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Aluminium Foam Heat Exchangers for Future Zero-Energy Buildings

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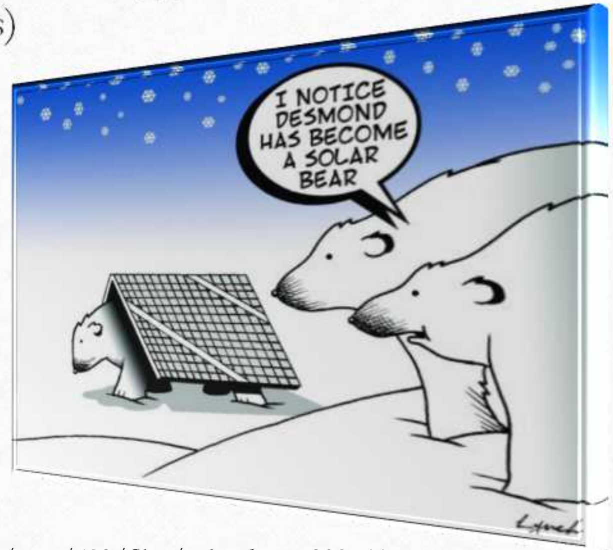
TU Graz

Graz University of Technology

Renewable Energy – General Remarks

- Energy is not produced, nor consumed – is just here and we convert it from existing to better usable form
  (1st **thermodynamic law** - energy of an isolated system is constant)
- Conversion process itself needs some energy and is easier when the "quality" is reduced – growth of entropy
  (2nd **thermodynamic law** - entropy of an isolated system never decreases)
- The efficiency of conversion increases with increasing potential difference
- Even low efficiency can be accepted if the source is available for free and the process (including investment) is economically feasible



Source: www.toonpool.com/user/589/files/solar_bear_90875.jpg

Main mistakes in conversion and use of energy

Convertor is not used when external conditions are beneficial

(e.g. non working wind turbines in windy weather, stagnated thermosolar collectors in sunny days, etc.)

Main reason: energy is not instantly required and cannot be stored

Solution: alternative storage system enabling energy recovery (in the same form) later when needed

Low efficient processes are ignored

- ✓ **Even low efficiency is beneficial when the source is free and investment costs are feasible.**
- ✓ **Low potential resources are widely available, their transfer and storage are cheaper.**

Sources:
www.sollarmillenium.de
http://pvshop.eu

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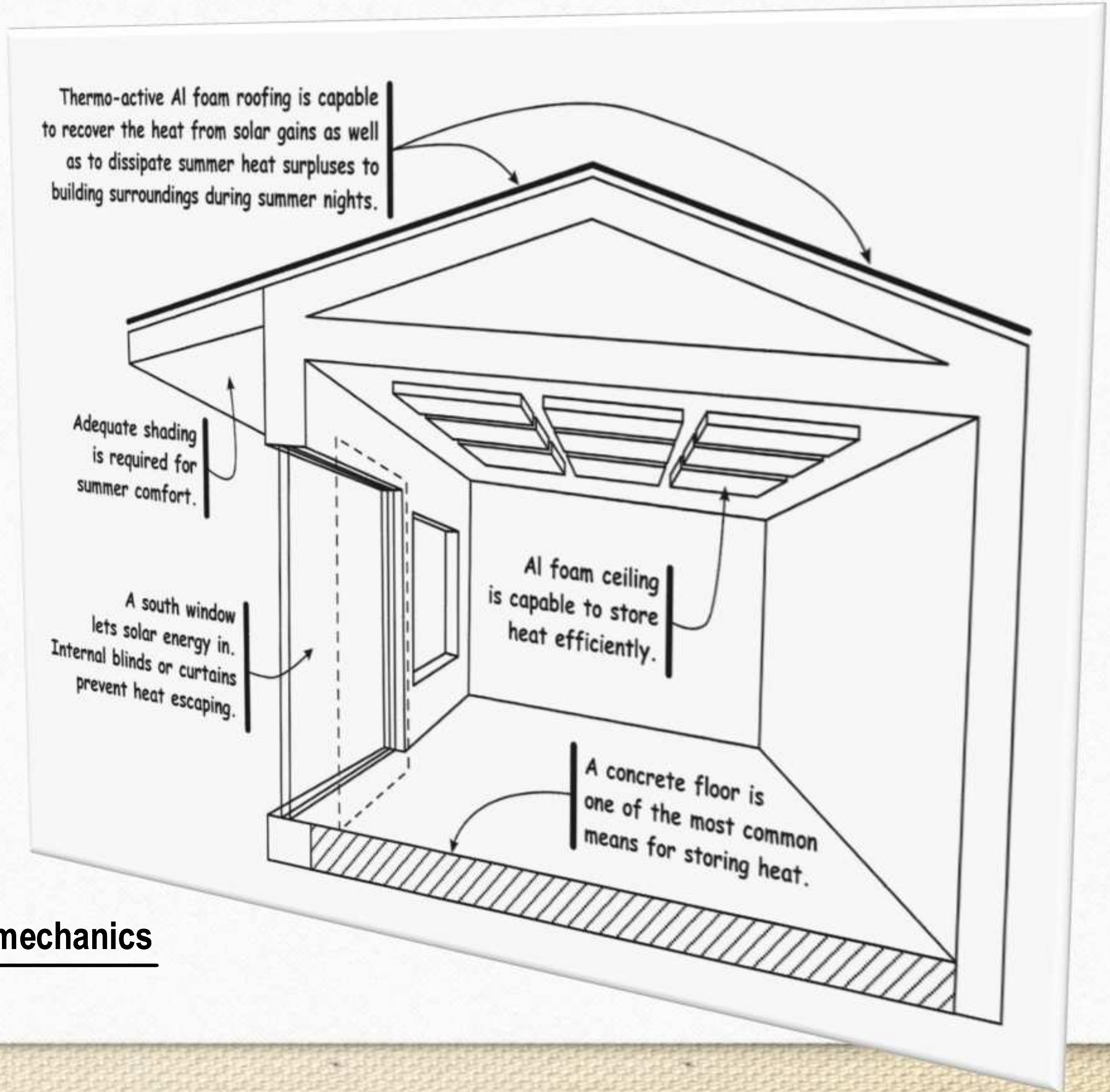
Reduction of the energy demands by aluminium foam heat exchangers

- aluminium foam thermo-active roofing capable to recover the heat from solar gains as well as to dissipate excessive summer heat surpluses
- aluminium foam heating/cooling ceiling heat exchangers impregnated by Phase Change Materials (PCMs)
- a base plate with the capability for seasonal storage of summer heat surpluses that can be used for heating of interiors and DHW during winter season



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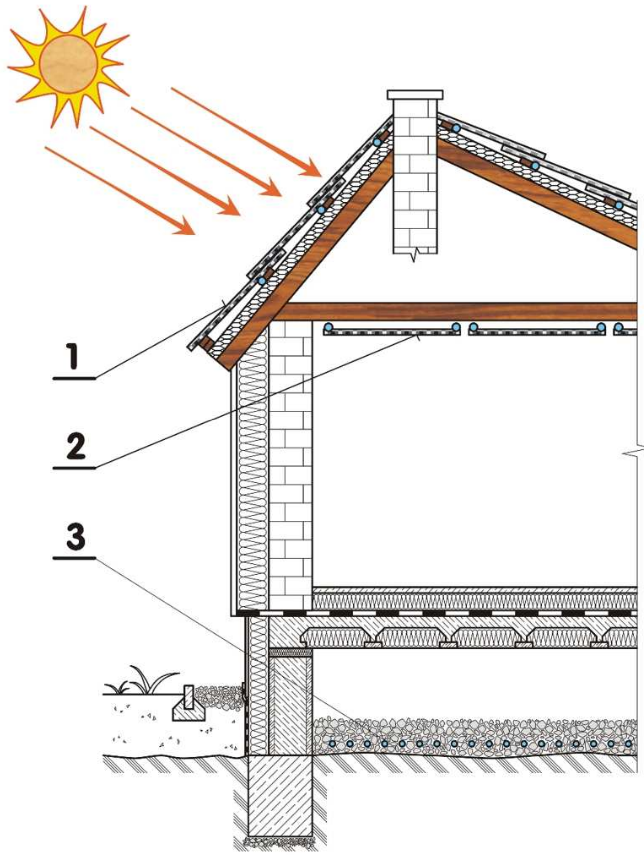
Novel technologies for nearly Zero-Energy Buildings (nZEBs)

1. thermo-active aluminium foam roofing
2. aluminium foam interior heating/cooling ceiling panels impregnated by PCM
3. an underground collector situated under the base plate of the building allowing the seasonal storage of summer heat surpluses



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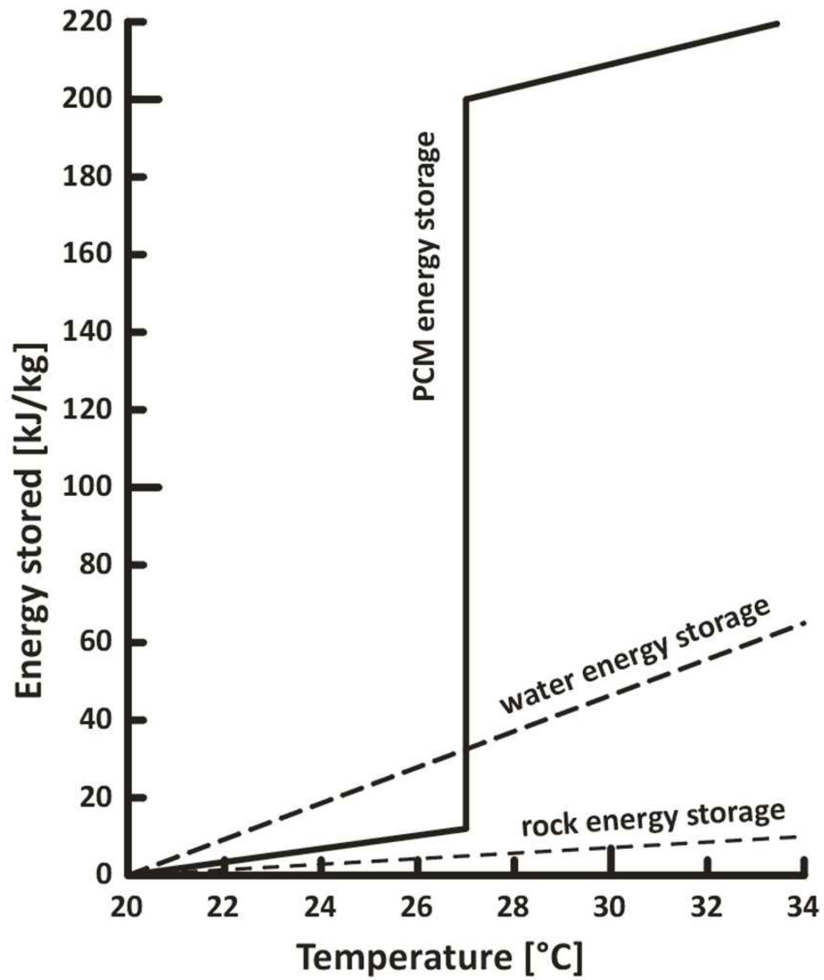
Performance comparison of PCM, water and rock heat storage system

- ✓ PCMs absorb and release heat at a nearly constant temperature
- ✓ PCMs are able to store even ten times more heat per unit volume than usually used sensible storage materials such as water, masonry, concrete or rock



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The capability to store heat into water, building materials and PCMs

	Water	Rock (Sandstone)	High density concrete	PCM (RT28HC)	Coconut oil
Specific heat capacity (J/kg·K)	4 175	840 – 920	473 – 867	2 000	2 100
Density (kg/m^3)	1 000	2 240 – 2 650	4 900 – 5 500	770 (liquid) 880 (solid)	920
Heat of fusion (J/g)	334	790 – 890	480 – 550	250	110 – 249
Melting temperature (°C)	0	1 300	1 000	27 – 29	22 – 27
Energy stored to 1 m^3 by ΔT 10 K* (kJ)	41 750	21 516	34 840	138 600	~ 120 520 (min.)
Thermal conductivity (W/m·K)	0.56 – 0.68	0.9 – 5.0	0.7 – 2.6	0.2	0.321
Price (EUR/kg)	0.001	0.4	0.2	5	~ 5

* in the temperature range between 20°C and 30°C

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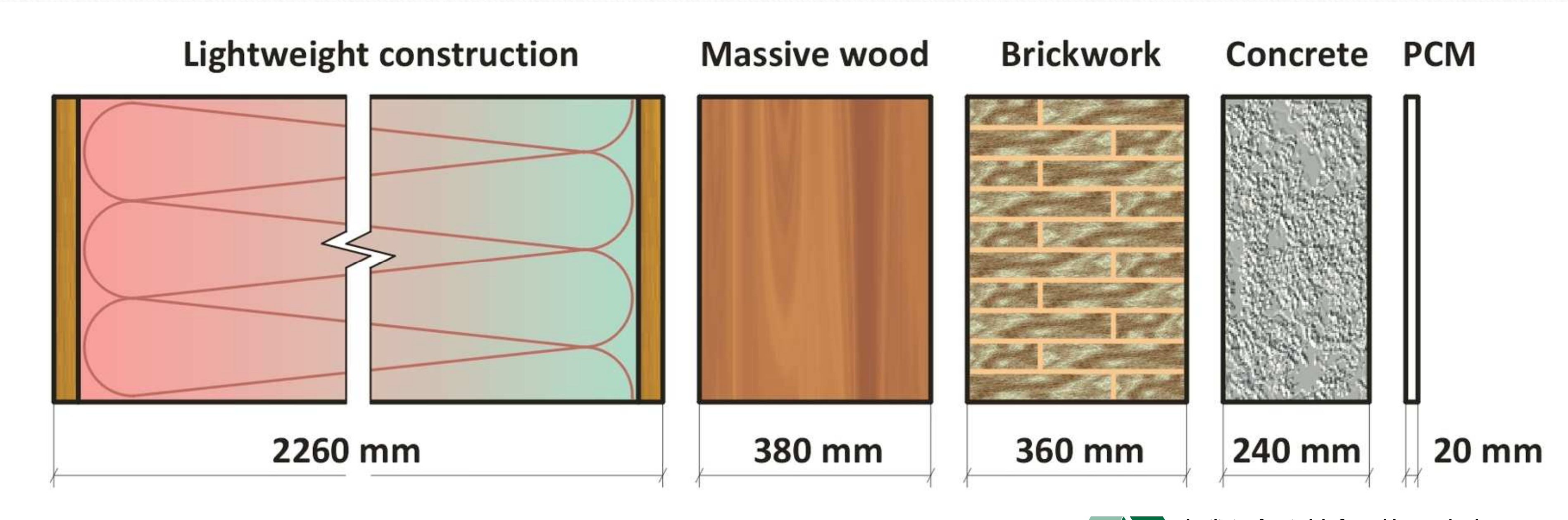
The thickness of building material required to store the same amount of heat during heating from 20°C to 30°C as concrete panel with a thickness of 240 mm



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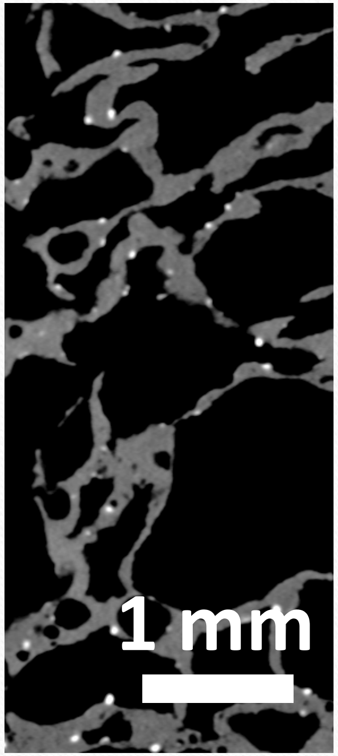
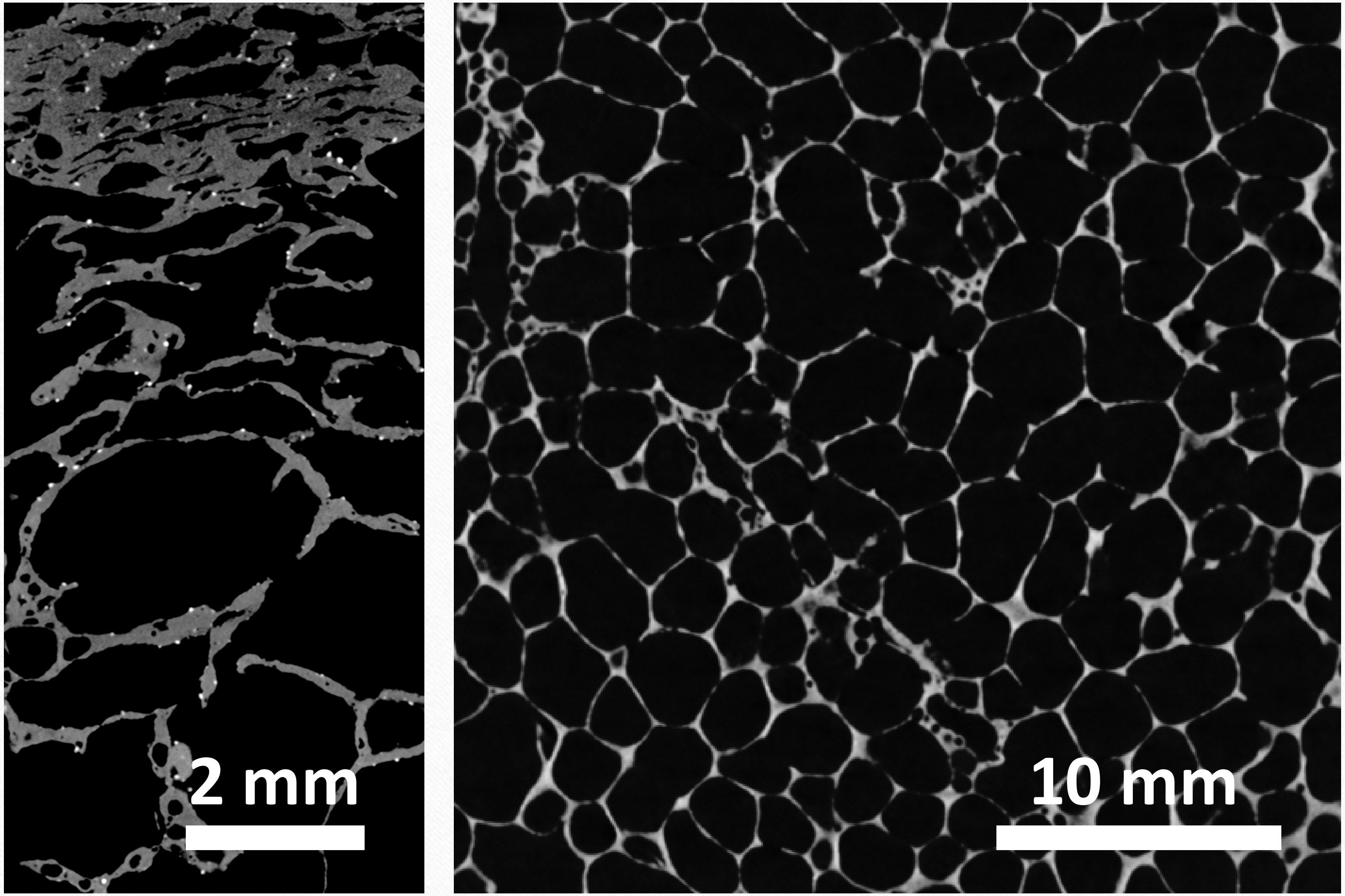
Al foam structure





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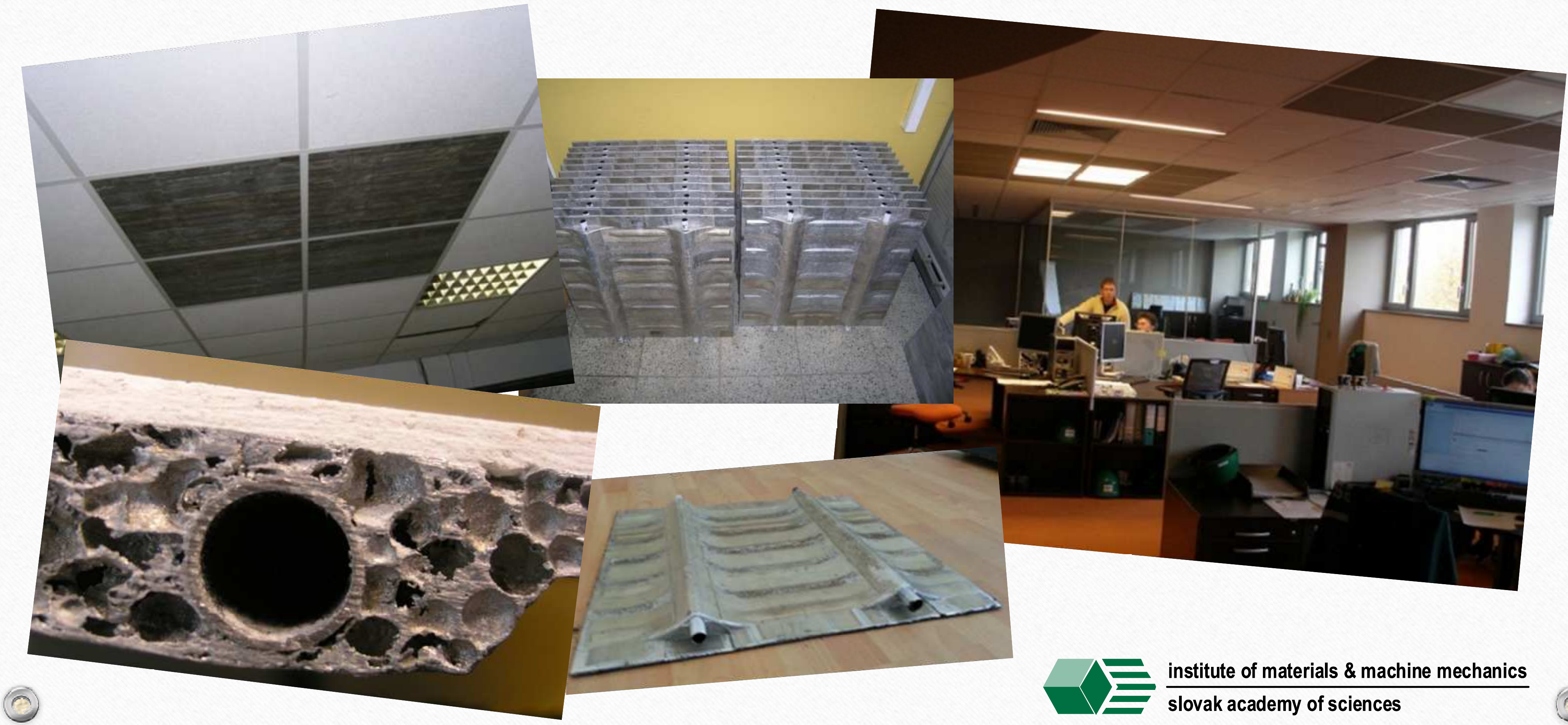
Heating/cooling aluminium foam ceiling panels



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Why radiant ceiling panels?

- ✓ **large surface** / transfer of heat mostly via radiation (70 %)
- ✓ **fixed installation on ceiling** (no constraints in arrangement)
- ✓ **provide coolness or heat directly to the occupants of room**
- ✓ **only a few degrees difference is required for sufficient comfort**
  (efficient energy generation – renewable energies possible)
- ✓ **less variation in room temperature due to radiant heat transfer**
- ✓ **lower losses due low temperature differences and piping distribution**
- ✓ **lower peak-power requirements**
- ✓ **less energy required to remove or add heat to the space**
- ✓ **air velocity is reduced significantly** (reduced dust movement)
- ✓ **draught and noise are completely eliminated**

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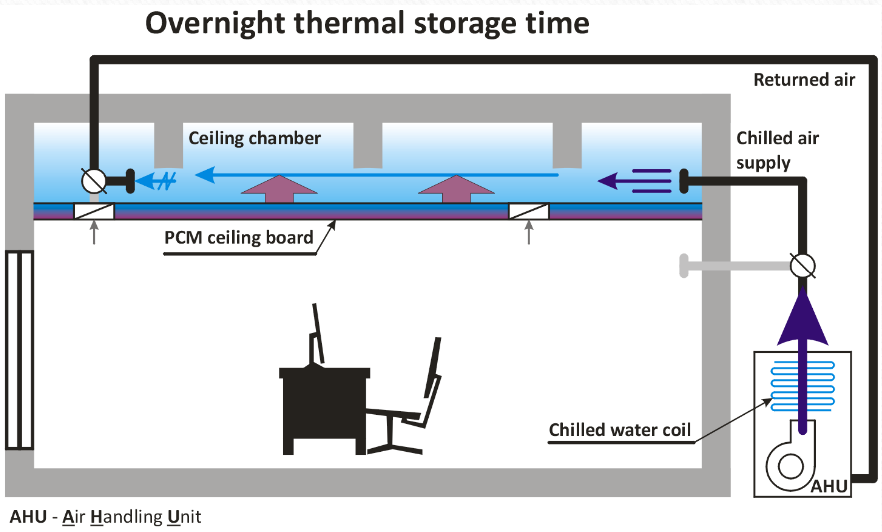

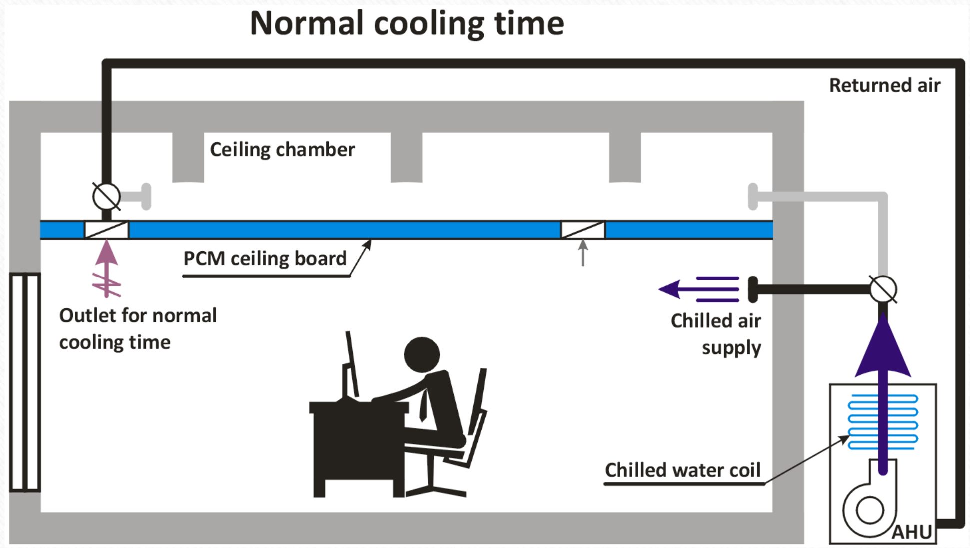

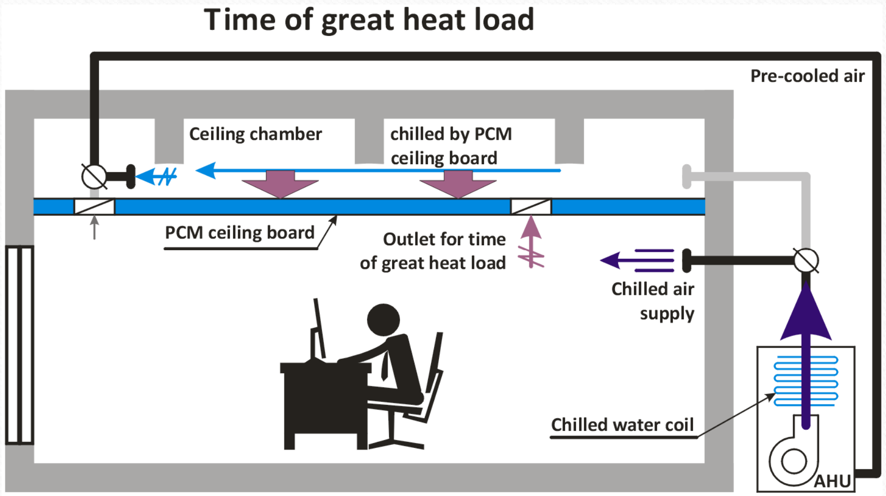

The system of ceiling board containing PCM with the function of latent heat storage during:

(a) overnight thermal storage time (~ from 2 a. m. to 7 a. m.)

(b) normal cooling time (~ from 7 a. m. to 1 p. m.) and

(c) time of great heat load (~ from 1 p. m. to 6 p. m.)

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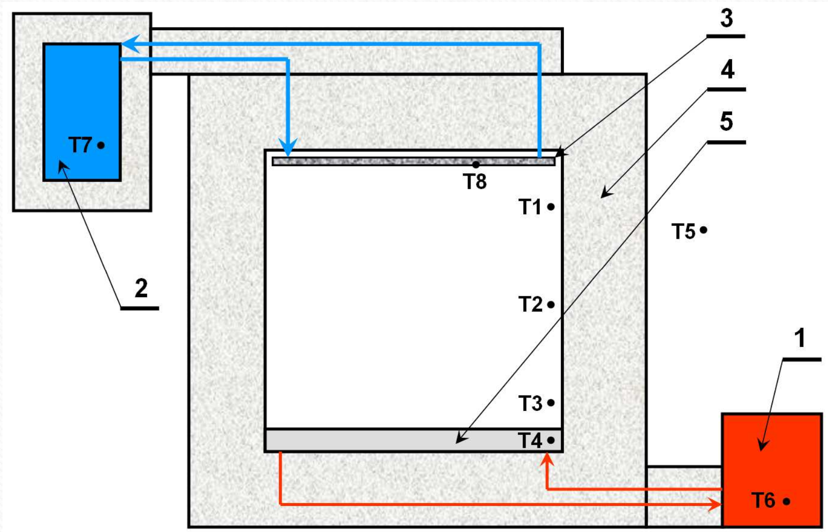
Climatic chamber for testing of the performance of Al foam heating/cooling panels impregnated by PCM



1 – thermostat

2 – reservoir with 12.6 liters of water

3 – tested panel of aluminium foam impregnated by PCM

4 – thermal insulation

5 – aluminium plate with dimensions 700 × 700 × 25 mm stabilizing the temperature in the chamber

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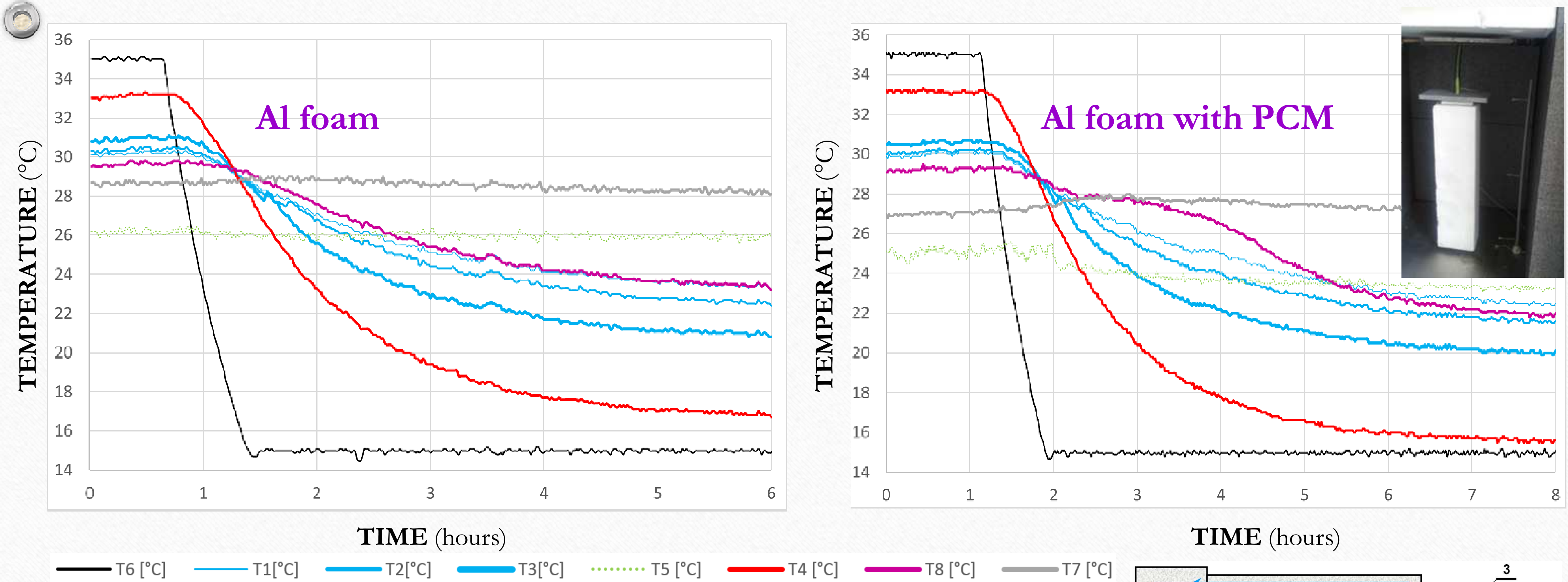
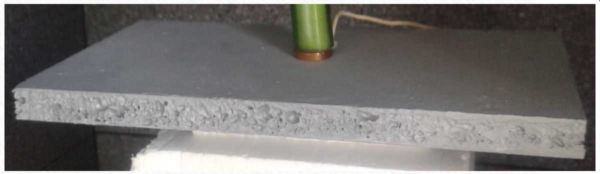
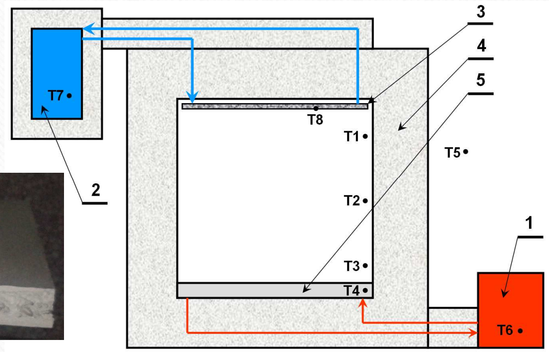


- ✓ *Al foam sample 290 × 130 × 15 mm (weight: 309 g; density 0.547 g/cm^3)*
- ✓ *PCM RUBITHERM® RT28HC (weight: 37 g)*





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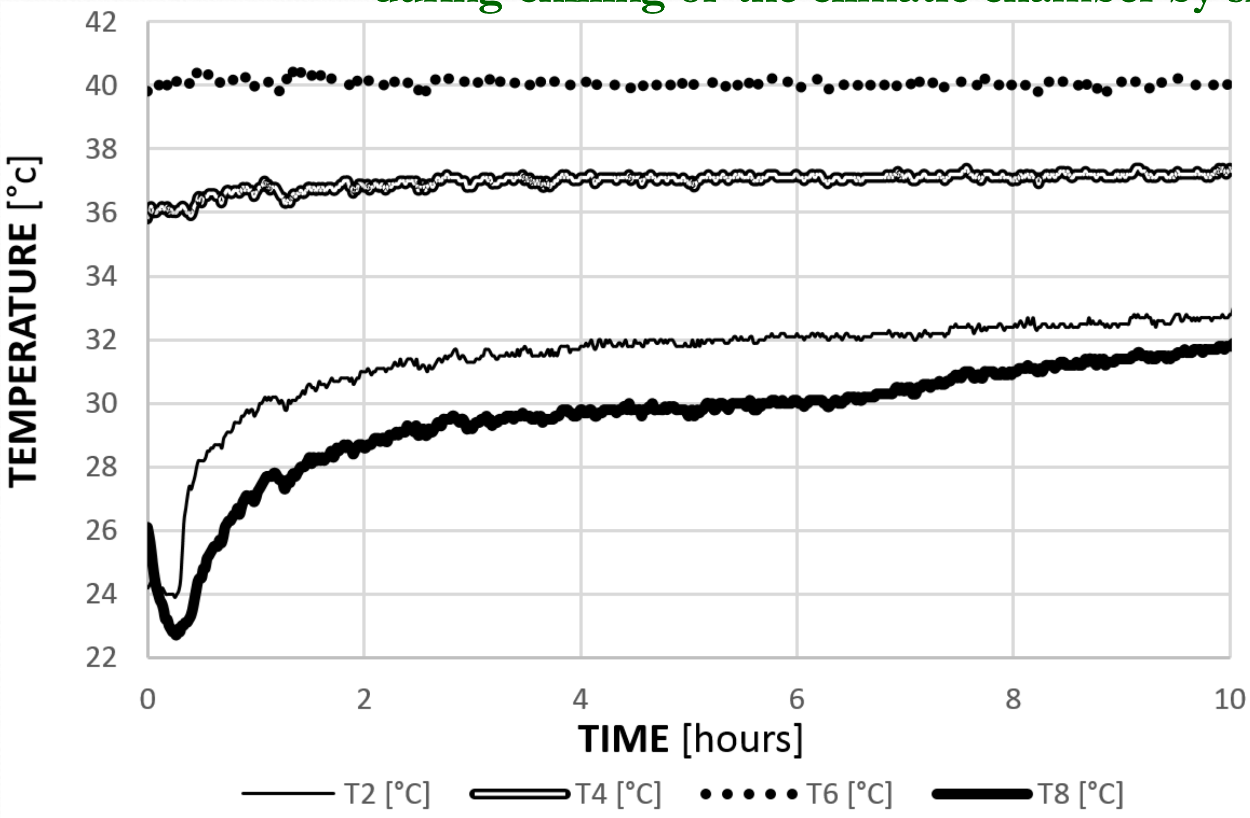
The thermal behavior of Al foam panel 600 × 600 mm during chilling of the climatic chamber by slowly melted PCM



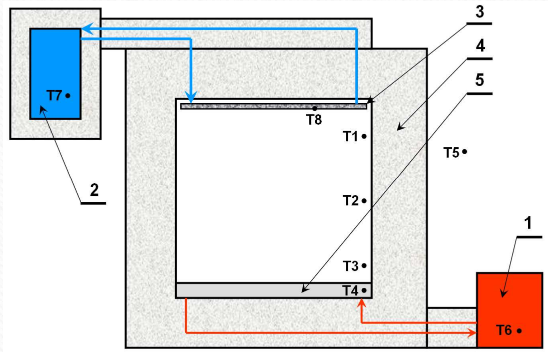
The temperature difference between tested panel impregnated by 770 g (1 l) of PCM RUBITHERM® RT28HC and Al plate with stabilized temperature (bottom of the chamber) was ~ 7°C

T2 *– air temperature at the middle space of the climatic chamber, i.e. at a distance of 500 mm from tested panel*

T4 *– temperature of Al plate*

T6 *– temperature of the water in thermostat and*

T8 *– temperature of the tested panel*



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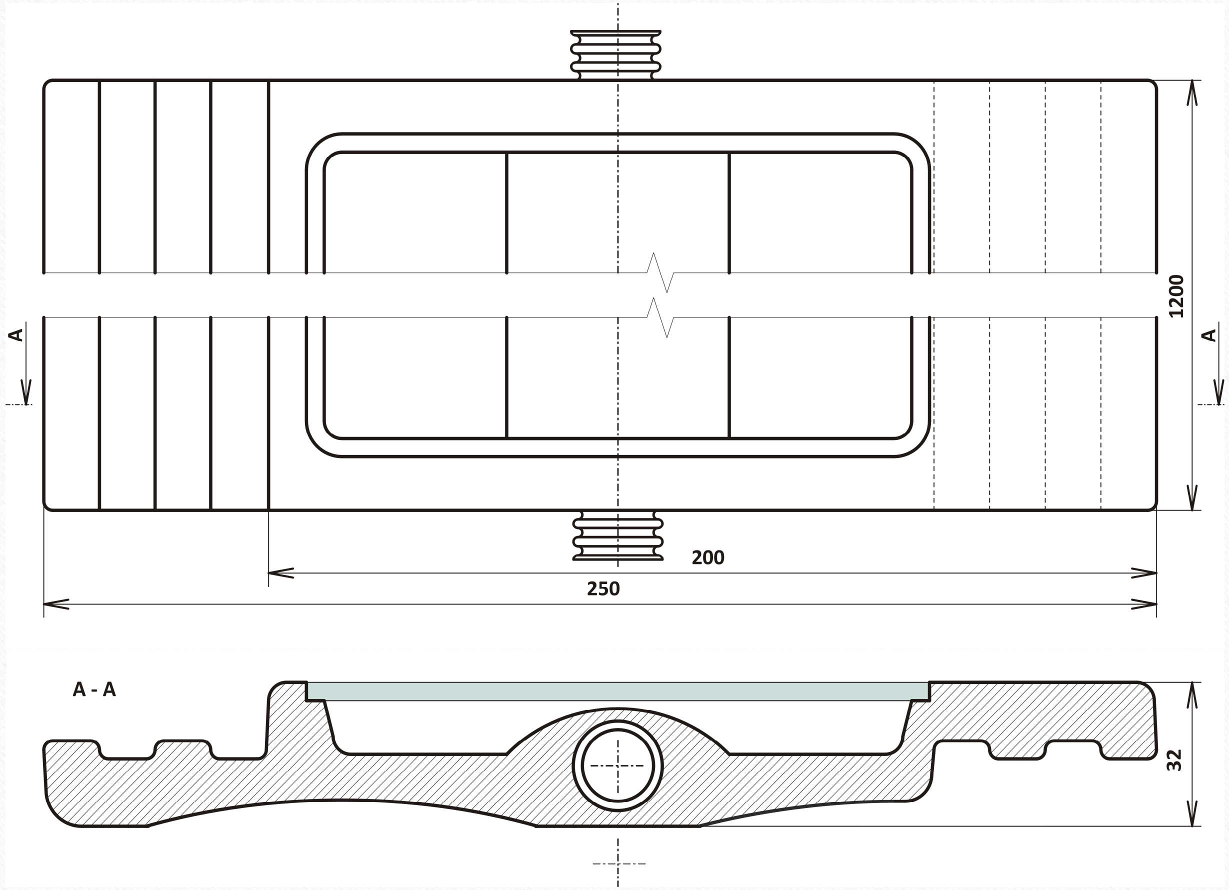
Thermo-active Al foam roofing for moderate climatic zone

- is able to efficiently recover the heat from solar gains even during colder sunny days
- the sun shines through the translucent glass panel, heats both the absorption surface layer of Al foam roofing and the air enclosed in the space under the glass cover



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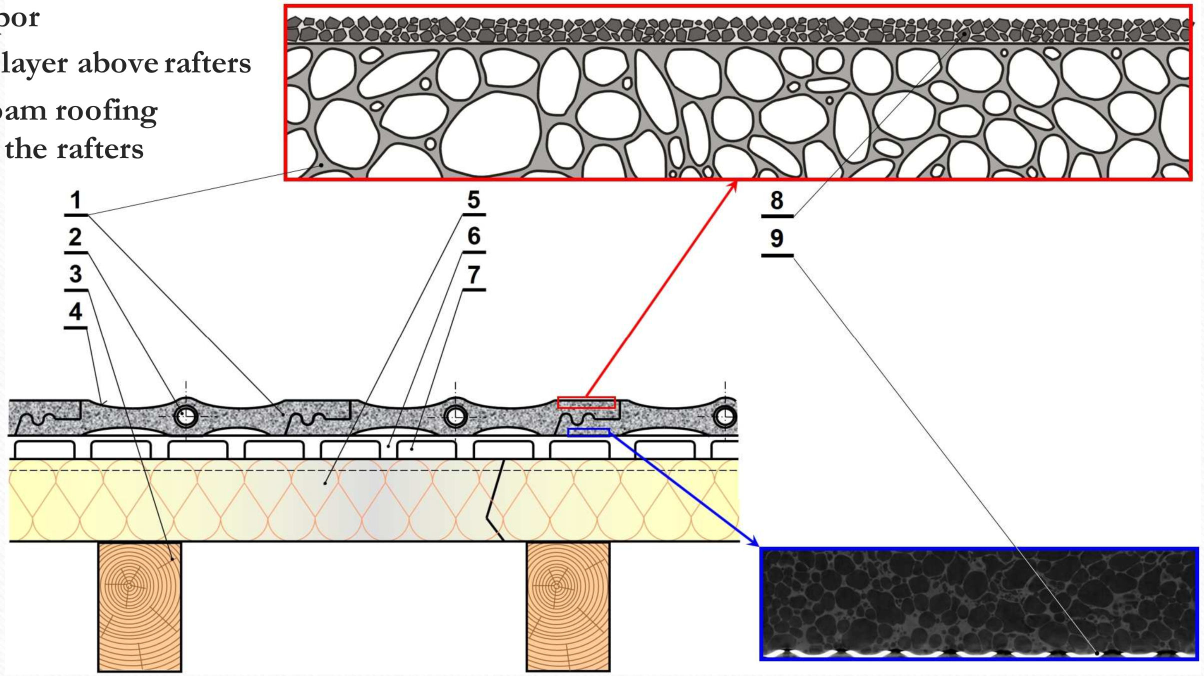
Thermo-active ultra-light Al foam roofing for subtropical regions

1 – roofing components made of aluminium alloy foam
2 – corrugated tubes made of corrosion-resistant chromium-nickel austenitic steel used for distribution of liquid heat-transfer fluid
3 – construction of pitched roof made from wooden rafters
4 – surface layer of aluminium foam roofing ensuring a high solar heat absorptivity
5 – the thermal insulation layer above the rafters of pitched roof ensuring its waterproofing and creating a barrier to water vapor
6 – rails of galvanized steel integrated into the insulation layer above rafters
7 – venting air gap between the top layer of aluminium foam roofing and waterproof insulation with vapor barrier above the rafters of pitched roof
8 – coating of polymer matrix composite reinforced with metallic or ceramic particles (alternatively basalt granules, crushed natural stones, etc.) protecting surface layer of aluminium foam casting against mechanical damage caused by adverse weather conditions and providing highly efficient heat transfer
9 – expanded stainless steel sheet reinforcing tensile loaded surface of thermo-active ultralight solar aluminium foam roofing



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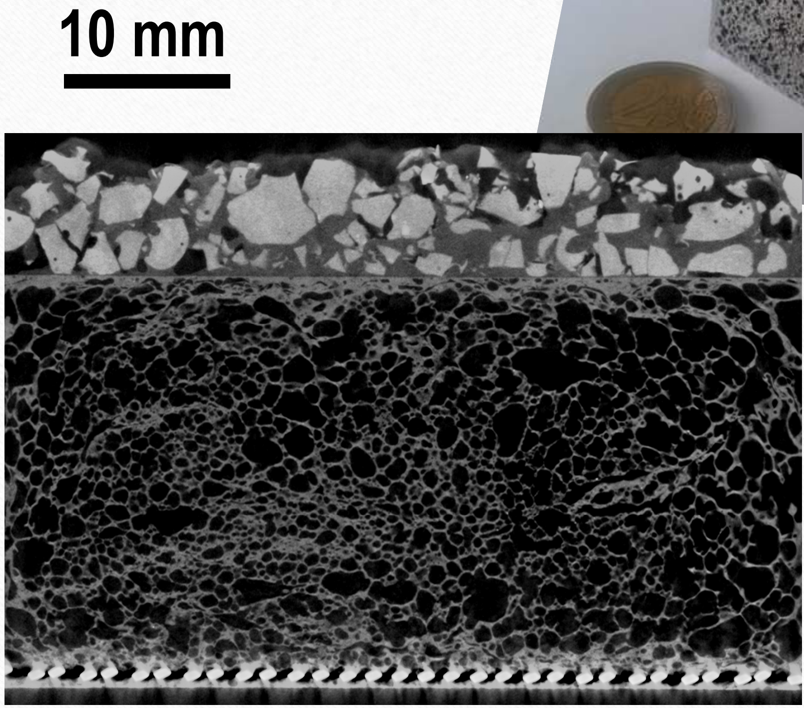

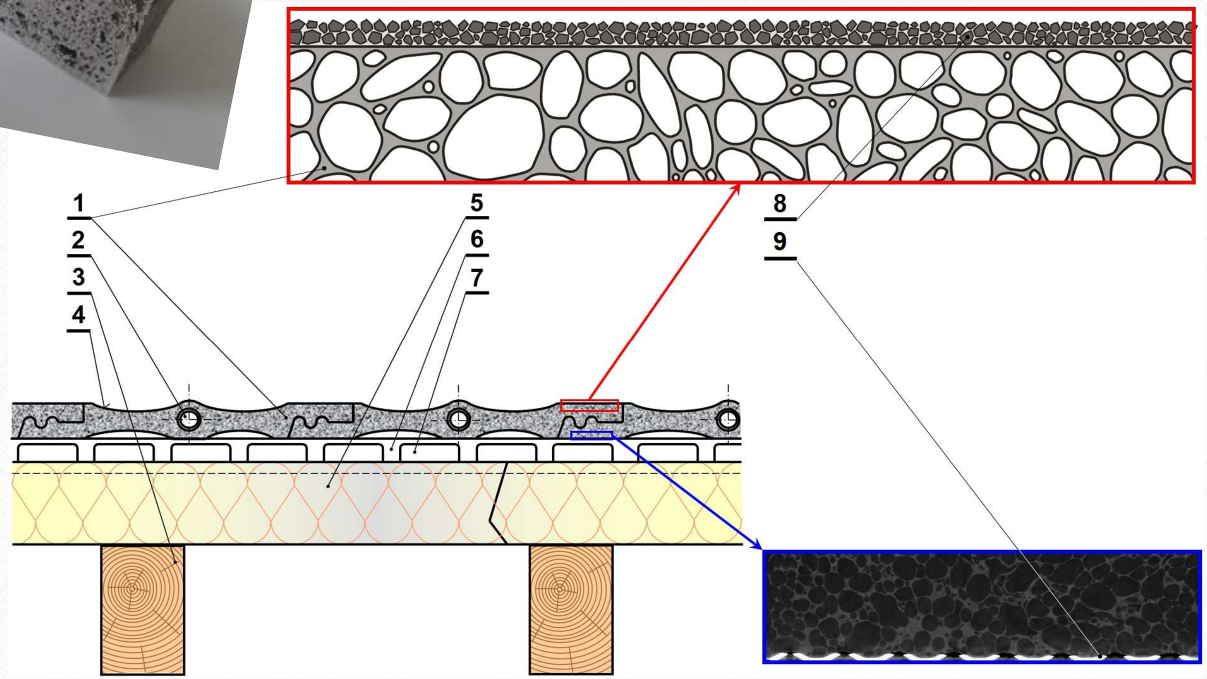

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Thank you for your attention !

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