TESSe²b

the smart energy storage

Thermal Energy
Storage Systems

for energy efficient building an integrated solution for residential building energy storage by solar and geothermal resources

Demonstration of the TESSe2b system in residential houses in Austria, Cyprus and Spain and their energy analysis

First Workshop & B2B Meeting

Luis Coelho, Amândio Rebola– IPS, Constantine Karytsas, Olympia Polyzou, Anastasia Benou – CRES; Heiko Gaich – GEOTEAM; Chrysis Chrysanthou, Maria Athanasiou – Z&X; Aniol Esquerra Alsius – ECOSERVEIS, Michalis Gr. Vrachopoulos, Maria K. Koukou, Nikos Tsolakoglou - TEISTE

European Commission

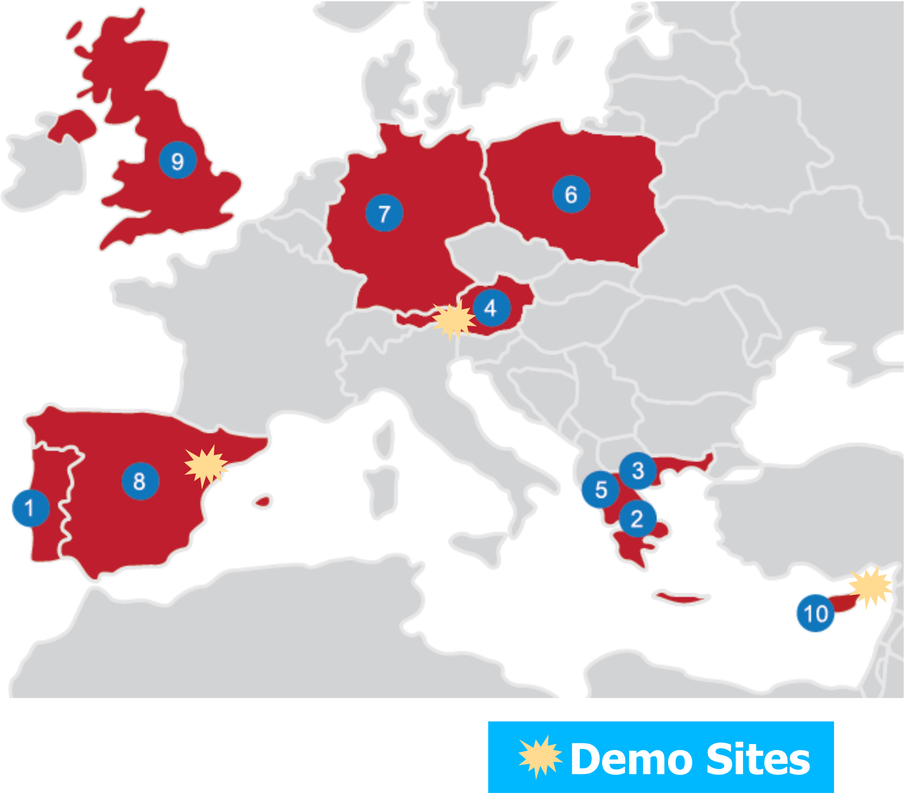
First Workshop & B2B Meeting, Bochum, Germany, 22nd of June of 2017

Objectives

- To present the three TESSe2b demo sites
- To present some results of the energy building simulations.

Three demo sites

- Single family houses
  - ✓Austria (Graz region);
  - ✓Cyprus (Pafos region);
  - ✓Spain (Barcelona region).



Main objective: to cover **three different climates**.

Workpackage 7: Small scale validation of the TESSe2b solution

Task 7.1 Small scale validation of TESSe2b solution in Austria

One of the three prototypes developed under WP6 will be tested in Austria. The demo site will be installed in Graz region. **The average high temperatures in the Summer in this region is about 24°C and the average low temperatures, in Winter, is about -5°C**.

Task 7.2: Small scale validation of TESSe2b solution in Cyprus

One of the three prototypes developed under WP6 will be tested in Cyprus. The demo site will be installed in Pafos region. **The average high temperatures in the Summer in this region is about 33ºC and the average low temperature, in Winter, is about 7ºC**.

Task 7.3 Small scale validation of TESSe2b solution in Spain

One of the three prototypes developed under WP6 will be tested in Spain. The demo site will be installed in Barcelona region. **The average high temperatures in the Summer in this region is about 29°C and the average low temperatures, in Winter, is about 5°C**.

Demo site preparation includes:

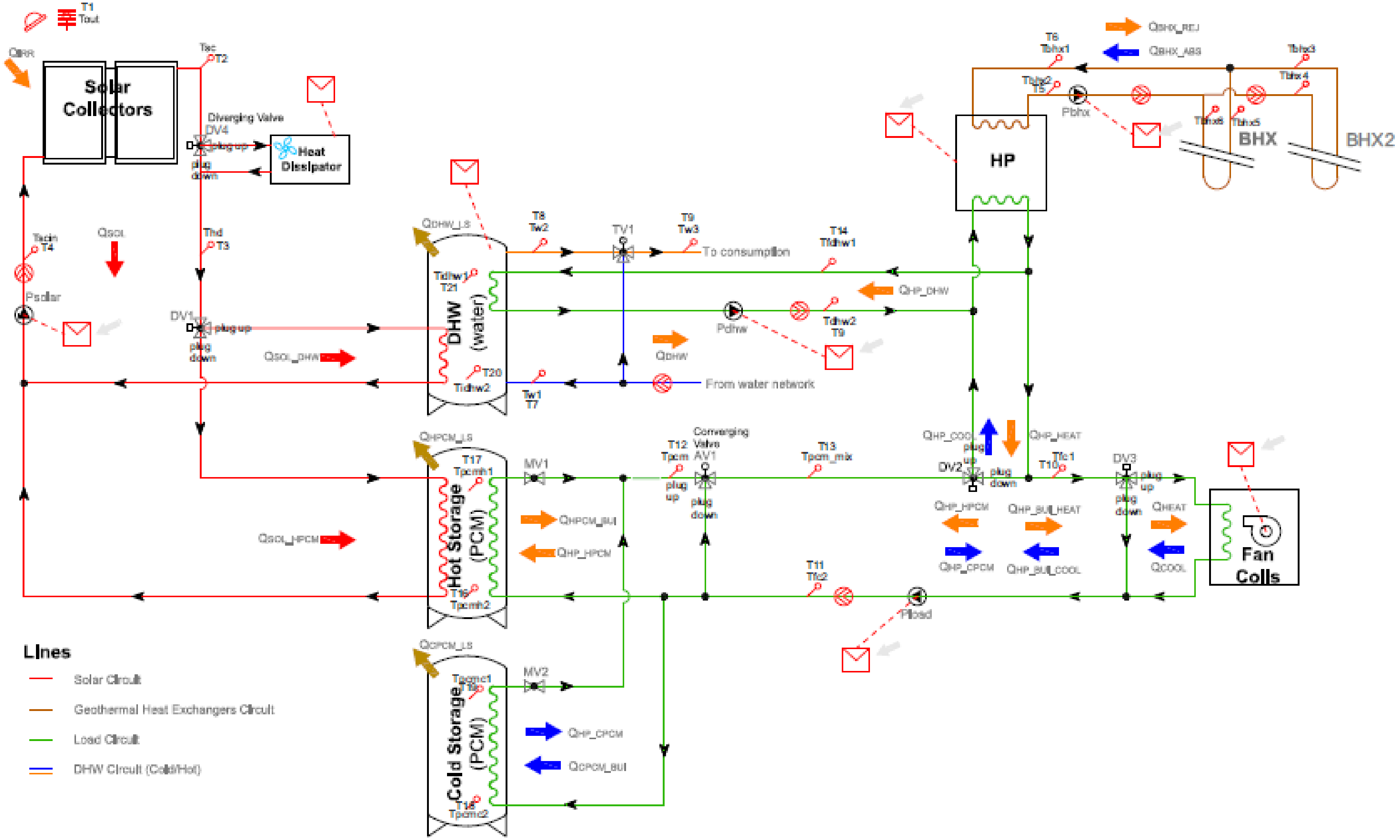
- Evaluation of demo-site **geology** and **petro-physical properties** of the rocks, suggestion of the **drilling method** to be used on the site;
- Approval process under **water law**;
- Technical and geological **supervision of the works**;
- **Geological drilling support**, support and analysis geophysical borehole logging;
- **Transport** of the **TESSe2b PCM thermal storage prototype** to the test building;
- **TESSe2b prototype installation** in the test building;
- Installation of **control equipment** and other **measuring and monitoring equipment**;
- **Testing of the TESSe2b solution** through monitoring of parameters that will assist the evaluation of system's performance in each climate. The evaluation of the system performance will take into account the soil temperature changes over 25 years;
- **Economical evaluation** of the TESSe2b solution by cost-benefit criteria in respect of all the parameters that affect its design, operation, maintenance and performances.

TESSe2B
the smart energy storage

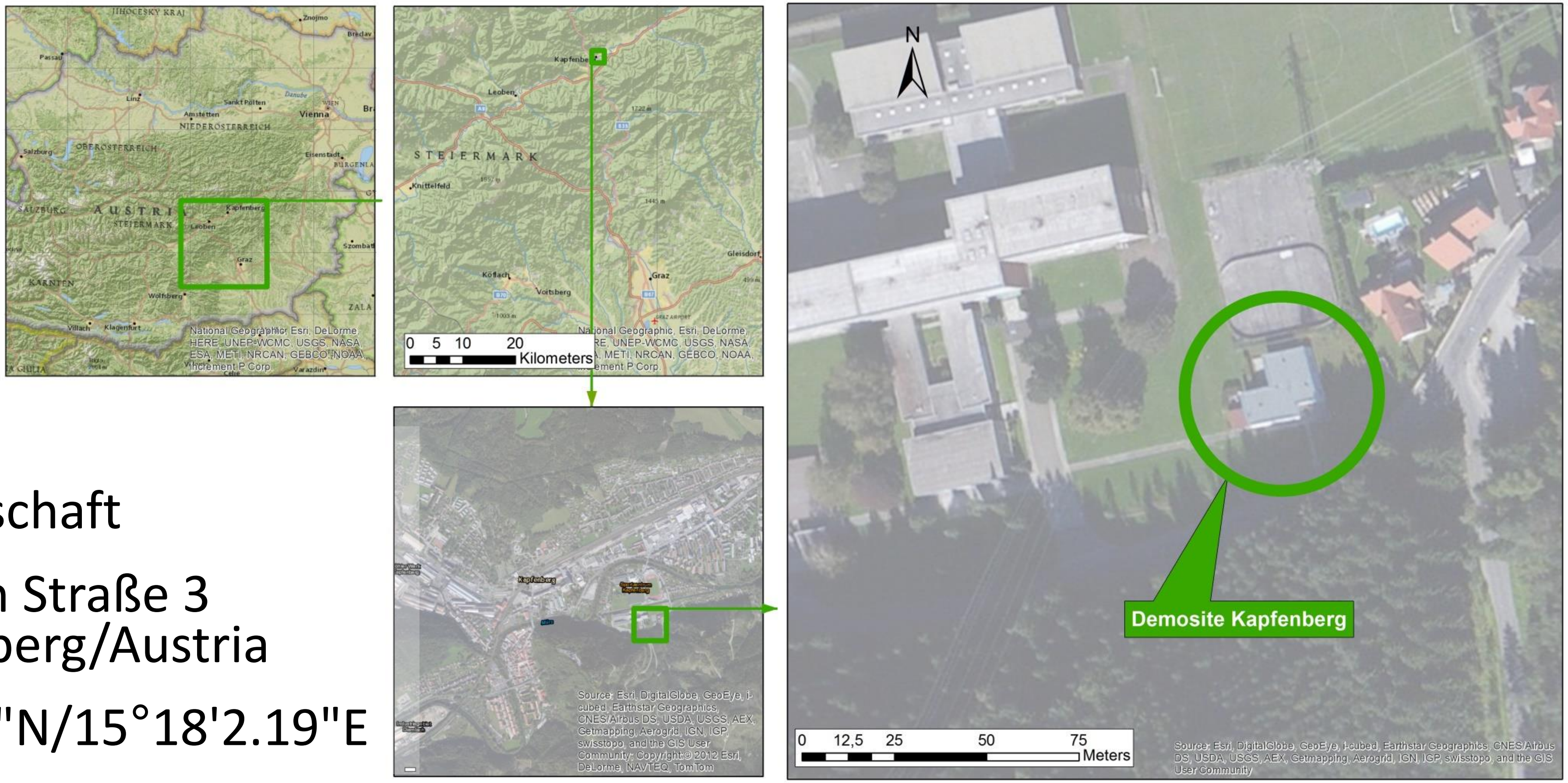
Thermal Energy Storage Systems
for energy efficient building an integrated solution for residential building energy storage by solar and geothermal resources

European Commission

TESSe2b Configuration



WP 7.1 – Demo Site Austria - Location



- Owner: BIG, Bundesimmobiliengesellschaft
- Address: Viktor-Kaplan Straße 3
  8605 Kapfenberg/Austria
- Coordinates:47°26'30.26"N/15°18'2.19"E

WP 7.1 – Demo Site Austria - Basics

Location: within the grounds of a technical school.

Utilisation: accomodation of the janitor and his family.

WP 7.1 – Demo Site Austria – Basics

- Dwelling Area: 202 m^2
- Year of construction: 2003
  38 cm Solid Brick
- Thermal insulation: 2010
  Base: 16 cm EPS
  Walls: 18 cm EPS (?)
  Roof: 14 cm Mineral Rock Wool
- Current tenants: 3 Pers.

WP 7.1 – Demo Site Austria – Heating System

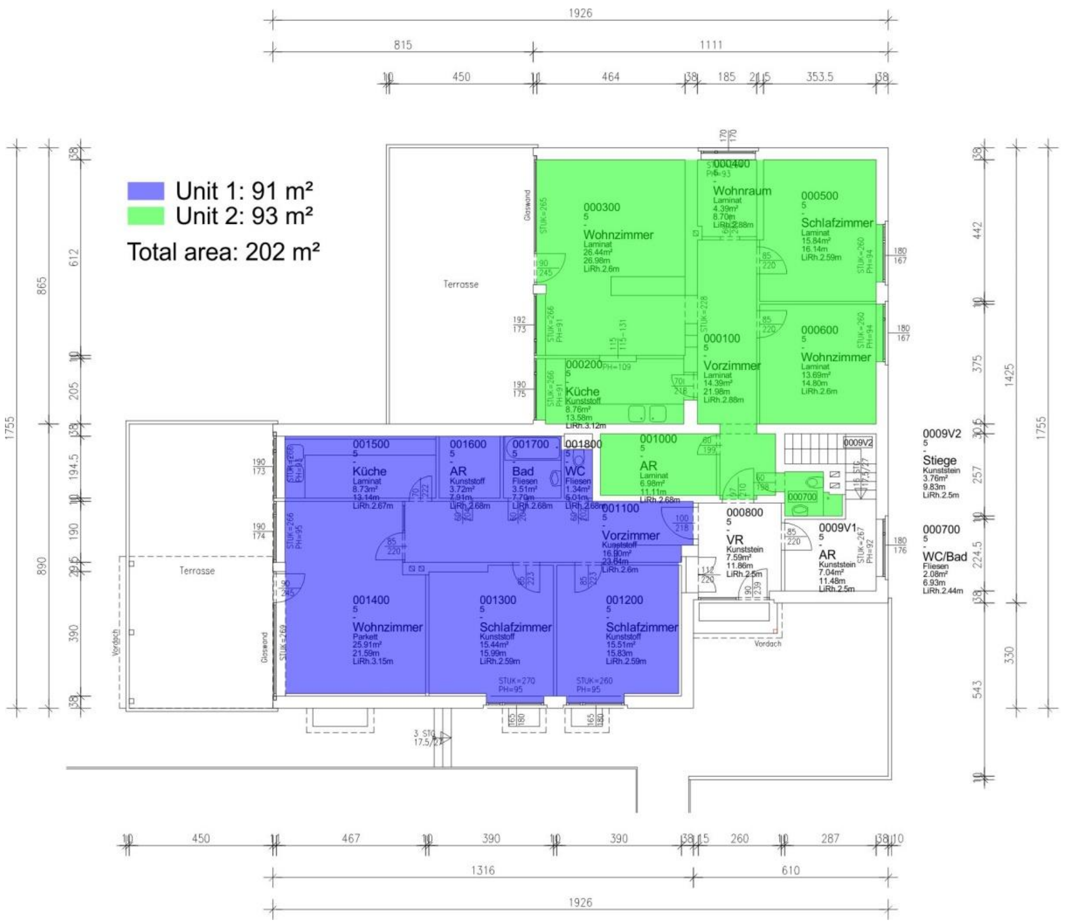
<u>Current solution:</u>

- Heating System:
  Oil, for heating and DHW
  Radiators; outgoing temperature ~60 °C

- Heating Power:
  33 – 37 kW
  (oversized since the thermal insulation 2010)

WP 7.1 – Demo Site Austria – Current Situation

- ▷ 2 dwelling units.
- ▷ Unit 1: 3 tenants.
- ▷ Unit 2: Currently not in use because of floor damages due to ground heaving; heated during winter.



WP 7.1 – Demo Site Austria – TESSe2b solution

- Unit 1:
  Can be adapted to **floor or wall heating**.
- With **wall heating cooling** will be possible.
- Unit 2:
  Renovation of floor damages scheduled for 2018. Installation of **floor or wall heating** is feasible.
- Energy sources:
  - Installation one **GSHP** and **BHE with PCMs**;
  - Installation of vacuum solar collectors;
- Thermal Energy Storage:
  - **Hot PCM tanks**, **Cold PCM tanks**, **DHW tank with PCM**.

WP 7.1 – Demo Site Austria – Area for BHEs

- Area for BHEs: 25 m x 12 m

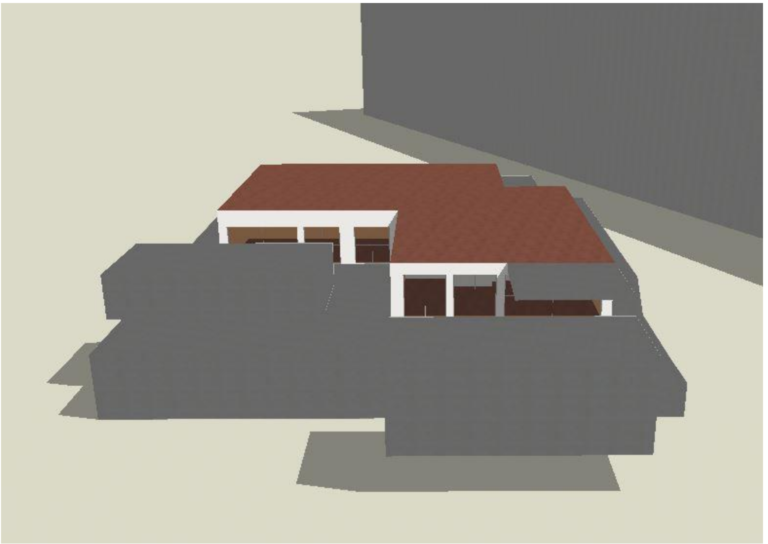
Energy Building Simulation

Preliminary remarks

- The results shown in the following slides have obtained from a **first analysis** done by the studies developed so far. **They are not the final results**.
- For these studies it was **assumed**, in case of doubts, **the most unfavorable conditions** to avoid negative surprises in the future.
- Thus **it is expected** that after studies in the next stages and after the optimization of the system and their components, **obtain better results.**

Energy Building Simulation – Demo Site in Austria

Energy simulation made by Design Builder software (http://www.designbuilder.co.uk/).



Hourly Heating Analysis, including solar collectors and DHW needs.

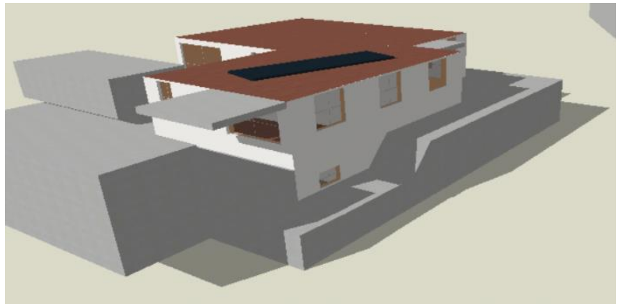
Assumptions:

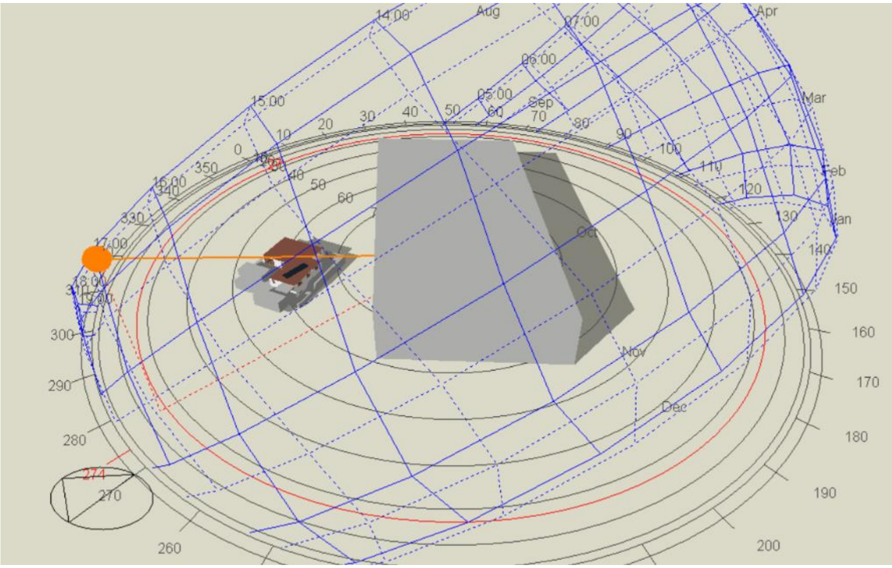
- Indoor temperatures: 22ºC (heating); 25ºC (cooling);
- Solar Collectors: Vacuum tubes; Efficiency=0.768-1.36T*-0.0053GT*^{2}
- DWH: 4 persons, 160 liters per day; 45ºC; estimated usage profile;
- Heating and cooling diffusion system: heating floor, cooling walls;
- Utilization Schedules for heating and cooling: 24h/per day, 365 days per year;
- Available solar energy priorities: 1st: DHW; 2nd: Heating Needs and Charging of HPCM tank.

Predicted heating and cooling capacities and energy needs

Mode	Capacity (kW)	Capacity (W/m^2) c)	Capacity (W/m^2) d)	Anual needs (kWh)	Anual needs (kWh/m^2) c)	Anual needs (kWh/m^2) d)	Worst Daily needs (kWh)
Heating	17,51 a)	55,2	87,7	26168,3	81,4	129,3	260,9 e)
Cooling	6,52 b)	19,5	30,9	4226,4	13,1	20,9	102,1 f)

a) February 18; 07:00
b) August 11; 18:00
c) Total area: 321,5 m^2
d) Occupied area: 202,4 m^2
e) February 14
f) August 11



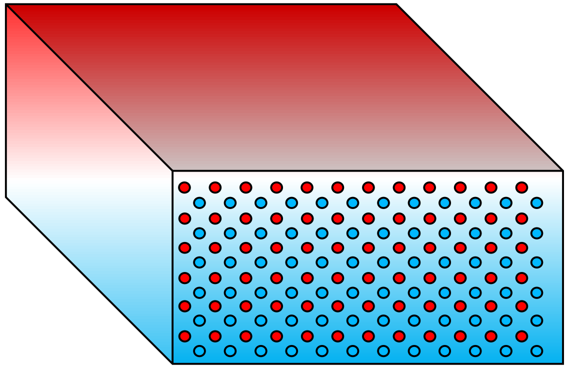


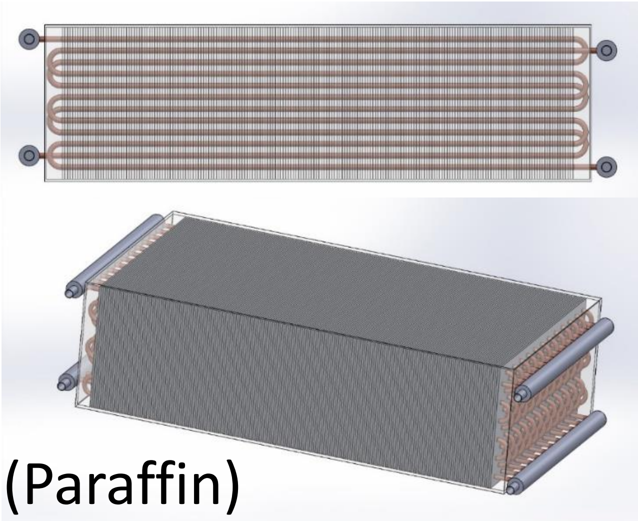
- Heating season: October to May;
- Cooling season: June to September

Solar Collectors
(10, 21.5m^2)

Vacuum tubes

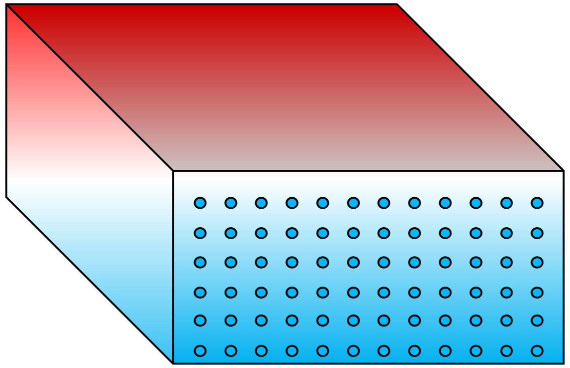
Hot PCM Tanks
(4 tanks)





A44 (Paraffin)

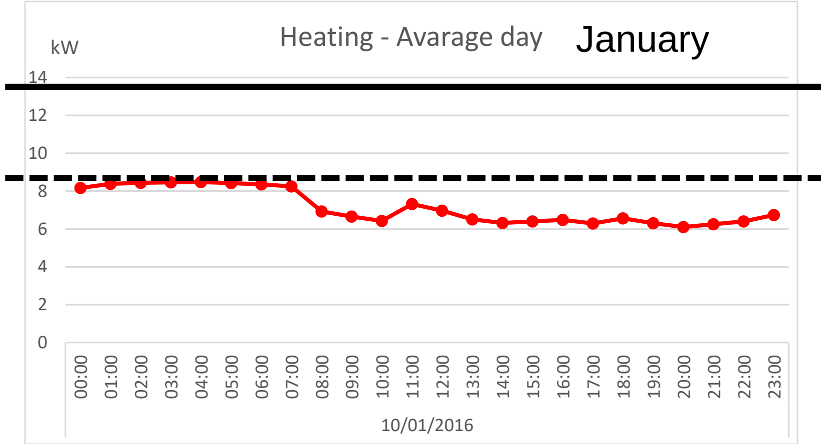
Cold PCM Tanks
(2 tanks)



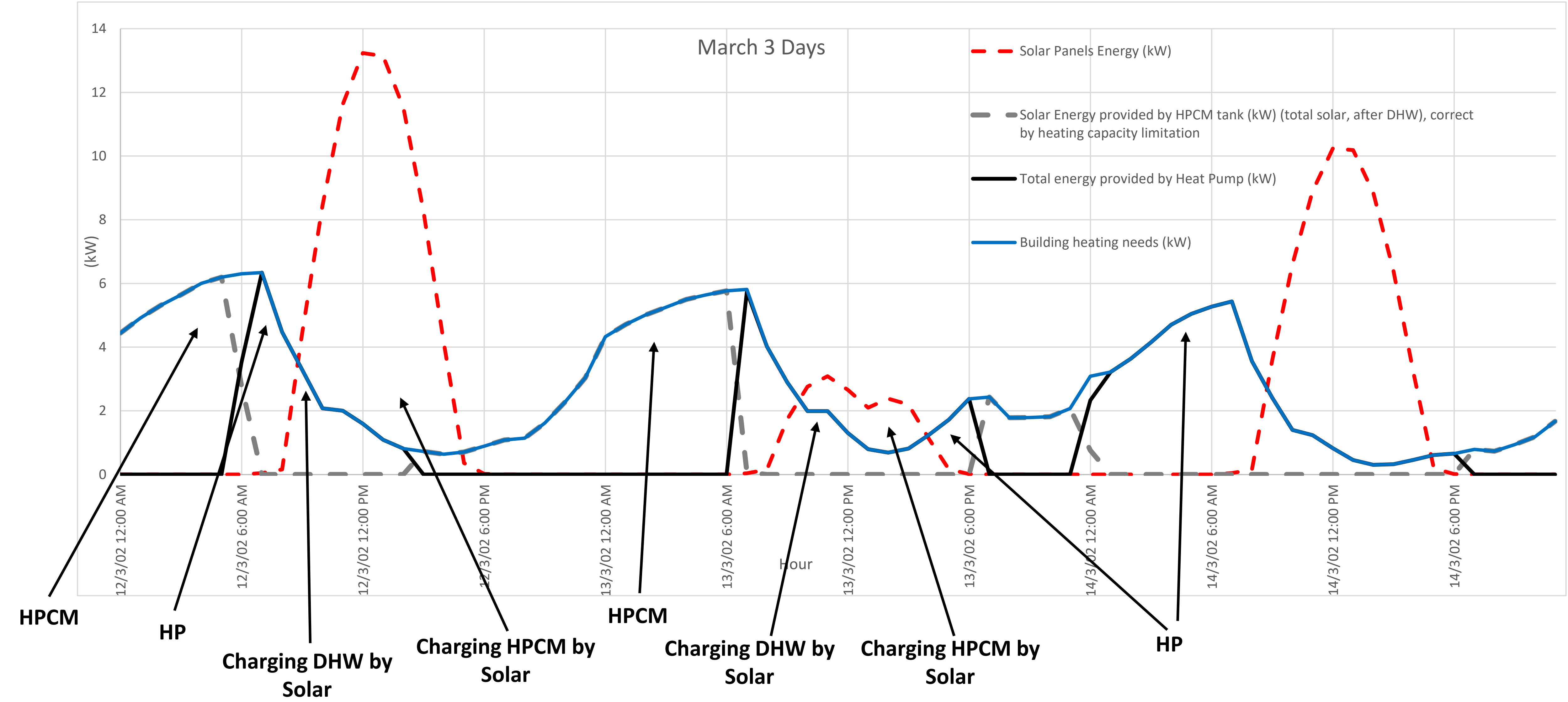
A9 (Paraffin)

± 250 liters each

Operation with the Hot PCM Tanks.



- <u>**Maximum heating capacity needed from house:**</u> **13.7 kW**
- <u>**Maximum heating capacity of HPCM tanks (4 tanks):**</u> **8,6 kW**
- <u>**Maximum heating needs, per day:**</u> **260,9 kWh**
- <u>**Maximum heat energy storage, per day (4 tanks):**</u> **48,4 kWh**

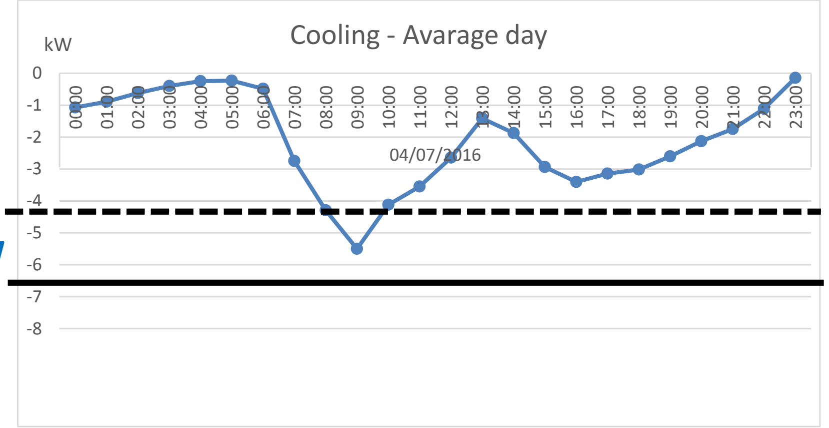

March 3 Days
Solar Panels Energy (kW)
Solar Energy provided by HPCM tank (kW) (total solar, after DHW), correct by heating capacity limitation
Total energy provided by Heat Pump (kW)
Building heating needs (kW)
(kW)
Hour
14
12
10
8
6
4
2
0
12/3/02 12:00 AM
12/3/02 6:00 AM
12/3/02 12:00 PM
12/3/02 6:00 PM
13/3/02 12:00 AM
13/3/02 6:00 AM
13/3/02 12:00 PM
13/3/02 6:00 PM
14/3/02 12:00 AM
14/3/02 6:00 AM
14/3/02 12:00 PM
14/3/02 6:00 PM
HPCM
HP
Charging DHW by Solar
Charging HPCM by Solar
HPCM
Charging DHW by Solar
Charging HPCM by Solar
HP

Energy Analysis Results heating and DHW (annual)	
Total of solar energy absorbed by solar collectors (kWh)	20,0
Building heating needs (kWh)	26168,3
DHW needs (kWh)	2416,4
Total needs (kWh)	28584,6
DHW needs covered by solar (kWh)	2141,3
Solar Fraction DHW	**88,6%**
Building heating needs Oct-May (kWh)	25855,3
Building heating needs convered by Solar Oct-May (kWh)	2752,1
Solar Fraction building heating needs Oct-May	**10,6%**
Building heating needs and DHW convered by Solar Oct-May (kWh)	4893,4
Solar Fraction building heating needs Oct-May + DHW	**17,1%**

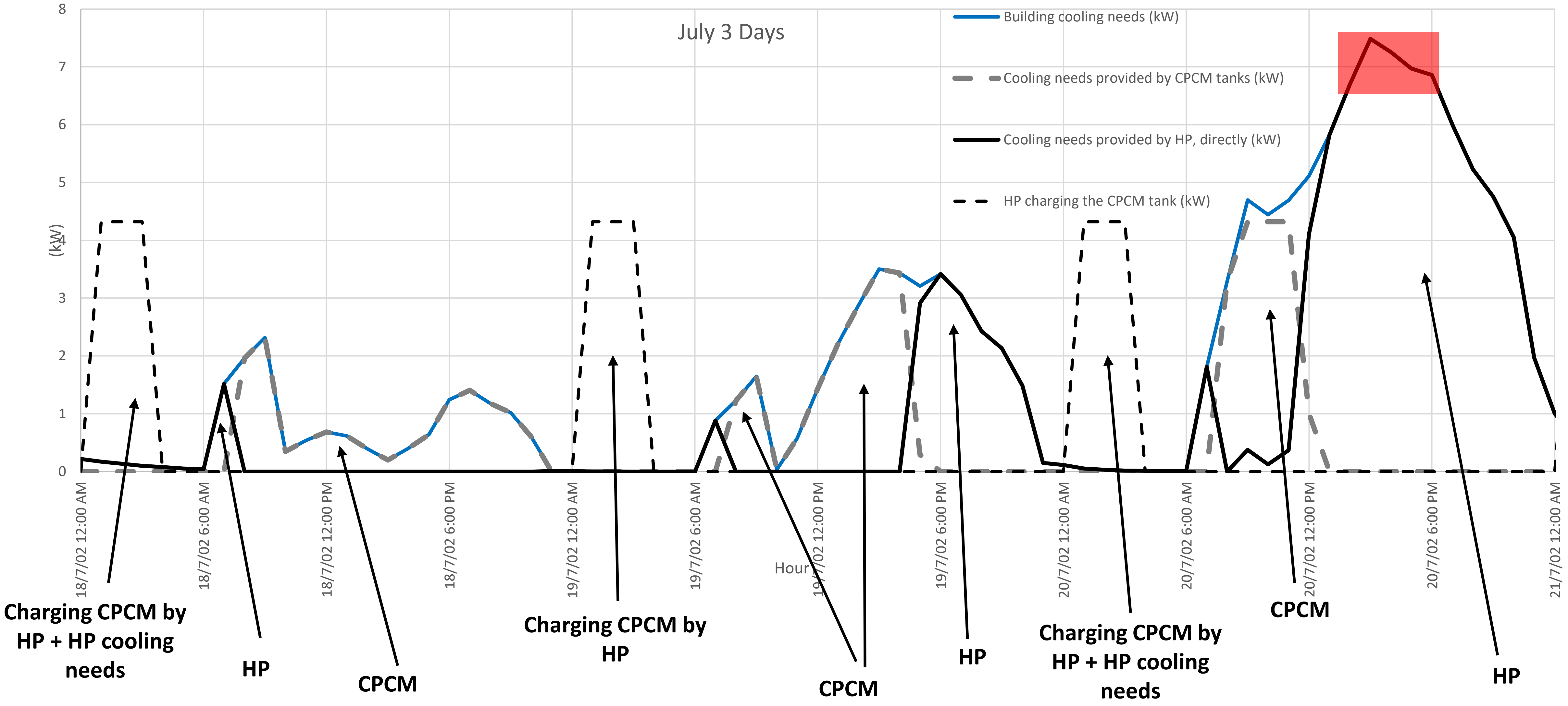
For the **Austria** demo site, due the **limitation of available solar energy**, and considering a **acceptable dimension of the installation**, it is possible to achieve only **11% of solar fraction for heating** needs and **17% for total heating and DHW** needs. Future effort it will be made to increase this value.

Building heating needs convered by Solar without HPCM tanks Oct-May (kWh)	947,1
Solar Fraction building heating needs without HPCM tanks Oct-May	**3,7%**
Increase of Solar Fraction building heating needsdue to the HPCM tanks Oct-May	**7,0%**

Operation of the Cold PCM Tank.



- ❑ **Maximum cooling capacity needed from house:** 6,5 kW
- ❑ **Maximum cooling capacity of CPCM tanks (2 tanks):** 4,3 kW
- ❑ **Maximum cooling needs, per day:** 102,1 kWh
- ❑ **Maximum cold energy storage, per day (2 tanks):** 17,3 kWh


July 3 Days
Building cooling needs (kW)
Cooling needs provided by CPCM tanks (kW)
Cooling needs provided by HP, directly (kW)
HP charging the CPCM tank (kW)
(kW)
8
7
6
5
4
3
2
1
0
18/7/02 12:00 AM
18/7/02 6:00 AM
18/7/02 12:00 PM
18/7/02 6:00 PM
19/7/02 12:00 AM
19/7/02 6:00 AM
19/7/02 12:00 PM
19/7/02 6:00 PM
20/7/02 12:00 AM
20/7/02 6:00 AM
20/7/02 12:00 PM
20/7/02 6:00 PM
21/7/02 12:00 AM
Hour
Charging CPCM by HP + HP cooling needs
HP
CPCM
Charging CPCM by HP
CPCM
HP
Charging CPCM by HP + HP cooling needs
CPCM
HP

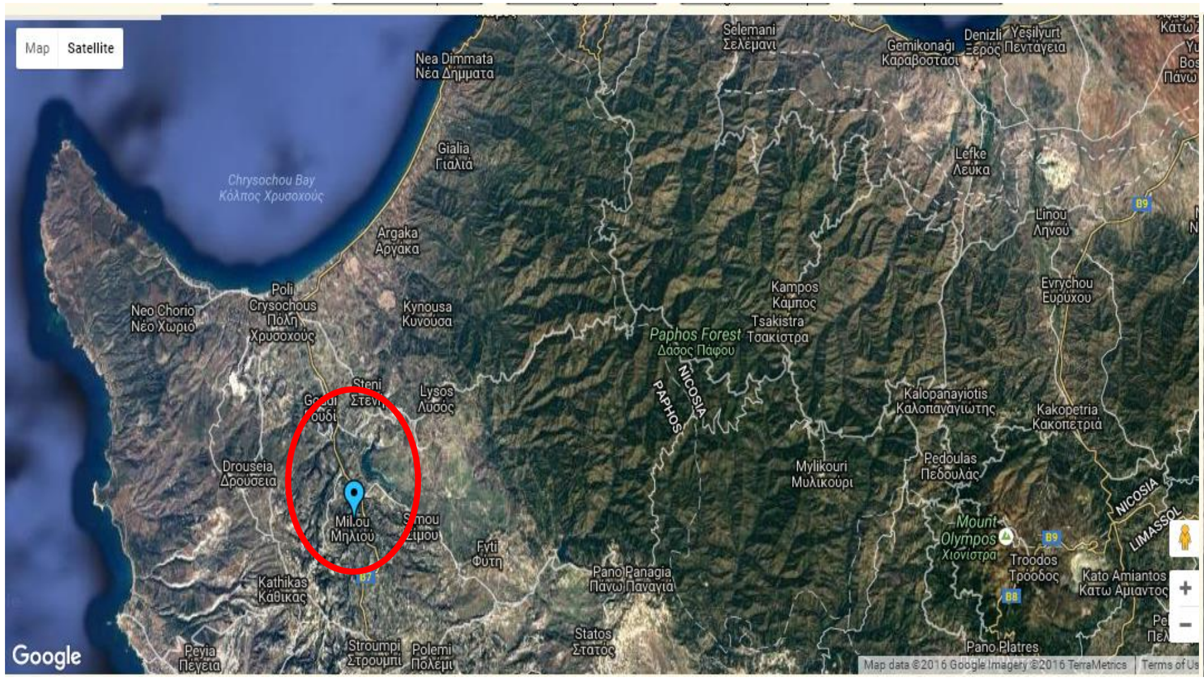
Energy Analysis Results Cooling Needs (annual)	
Building cooling needs (kWh)	4226
Building cooling needs April-Oct (kWh)	4222
Building cooling needs April-Oct (kWh) 08:00 - 24:00	4092
Building cooling needs April-Oct (kWh) 00:00 - 07:00	134
Provide cooling needs, shifted to the night period, 00:00 - 07:00	1804
Percentage of shifted provide cooling needs	**44,1%**

For **Austria**, installing **2 CPCM tanks** it is possible to **shift 44%** of cooling production from the day period to the night period.

Task 7.2 – Demo Site Cyprus

Selected House

- **Use:** residential house
- **Owner:** Mrs Despo Christou
- **Location:** Meliou village, a small traditional village, 35km from Pafos town airport and 14km from the Latchi beach area. The house is built in a plot of 3500m^2, which is at a high of 420 m from the sea level.
- **Area (m^2):** 180m^2 (100m^2 of ground floor and 80m^2 of first floor).



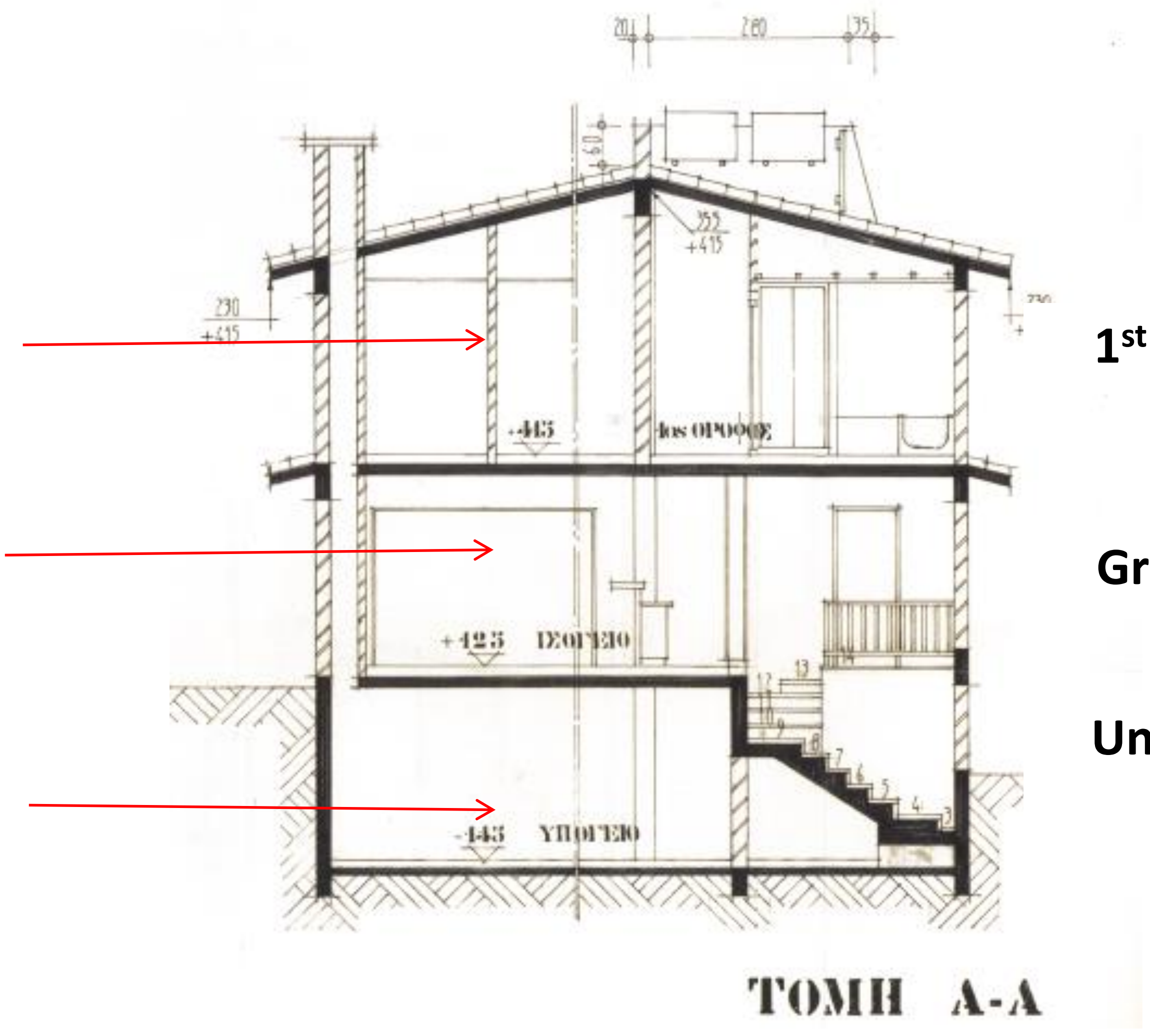
THE LOCATION OF THE VILLAGE MILIOU

Selected House (PHOTOS)

Task 7.2 – Demo Site Cyprus

Selected House

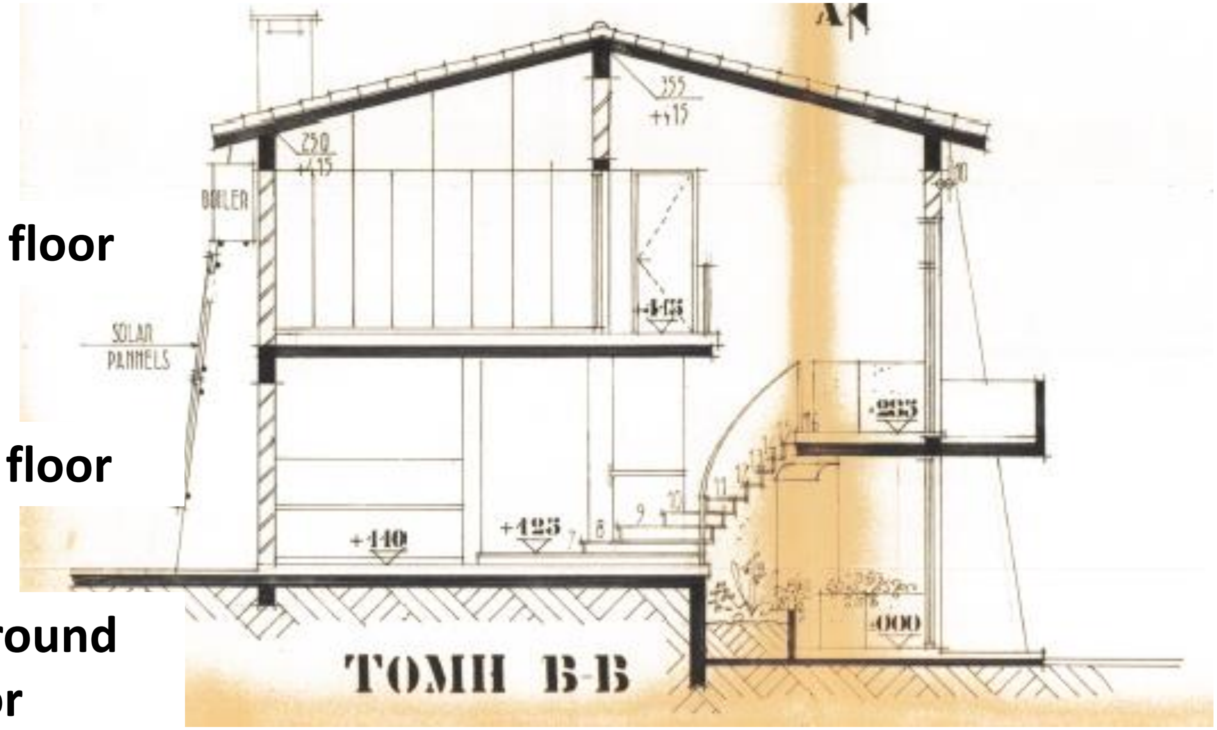
- **Construction details:**
  - The house is 28 years old and it's in good condition.
  - The building is made of brick plastered walls and roof tiling.
  - The underground area is rich in geothermal energy due to the number of water springs and underground waters.
- **Heating and Cooling (current solution):**
  - Oil fired boiler and burner and radiators.
  - Split units.
- **DHW production (current solution):**
  - The existing domestic hot water system is a solar system with two solar panels and hot water cylinder on the roof with emergency 3 kW electronic element. The hot water cylinder is also connected to the oil boiler.



1st floor floor

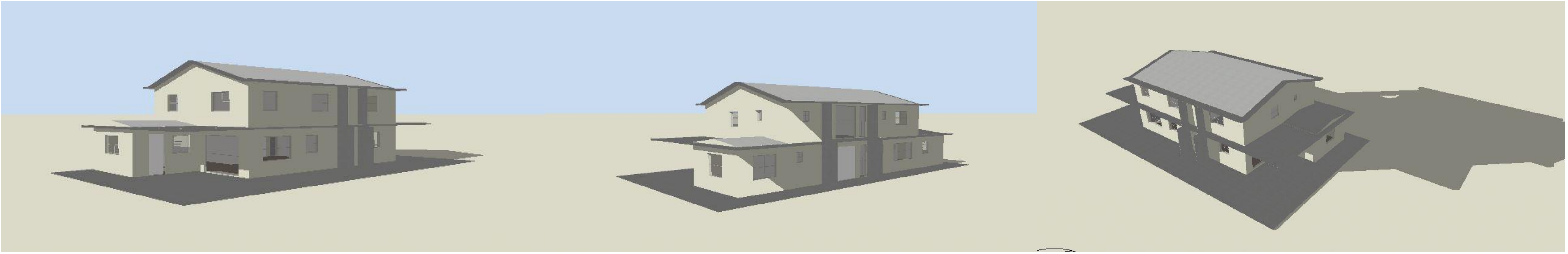
Ground floor

Underground floor



Energy Building Simulation – Demo Site in Cyprus

Energy simulation made by Design Builder software (http://www.designbuilder.co.uk/).



Hourly Heating Analysis, including solar collectors and DHW needs.

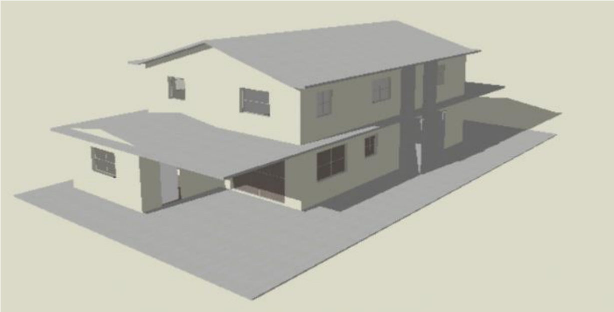
Assumptions:

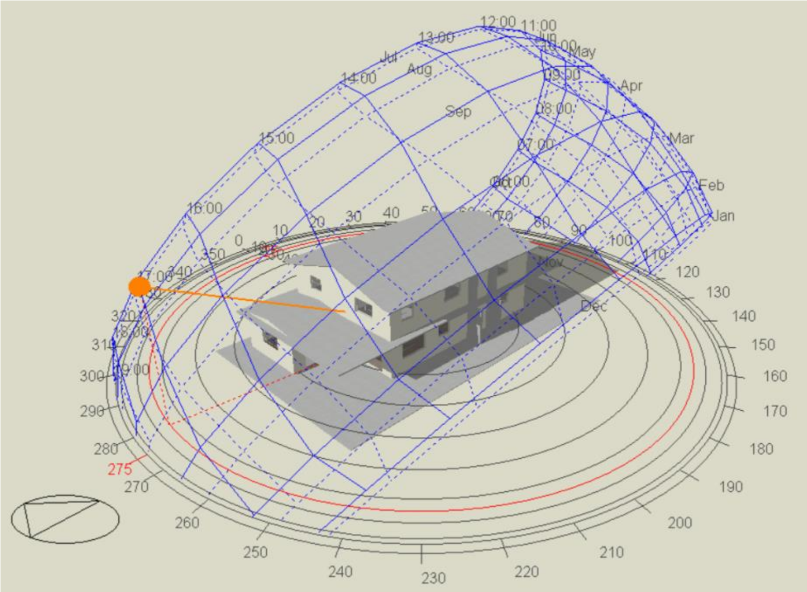
- Indoor temperatures: 20ºC (heating); 25ºC (cooling);
- Solar Collectors: Flat Panel; Efficiency=0.818-3.748T*-0.0016GT*^{2}
- DWH: 4 persons, 160 liters per day; 45ºC; estimated usage profile;
- Heating and cooling diffusion system: fan-coils;
- Utilization Schedules for heating or cooling: depending of the room;
- Available solar energy priorities: 1st: DHW; 2nd: Heating Needs and Charging of HPCM tank.

Predicted heating and cooling capacities and energy needs

Mode	Capacity (kW)	Capacity (W/m²) c)	Capacity (W/m²) d)	Anual needs (kWh)	Anual needs (kWh/m²) c)	Anual needs (kWh/m²) d)	Worst Daily needs (kWh)
Heating	17,03 a) g)	82,7	82,7	10020,2	45,4	45,4	186,3 e)
Cooling	18,56 b)	84,1	84,1	15559,1	70,5	70,5	161,5 f)

Notes:
a) February 04; 06:00
b) August 10; 20:00
c) Total area: 220,68 m^2
d) Occupied area: 220,68 m^2
e) February 05
f) July 28
g) 50% steady state (without internal loads), 50% dynamic conditions





- ❑ <u>Heating season</u>: November to April (middle);
- ❑ <u>Cooling season</u>: April (middle) to October

Energy Analysis Results heating and DHW (annual)	
Total of solar energy absorbed by solar collectors (kWh)	14,0
Building heating needs (kWh)	10020,2
DHW needs (kWh)	2416,4
Total needs (kWh)	12436,6
DHW needs covered by solar (kWh)	2523,3
Solar Fraction DHW	**100,0%**
Building heating needs Nov-Apr (kWh)	10006,4
Building heating needs convered by Solar Nov-Apr (kWh)	2934,6
Solar Fraction building heating needs Nov-Apr	**29,3%**
Building heating needs and DHW convered by Solar Nov-Apr (kWh)	5457,9
Solar Fraction building heating needs Nov-Apr + DHW	**43,9%**

Solar Collectors, flat plate (10, 23.7m^2)

Hot PCM Tanks (3 tanks)

Cold PCM Tanks (3 tanks)

For **Cyprus** demo site, with the proposed system it is possible to achieve about **30% of solar fraction for heating** needs and **44% for total heating and DHW** needs.

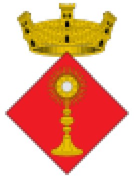
Building heating needs convered by Solar without HPCM tanks Oct-May (kWh)	296,1
Solar Fraction building heating needs without HPCM tanks Oct-May	**3,0%**
Increase of Solar Fraction building heating needsdue to the HPCM tanks Oct-May	**26,4%**

Energy Analysis Results Cooling Needs (annual)	
Building cooling needs (kWh)	15559
Building cooling needs May-Oct (kWh)	15431
Building cooling needs May-Oct (kWh) 08:00 - 24:00	13172
Building cooling needs May-Oct (kWh) 00:00 - 07:00	2387
Provide cooling needs, shifted to the night period, 00:00 - 07:00	3930
Percentage of shifted provide cooling needs	**29,8%**

For **Cyprus**, installing **3 CPCM tanks** it is possible to **shift 30%** of cooling production from the day period to the night period.

Task 7.3 Demo site Spain

Selection process in Spain



- Location: Calonge de Segarra
  - Population: 202
  - Surface: 37 km^2
  - Mayor: Xavier Nadal Massana
  - Last elections: 2015

Selection process in Spain

- **House**
  - Surface: 150 m^2
  - Ownership: Municipality
  - Use: Social Housing
  - Tenants: Family 4 members
  - Garden: Yes

Part of the house will be renovated this winter (windows, new coating of walls and pavements, new arrangement of the rooms and new heating, cooling and DHW system)

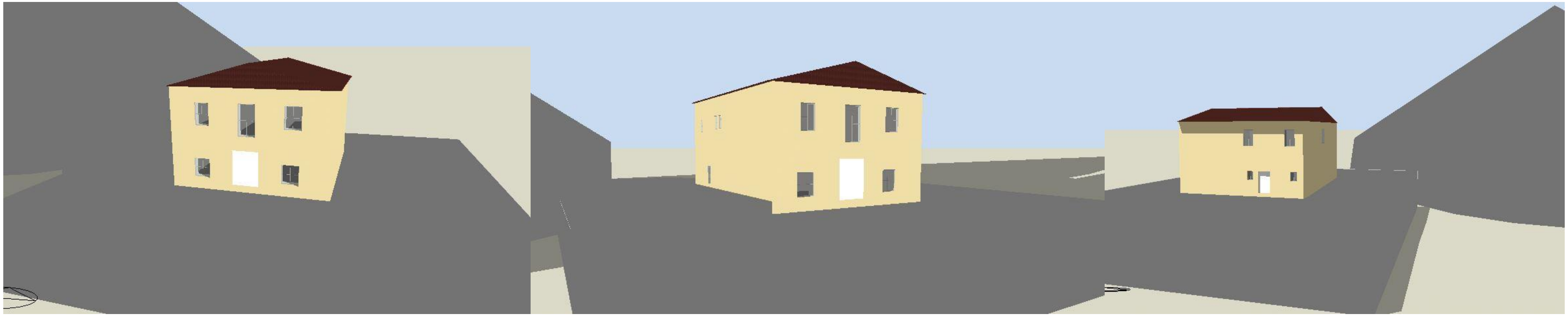
Thermal Energy Storage Systems
for energy efficient building an integrated solution for residential building energy storage by solar and geothermal resources






Energy Building Simulation – Demo Site in Spain

Energy simulation made by Design Builder software (http://www.designbuilder.co.uk/).



Hourly Heating Analysis, including solar collectors and DHW needs.

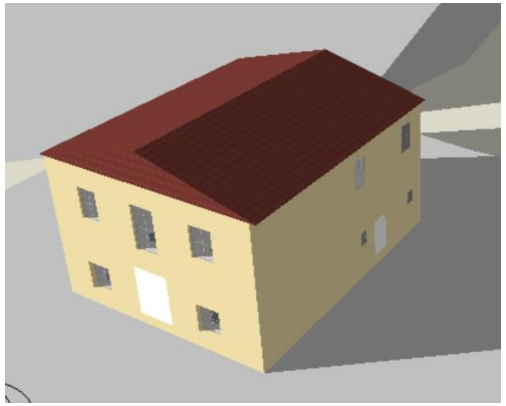
Assumptions:

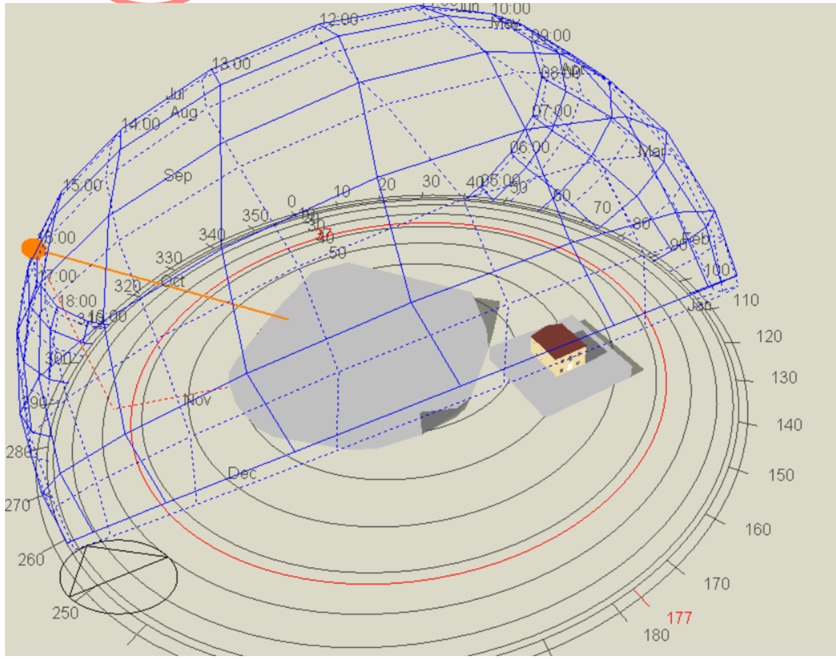
- Indoor temperatures: 20ºC (heating); 25ºC (cooling);
- Solar Collectors: Flat Panel; Efficiency=0.818-3.748T*-0.0016GT*^{2}
- DWH: 4 persons, 160 liters per day; 45ºC; estimated usage profile;
- Heating and cooling diffusion system: fan-coils;
- Utilization Schedules for heating or cooling: depending of the room;
- Available solar energy priorities: 1st: DHW; 2nd: Heating Needs and Charging of HPCM tank.

Predicted heating and cooling capacities and energy needs

Mode	Capacity (kW)	Capacity (W/m^2) c)	Capacity (W/m^2) d)	Anual needs (kWh)	Anual needs (kWh/m^2) c)	Anual needs (kWh/m^2) d)	Worst Daily needs (kWh)
Heating	15,0 a) g)	109,8	109,8	8863,0	64,9	64,9	139,1 e)
Cooling	7,03 b)	51,5	51,5	2034,6	14,9	14,9	46,2 f)

a) January 12; 07:00
b) July 26; 20:00
c) Total area: 136,61 m2
d) Occupied area: 136,61 m2
e) January 12
f) August 10
g) 50% steady state (without internal loads), 50% dynamic conditions





- Heating season: October to May;
- Cooling season: June to September

Energy Analysis Results heating and DHW (annual)	
Total of solar energy absorbed by solar collectors (kWh)	14,0
Building heating needs (kWh)	8863,0
DHW needs (kWh)	2416,4
Total needs (kWh)	11279,4
DHW needs covered by solar (kWh)	2307,8
Solar Fraction DHW	**95,5%**
Building heating needs Oct-May (kWh)	8860,1
Building heating needs convered by Solar Oct-May (kWh)	2630,3
Solar Fraction building heating needs Oct-May	**29,7%**
Building heating needs and DHW convered by Solar Oct-May (kWh)	4938,1
Solar Fraction building heating needs Oct-May + DHW	**43,8%**

Solar Collectors, flat plate (9, 21.3m^2)

Hot PCM Tanks (3 tanks)

Cold PCM Tanks (3 tanks)

For **Spain** demo site, with the proposed system it is possible to achieve about **30% of solar fraction for heating** needs and **44% for total heating and DHW** needs.

Building heating needs convered by Solar without HPCM tanks Oct-May (kWh)	299,8
Solar Fraction building heating needs without HPCM tanks Oct-May	**3,4%**
Increase of Solar Fraction building heating needsdue to the HPCM tanks Oct-May	**26,3%**

Energy Analysis Results Cooling Needs (annual)	
Building cooling needs (kWh)	2035
Building cooling needs April-Oct (kWh)	2033
Building cooling needs April-Oct (kWh) 08:00 - 24:00	1697
Building cooling needs April-Oct (kWh) 00:00 - 07:00	338
Provide cooling needs, shifted to the night period, 00:00 - 07:00	1231
Percentage of shifted provide cooling needs	**72,6%**

For **Spain**, installing **2 CPCM tanks** it is possible to **shift 73%** of cooling production from the day period to the night period.

Conclusions:

- The **first design** of the installation is done for the three demo sites;
- The **heating and cooling capacities** as well as the **heating and cooling needs** are **already defined**;
- The **number of solar collectors** and **Hot PCM Tanks**, for each demo site is **already estimated**;
- The **performance of HPCM tanks** has the possibility to **be improved**, by **improving the heat transfer rate** inside the tank using **nano enhanced paraffin PCM**;
- In the next period it **will be made optimization** tests based on the **CFD simulations** and on **experimental works**;

Conclusions:

- To optimize the **number of the HPCM tanks**, for **Austria and Spain**, it is also necessary to **study the effect of the PCM in the BHEs** and its effect in the **efficiency of the Heat Pump**;
- It was made a **pre-design of the Cold PCM Tanks**, based in the **shift of some cooling production from day period to the night period** (0 A.M to 8 A.M., **low electricity tariffs typical period**);
- To optimize the **number of CPCM tanks**, for **Cyprus**, it is also necessary to **study the effect of the PCM in the BHEs** and its effect in the **efficiency of the Heat Pump**;
- It is necessary to **extend the study to all tariff schemes** for each demo site;

Conclusions:

- The development of the **TESSe2b smart control system** will **increase the energy performance** of the entire proposed system.

- The **final configuration** of the installation for each demo site (solar collectors area; number of HPCM and CPCM tanks, it **will be defined after the economical study**;

- **With the work developed so far**, the **solution proposed** by the project seems to be **quite promising, with regard to the previously defined objectives**.

TESSe2B
the smart energy storage

Thank for your attention

Thermal Energy
Storage Systems

for energy efficient building an integrated solution for residential building energy storage by solar and geothermal resources

European Commission