Integrated solar flat plate collectors and passive solar floor heating in buildings

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Introduction / Summary

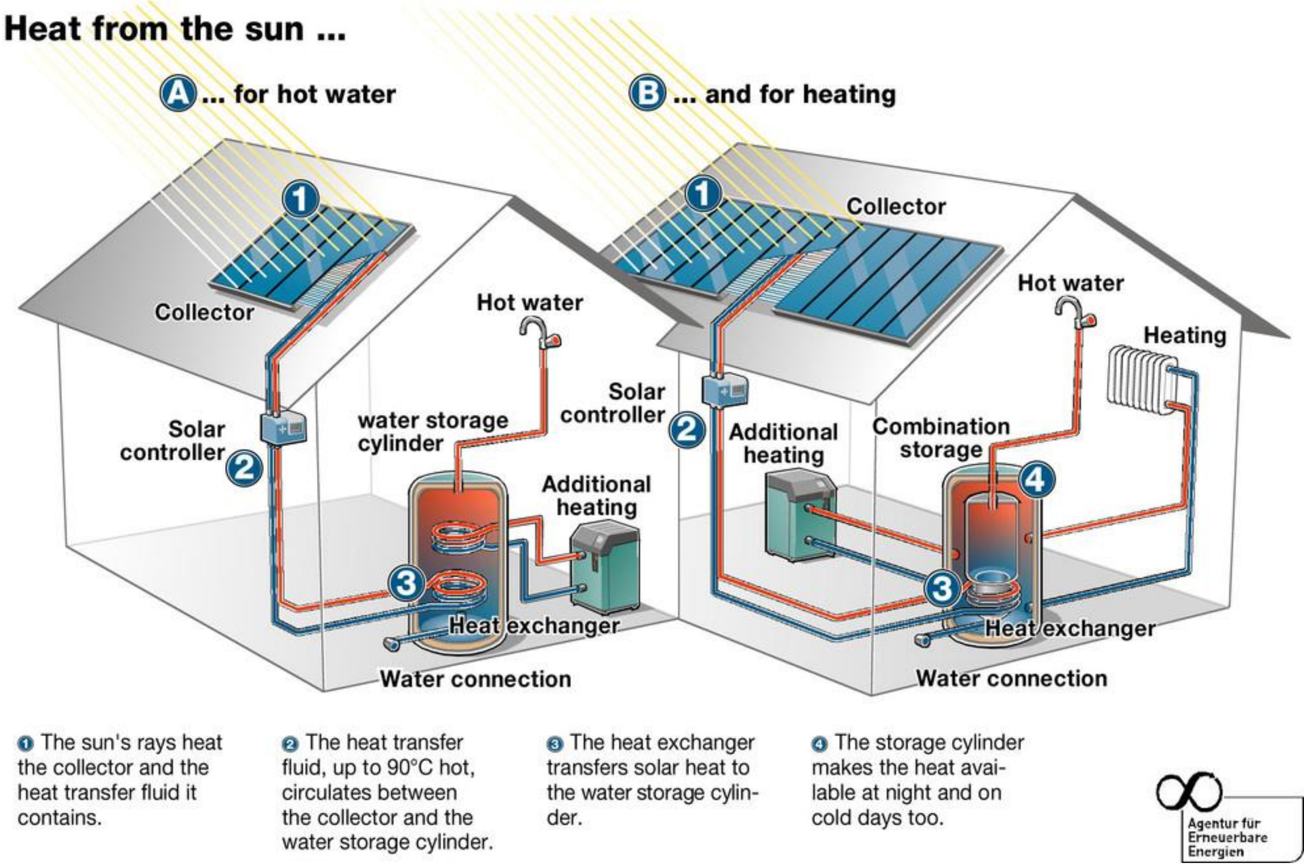
- Floor heating systems allow heat to flow slowly in a natural way from the floor upwards, offering more comfort through the temperature uniformity
- Thermal mass integrated to the floor can act as a thermal reservoir that can store the solar gains of the day
- The foundation concrete in a new building is examined as a storing material, where the heat gains of a flat plate collector array on the south wall are driven and accumulated
- The model is a building typically insulated with walls facing the four cardinal points. The south wall area is covered with *Integrated-Solar-Flat-Plate Collectors*, with water being circulated with a pump between the collectors and the foundation concrete when its temperature exceeds 40°C
- A simulation model for the chosen regime, built in TRNSYS software, computes hourly results of the collected solar energy and the building thermal load under the climatic conditions of Limassol, Cyprus
- The hourly results of TRNSYS are used as input for simulations in COMSOL Multiphysics software. The solar energy collected is directed for storing in the foundation concrete. After an initial time priming, the foundation's temperature becomes sufficiently high to provide the daily heating load of the building
- The effect of parameters, such as thickness of the concrete, amount of heat available and that stored, as well as the controlling technique are to be examined

Objective

- Solar energy is usually turned vastly into electricity, but it is also used for domestic hot water (DHW) applications
- Efficiency of a Solar/Thermal system ranges within 30-40%; for electricity production the Photovoltaics efficiency ranges within 10-20%

Objective:

- To examine the use of the foundation concrete in new buildings as a storing material, where the heat gains of a flat plate collector array on the south wall are driven and accumulated
- To decide under which conditions the system chosen can cover completely the heat requirements of the building and provide thermal comfort during winter in given climatic conditions



Thermal storage

Thermal storage concept:

- active - using of forced convection
- passive - gravitational forces being utilized to circulate the fluid of the system

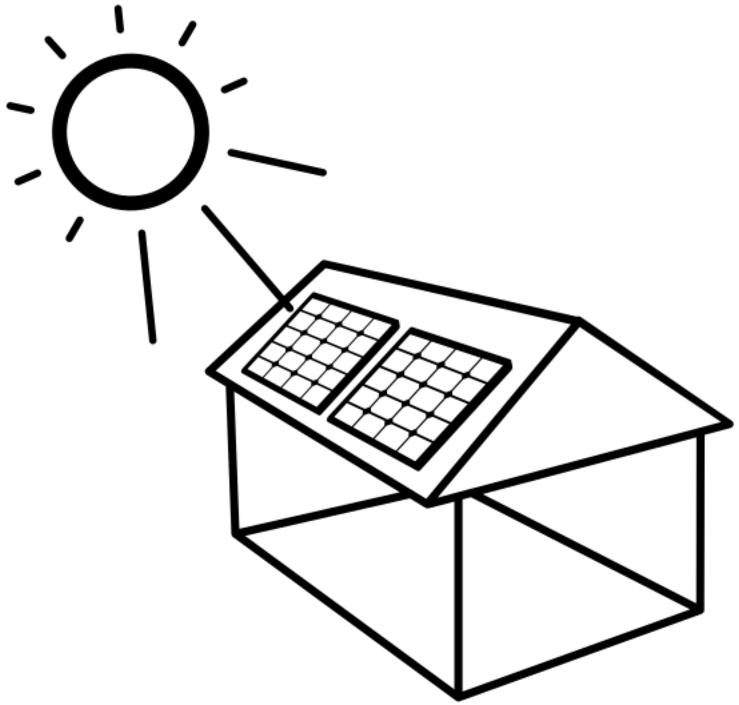
Storage mechanisms:

- latent systems - using phase changing materials (PCM)
- chemical systems - using a chemical reaction
- sensible systems - heat being stored as internal energy in the medium that is either liquid or solid (*most commonly used*)
  - water, rocks and soil are the most common materials
  - concrete, brick, gypsum have also been studied as sensible thermal storage building materials

Building

The building modelled has a rectangular shape with the elongated side facing south, with its dimensions being 4m x 8m x 3m (height).

- Wall layers:
  - 0.025m of plaster
  - 0.2m hollow clay brick
  - 0.05m of extruded polystyrene
  - 0.025m of plaster on the outer surface
- Roof layer: (*not the configuration shown here*)
  - 0.025m plaster
  - 0.15m reinforced concrete with 1% iron
  - 0.05m of extruded polystyrene
- The floor was considered to have no heat losses through the ground
- 24m^2 of solar collector



Computational Modeling

The computational modelling is performed in two stages:

- TRNSYS software - to simulate a building with the south facing wall surface covered in solar collectors. Calculates the house load to keep a steady room temperature, with the collected heat of the solar collectors being estimated in one hour steps.
- COMSOL Multiphysics software - to further examine the use of the building's concrete foundation as a sensible thermal storage.

Computational Modeling - TRNSYS

heating mode: 21°C

cooling mode: 27°C

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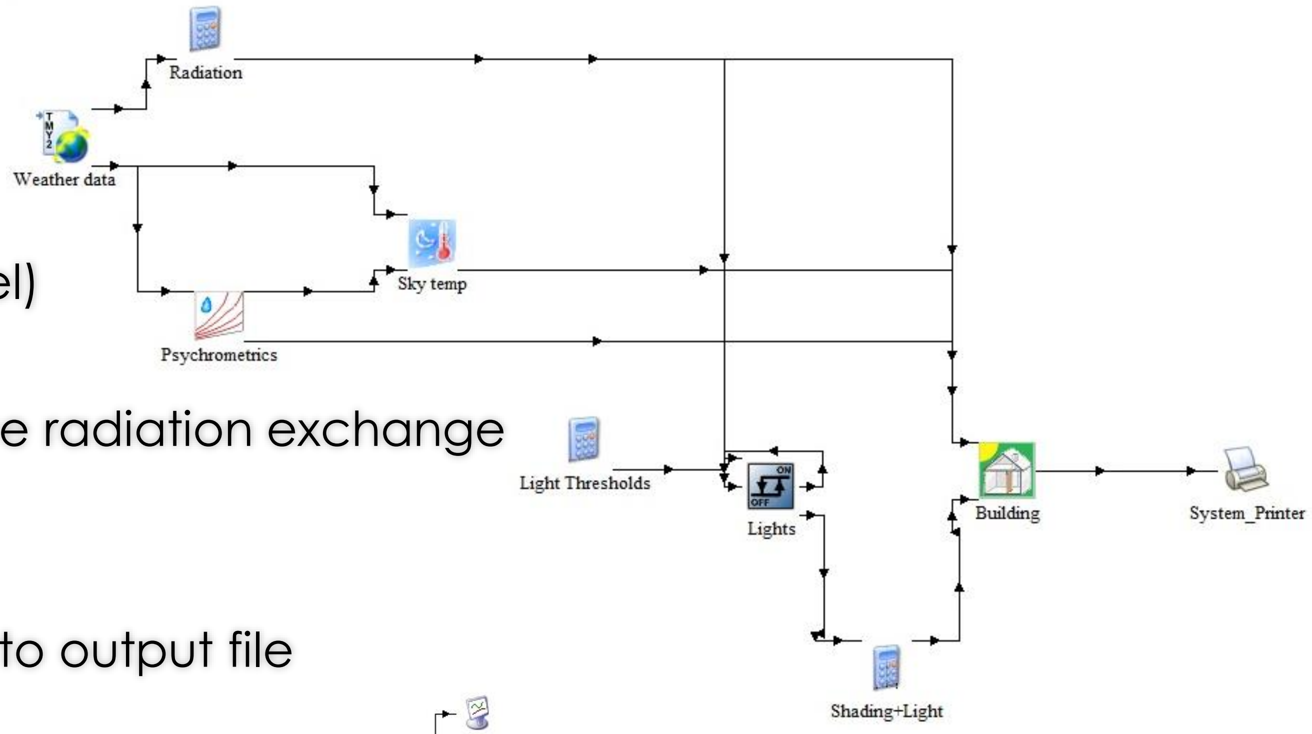

Components:

- Type 109 - TMY2 (weather data processing model)
- Type 33 - psychrometrics
- Type 69 - effective sky temperature for long-wave radiation exchange
- Type 2 - ON/OFF differential controller
- Type 65 - online graphical plotter
- Type 25 - printer - TRNSYS - supplied units printed to output file
- Type 56 - multi-zone building
- Type 114 - pump
- Type 1b - solar collector

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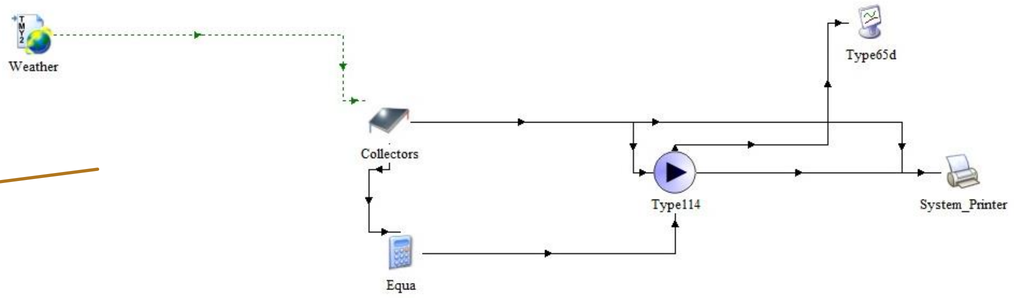


Computational Modeling - COMSOL

Model set-up:

- 2D model
- 8m overall domain width
- 4 layers – 4 materials
- Boundary conditions:
  - Heat source
    - Top surface
    - Pipe
- Physics regime:
  - Heat transfer in solid
- Transient solution:
  - Time step: 1hr

Material	Domain	Height (m)
Tile	1	0.01
Screed	2	0.05
Concrete	3	0.5-1.5
Pipe-Water	4	0.02

COMSOL - Equations

Transient heat equation for an incompressible fluid:

$$\rho c_p \frac{\partial T}{\partial t} + \nabla \cdot q = Q$$

Boundary conditions:

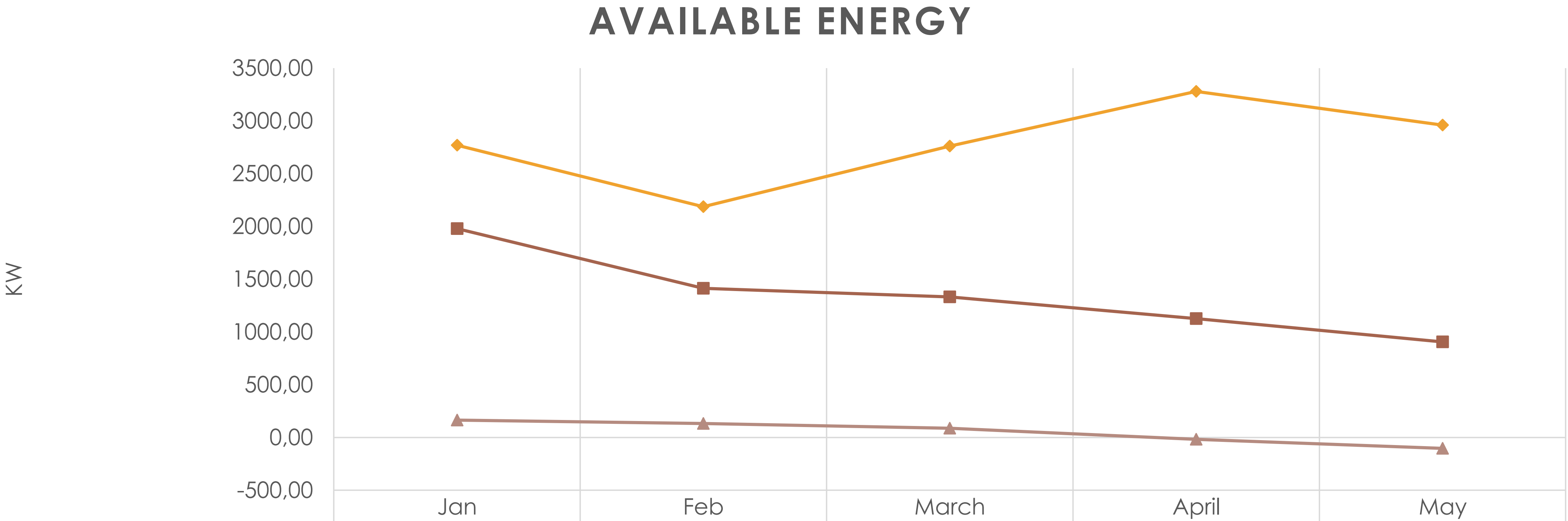
- House load on top surface of the tile - provided from TRNSYS:

  $$Q_b = Q_{houseload}(t)/Area$$

- Pipe domain: Heat source - provided from TRNSYS - average load for January = 222 W h^{-1}
- Thermostat like parameter to maintain a comfortable temperature environment with the floor at 35°C

Temperature (AveTemp)	Heat Transfer Rate Q (W)	Pipe General Heat Source Q_0 (W m^{-3}), $Q_0 = Q/Volume$	Steps
>35.5	0	0	1
34.5<AveTemp<35.5	222	71.04	2
33.5<AveTemp<34.5	222*2	142.08	3
<33.5	222*4.5	319.68	4

Results - Available energy



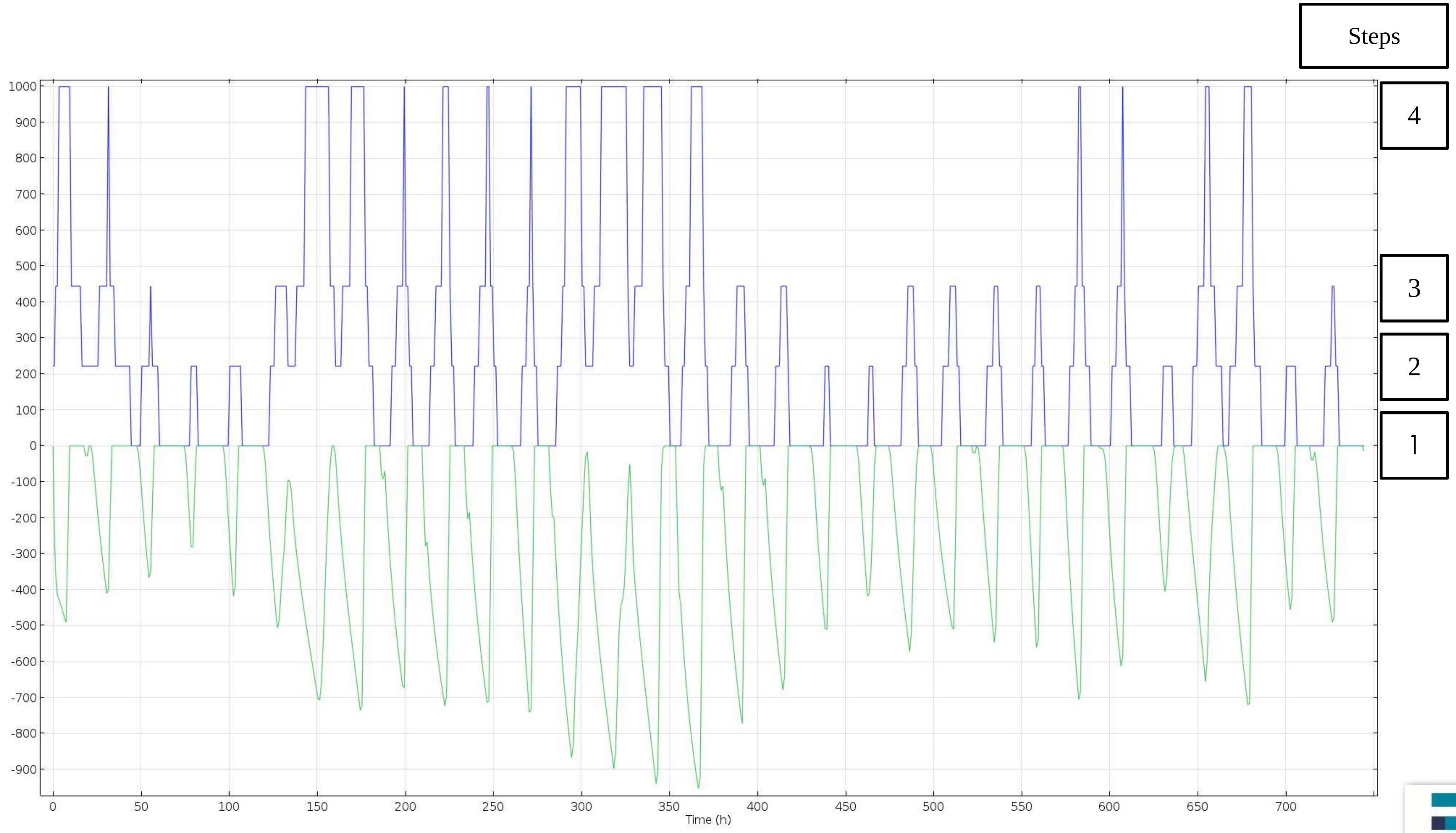
	Jan	Feb	March	April	May
Horizontal solar collectors	2770,07	2187,34	2760,76	3278,62	2959,41
Vertical Solar collectors	1978,58	1413,02	1332,17	1125,82	906,63
House load	165,21	133,13	87,74	-18,04	-103,90

MONTH

Results - Loads

Loads

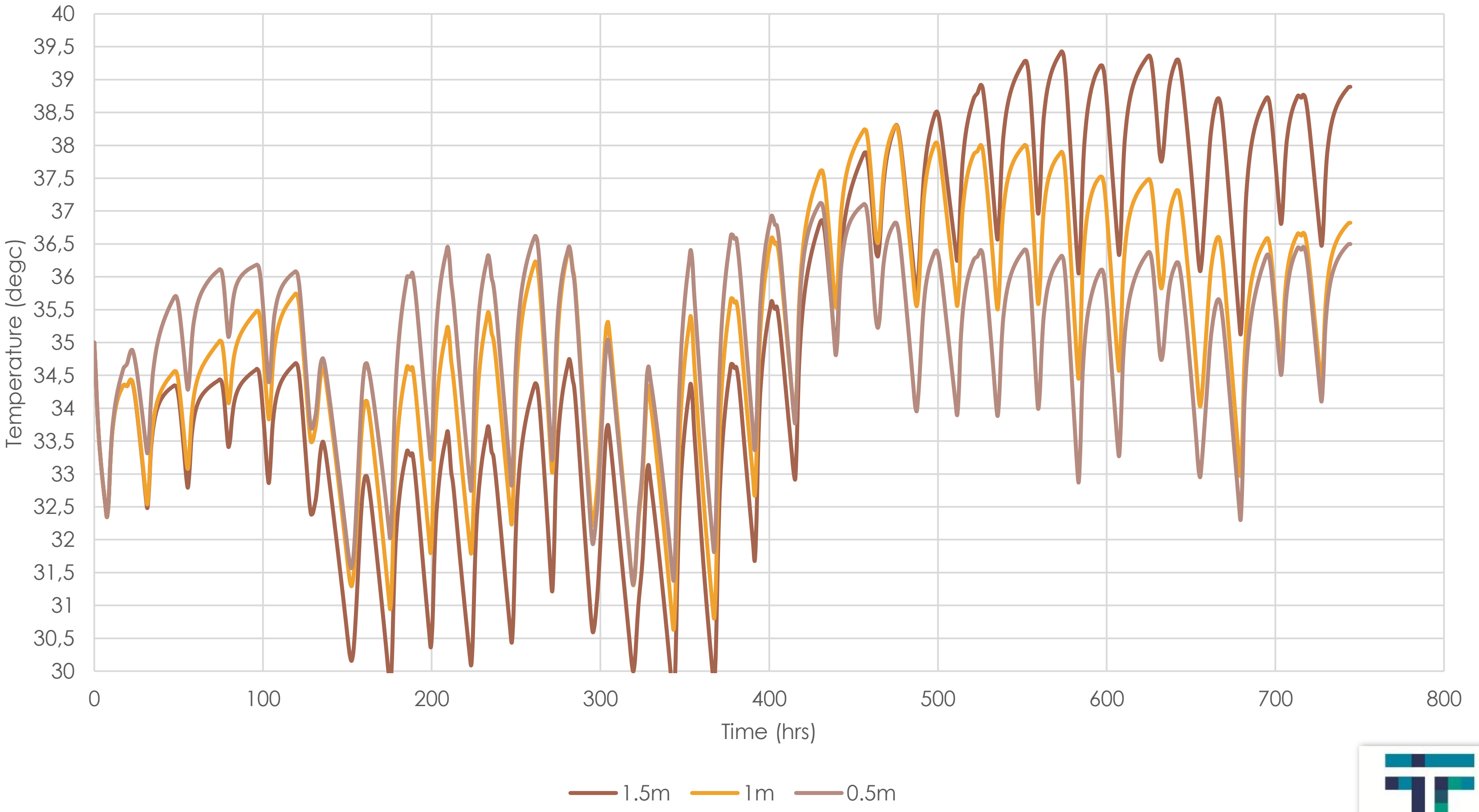
- Steps as described in the thermostat like parameter
- Balanced loads (W):
  - blue line represents the Q values in the pipe domain,
  - green line represents the house load



Results – concrete thickness

Concrete thickness:

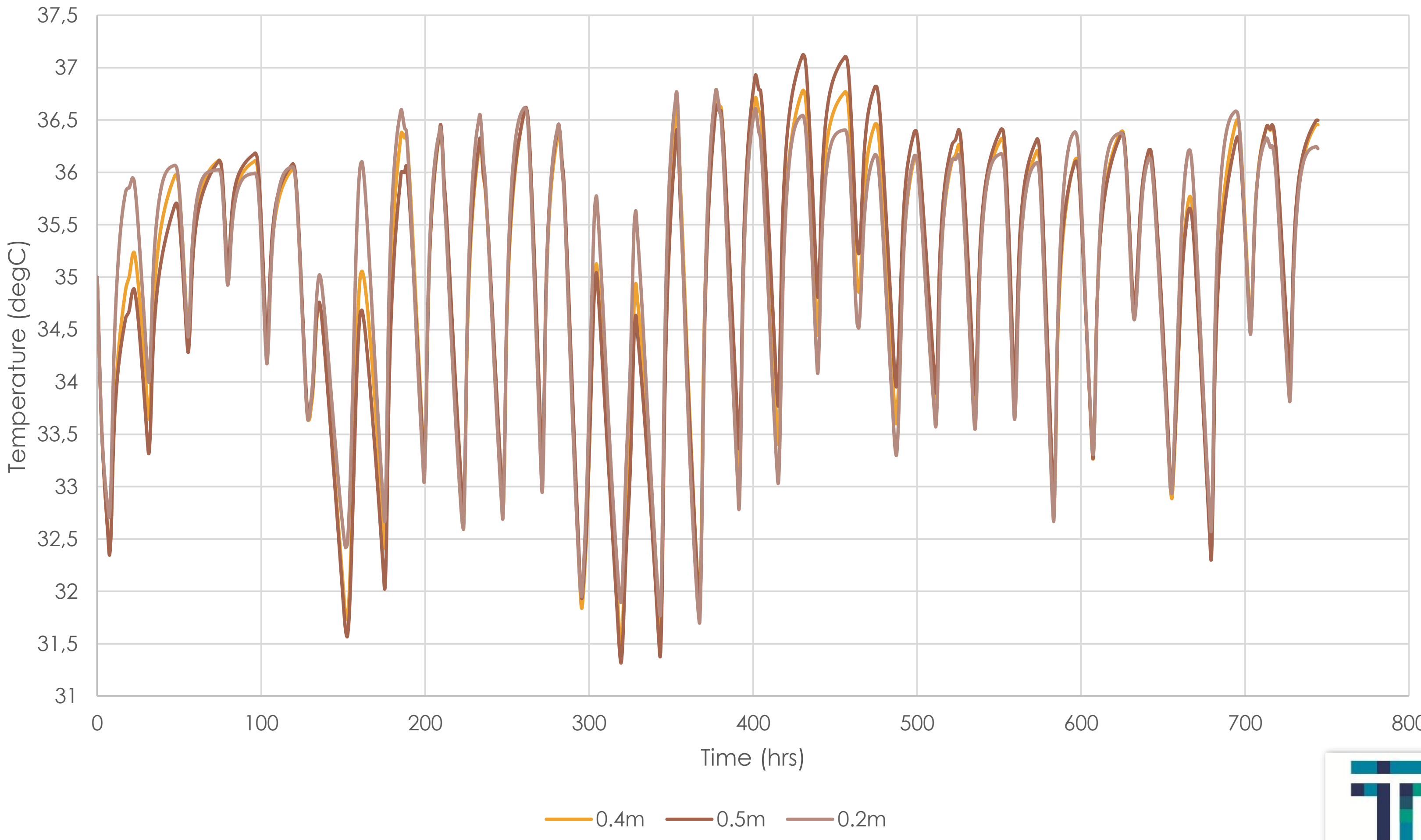
- to examine the stability and control over the temperature that the house floor retains
- concrete thicknesses: 0.5m, 1m and 1.5m
- 0.5m concrete:
  - max 37.125°C
  - min 31.317°C
  - commercial thermostats have tolerance of ±2°C
- Concrete greater that 0.5m:
  - leads to a larger temperature variation in the room



Results – concrete thickness

Concrete thickness:

- concrete thicknesses: 0.2m, 0.4m and 0.5m
- Similar results
- commonly used concrete thickness of 0.5m as a house base layer gives good results



Conclusions

- Concrete base of a house can be used as a thermal storage unit using natural convection
- In cooperation with the solar collectors the system can reduce the energy required for the house heating and can offer an alternative possibility for an HVAC system
- Investigation regarding the solar collectors, concrete thickness and thermal storage unit needs to be carried out in advance before a system can be incorporated

Future research:

- Reduce the fluctuations of the temperature against time
- Examine different materials for the concrete base
- The whole year can be examined with the current CFD method

Thank you for your attention

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