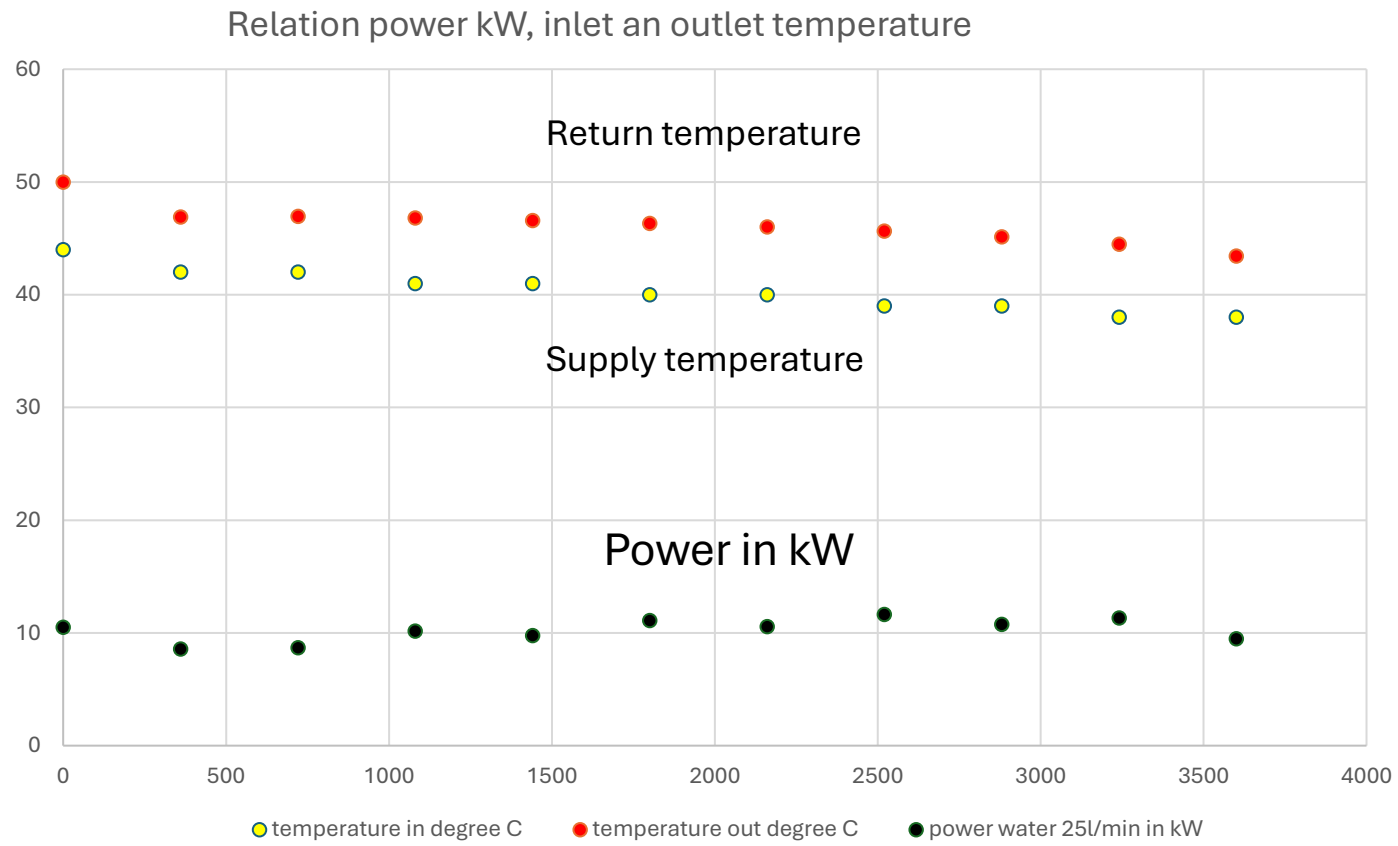
- Buffer of 10 kWh can be discharged in 60 minutes. A fixed capacity of 10 kW is difficult to realize with a fixed return temperature of 38 °C. Capacity varies from 17.5 to 5 kW in steps of 6 minutes.

- For 10 kW a fixed flow of circa 25 l/m and a delta T of 5 K is preferred.



Improved control

- Fixed delta T via heat exchanger and fixed flow, controlled by BMS



Discussion water to PCM buffer

- Investments, based on circa 15 kW
  - Water-PCM buffer € 150,- to 400,- per kWh — € 2,000,- per kW (45 °C, ΔT = 5)
  - Heat pump with ground storage — € 3,000,- per kW (45 °C)
  - Water buffer 200 kWh, € 100,- per kWh — € 1,000,- per kW (65 °C, ΔT =5)
  - Electrical battery € 400,- per kWh

- Example 15 kW, 200 kWh

• Heat pump and ground storage	COP = 5	€ 50,000,-
• Only ground storage (cooling)	COP = 12	€ 20,000,-
• Water-PCM battery	COP = 5	€ 30,000,-
• Water battery	COP = 2	€ 20,000,-

Calculation example

- Optimal size not clear yet. With a 20 kWh buffer active at 150 hours ca save 3.000 kWh thermal energy (COP heat pump = 2)

  = 25 % total thermal energy consumption.

- Direct savings by a buffer in CCC Centre are with PV or low grid prices, 1,500 kWh/y electrical energy = 1,500 x 0.30 ct (maximum price at direct PV-usage) = € 450/y.

- Maximum investment for pay-back time 10 years needs a maximum investment of € 4,500,-.

Discussion water-PCM buffer

- Buffers can reduce the peaks in the grid, normally two times a day.
- A water-PCM-buffer of 45 ^{o}C can deliver 70 % more thermal energy, with a much higher COP than a water-buffer of 65 ^{o}C at the same weight.
- Smart electricity and heat load strategy important (AI) and is also effective with sufficient PV-capacity for direct usage.
- Electrical batteries are competing (€ 400 per kWh) but have much impact on the environment.
- CO_2-savings should be considered as well.

Discussion air- and water to PCM buffers

- Building physical boundary conditions, like glass percentage, are still dominant. The smaller the heat loss, the better.

- With PCM buffers often a smaller heat pump can be applied. This depends on the balance of heating and cooling demand.

- The size of the buffers is a dominant factor of the investment: casing and heat-exchanger have much effect.

Thank you for you for your attention

Questions?