ENERGY EFFICIENCY OF DRY WALL CONSTRUCTION WITH THERMAL STORAGE

Projects financed by the EC:

- **I-SSB, FP6 - Thematic priority 3 – NMP (2007-2011): www.issb-project.com**
- **MESSIB, FP7 – Theme 4 – NMP (2009-2013): www.messib.eu**
- **FC-DISTRICT, FP7 – Theme 4 – NMP (2010-2014): www.fc-district.eu**

CONTENTS OF PRESENTATION

- Overall characteristics of Dry-Wall construction
- Amphilochia Demo House
  - Construction
  - Energy Systems
- Energy Assessment of the Demo House
  - Monitoring
  - Results
  - Simulations
- Assessment of the Demo House
  - I-SSB: Environmental
  - I-SSB: Fire

Advantages of lightweight dry-wall, steel-frame as compared to massive construction

- Low dead load (= lower earthquake loads)
- Effective coupling of soft and rigid structures to reduce resonance effects
- In contrast to solid constructions, lightweight constructions support the earthquake safety.
- Ductile deformation behavior prior to collapse; infill masonry walls exhibit brittle and comparatively rigid deformation patterns that cause significant load transfer with dangerous, brittle and unannounced collapse that can even lead to total building collapse.
- Preservation of enclosing function even after severe structural damage
- Noise and low frequency ambient vibration insulation
- Drywall materials are a major advantage in re-modeling and renovation
- Flexible for re-decorations. Buildings are easier to adjust on the requirements.
- Less weight leads to less energy consumption and saves resources.
- Lightness has a positive impact on the stability and therefore the quality of the construction.

DEMO HOUSE AT KNAUF GYPSOPIIA ABEE- GR

The Amfilochia demo house in mid-west Greece, constructed at the premises of Knauf Gypsopiia ABEE at Stanos-Amphilochia

DEMO HOUSE AT KNAUF GYPSOPIIA ABEE- GR

HOUSE CHARACTERISTICS

Two-Storey building (ca. 140 m^2 area):

- Modular - Steel skeleton -Dry-wall systems
- *Ground floor* :kitchen, office and living room,
- *First floor*: master and auxiliary bedroom separated by a bathroom


The AMFILOCHIA demo house in Greece

Amfilochia Demo House

HOUSE CHARACTERISTICS



Construction within the **I-SSB project**:

- Steel Frame Building with Dry Wall Systems
- Special design to withstand earthquake loads – Special components with increased fire and earthquake resistance
- Equipped with sensors for passive and active control of wind loads and traffic noise – Wireless Monitoring over internet
- WiMAX System – Open Platform to accommodate various sensors

Thermal storage in wall elements and energy production/distribution systems **within the MESSIB project**:

- Wall elements equipped with temperature – humidity sensors for monitoring indoor air-conditions

m-CHP system installation based on SOFC **within the FC-DISTRICT project**:

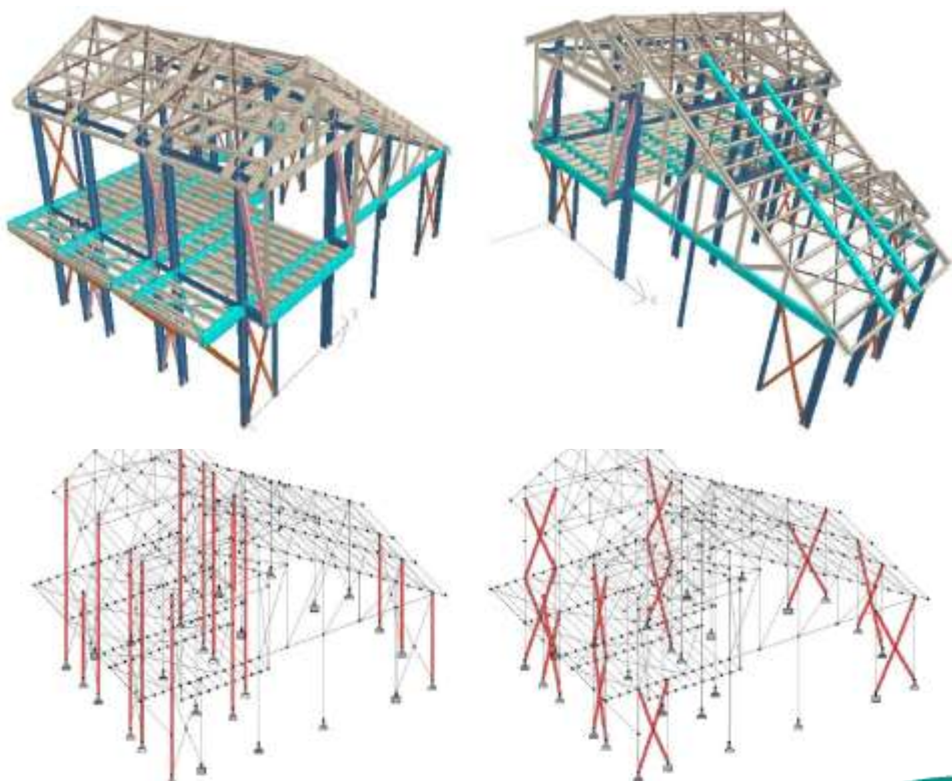
- Optimization of energy system control – Operational scenarios
- On line building monitoring: **http://demohouse.hmcs.mech.ntua.gr/demohouse_site/?lang=en_us**

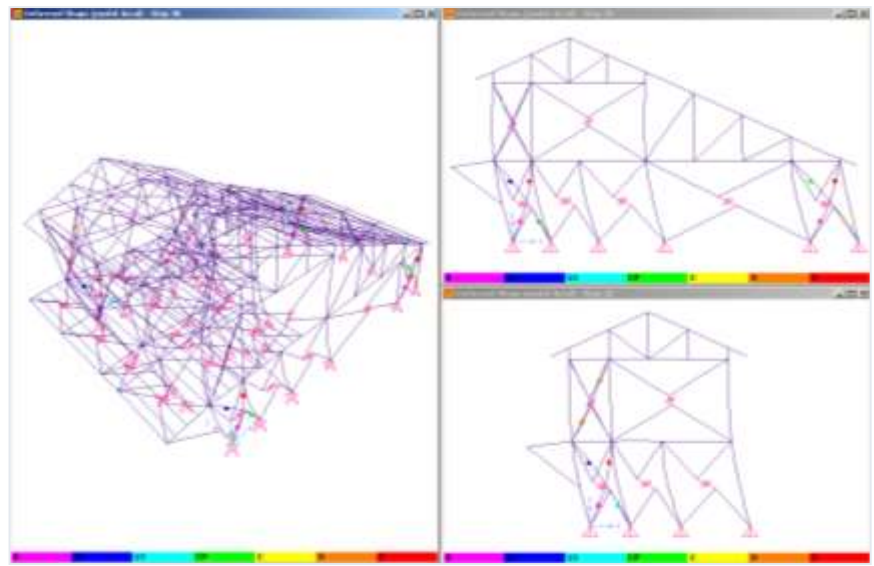
Amfilochia Demo House

ARCHITECTURAL - DESIGN

STATIC and DYNAMIC STRUCTURAL IMPROVEMENTS:

FEM analysis of wall and floor/ceiling elements. Mapping of seismic loads, wind loads and snow loads; Fragility Analyses; Failure Probabilities for different damage states; assessment of structural and non-structural damages



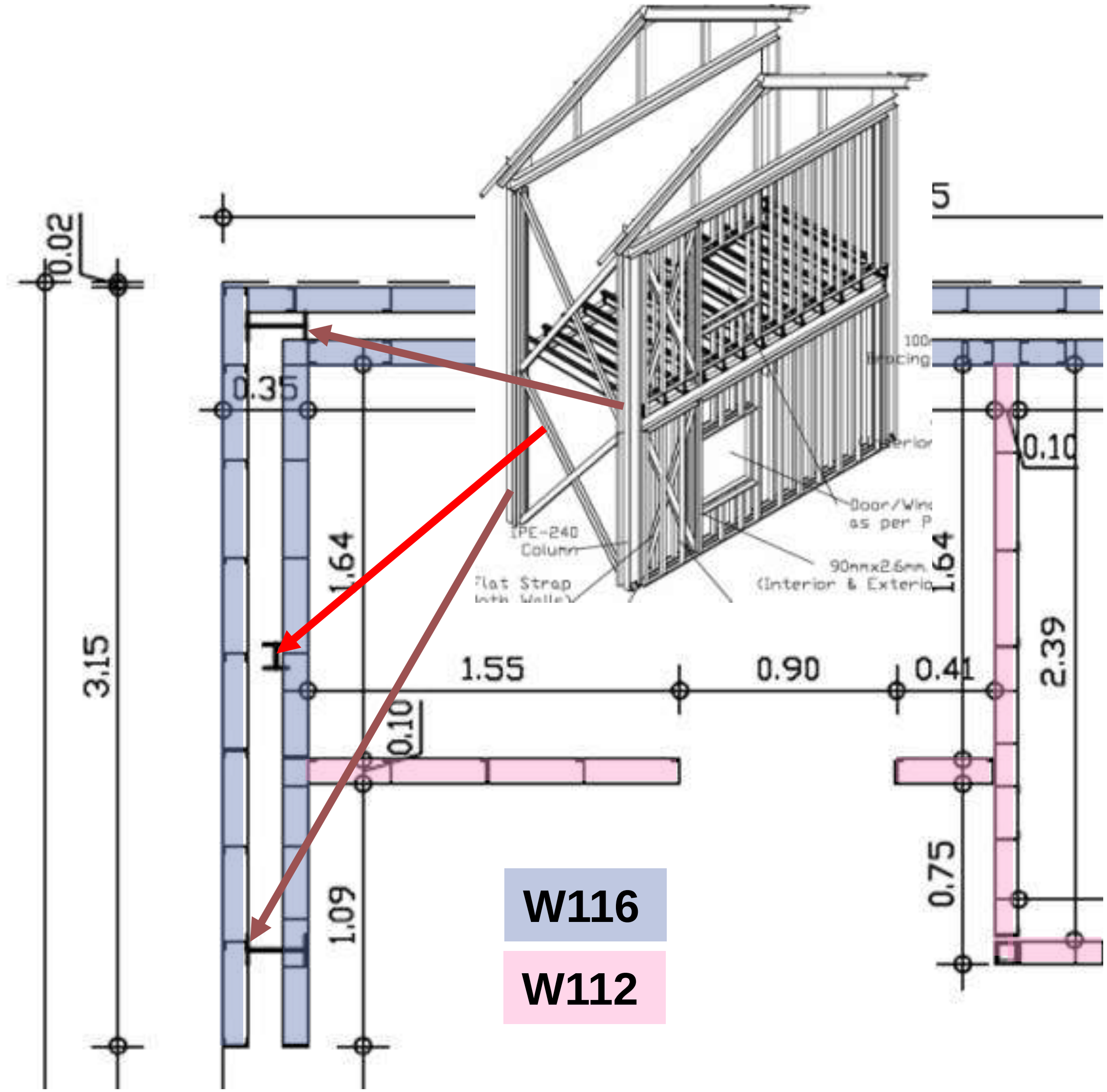


Work performed by IKODOMIA, WBI, CER, REL

Amfilochia Demo House

WALL CONSTRUCTION

- External wall (detail)
  - Double wall
  - 2 x W116
  - 100mm gap
    for steel frame
    and piping
- Internal wall (detail)
  - Single wall
  - 1 x W112
- Internal Walls/floors/roof: Special Dry Wall Systems
  - Grpahite-Thermoboards, Fireboards, PCM-Smartboards



Amfilochia Demo House

EXTERNAL WALLS

Construction

- Heavy Steel skeleton with CFS members (Compliance with EuroCode 8)
- External Walls: External Aquapanel, Knauf Betocoat, “Thermoprosopsis” EPS80/SM700

Thermoprosopsis EPS 80/SM700

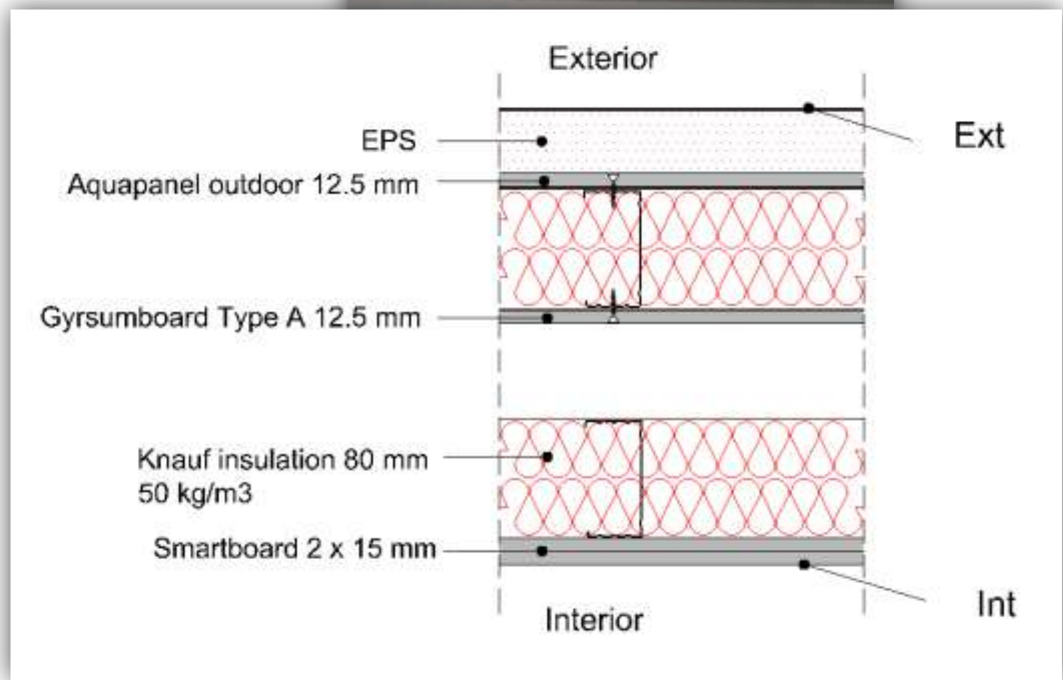
Amfilochia Demo House

PCM Smartboard™

Construction

- Interior side of External Walls (one side)
- Partitions

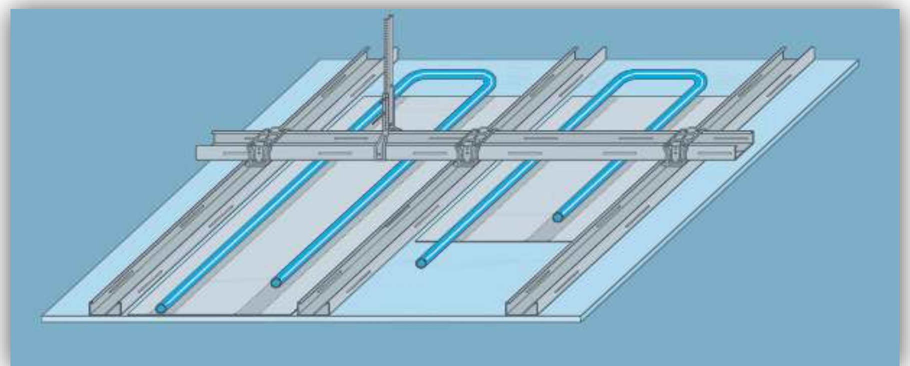
with **K764 Knauf PCM Smartboard™ 23**



Amfilochia Demo House

PCM Smartboard™

GRAPHITE BOARDS



K713 Knauf Thermoboard

- Knauf Thermoboard graphite enhanced panels installed on ceiling

Product description

- Thickness: 10 mm
- Dimensions: 1250 x 2000 m
- Edge type: HRAK, SFK
- Weight: approx. 10.2 kg/m²

Board Type

- DIN 18180: GKF
- DIN EN 520: DF

Reaction to Fire (Building Material Class)

- DIN 4102-4: A2
- DIN EN 13501: A2-s1,d0 (B)

Order Information

Thermoboard, non-perforated, 1250 mm wide, 2000 mm long Material-no. 00008380
Customized lengths on request

- Perforated type with air-cleaning effect available (Cleaneo® Acoustic Thermoboard), see Technical Data Sheet K713C

Fields of Application

Knauf Thermoboards are used for

- Cooling systems as suspended ceilings
- Heating systems on walls and as suspended ceilings

The heating or cooling performance depends on the used system and will be stated by the system supplier.

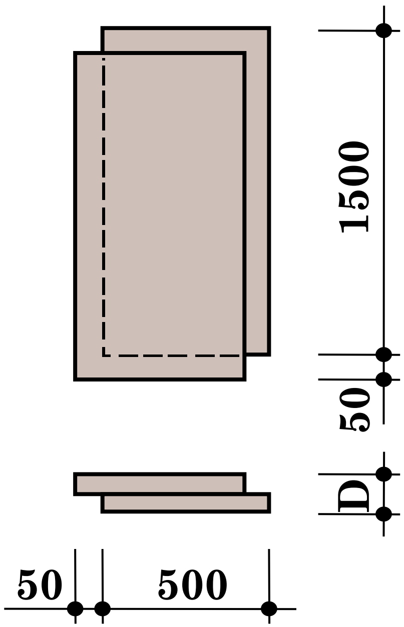
Properties

- Improvement of cooling or heating performance compared to standard gypsum boards (depending on used system)
- Thermal conductivity: approx. 0.30 W/(m•K)
- Side lengths up to 15 m possible for purely cooling ceilings
- Suitable for plaster and paint coats
- Concave and convex moulding is possible: radii on request
- Fire-resistant board GKF acc. to DIN 18180

Amfilochia Demo House

FLOOR COVER

System F131: Knauf Vidifloor (fibre reinforced boards), physical properties



Sizes			Weight	Breaking load	Thermal conductivity		
Thickness		Sizes	Element	4x4 cm	λ_{10} Vidifloor	λ_R PS/MF	λ_R Dry fill material
mm	D mm	b x l mm	kg/m²	kN	W/ (m • K)	W/ (m • K)	W/ (m • K)
2 x 10	20	550/1550 Covers size of 500/1500	24	4 (on PS 20 20 mm)	0,29	0,04	0,13
2 x 12,5	25		30	6 (on PS 20 20 mm)			

Amfilochia Demo House

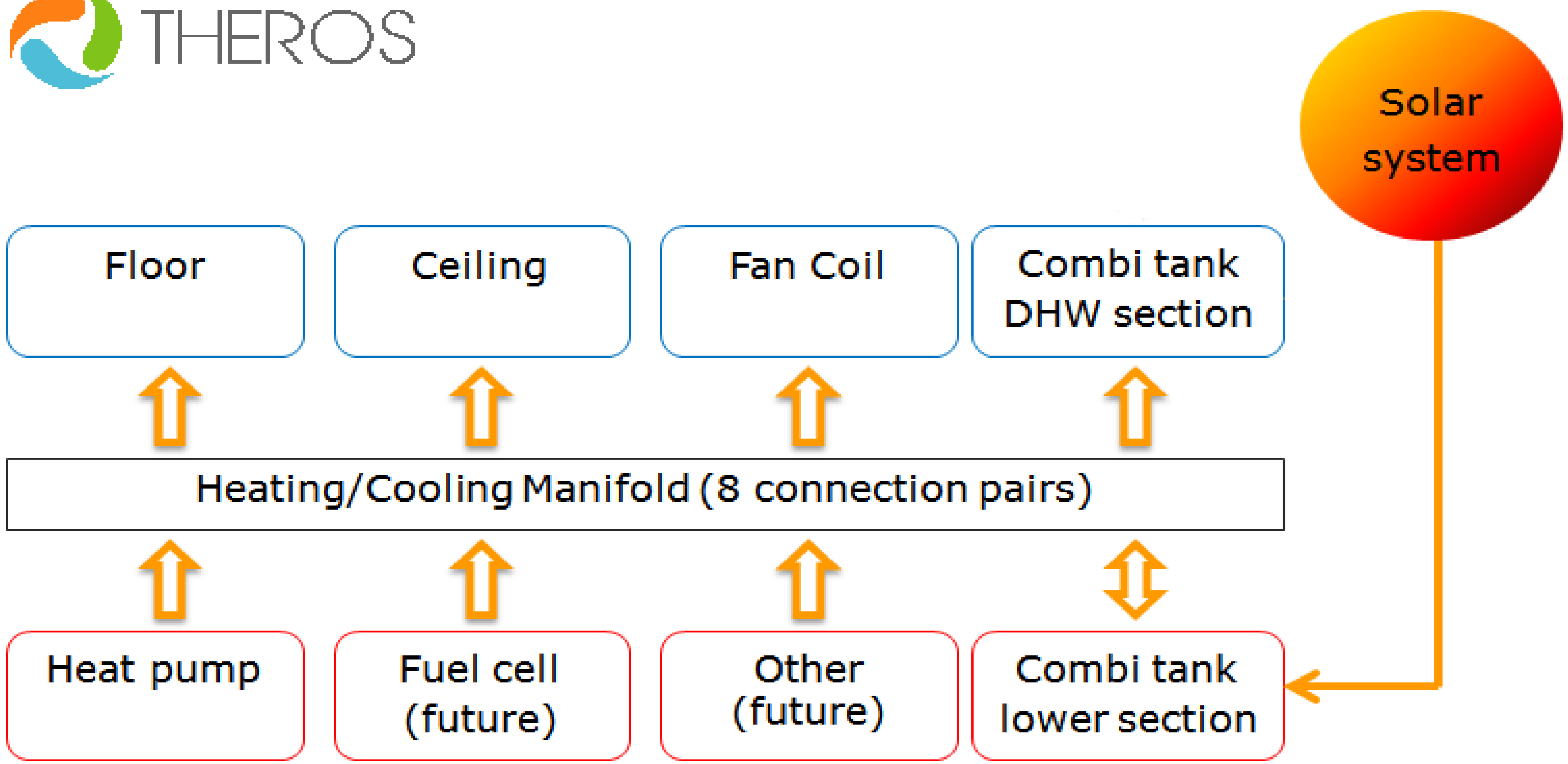
ENERGY SYSTEMS

The boiler/control room:

- heat pump
- water storage tank
- Fuel cell (summer 2013)
- Solar-thermal control
- Control manifold - BMS
- Valves and pumps

Amfilochia Demo House

ENERGY SYSTEMS



ENERGY PRODUCTION SYSTEMS

Heat & cold production:

- Heat Pump
  - Hitachi Model Nr. RWM-4FSN3E
  - COP: 4.47, EER: 3.88
  - Underfloor Ceiling Heating and Cooling

Amfilochia Demo House

ENERGY PRODUCTION SYSTEMS

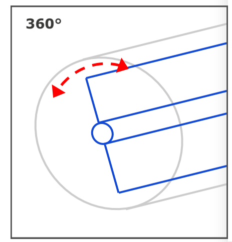
Heat & cold production:

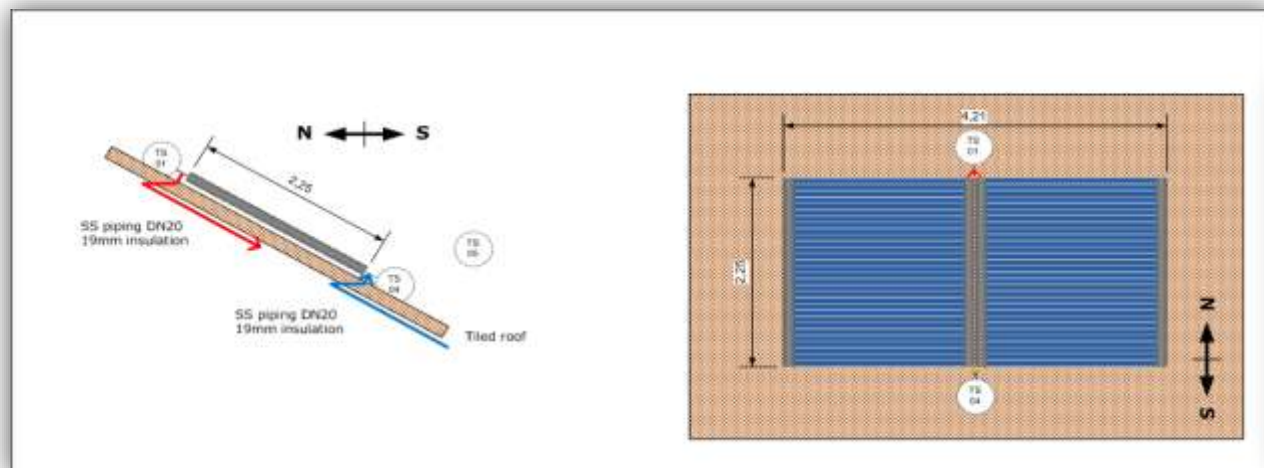
- Solar Panels
  - Panels with total area of $10m^2$
  - Nominal power output of 6kW

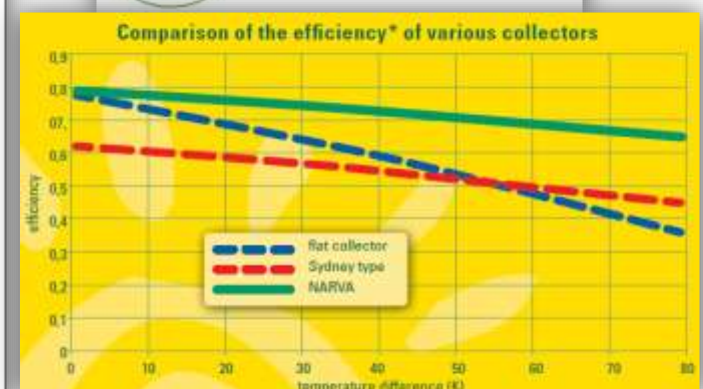
Amfilochia Demo House

SOLAR COLLECTORS

- Made by AkoTec, Germany.
- High efficiency, high temperature type.
- Each solar tube is 360° rotatable during assembly.
- Light weight construction.
- 10 year warranty.
- Can be used in solar cooling.







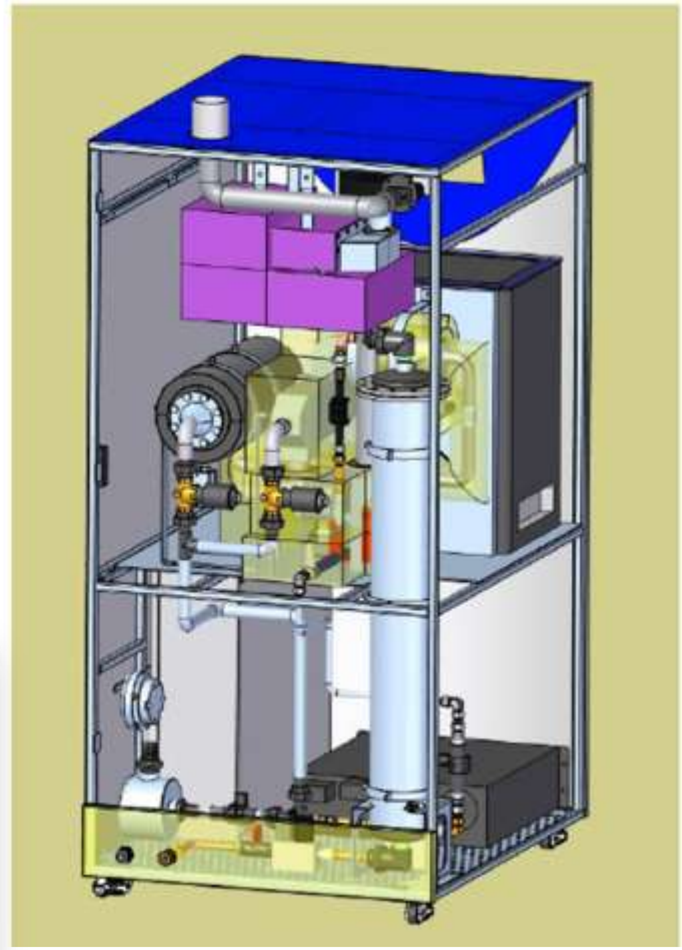
Amfilochia Demo House

Future Addition: SOFC (FC-District FP7)

Towards a positive energy building.

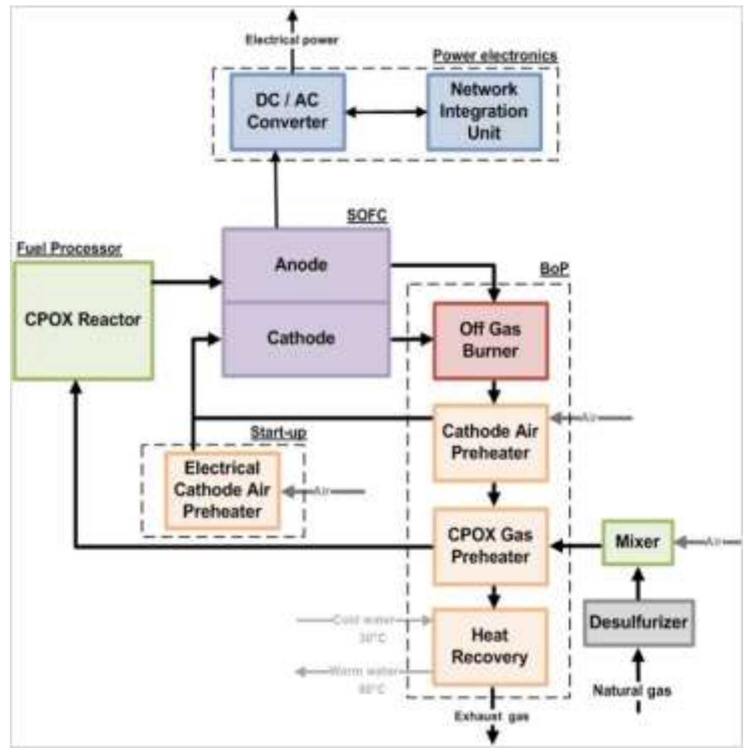
The SOFC based μ-CHP unit will provide demand–flexible heat and electricity at the demonstration site –

The μ-CHP unit will be directly connected to the manifold of the demo house and its operation will be in accordance with identified winter and summer operation scenarios.



The m-CHP /SOFC specifications:

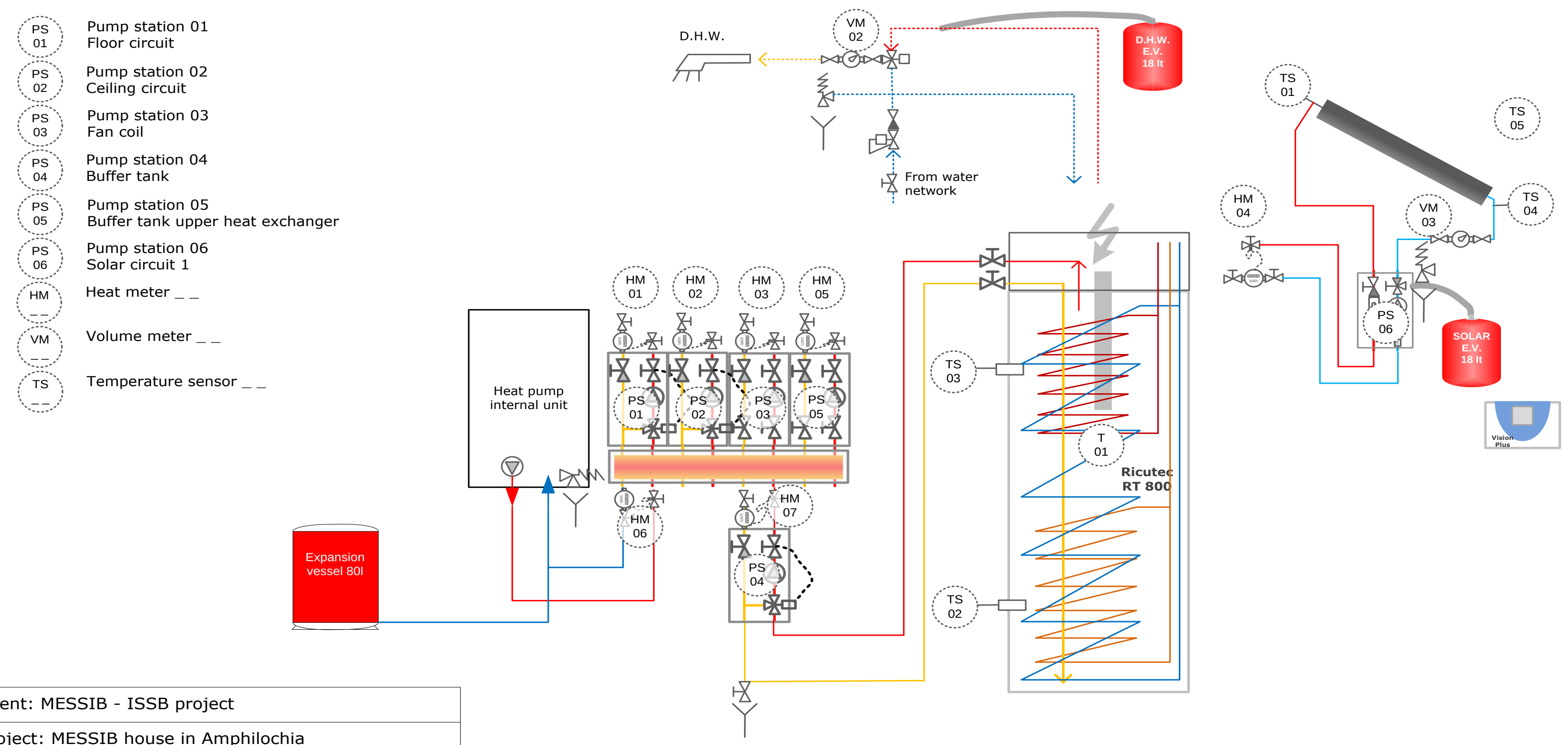
- max. electrical output 1.5 kW_{el}
- max. thermal output 2.75 kW_{th}
- Electrical efficiency > 30 %
- Overall efficiency > 85 % (targeting 90%)
- CPOX reforming of Natural Gas
- Electrical connection: 230V, 50Hz
- CE certified
- Inter-connection with a district heat distribution system and an electrical micro-grid
- Potential for tri-generative use (power/heating/cooling) at building level



Amfilochia Demo House

ENERGY DISTRIBUTION SYSTEMS

Manifold



Client: MESSIB - ISSB project	
Project: MESSIB house in Amphilochia	
Περιοχή: Knauf factory, Amphilochia	
Prepared by: Panos Xanthakos	
Our ref.: AIT-00027	
Scale: No scale	Date: 21.09.2010
Preliminary machine room piping drawing	THEROS

Amfilochia Demo House

THERMAL ENERGY DISTRIBUTION SYSTEMS

"boiler"/ control Room

Amfilochia Demo House

THERMAL ENERGY DISTRIBUTION SYSTEMS

Pump Stations

- Two UPONOR C-46 controllers installed (floor and ceiling loop)
- based on the Meibes GmbH modular system
- 6 pump stations installed
  - floors loops
  - ceiling loops
  - Dehumidifier
  - DHW coil
  - main manifold
  - solar panels' circuit

Amfilochia Demo House

THERMAL ENERGY DISTRIBUTION SYSTEMS

Storage Tank

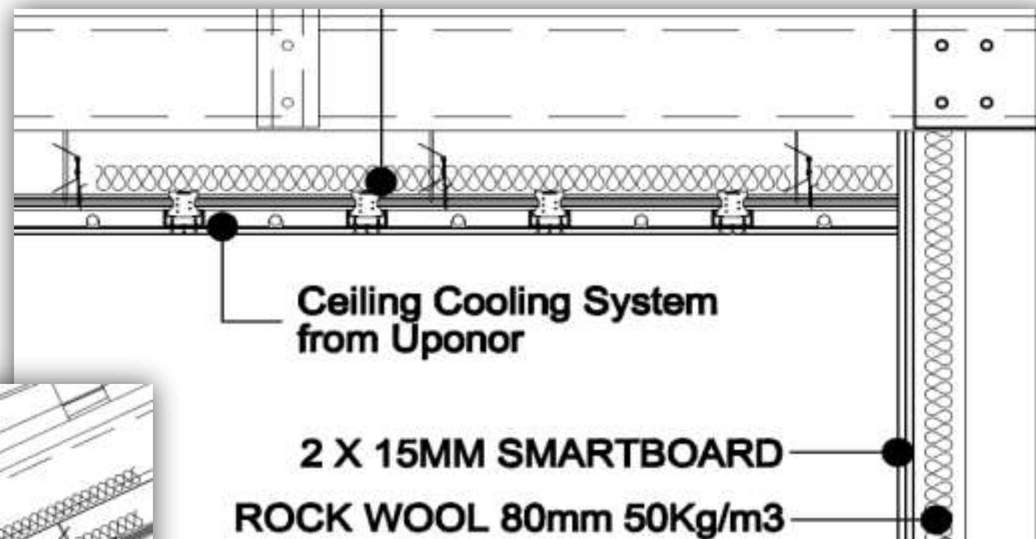
- 800 lt capacity and low heat losses
- Used for Domestic Heating and DHW
- Max Temperature of water ~80-90C
- 3 coils made of inox steel immersed into the water operating as heat exchangers.
  - One for the solar panels circuit
  - One for the secondary loading heat exchanger (DHW demand-connected directly to the Heat Pump)
  - One to warm up the DHW

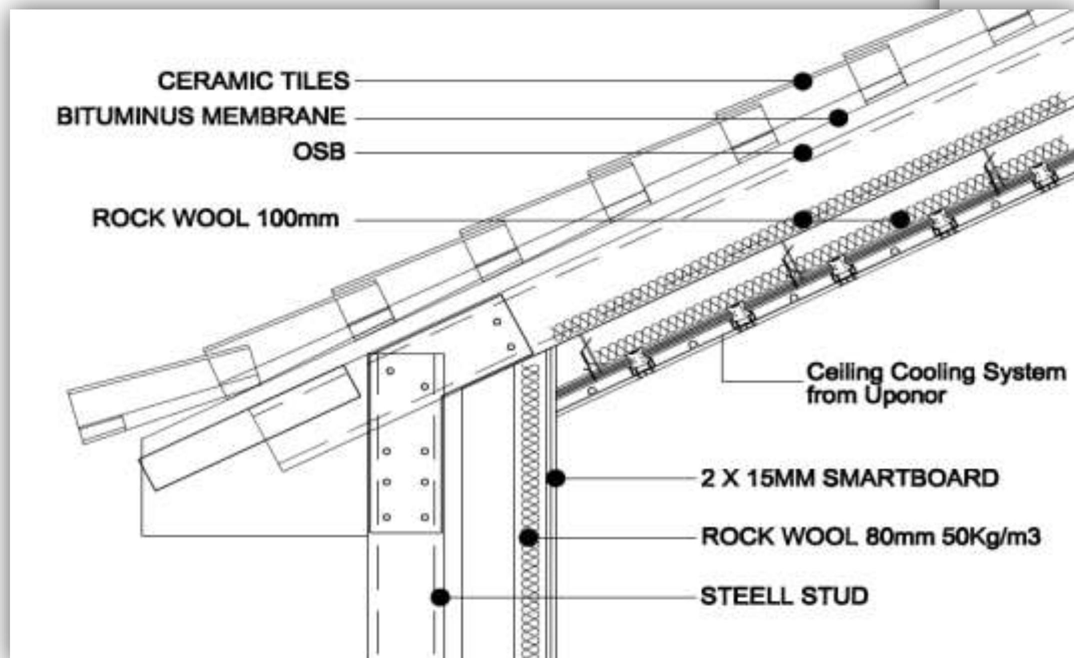
Amfilochia Demo House

THERMAL ENERGY DISTRIBUTION SYSTEMS

Ceiling cooling system

- Uponor Siccus System
- Knauf Thermoboard panels





Amfilochia Demo House

THERMAL ENERGY DISTRIBUTION SYSTEMS

Ceiling cooling system :

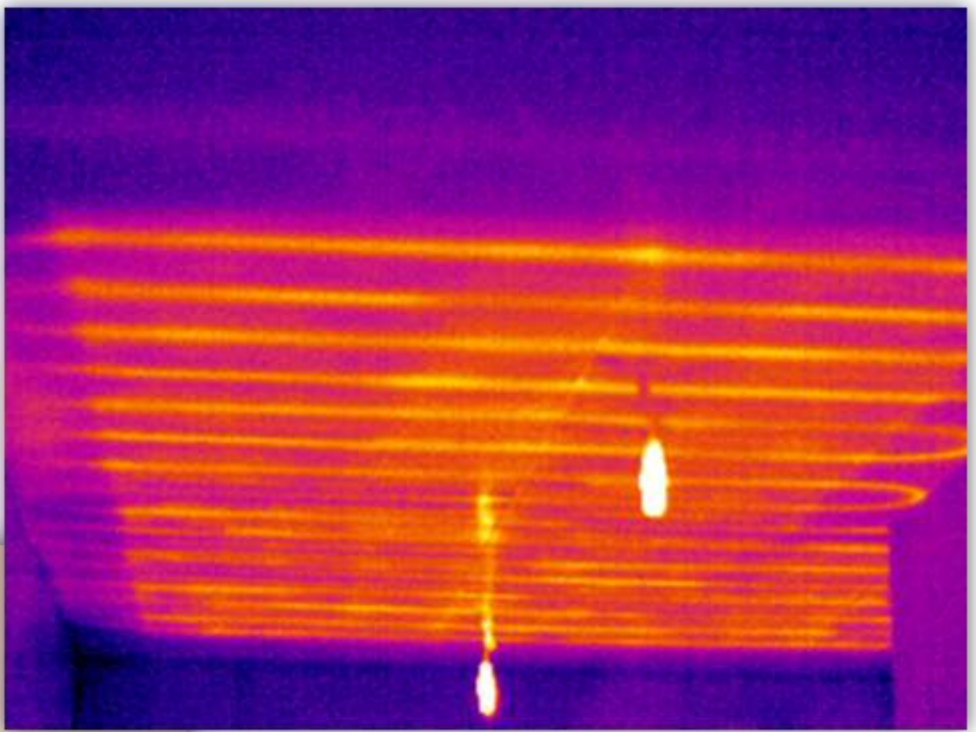
Pipes inserted in aluminium plates

Amfilochia Demo House

THERMAL ENERGY DISTRIBUTION SYSTEMS

Ceiling heating/cooling system :

First floor: IR-picture during operation



Amfilochia Demo House

THERMAL ENERGY DISTRIBUTION SYSTEMS

Underfloor heating system

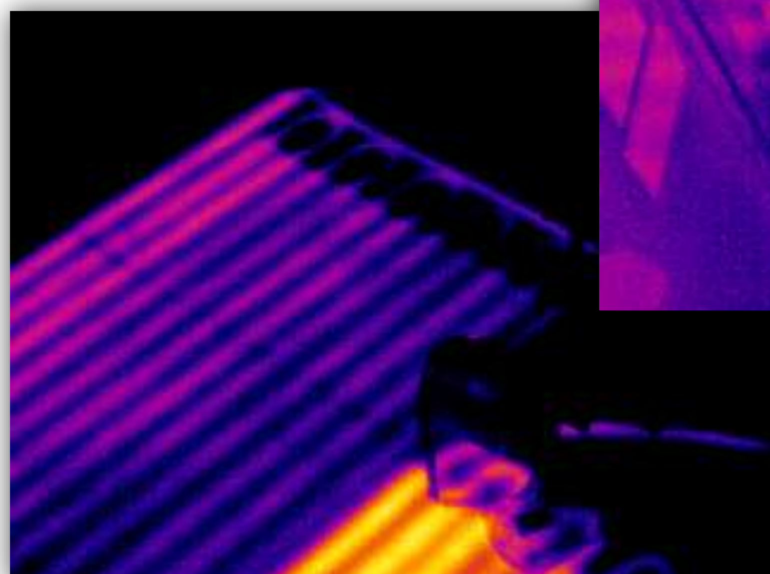
- Uponor Siccus System
- Knauf Vidifloor®

Water for floor heating < 40 ^{o}C

Amfilochia Demo House

THERMAL ENERGY DISTRIBUTION SYSTEMS

Underfloor heating system – IR pictures during operation



Floor details

- The 25 mm-thick lightweight panel basic element, which is made of polystyrene foam EPS has a thermal insulation resistance of R_{hS} = 0.62 m2 K/W.

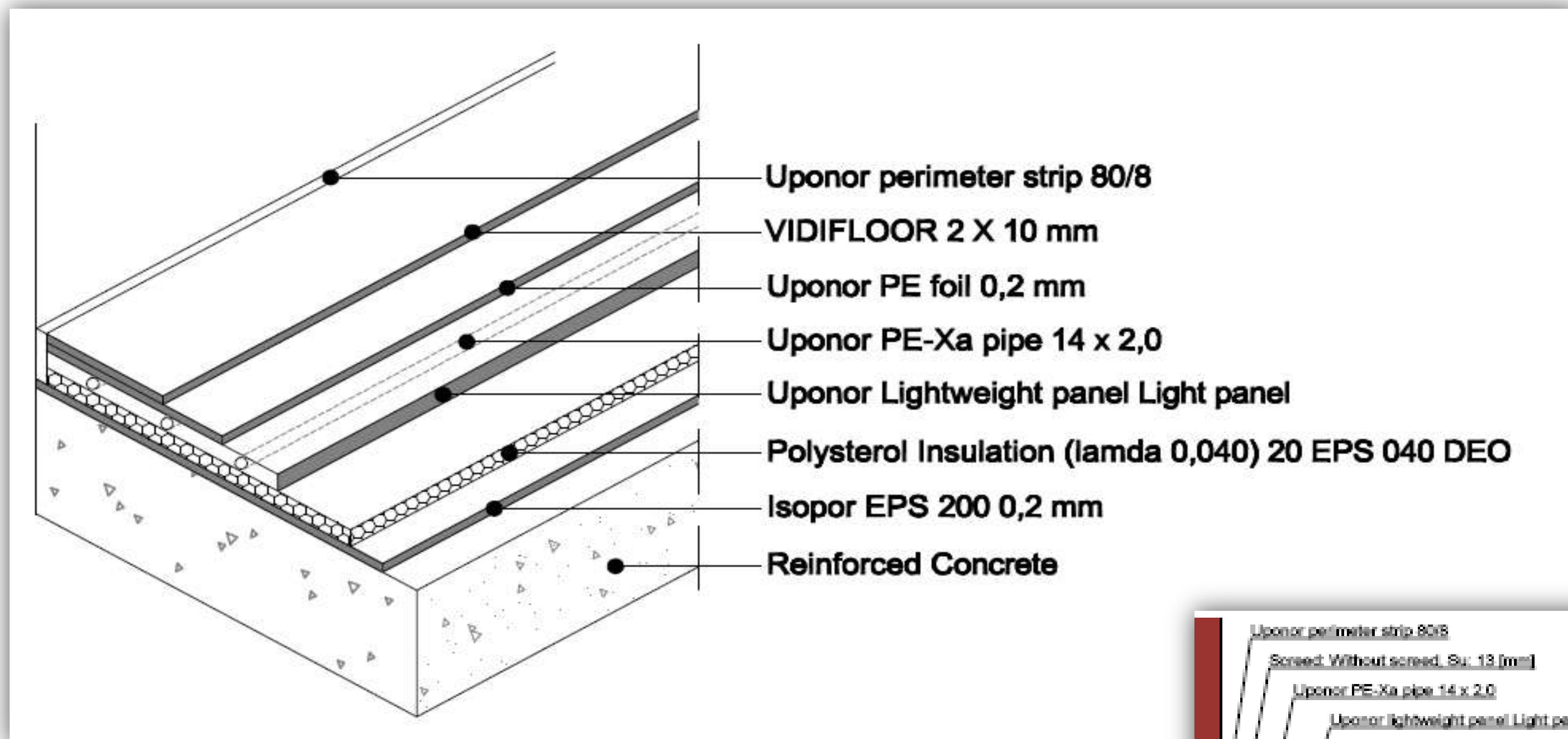
- For the ground floor where an extra thermal resistance is required , additional 10mm polystyrene insulation board (thermal conductivity rating 040) is placed underneath the basic element.

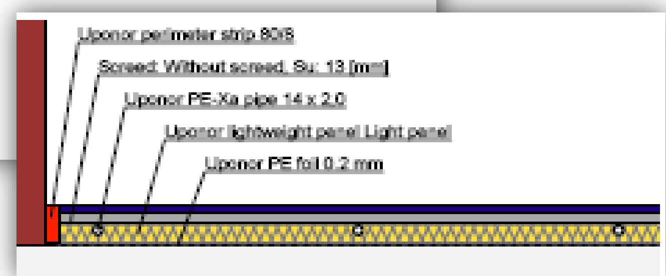
- The 0.5 mm thick heat emission plate of the lightweight panel (made of aluminium sheet, λ = 200 W/mK) provides optimum transmission of heat to the dry-screed elements. Two integrated pre-cuts ensure easy shortening and installation.

Amfilochia Demo House

THERMAL ENERGY DISTRIBUTION SYSTEMS

Underfloor heating system: Ground floor detail

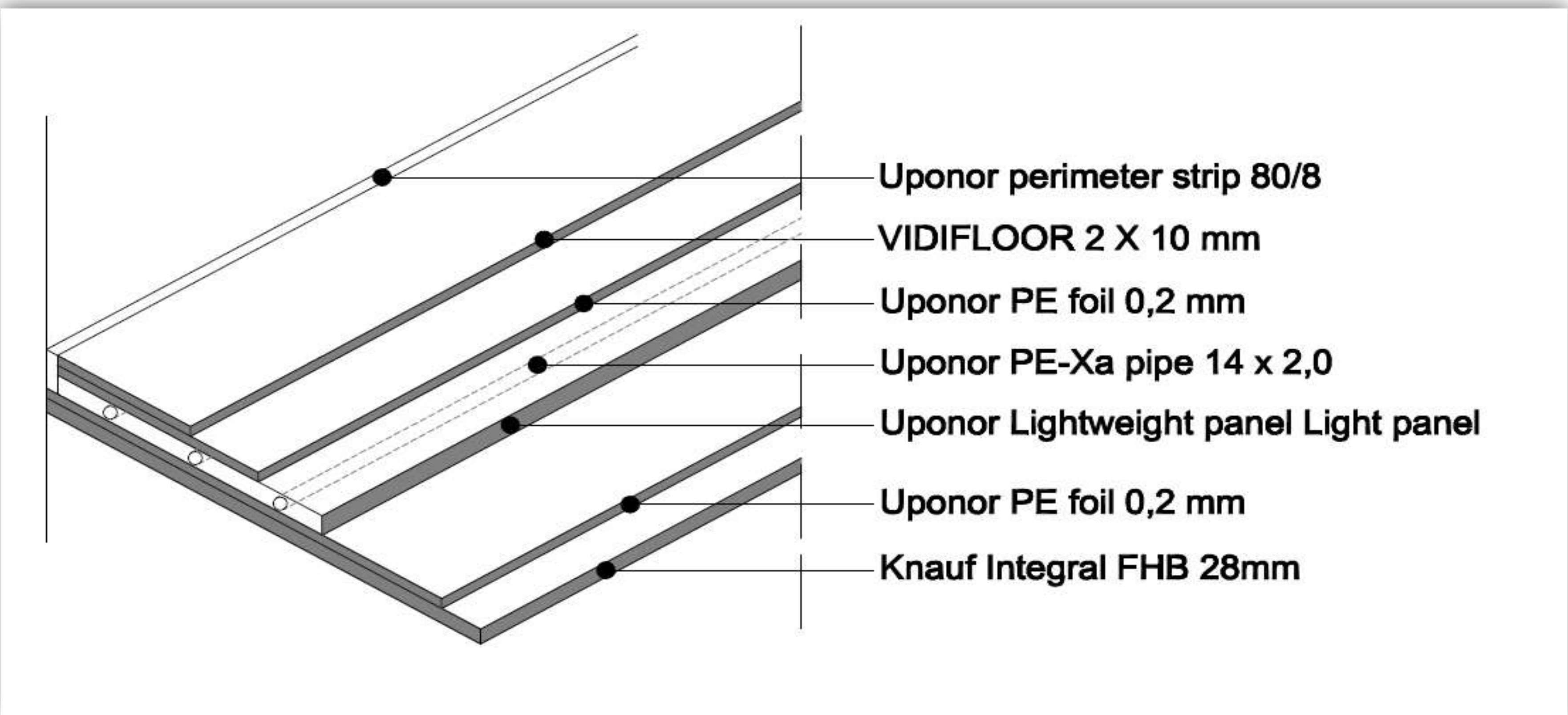




Amfilochia Demo House

THERMAL ENERGY DISTRIBUTION SYSTEMS

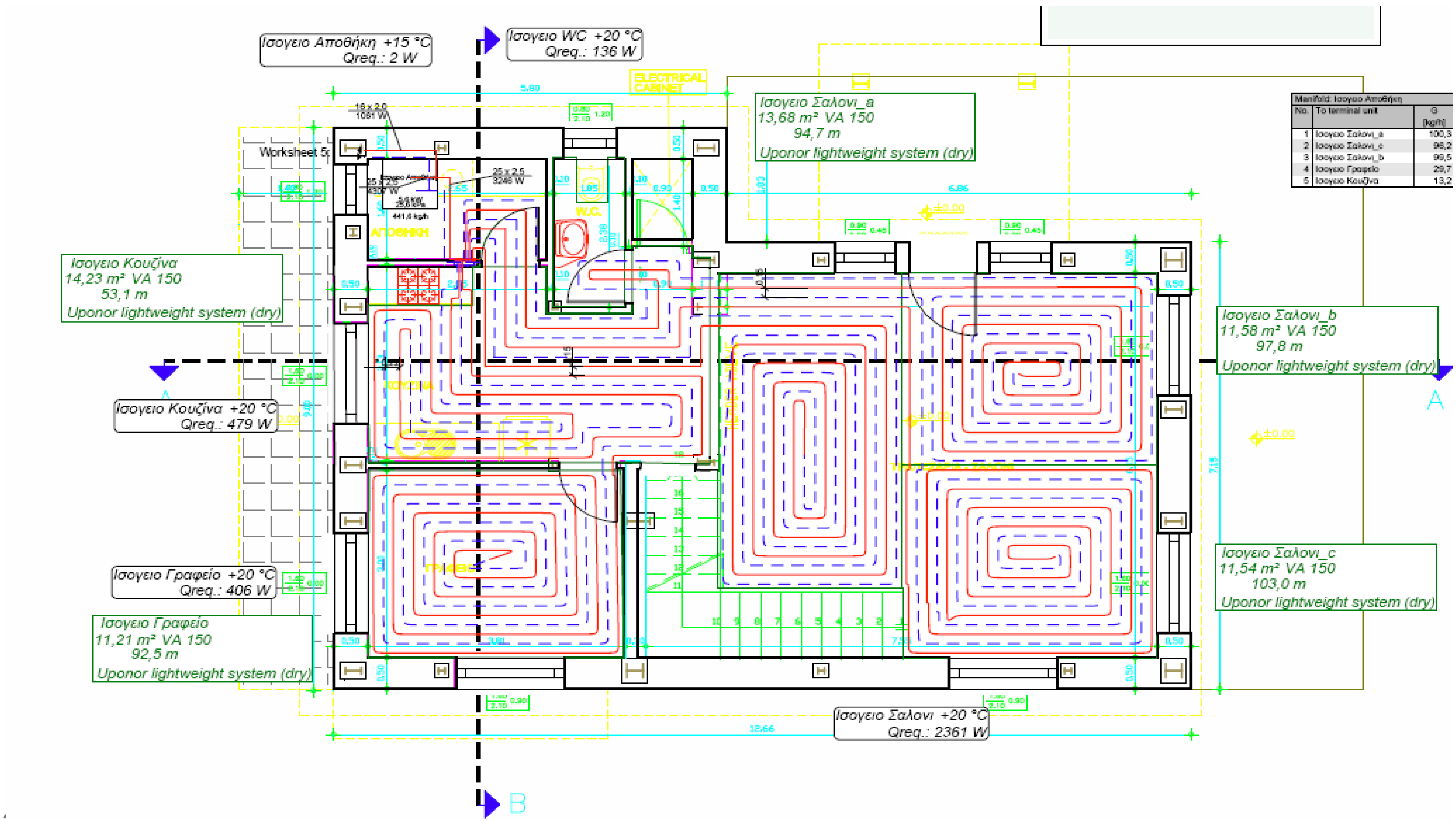
Underfloor heating system: First floor detail



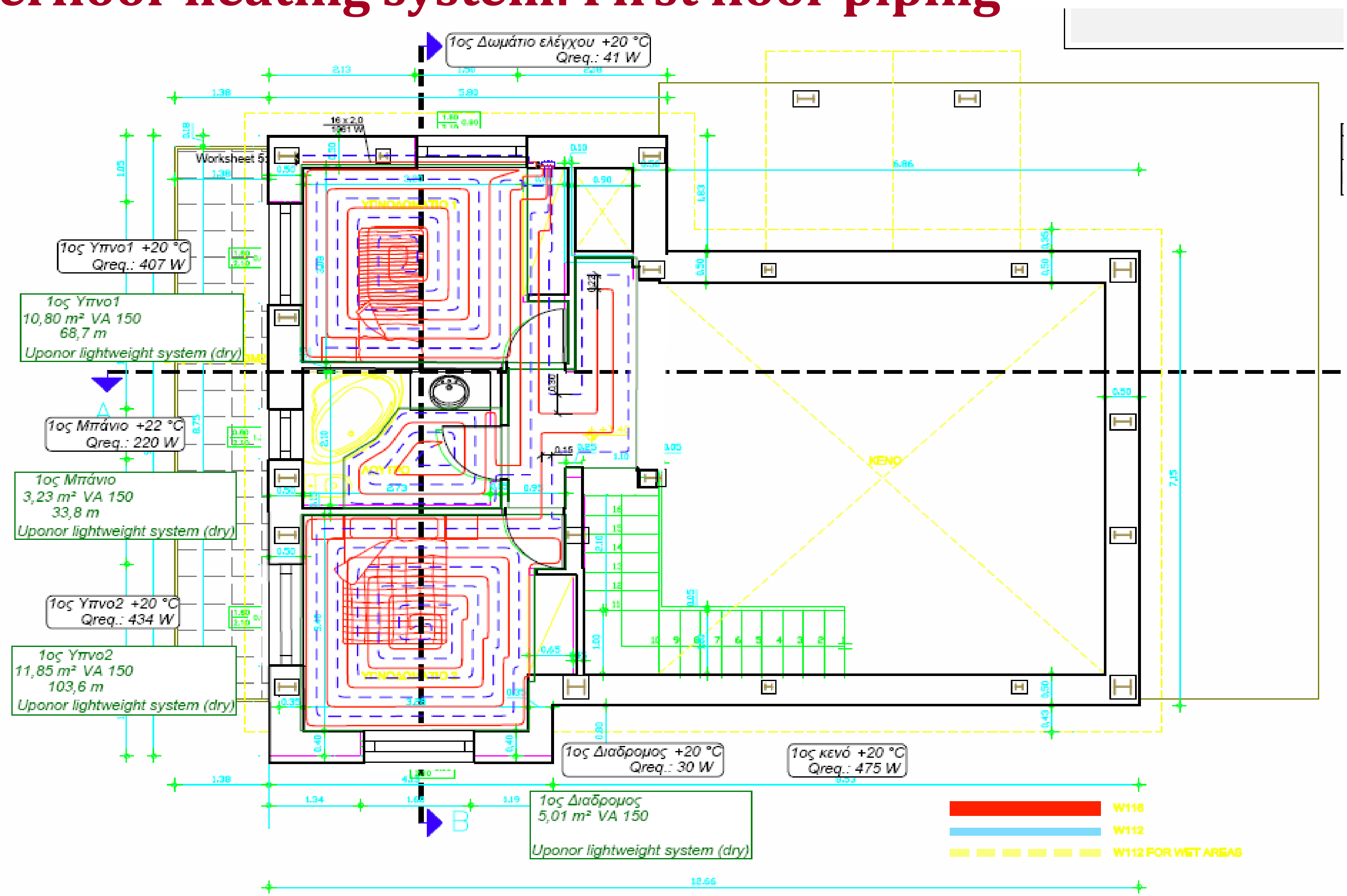
Amfilochia Demo House

THERMAL ENERGY DISTRIBUTION SYSTEMS

Underfloor heating system: Ground floor piping



Underfloor heating system: First floor piping



Amfilochia Demo House

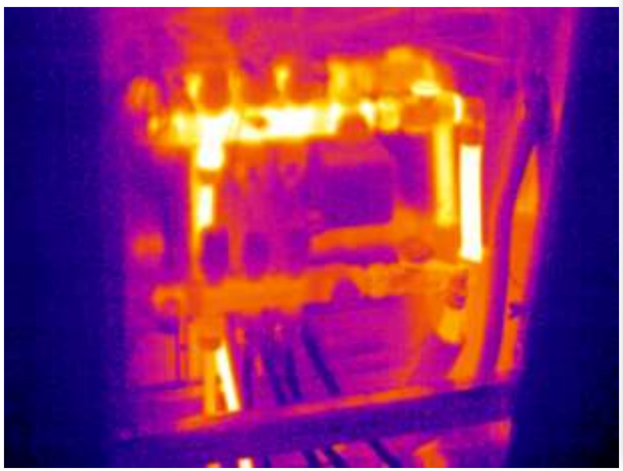
THERMAL ENERGY DISTRIBUTION SYSTEMS

Underfloor heating system

Uponor Siccus System

Valves circulating water to floor and ceiling

uponor



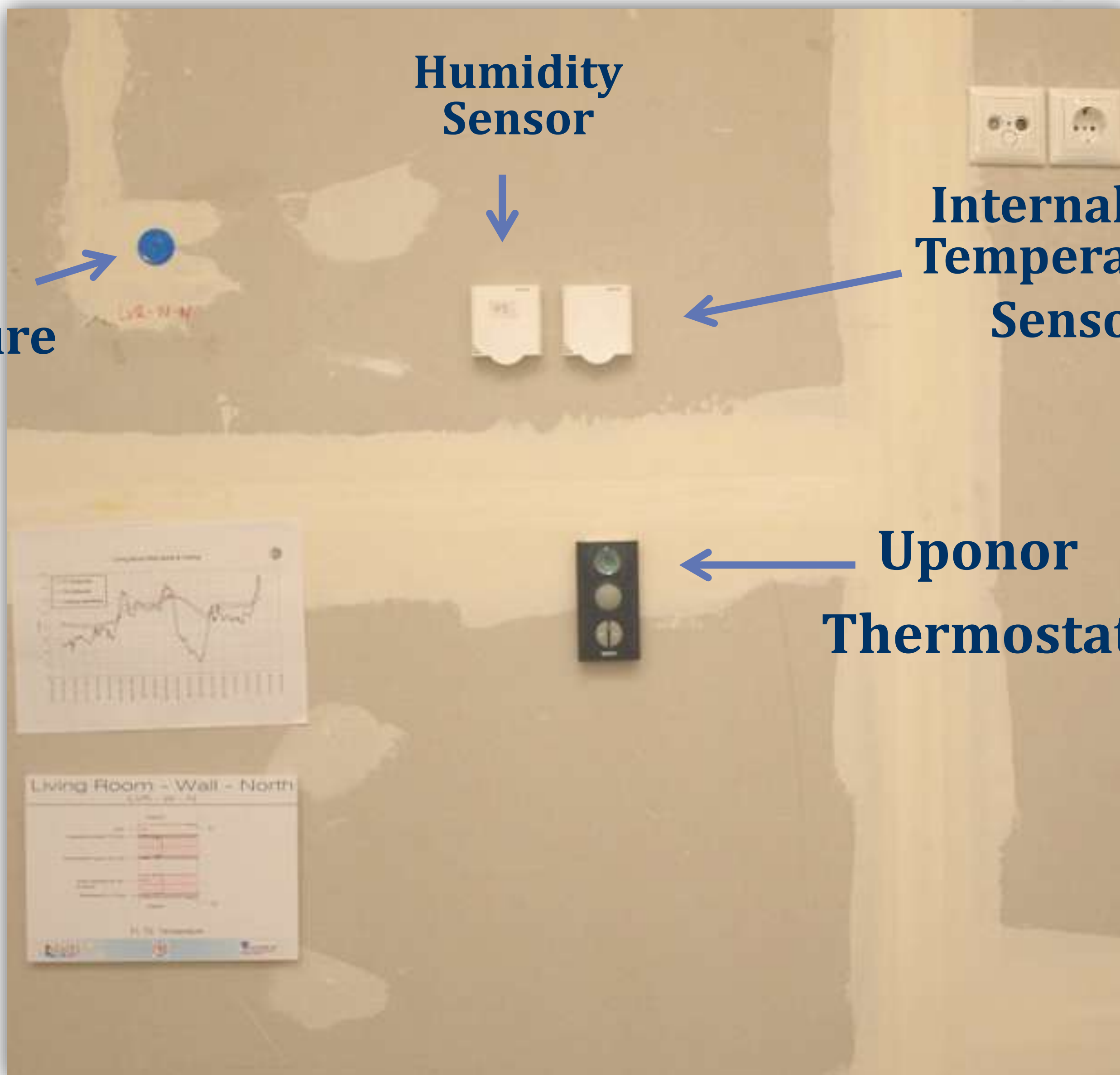
uponor C-56 radio controllers with Dynamic Energy Management (DEM)

- Two C-56 controllers installed (floor – ceiling loops - simultaneous or individual operation)
- 4 wireless thermostats installed in living room, kitchen and two in bedrooms in first floor
- Each area can have different temperature.
- The DEM controls 7 ceiling pipe loops and 7 heating pipe loops individually and is also responsible for the temperature compensation by controlling the 3-way valve.

Amfilochia Demo House

CONTROL

Living Room



Amfilochia Demo House

CONTROL

C-46 Indoor Climate Controllers

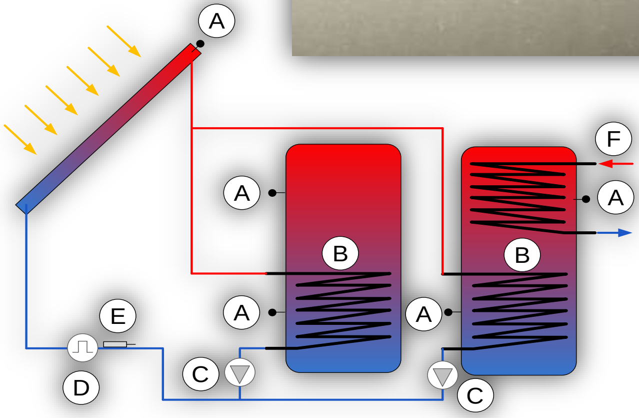
- Two C-46 controllers installed (floor and ceiling loop)
- Responsible to adjust the temperature of the supply water by controlling the mixing valve (external and internal temperature)
- Controlling the pumps which supply the loops according to demand.
- 3 wireless humidity sensors provide data so as to calculate the dew point and adjust the temperature of the supply water (avoiding water condensation on the chilled surfaces)
- They control a dehumidifier.

Amfilochia Demo House

CONTROL

Solar system controller

- Made by prozeda, Germany.
- Proportional speed control – reduces the pump speed according to the available solar energy.
- Twin differential controller – gives priority to the desired consumer according to the temperature of the solar collectors.
- Monitors and protects the system.
- Suitable for use with Vacuum Tube collectors

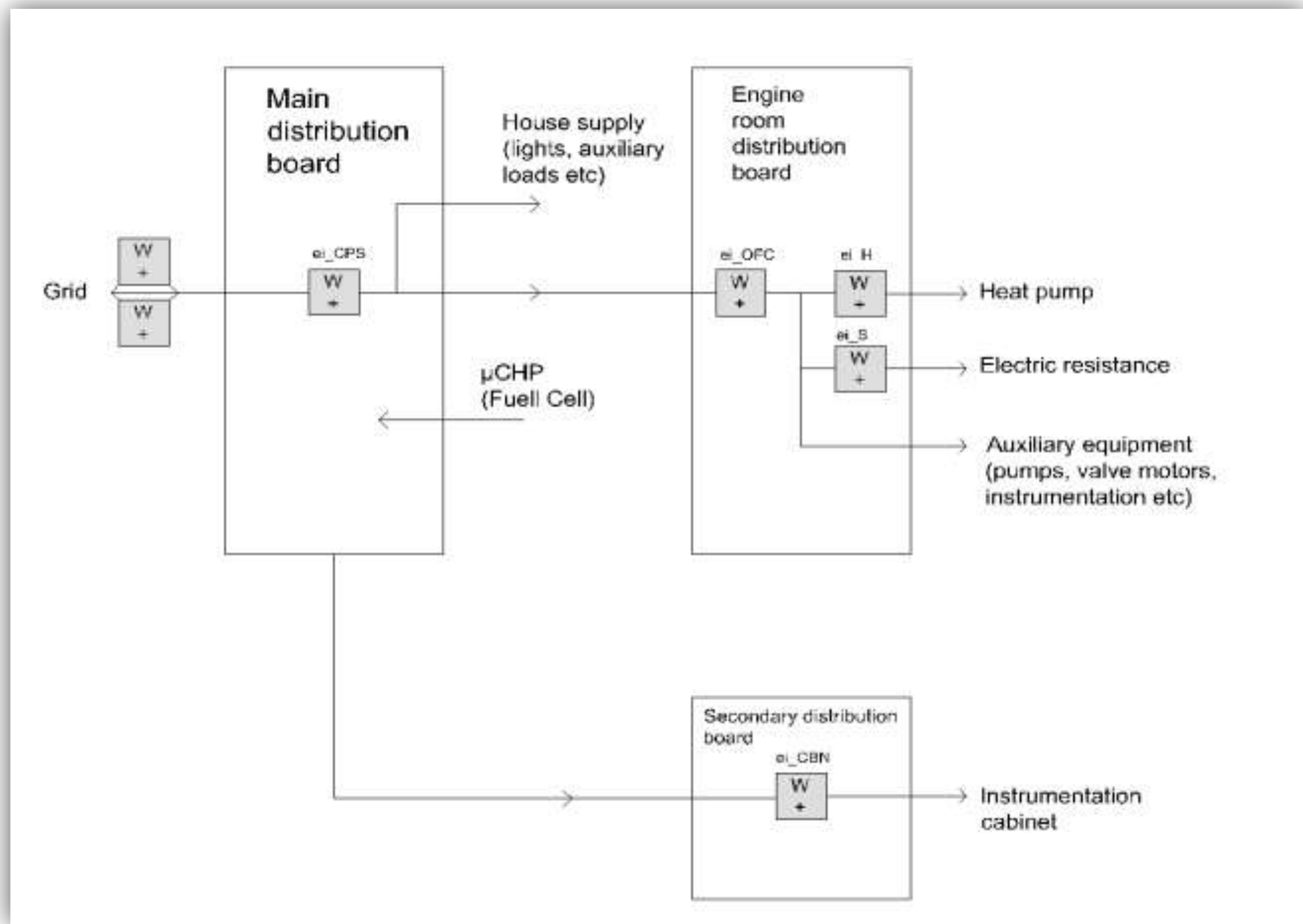


Amfilochia Demo House

CONTROL

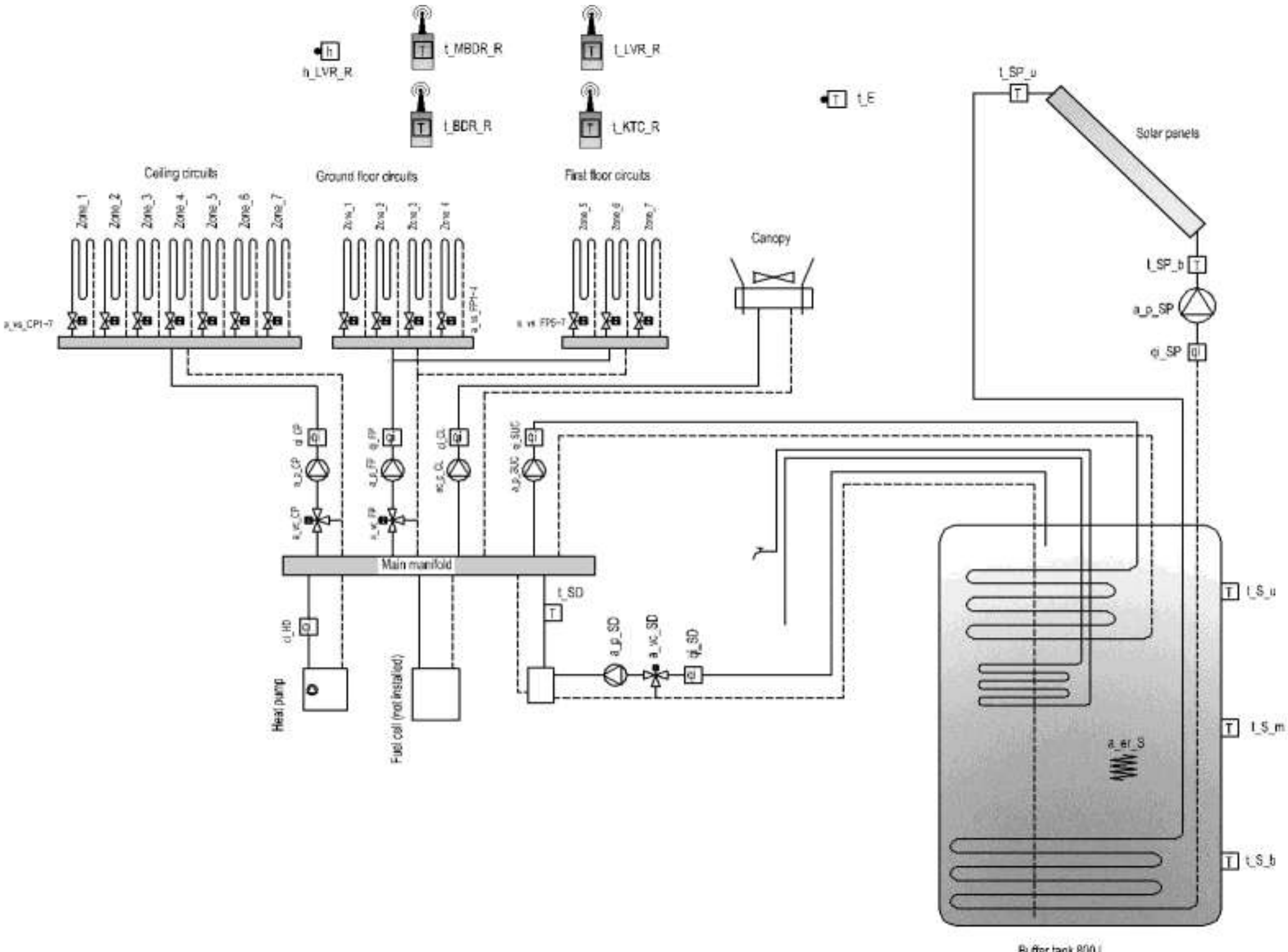
Amfilochia Demo House

ELECTRIC SCHEME



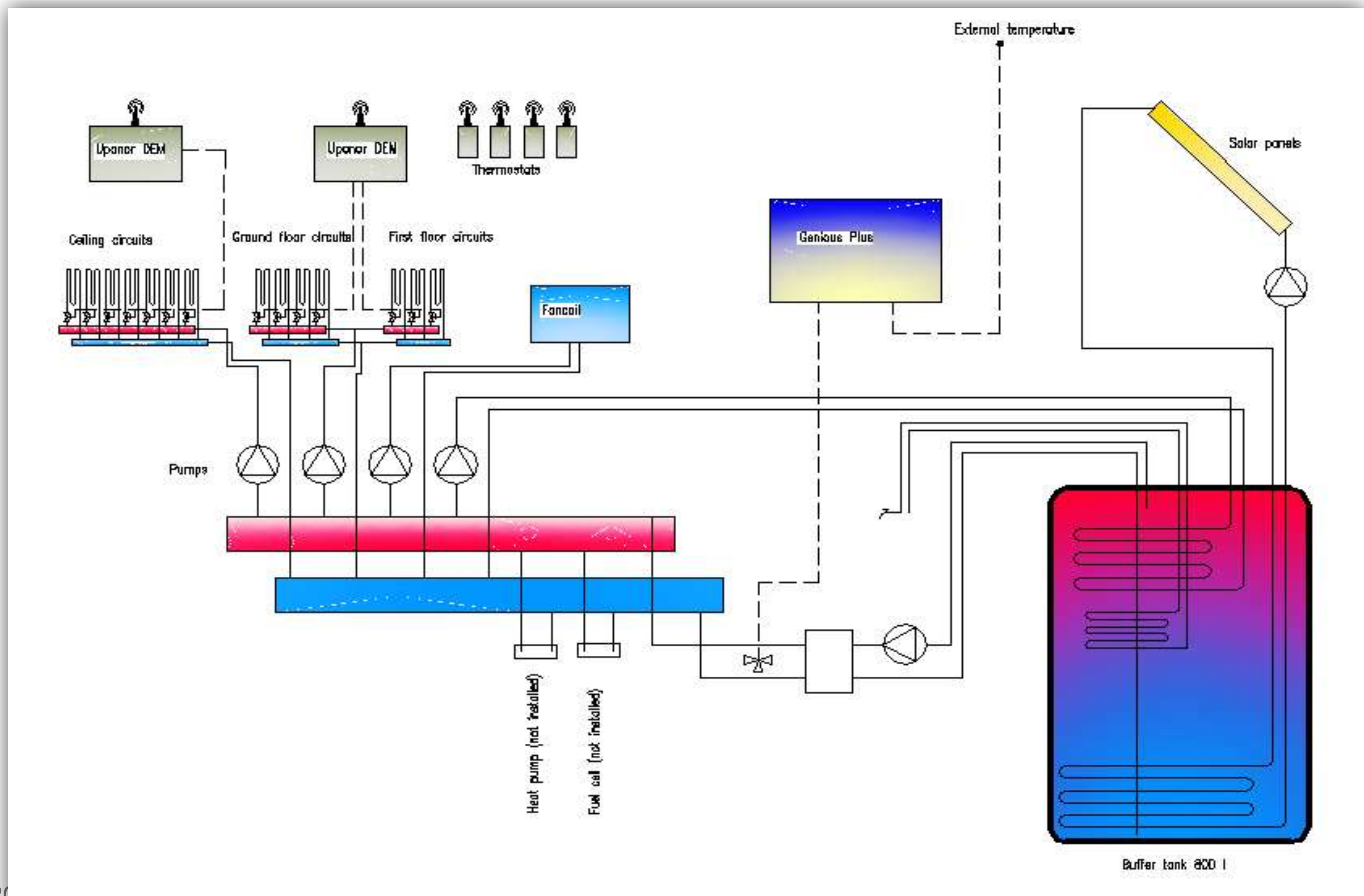
Amfilochia Demo House

HYDRAULIC SCHEME



Amfilochia Demo House

Energy Systems



Temperature Sensors

10 K Ohms Resistance @25°C
±0.2°C Tolerance from 0°C to +70°C
Fast Time Response
Small Tip Diameter

Parameters	Units	Value
Resistance @ +25°C	kOhms	10,00
Resistance tolerance @ 25°C	°C	± 0.2
Alpha Value @ 25°C	%/°C	- 4.39
Time response in Liquids	milliseconds	200
Dissipation Constant in still air	mW/°C	0.3

Heat flux Sensors

Response Time (seconds)	
HFS-3:	0.20
HFS-4:	0.20
Thermal Capacitance (BTU/ft²°F)	
HFS-3:	0.01
HFS-4:	0.01
Thermal Resistance (°F/BTU/ft²Hr)	
HFS-3:	0.01
HFS-4:	0.01
Nominal Thickness (inches)	
HFS-3:	0.007
HFS-4:	0.007

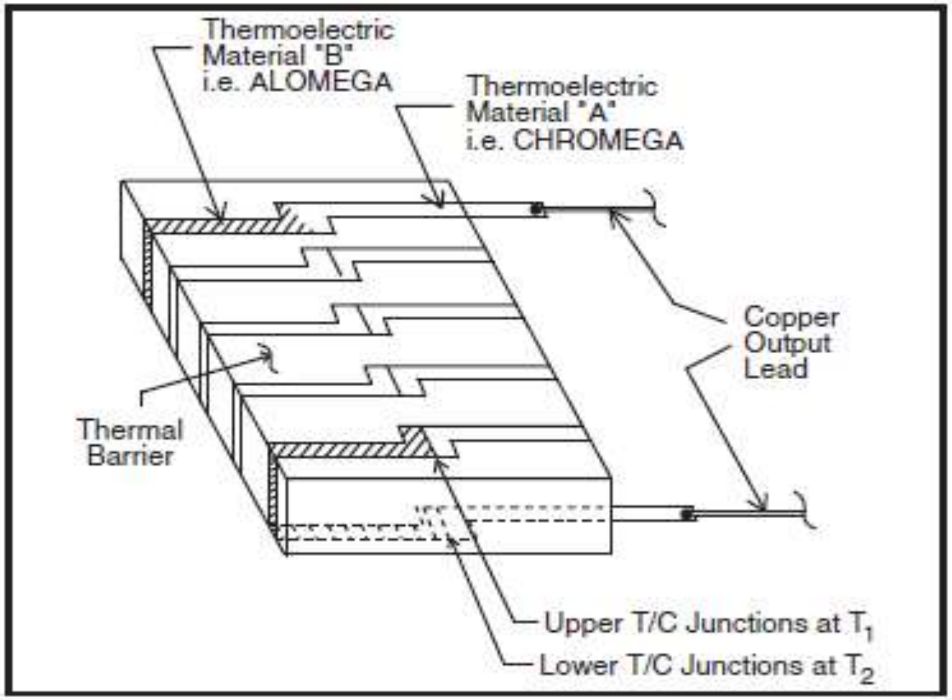


Figure 1-1. Construction of the Sensors

Humidity Sensors

Specifications

Power Supply	24V AC 50/60Hz , 24V DC	
Humidity Range	0…100%RH	
Accuracy	±3% at 25°C	
Hysterisis	±3%	
Repeatability	±0.5%	
Stability	±0.5% per year if used within 0 to 50°C	
Temperature Range	-70…150°C	
Accuracy	±0.2K at 25°C	
Output	Output Signal	DC 0-10V or 0…20mA
	Resolution	10Bit, 9.7mV, 0.0195 mA
	Accuracy	±2%

Amfilochia Demo House

MONITORING

Data Acquisition System

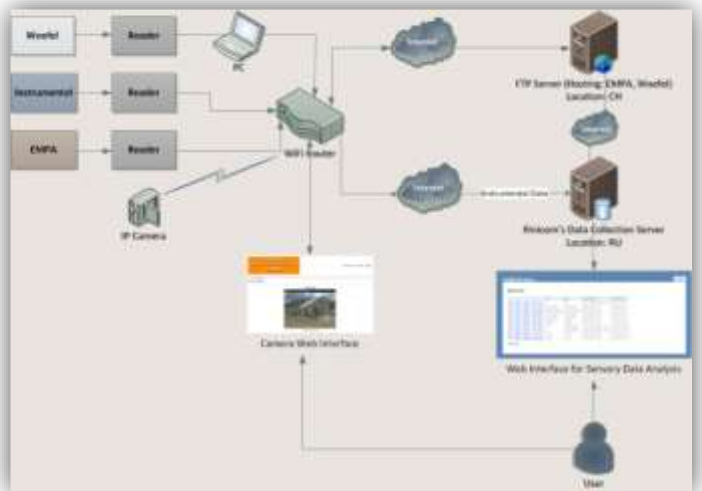
Agilent 34970A Data Acquisition/ Switch Unit Family

Product Overview
34970A
34972A

	Range [3]	1 Year 23 °C± 5 °C
DC voltage		
	100.0000 mV	0.0050 + 0.0040
Resistance [6]		
	100.0000 kΩ	0.010 + 0.004

Amfilochia Demo House

WIRELESS MONITORING SYSTEM

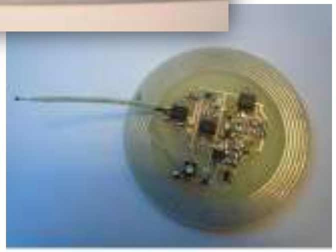


RINICOM: System Architecture

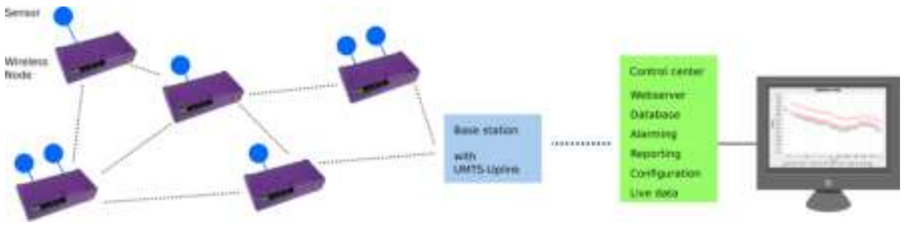
- Zigbee sub-network
- Sensors-Actuators
- Embedded inductively coupled telemetry nodes to the network.
- WiMax network to communicate data to and from the house with a remote control station.

EMPA: Sensor node hardware

- 8 channel
  - Digital or analog
  - individually configurable
- Power supply 3V – 24V
- Power consumption ~10mW
- Range per hop (line of sight) ~80m



INSTRUMENTEL: Temperature Tag & reader



rinicom generation wireless

EMPA Materials Science & Technology

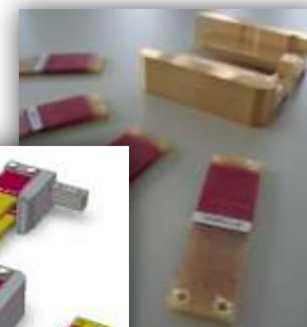
Amfilochia Demo House

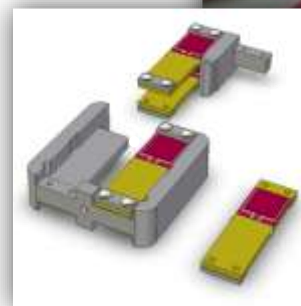
SEISMIC/VIBRATION SENSORS & ACTUATORS

New 3D-Piezofibre Earthquake Sensor

The earthquake sensors are connected to the internet.

Low tech /cost „body shaker" (acoustic absorber)





New concept - Acoustic mass actuator (patented)

The acoustical mass actuators will be installed at the demo house for one week for demonstration – active noise reduction

Amfilochia Demo House

SEISMIC/VIBRATION SENSORS & ACTUATORS

Acceleration Sensor

Electrical control cabinet

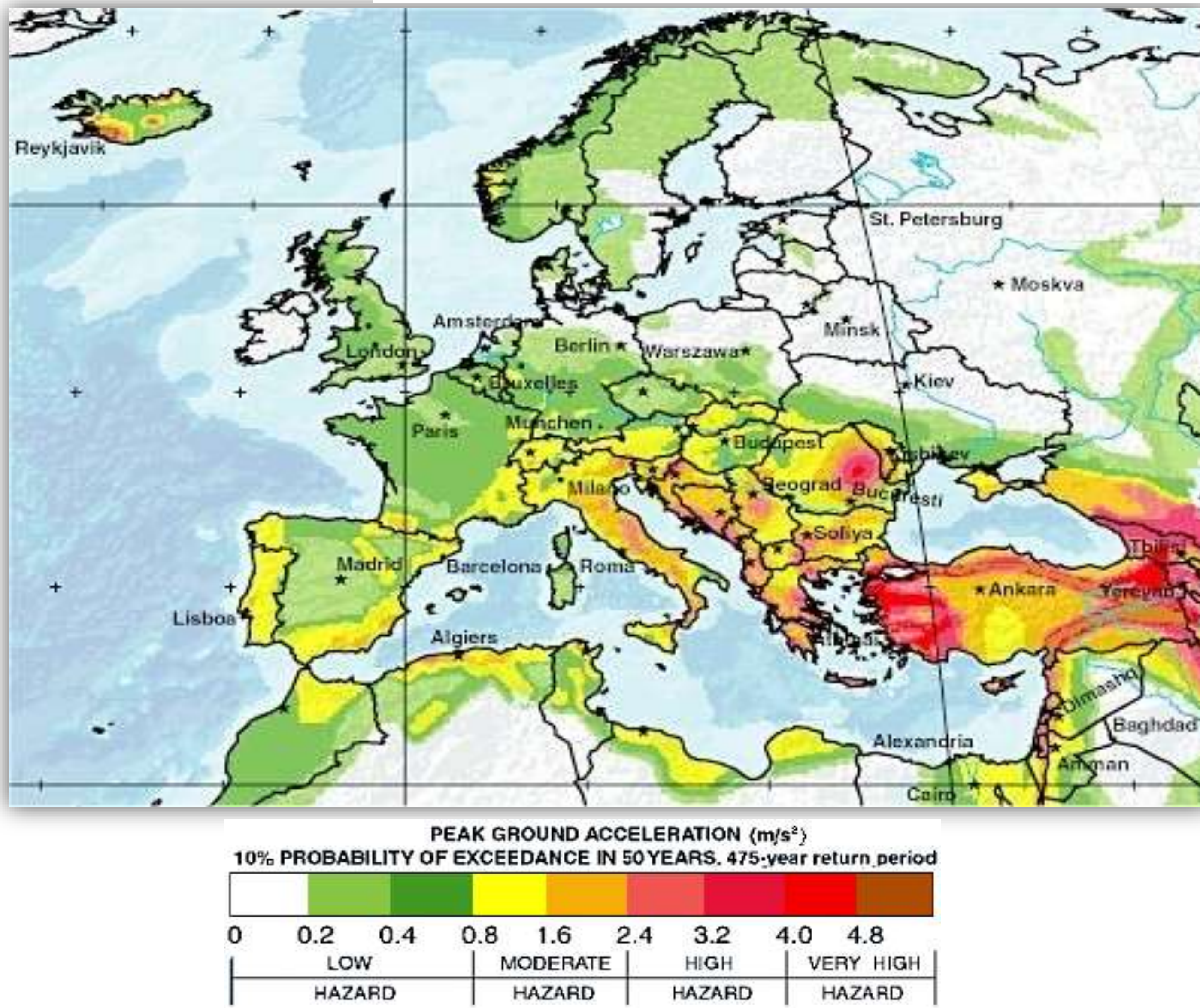
MR damping system

MR damping system installed

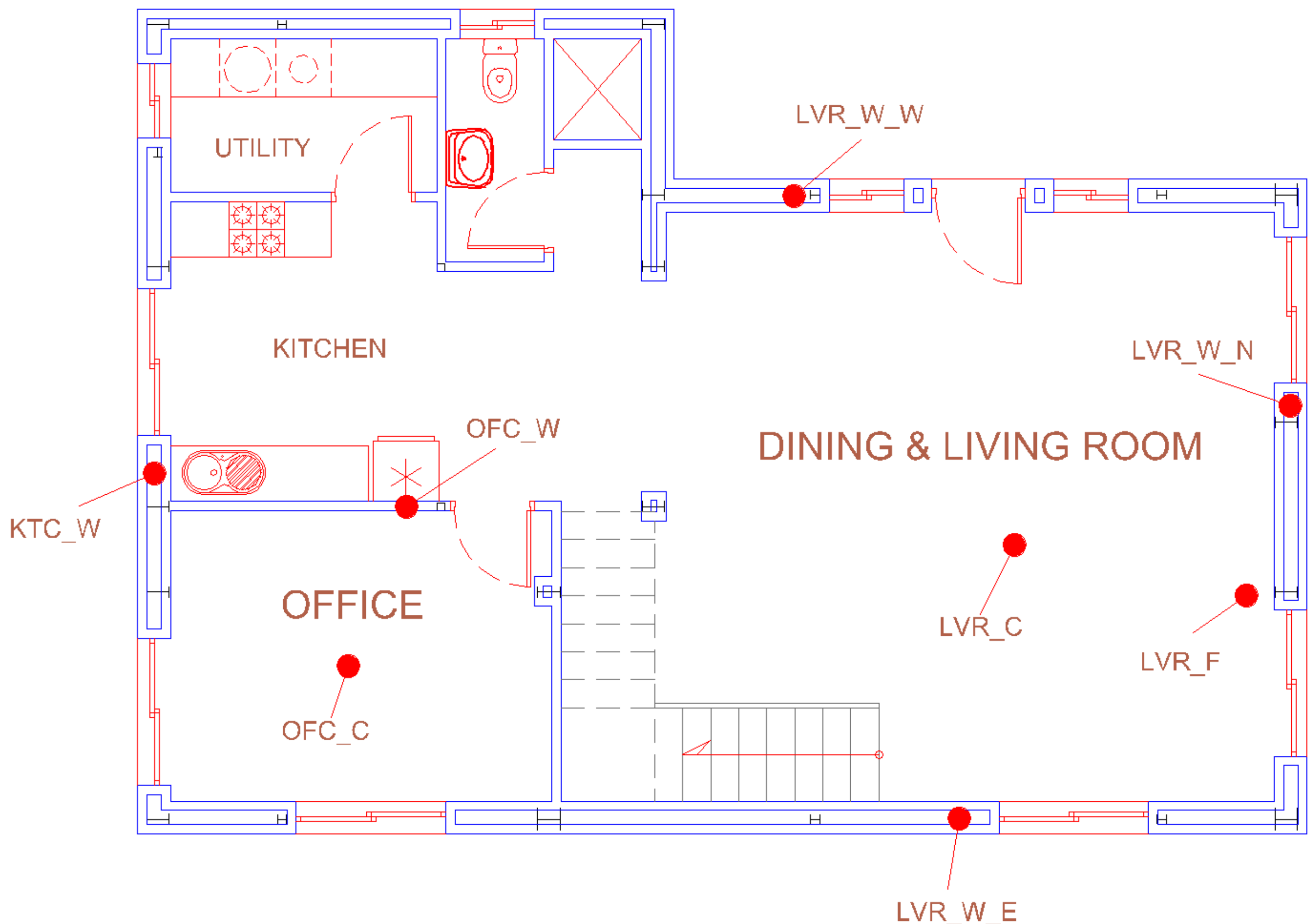
- Installation of the MR damping system in the Amfilochia Demo house
- Acceleration sensor attached to MR damping system triggers the automatic turn-on of the magnetic field in case of an earthquake
- Installation of measurement equipment in the electrical control cabinet by WBI and EMPA

Amfilochia Demo House

COUNTRIES WITH INCREASED SEISMIC HAZARD



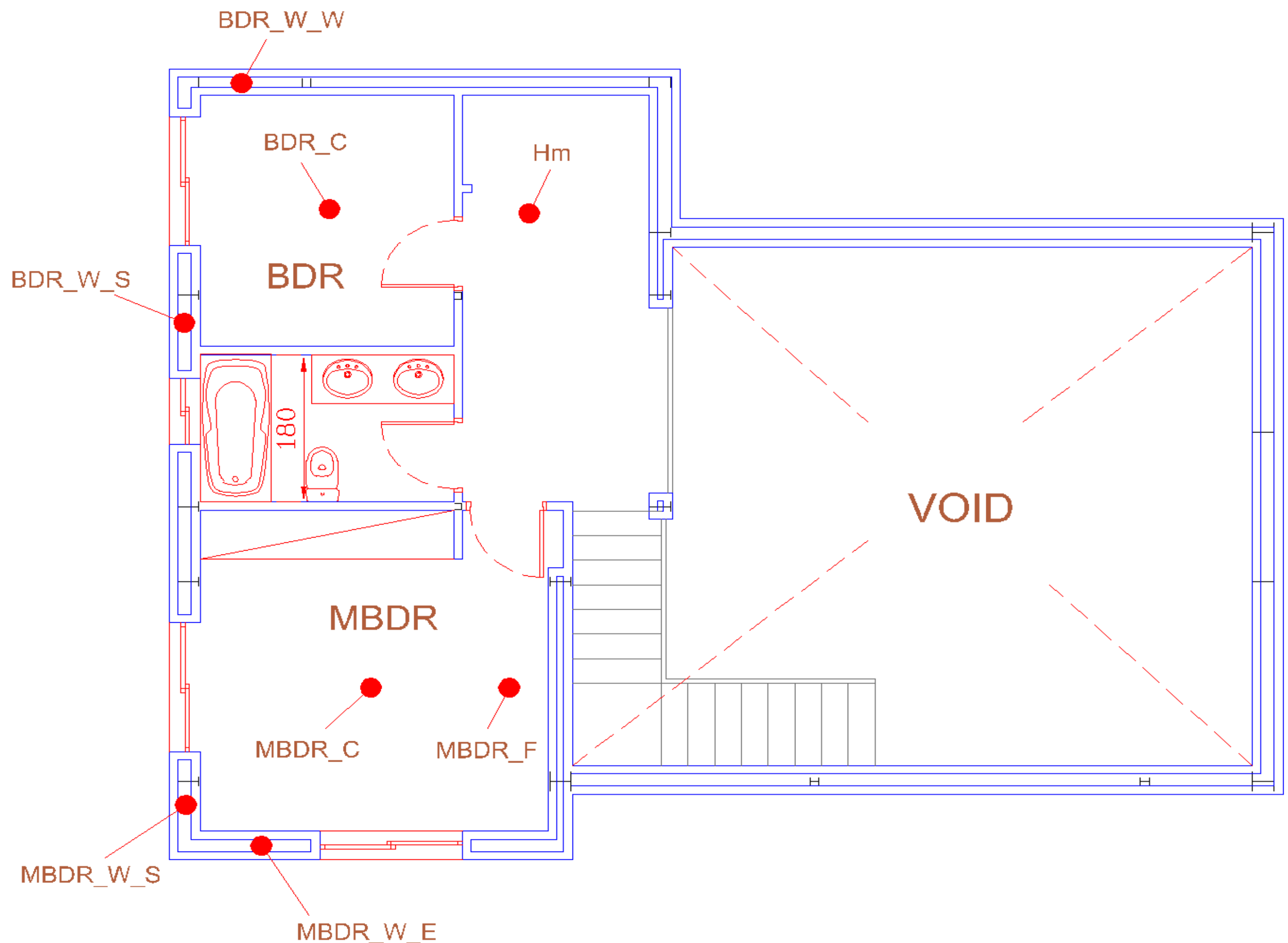
Location of Sensors (ground floor)



Amfilochia Demo House

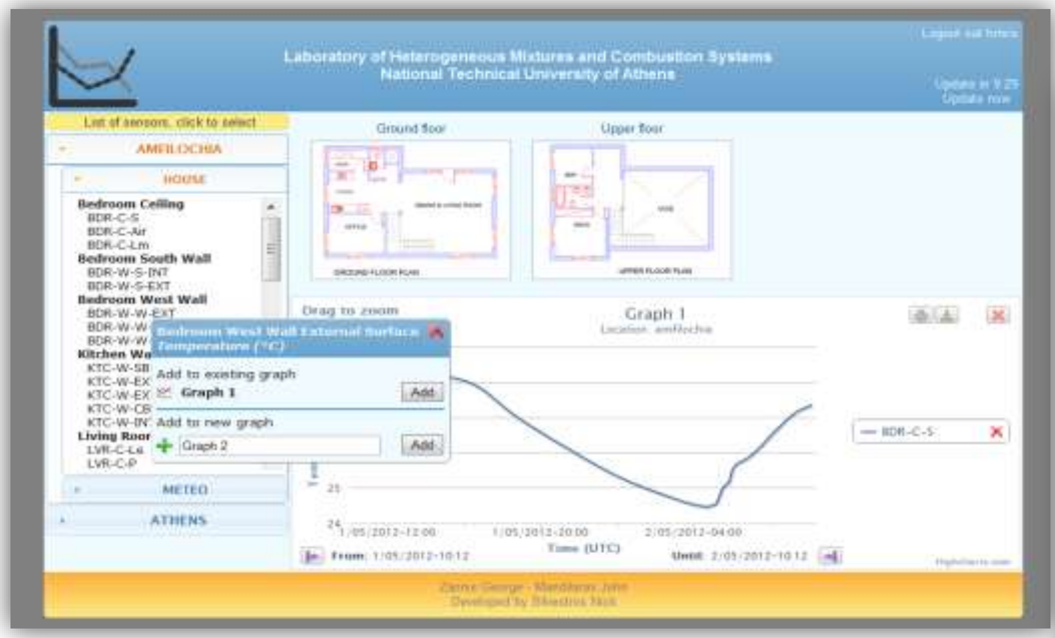
MONITORING OF ENERGY PERFORMANCE

Location of Sensors (first floor)



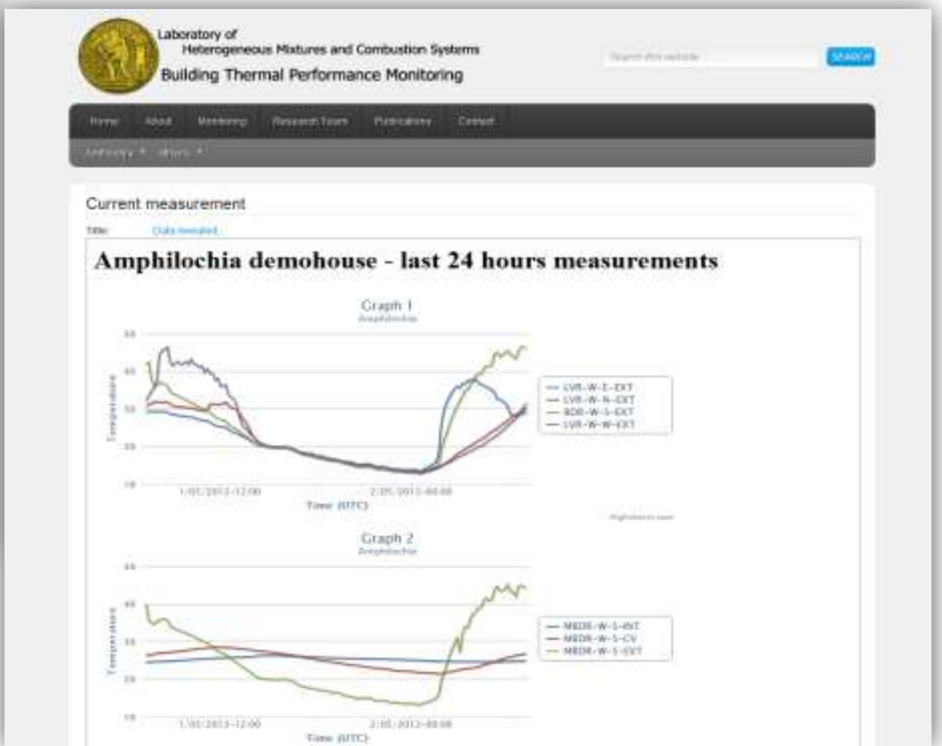
Amfilochia Demo House

MONITORING OF ENERGY PERFORMANCE



Internal Website (NTUA.HMCS)

http://demohouse.hmcs.mech.ntua.gr/monitor/

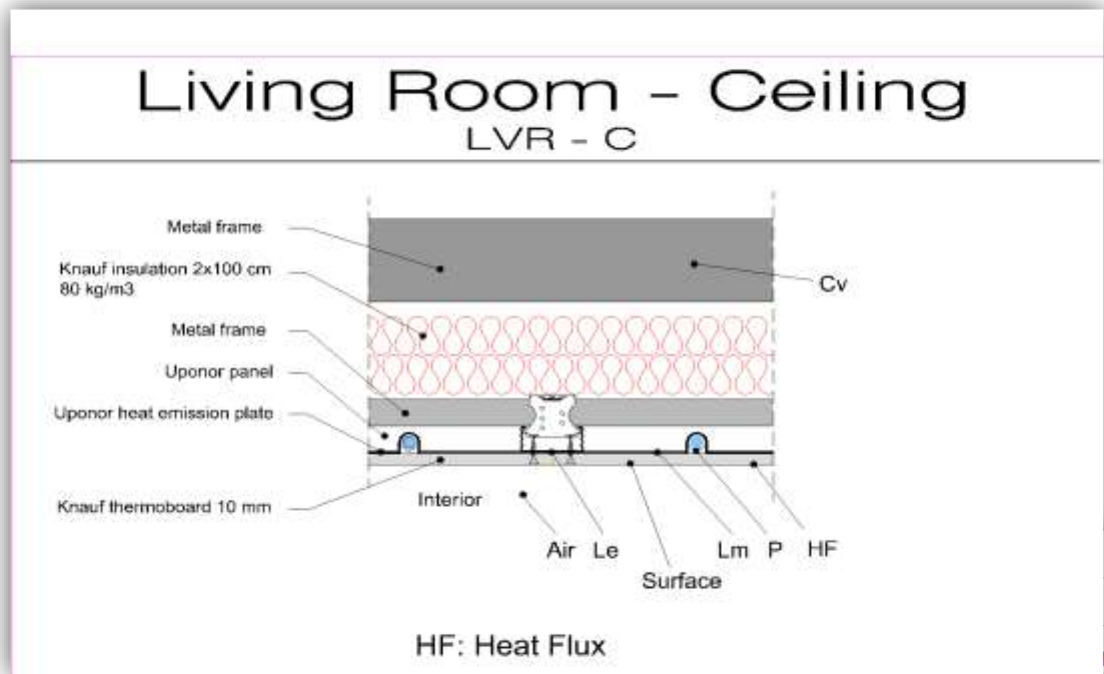


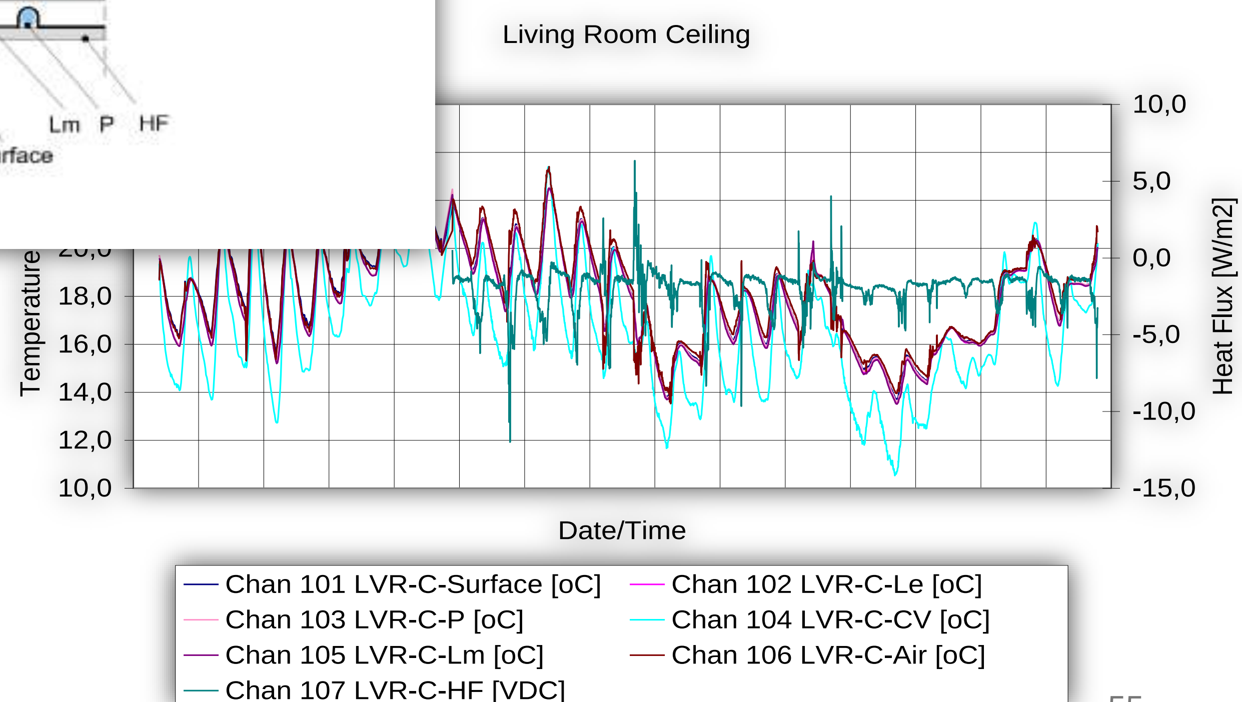
Website (NTUA.HMCS)

http://demohouse.hmcs.mech.ntua.gr/

Amfilochia Demo House

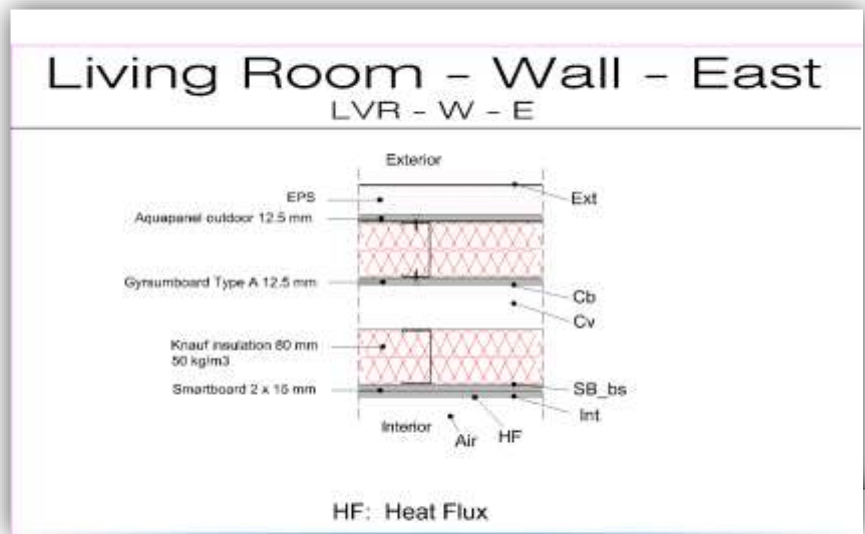
MEASUREMENTS

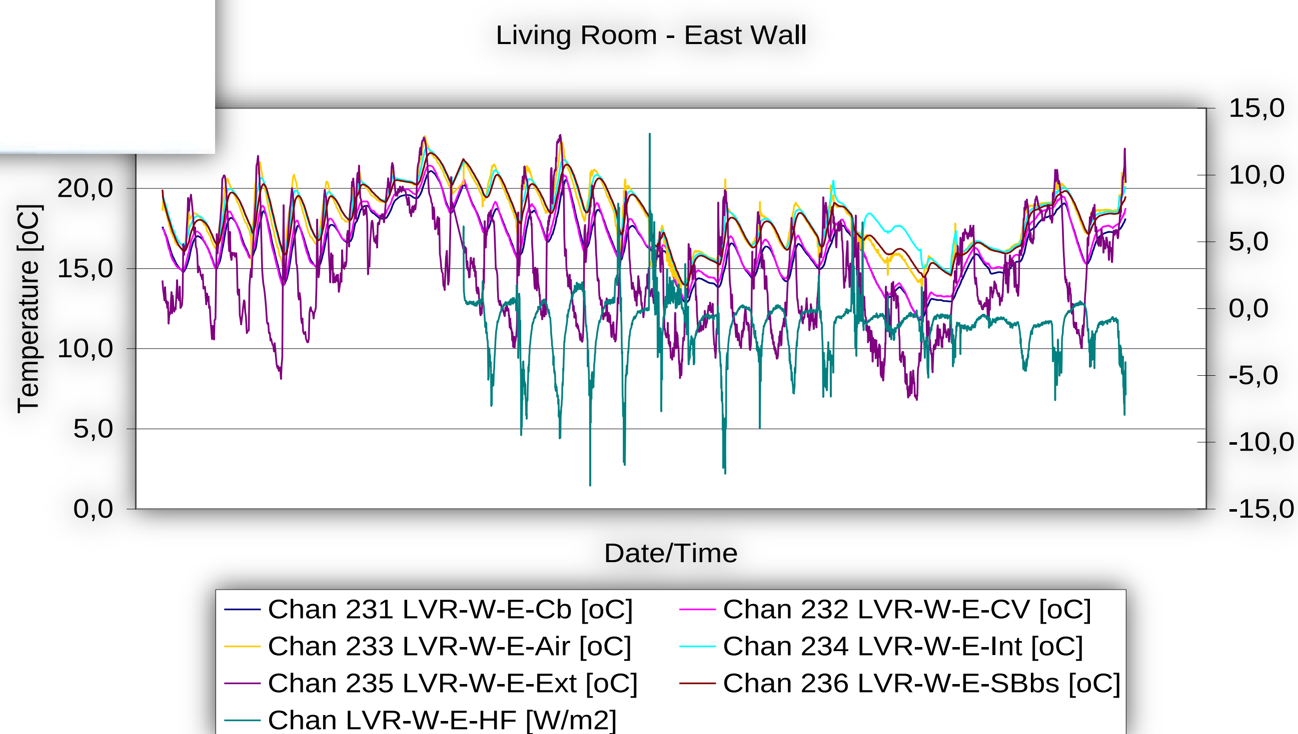




Amfilochia Demo House

MEASUREMENTS

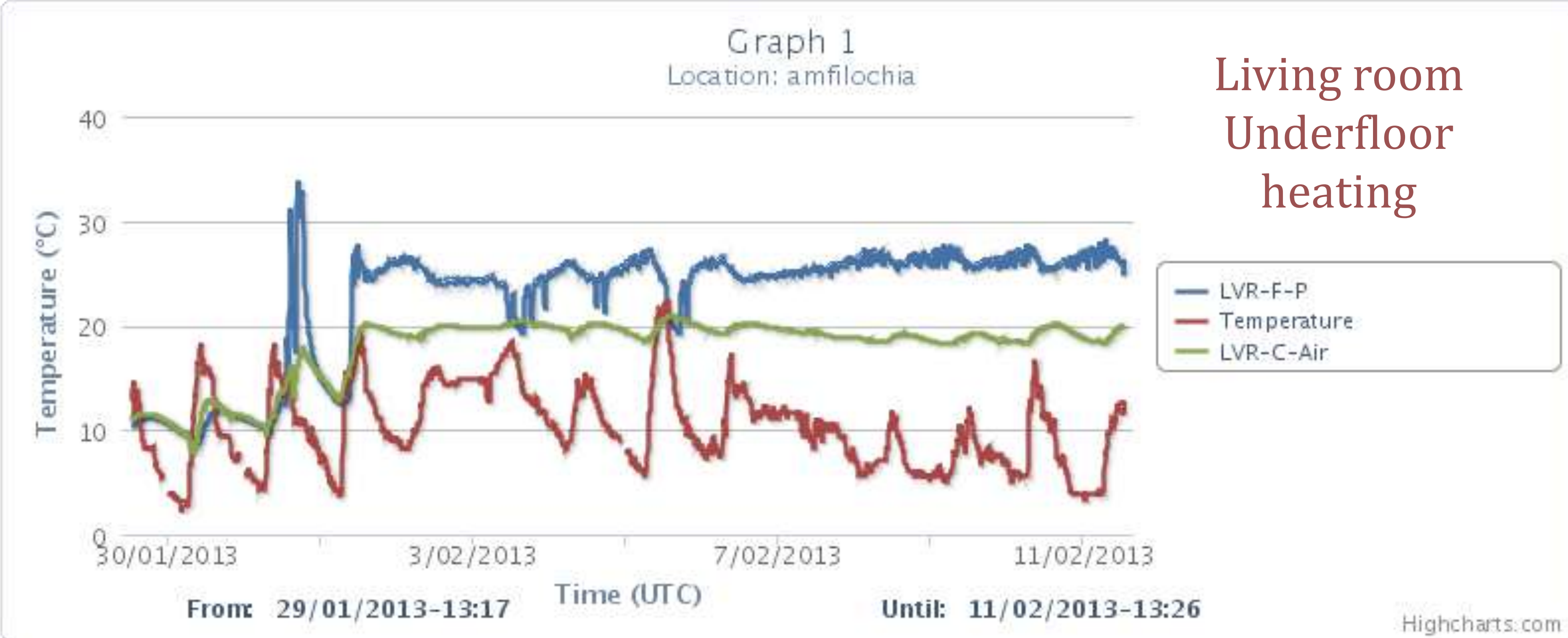




Amfilochia Demo House

MEASUREMENTS

Living room Underfloor heating

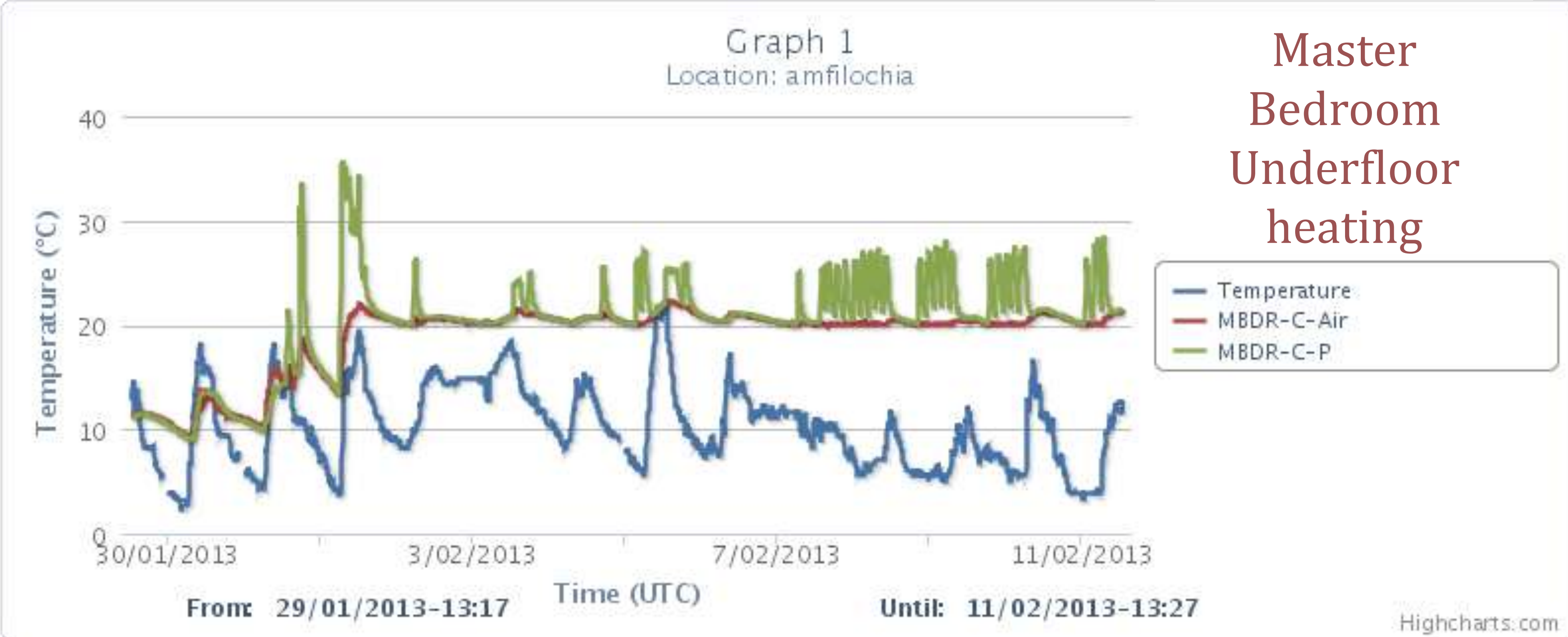


Heat pump Set Point 20ºC.
LVR-F-P: Temperature of water in LVR loop
Compensation (Uponor C46) with Tambient.

Amfilochia Demo House

MEASUREMENTS

Master Bedroom Underfloor heating



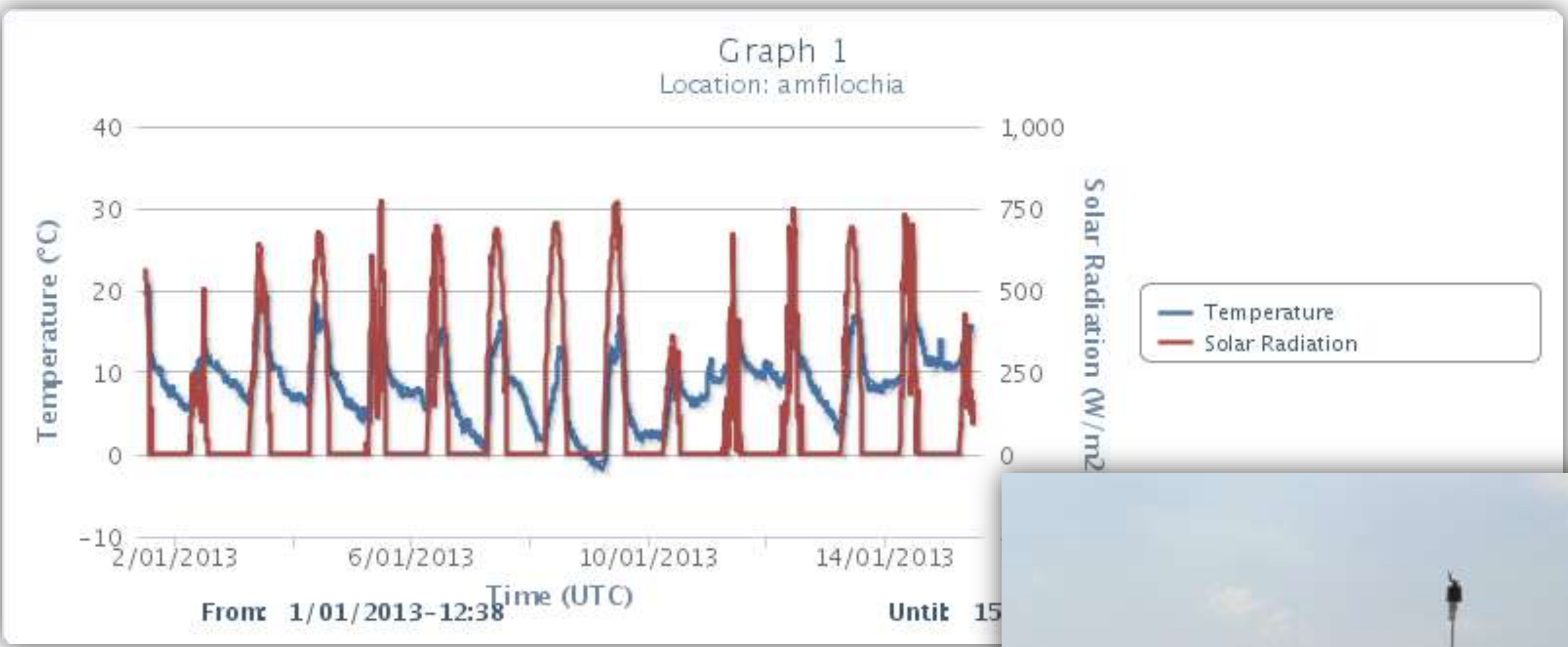
Heat pump Set Point **20°C**.

MBDR-C-P: Temperature of water in MBDR loop

Compensation (Uponor C46) with Tambient.

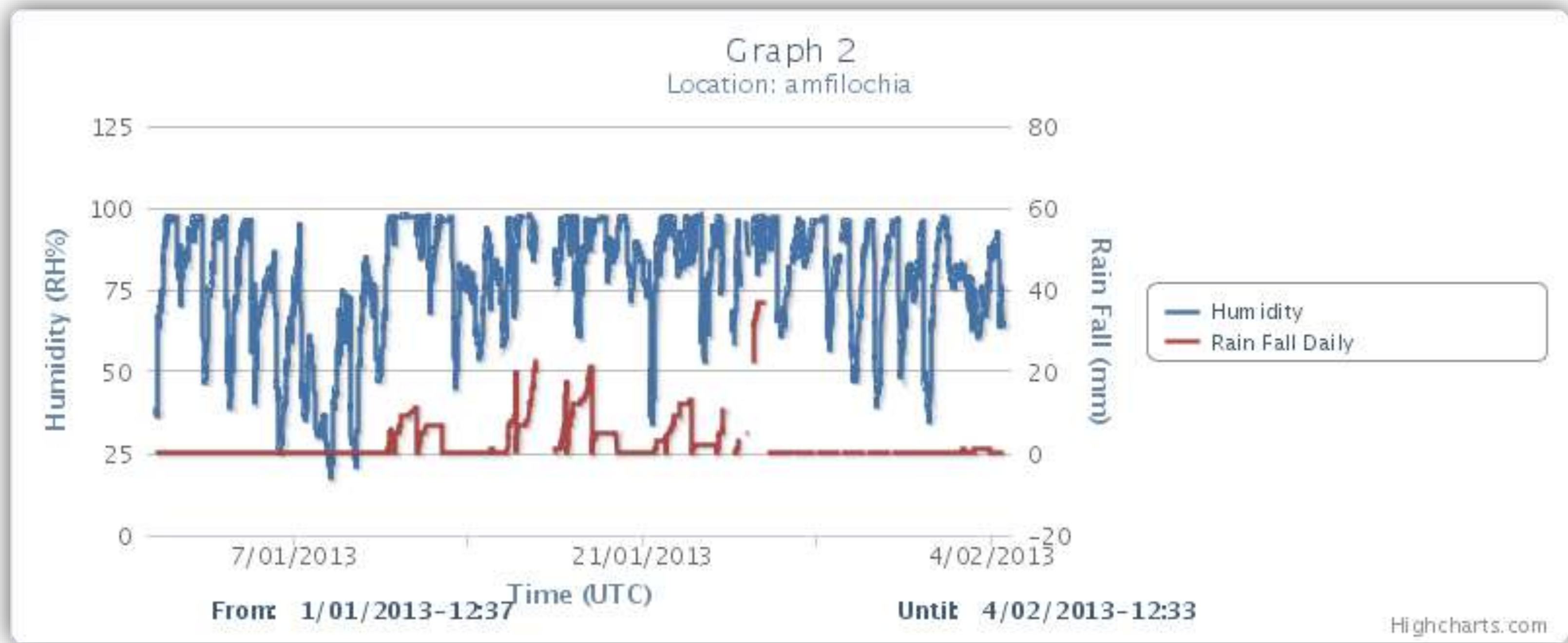
Amfilochia Demo House

WEATHER MEASUREMENTS



Amfilochia Demo House

WEATHER MEASUREMENTS



Measured Data

- Temperature
- Solar Radiation
- Humidity
- Barometric Pressure
- Rain fall
- Wind direction
- Wind speed

Amfilochia Demo House

DISCUSSION OF MONITORING RESULTS

- The house is monitored since 2011 without energy systems (PCM effect). In Jan.2013 systems were set in operation.
- During the monitoring period the house remains purposely closed and unoccupied
- Measurements were interrupted for two months during the summer 2011 (July – August) for maintenance reasons

Amfilochia Demo House

DISCUSSION OF MONITORING RESULTS

External Walls – LVR East Wall

- Layers of external walls (from the exterior to the interior)

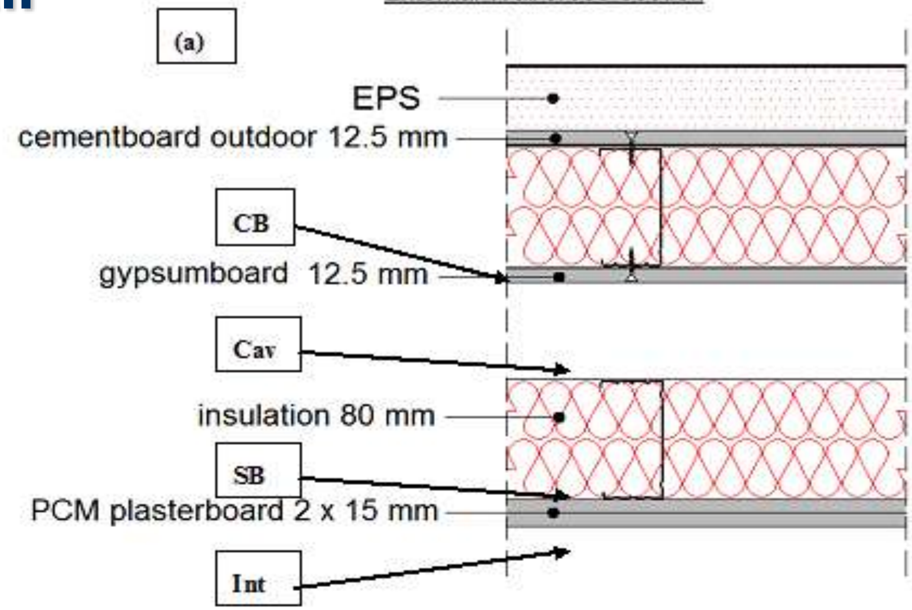
- EPS 80 insulation (50 mm)
- Cementboard Panel (15 mm)
- Rockwool insulation (80 mm)
- Gypsum plasterboard (12.5 mm)
- Air Gap (300 mm)
- Rockwool insulation (80 mm)
- PCM plasterboard (30mm)

- Composite structure of the demo house partitions

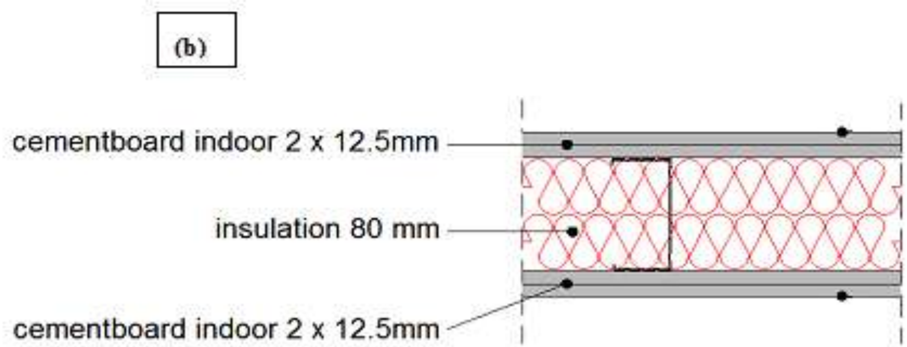
- LVR East Wall

Three additional temperature sensors (CB, Cav, SB)

External Wall cross-section



Internal Wall cross-section



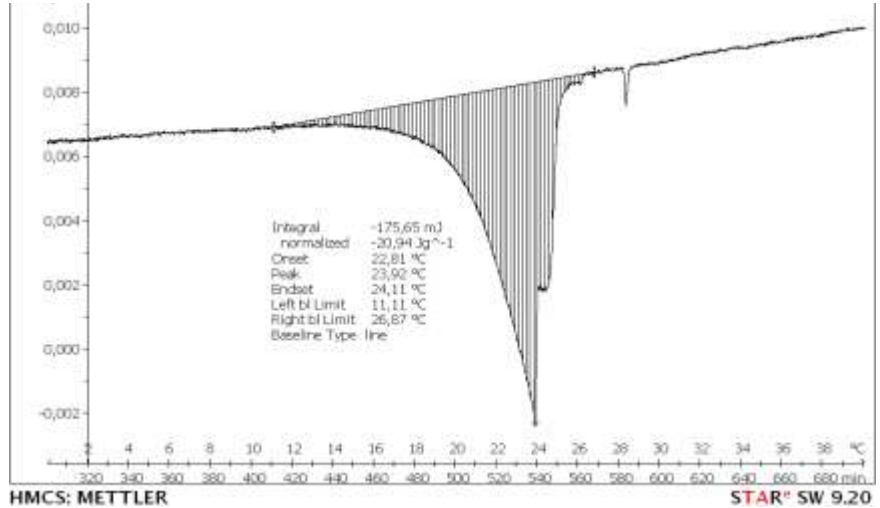
Amfilochia Demo House

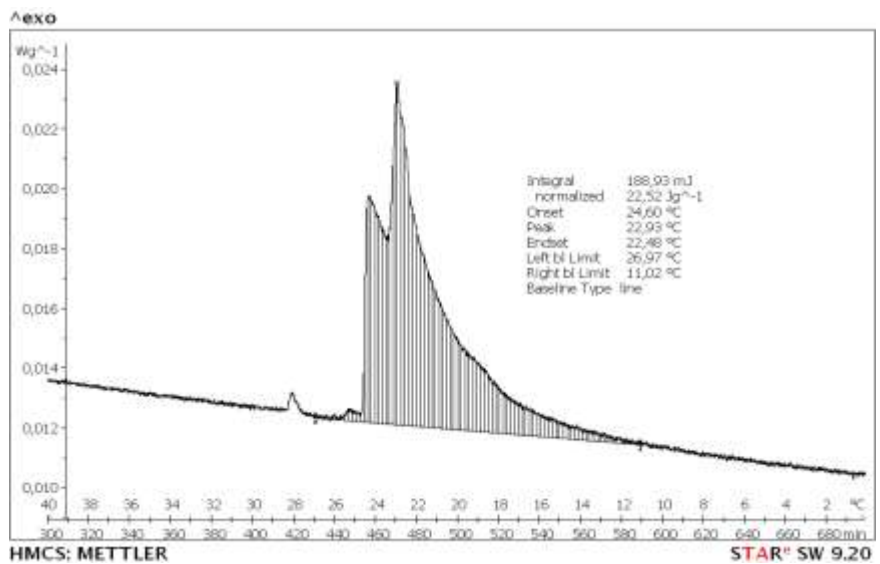
DISCUSSION OF MONITORING RESULTS

Gypsum Plasterboard with PCMs

DSC Curves

- According to these experimentally determined curves, the phase change phenomena occur in a temperature range between 16 and 26 °C and thus the implemented PCM is expected to be activated within this range.

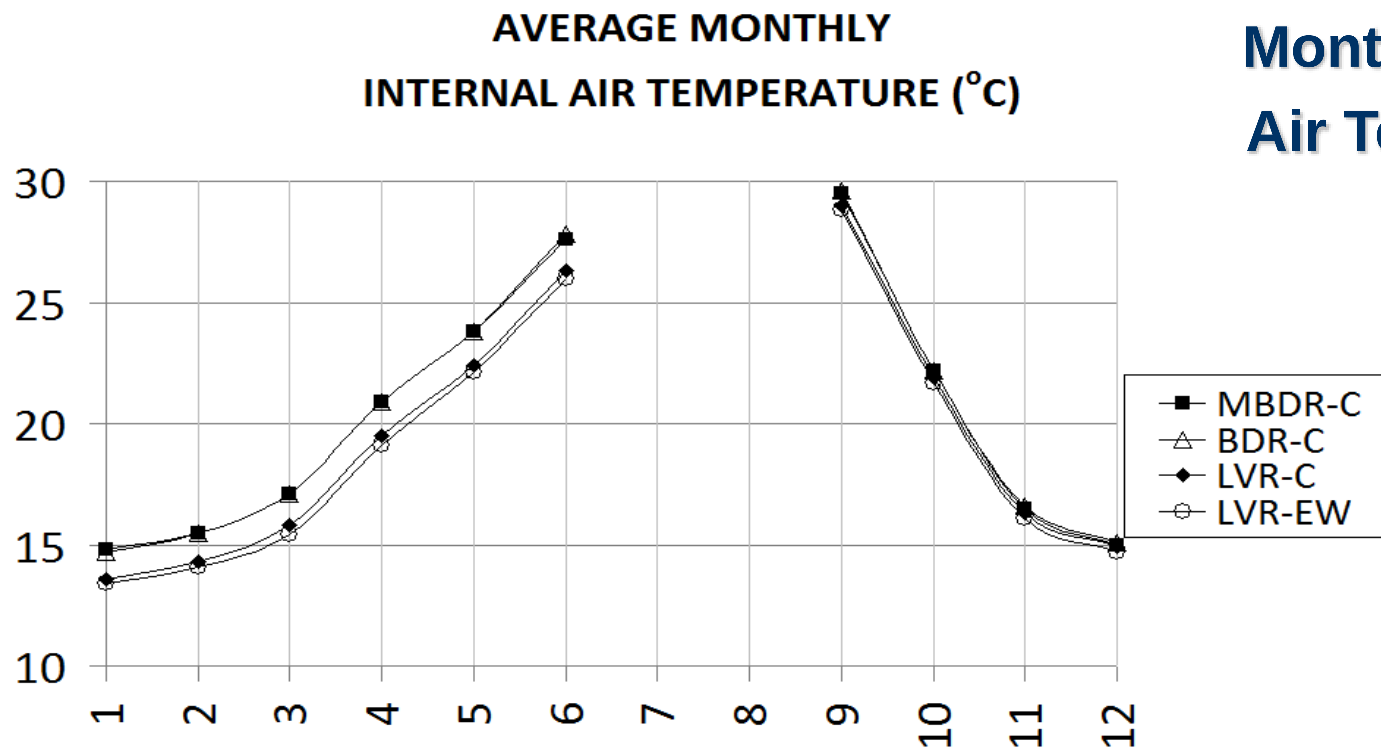




Amfilochia Demo House

DISCUSSION OF MONITORING RESULTS

Monthly Average Indoor Air Temperatures - 2011



- Monthly average indoor air temperatures per thermal zone.
- Since no heating/cooling devices were operated, indoor temperatures occasionally exceed the human comfort temperature range.
- Measurements show that both MBDR and BDR systematically depict higher indoor air temperatures than the LVR, for all time periods examined.

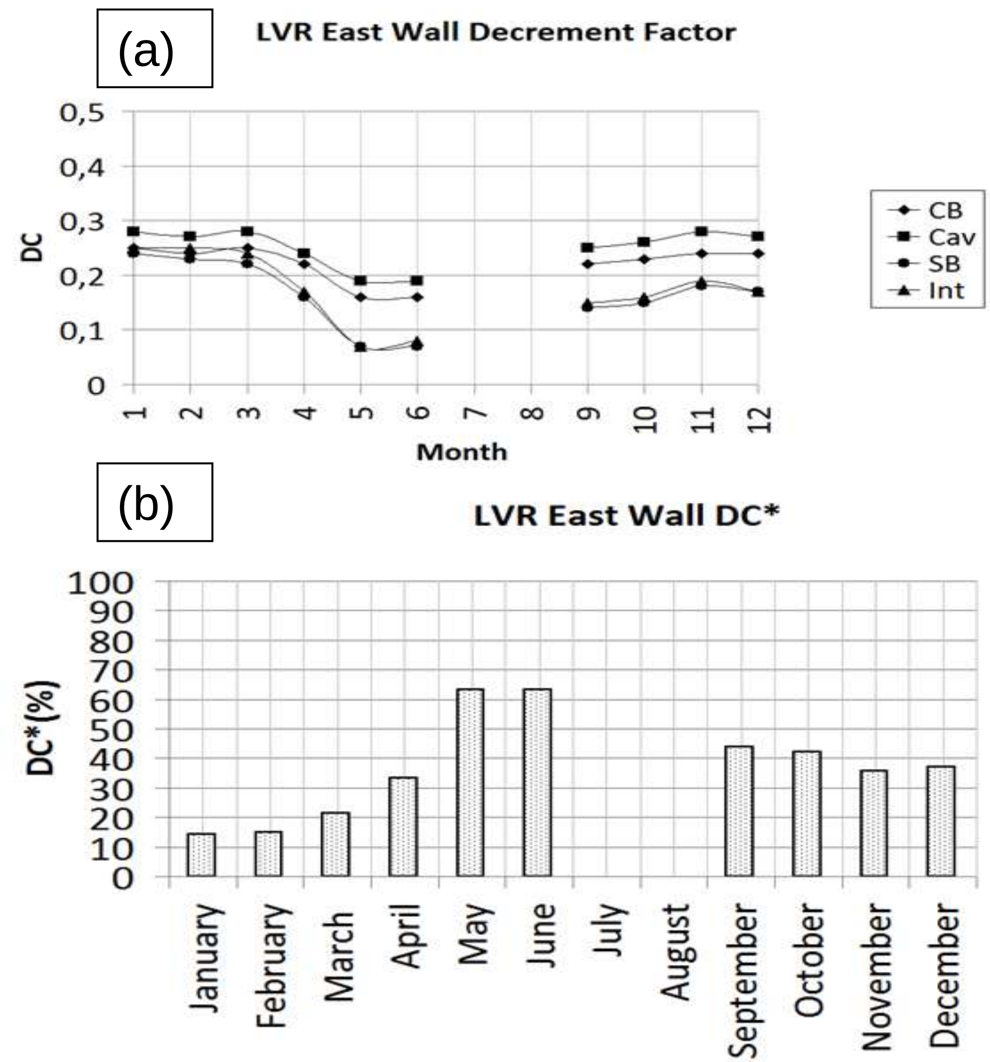
Amfilochia Demo House

DISCUSSION OF MONITORING RESULTS

PCM Activation (I) - 2011

- a) Monthly average DC *(Decrement Factor)* in various layers of the LVR's east wall, b) Relative decrement factor DC* between cavity and the "SB" layer

- The influence of PCMs on the smoothing of the wall temperature fluctuations is apparent. Their contribution can reach a maximum of *30-40%* to the wall's DC during late spring, early summer and autumn.



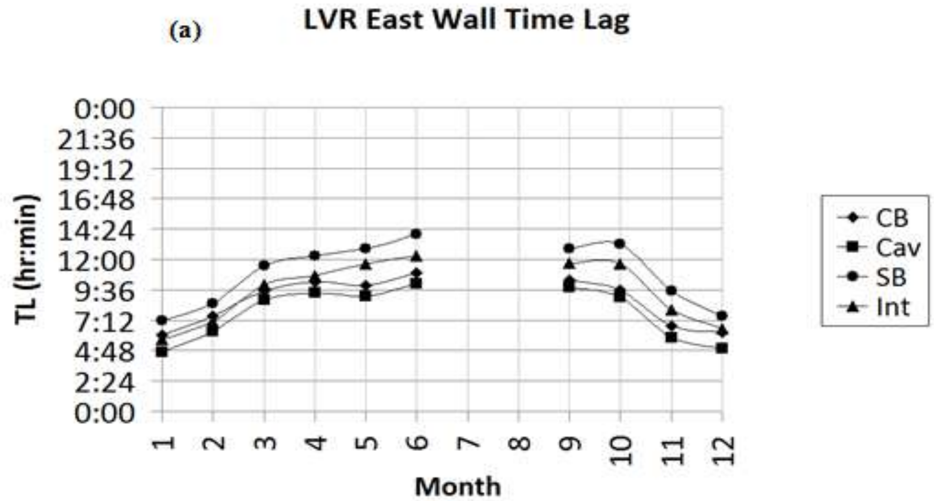
Amfilochia Demo House

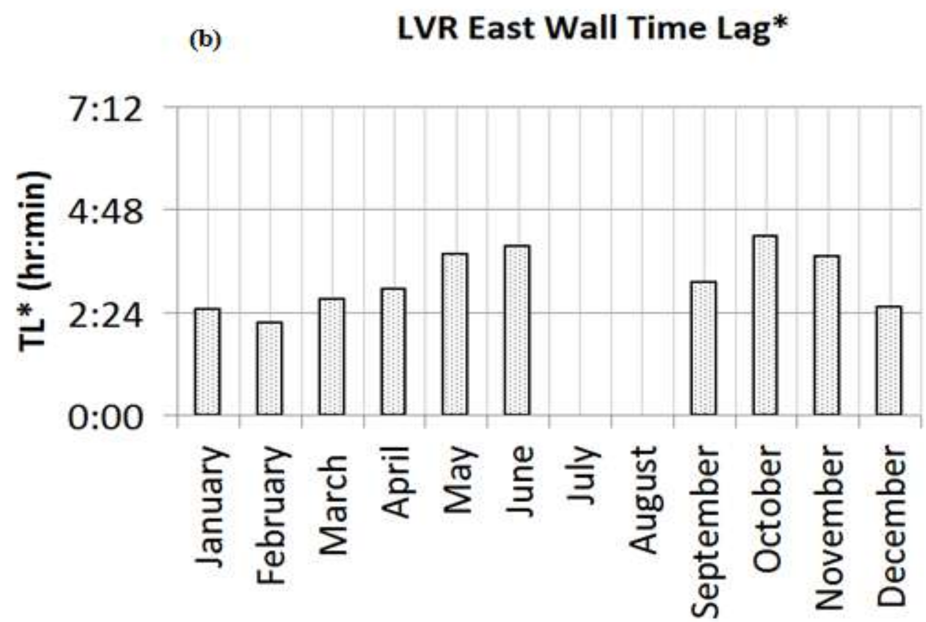
DISCUSSION OF MONITORING RESULTS

PCM Activation (II) - 2011

- a) Monthly average TL (Time Lag) values for various layers of the LVR east wall, b) Relative time lag (TL*) between "Cav" and the SB layer.

- The integration of PCMs in the house's walls can aid in enhancing the envelope's thermal inertia by at most <u>*100 min*</u>, since the TL* obtains values close to 4 h during late spring, June and autumn, whereas in winter the respective TL* values remain almost steady at approximately 2-2:30 h.



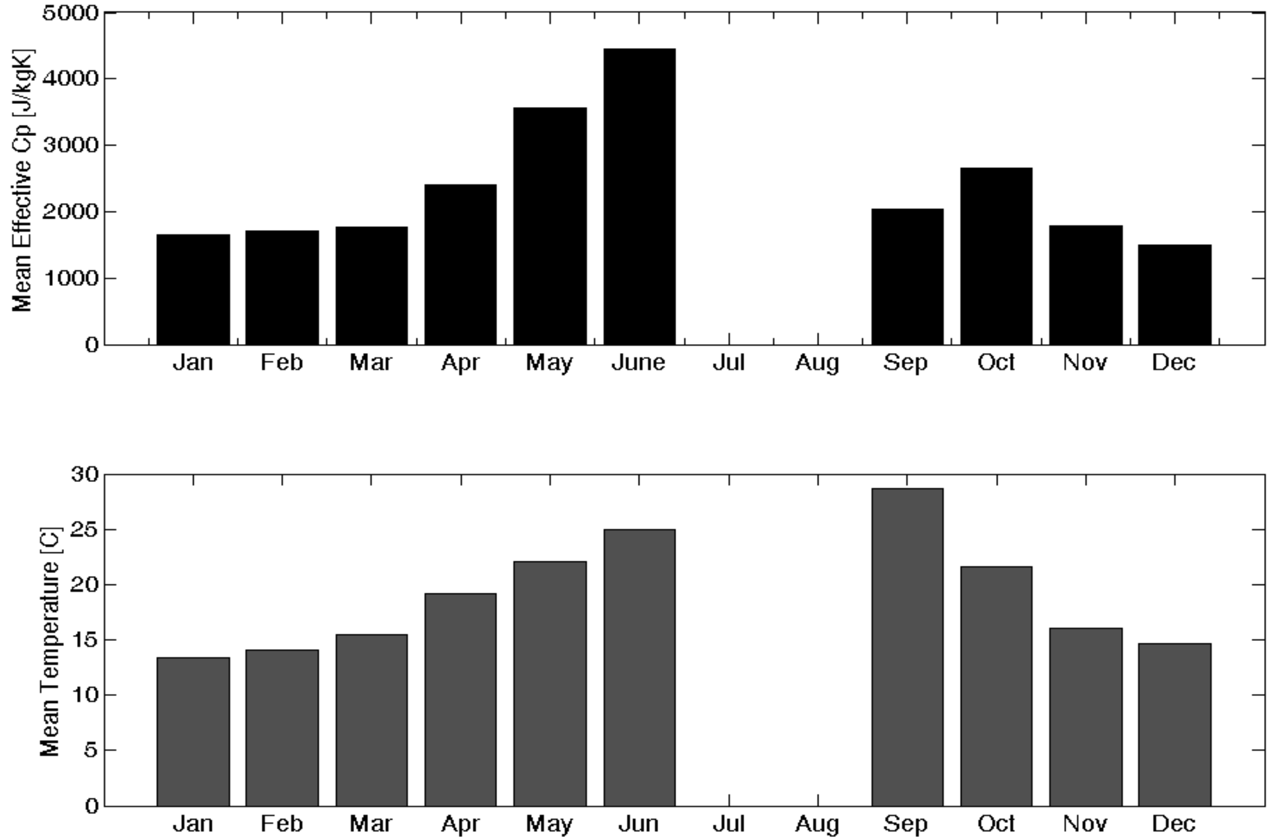


Amfilochia Demo House

DISCUSSION OF MONITORING RESULTS

PCM Activation (III) - 2011

The abrupt increase of the "mean-effective" specific heat capacity during spring, early summer and autumn is an indication of the enhanced thermal mass of the walling system, when PCMs are activated.



- The "mean-effective" specific heat capacity of the "SB" layer has been calculated by an energy balance performed on the "SB" layer of the LVR east wall based on the indoor temperatures, and temperatures measured in the "SB" layer and in the "Cav".

Amfilochia Demo House

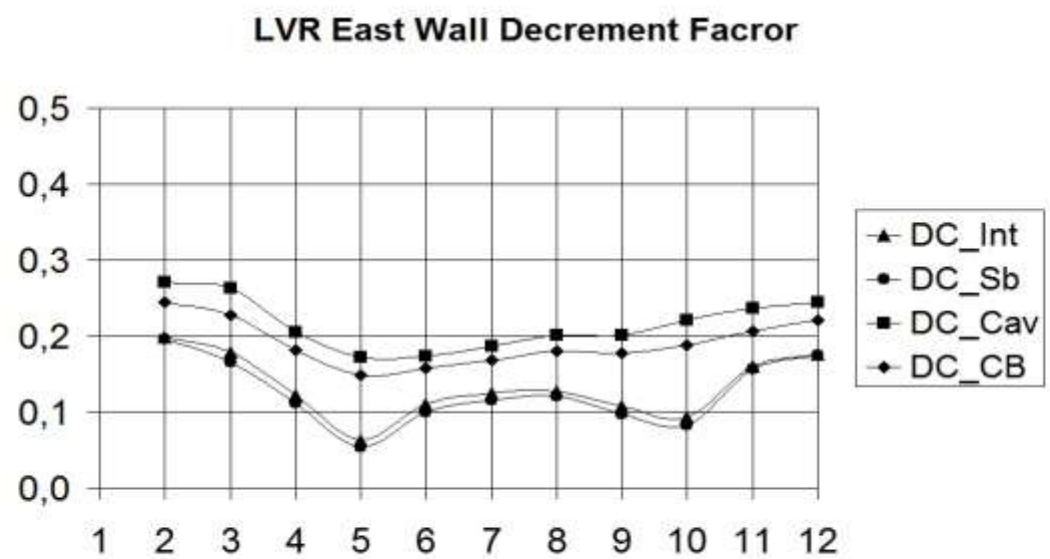
DISCUSSION OF MONITORING RESULTS

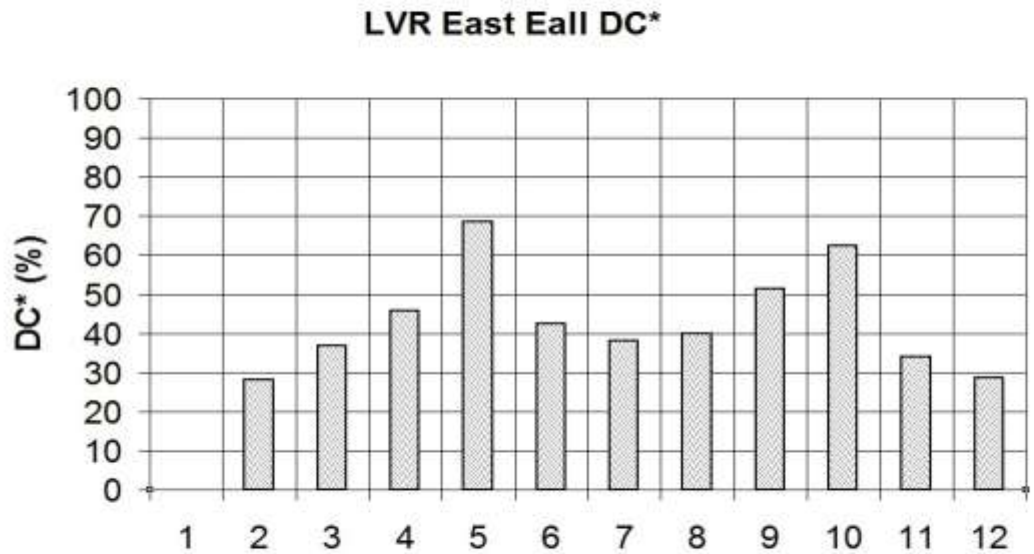
PCM Activation (IV) – 2012

- a) Monthly average DC *(Decrement Factor)* in various layers of the LVR's east wall, b) Relative decrement factor DC* between cavity and the "SB" layer.

- The influence of PCMs on the smoothing of the wall temperature fluctuations is apparent. Their contribution can reach a maximum of *30-40%* to the wall's DC during late spring, early summer and autumn.

- During the summer months due to the high levels of temperatures PCMs are not activated.

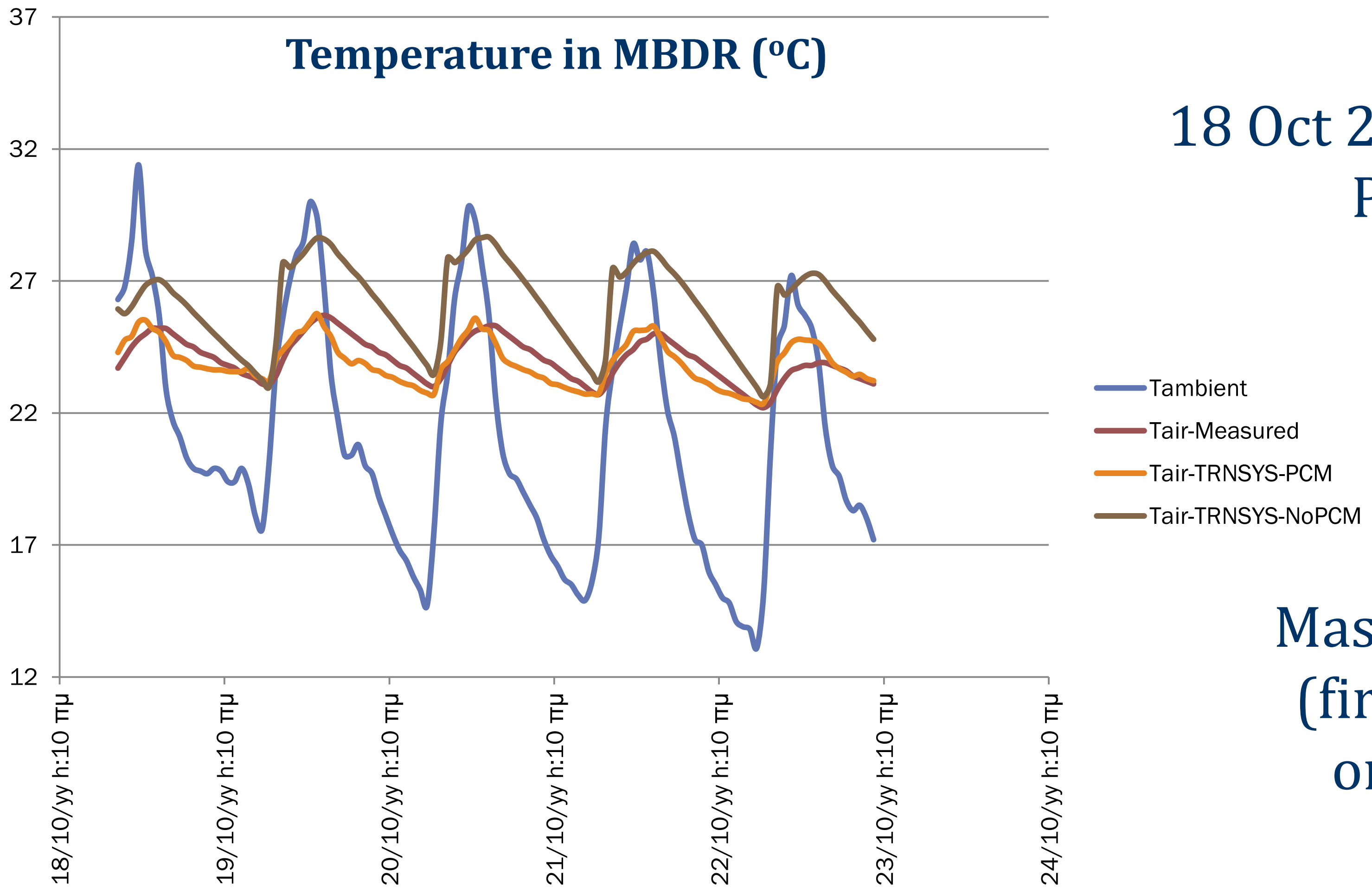




Amfilochia Demo House

SIMULATION RESULTS

Simulations using coupled solver TRNSYS-MATLAB



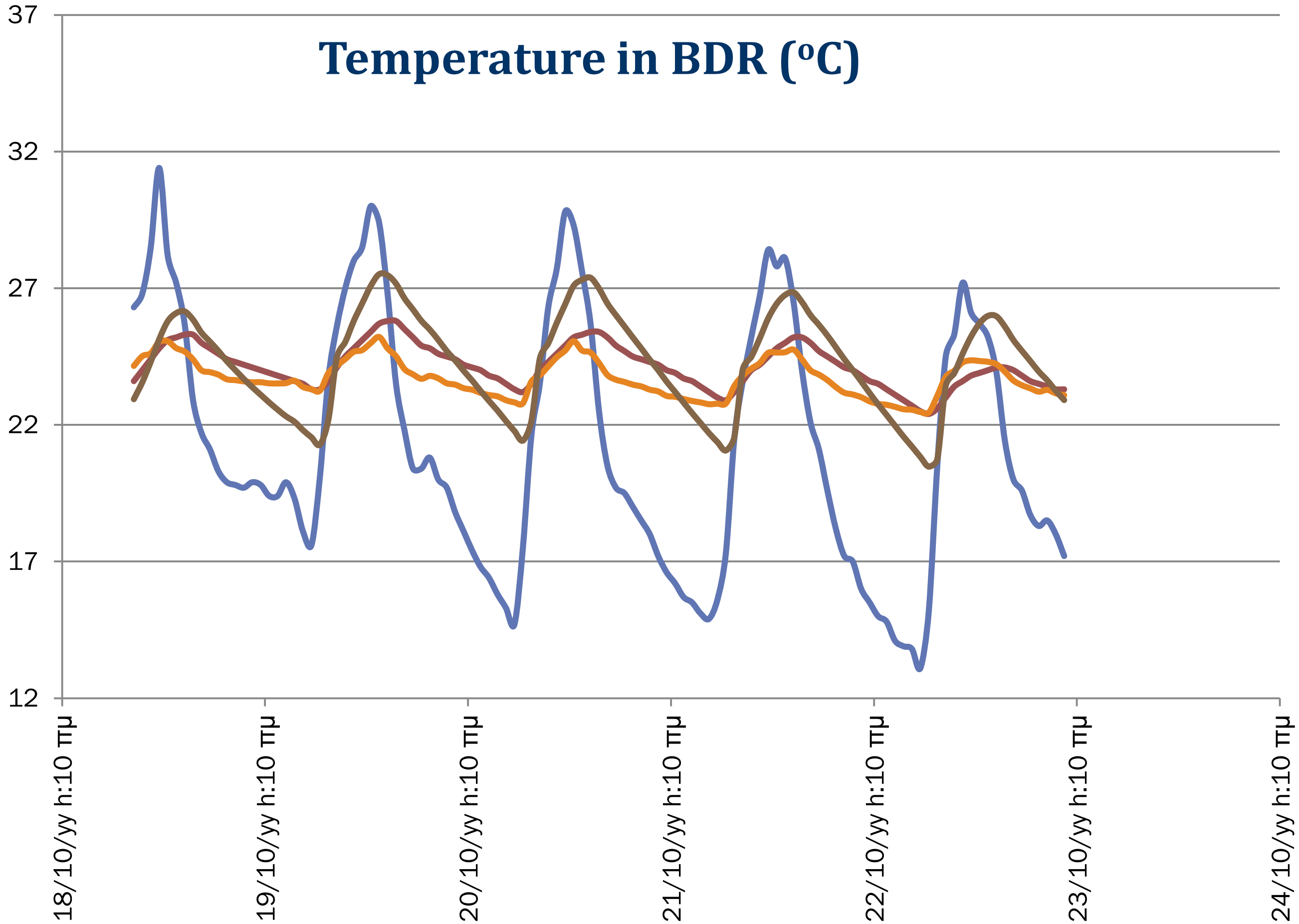
Period:
18 Oct 2012- 24 Oct2012
PCM effect

Master Bedroom
(first floor – SE orientation)

Amfilochia Demo House

SIMULATION RESULTS

Simulations using coupled solver TRNSYS-MATLAB



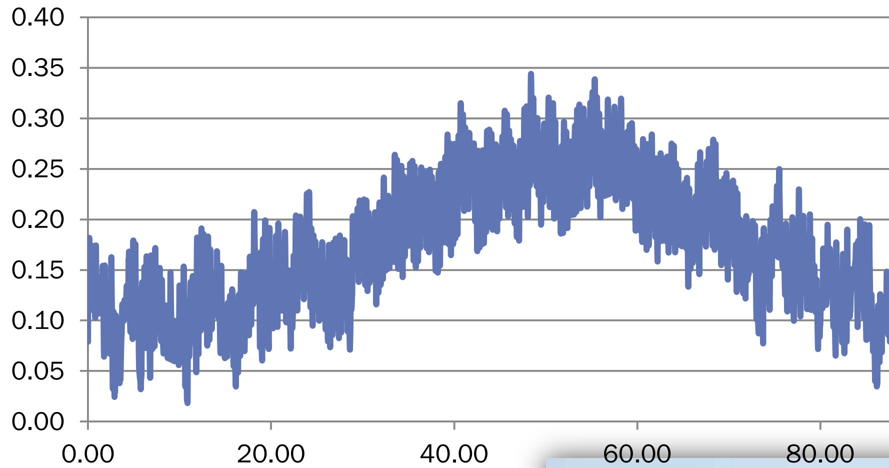
Period:
18 Oct 2012- 24 Oct2012
PCM effect

Bedroom
(first floor – SW orientation)

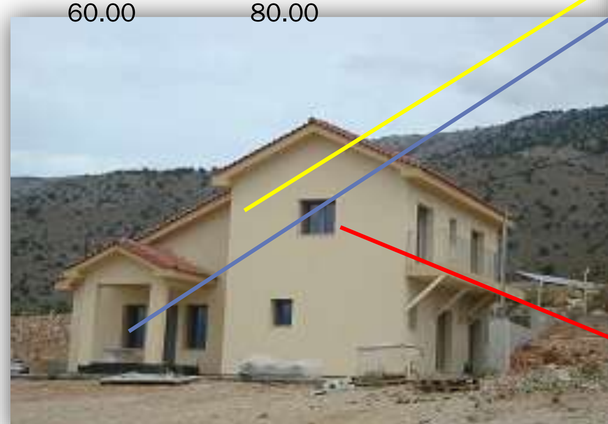
Amfilochia Demo House

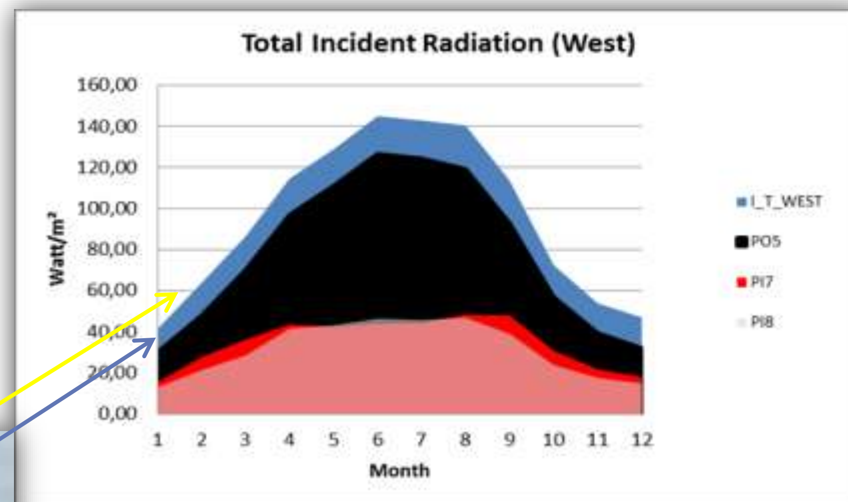
SIMULATION RESULTS

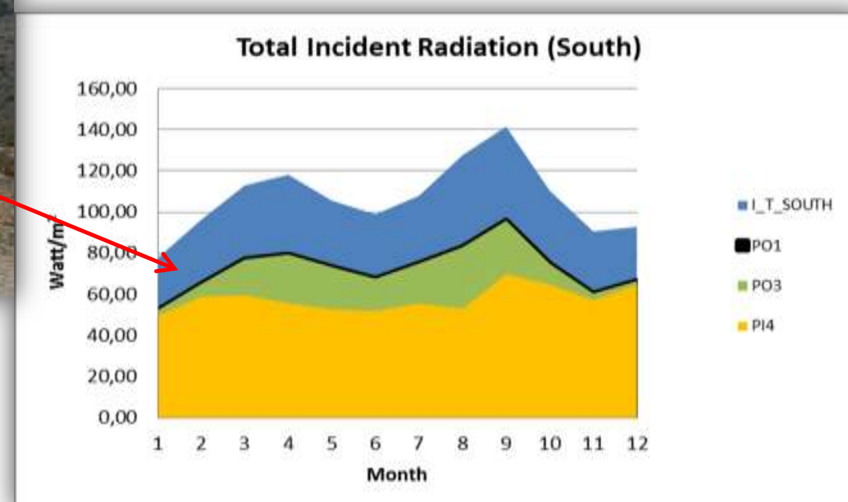
Tambient -TRNSYS weather file - (^oC)



Incident Radiation on West and South Surface







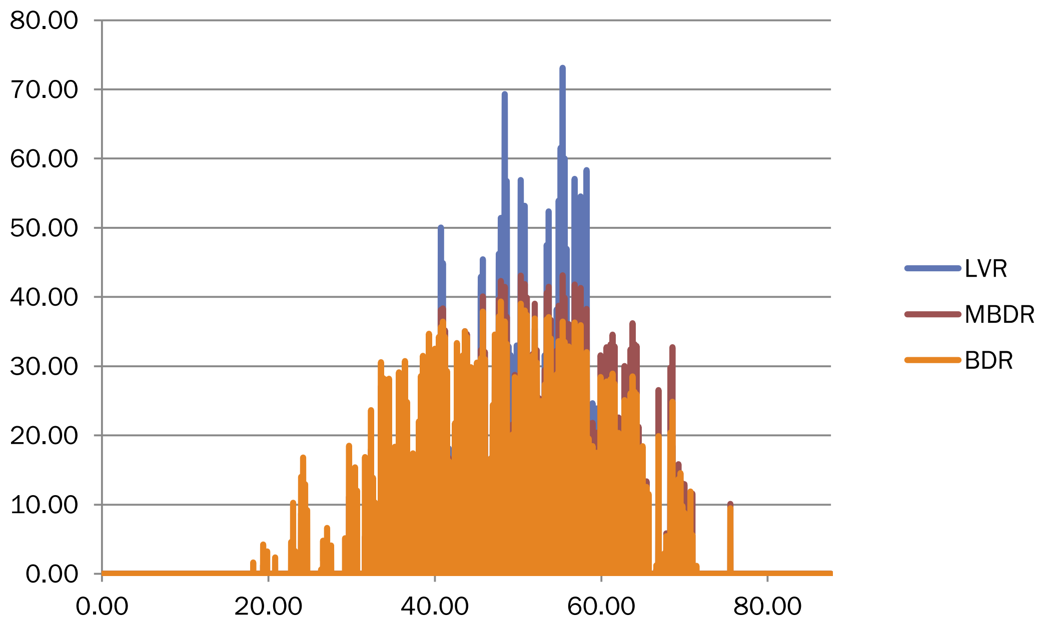
TRNSYS weather file:
Used for simulation of
cooling loads

Amfilochia Demo House

SIMULATION RESULTS

Simulations using coupled solver TRNSYS-MATLAB

Cooling Demand (entire house)	
No PCM case	PCM case
19.54(kWh/m^{2}year)	13.88(kWh/m^{2}year)



Cooling demand (kWh/year)

Annual cooling demand for
MBDR: Master Bedroom
BDR: Bedroom
LVR: Living Room

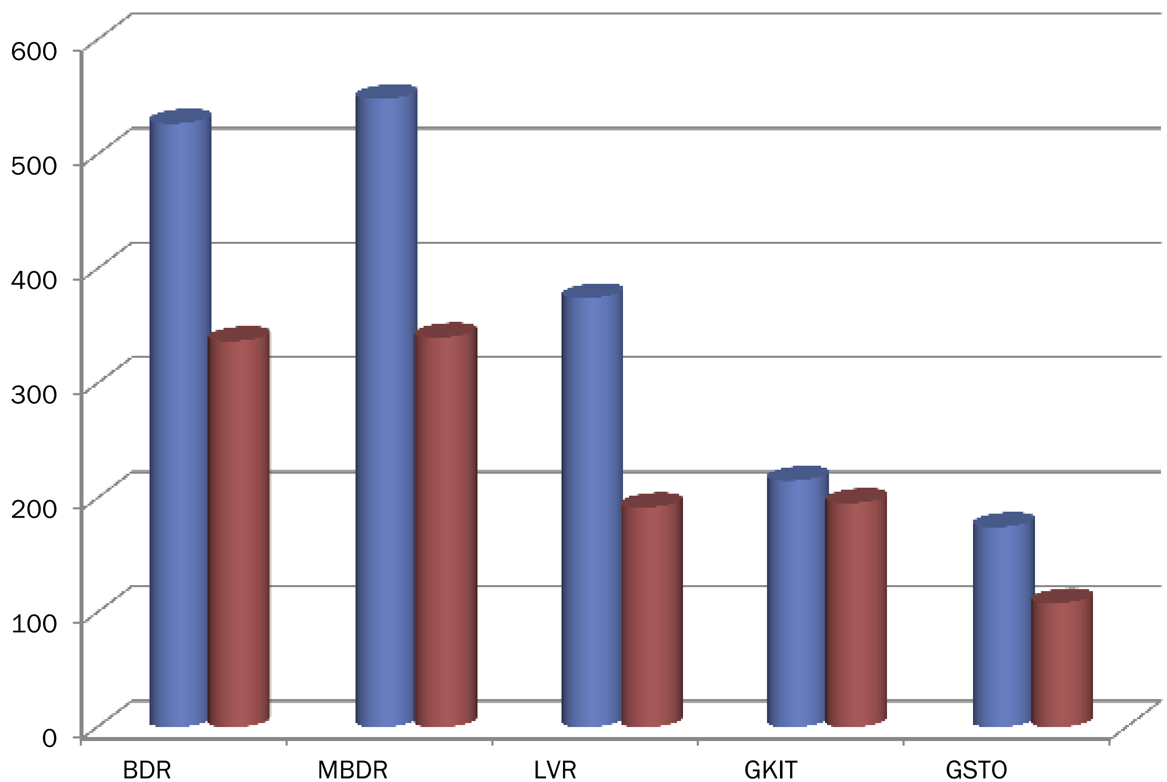
Cooling set point at 26°C – one year simulation

Amfilochia Demo House

SIMULATION RESULTS

Simulations using coupled solver TRNSYS-MATLAB

Cooling demand (kWh/year) for each room

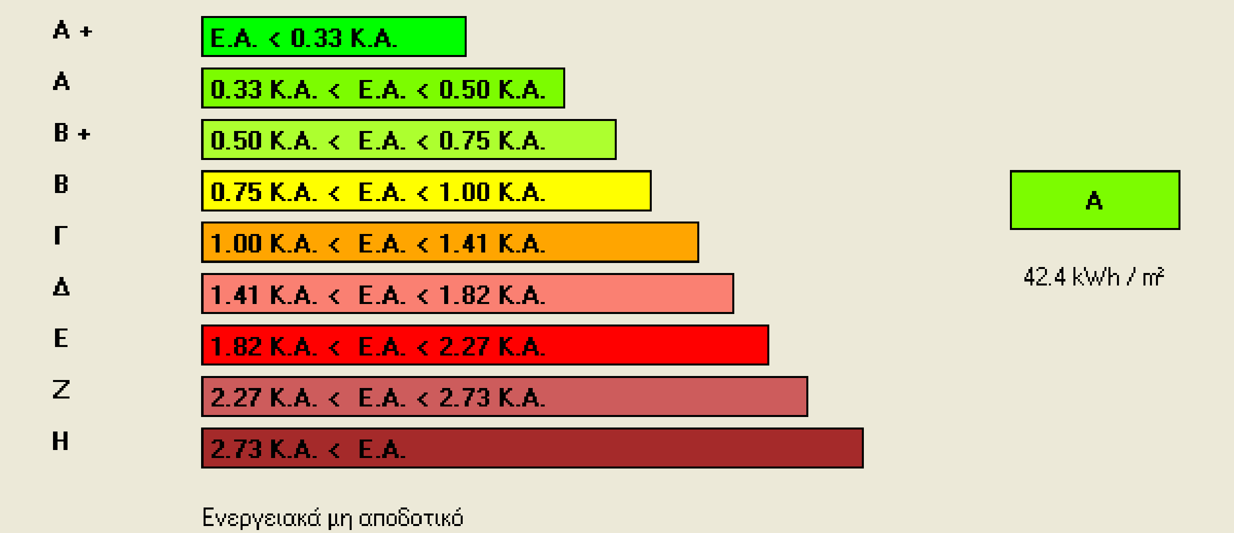


Cooling set point at 26^{o}C.
Unlimited power for one year.

Amfilochia Demo House

SIMULATION RESULTS

Energy performance assessment for Amfilochia using national audit simulation tool (TEE-KENAK)



Πρωτογενής ενέργεια ανα τελική χρήση (kWh/m²)

Τελική χρήση	Κτίριο αναφοράς	Υπάρχον κτίριο
Θέρμανση	46.8	14.6
Ψύξη	29.8	25.8
ΖΝΧ	16.6	2.0
Φωτισμός	0.0	0.0
Συνεισφορά ΑΠΕ - ΣΗΘ	0.0	0.0
Σύνολο	93.2	42.4
Κατάταξη	-	A

The TEE-KENAK software is the official national platform used for the energy performance assessment of buildings in Greece.

Consumption of primary energy (kWh/m²) per end-use (PCM effect not taken into account)

- Space heating
- Space cooling
- Domestic hot water
- Lighting

Amfilochia Demo House

SIMULATION RESULTS

Υπάρχον κτίριο

Ενεργειακές απαιτήσεις (kWh/m²)	Ιαν.	Φεβ.	Μαρ.	Απρ.	Μαι.	Ιουν.	Ιουλ.	Αυγ.	Σεπ.	Οκτ.	Νοε.	Δεκ.	Ετήσιο
Θέρμανση	7.3	5.3	3.5	0.4	0.0	0.0	0.0	0.0	0.0	0.0	2.3	6.0	24.7
Ψύξη	0.0	0.0	0.0	0.0	1.8	8.7	12.4	11.8	2.8	0.0	0.0	0.0	37.4
Ύγρανση	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ΖΝΧ	1.5	1.4	1.5	1.3	1.2	0.9	0.9	0.8	0.9	1.1	1.3	1.4	14.2

Ενεργειακή κατανάλωση (kWh/m²)	Ιαν.	Φεβ.	Μαρ.	Απρ.	Μαι.	Ιουν.	Ιουλ.	Αυγ.	Σεπ.	Οκτ.	Νοε.	Δεκ.	Ετήσιο
Θέρμανση	1.5	1.1	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	1.3	5.0
Ηλιακή ενέργεια για θέρμανση χώρων	1.5	1.6	2.2	2.5	3.0	3.3	3.5	3.3	2.7	2.2	1.6	1.4	28.8
Ψύξη	0.0	0.0	0.0	0.0	0.4	2.1	2.9	2.8	0.7	0.0	0.0	0.0	8.9
ΖΝΧ	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.9
Ηλιακή ενέργεια για ζεστό νερό χρήσης	1.0	1.1	1.5	1.7	2.1	2.2	2.4	2.2	1.9	1.5	1.1	0.9	19.7
Φωτισμός	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ενέργεια απο φωτοβολταϊκά - ΣΗΘ	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Σύνολο	1.8	1.2	0.7	0.1	0.5	2.1	2.9	2.8	0.7	0.0	0.6	1.5	14.8

Πηγή ενέργειας	Κατανάλωση καυσίμων (kWh/m²)	Εκπομπές CO2 (kg/m²)
Ηλεκτρισμός	14.8	14.6
Πετρέλαιο	0.0	0.0
Φυσικό αέριο	0.0	0.0
Άλλα ορυκτά καύσιμα	0.0	0.0
Ηλιακή	48.5	0.0
Βιομάζα	0.0	0.0
Γεωθερμία	0.0	0.0
Άλλο ΑΠΕ	0.0	0.0
Σύνολο	14.8	14.6

Amfilochia Demo house

Amfilochia Demo House

SIMULATION RESULTS

Κτίριο αναφοράς

Ενεργειακές απαιτήσεις (kWh/m²)	Ιαν.	Φεβ.	Μαρ.	Απρ.	Μαι.	Ιουν.	Ιουλ.	Αυγ.	Σεπ.	Οκτ.	Νοε.	Δεκ.	Ετήσιο
Θέρμανση	13.8	10.3	6.7	0.9	0.0	0.0	0.0	0.0	0.0	0.0	4.7	11.7	48.0
Ψύξη	0.0	0.0	0.0	0.0	2.6	13.3	19.3	18.2	3.9	0.0	0.0	0.0	57.3
Ύγρανση	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ΖΝΧ	1.5	1.4	1.5	1.3	1.2	0.9	0.9	0.8	0.9	1.1	1.3	1.4	14.2

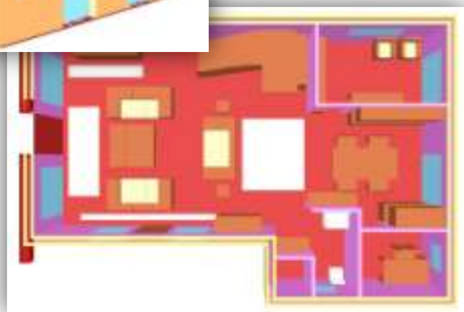
Ενεργειακή κατανάλωση (kWh/m²)	Ιαν.	Φεβ.	Μαρ.	Απρ.	Μαι.	Ιουν.	Ιουλ.	Αυγ.	Σεπ.	Οκτ.	Νοε.	Δεκ.	Ετήσιο
Θέρμανση	4.6	3.5	2.2	0.3	0.0	0.0	0.0	0.0	0.0	0.0	1.6	3.9	16.1
Ηλιακή ενέργεια για θέρμανση χώρων	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ψύξη	0.0	0.0	0.0	0.0	0.5	2.4	3.5	3.3	0.7	0.0	0.0	0.0	10.3
ΖΝΧ	1.6	1.5	1.6	1.4	1.2	1.0	0.9	0.9	1.0	1.2	1.3	1.5	15.1
Ηλιακή ενέργεια για ζεστό νερό χρήσης	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3	2.7
Φωτισμός	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ενέργεια απο φωτοβολταϊκά - ΣΗΘ	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Σύνολο	6.3	4.9	3.8	1.7	1.7	3.4	4.4	4.2	1.7	1.2	2.9	5.5	41.5

Πηγή ενέργειας	Κατανάλωση καυσίμων (kWh/m²)	Εκπομπές CO2 (kg/m²)
Ηλεκτρισμός	26.4	26.1
Πετρέλαιο	15.1	4.0
Φυσικό αέριο	0.0	0.0
Άλλα ορυκτά καύσιμα	0.0	0.0
Ηλιακή	2.7	0.0
Βιομάζα	0.0	0.0
Γεωθερμία	0.0	0.0
Άλλο ΑΠΕ	0.0	0.0
Σύνολο	41.5	30.1

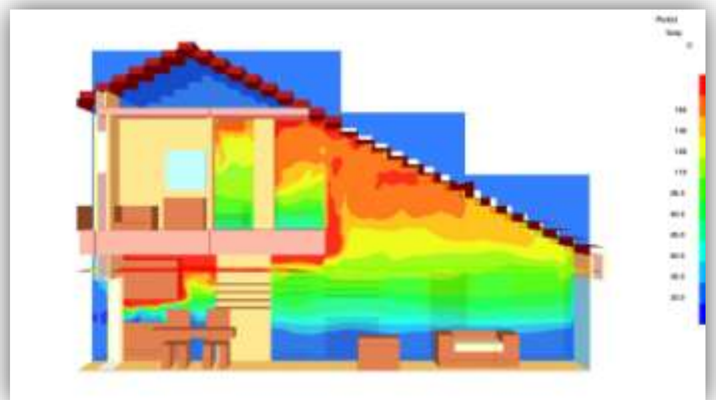
Reference house

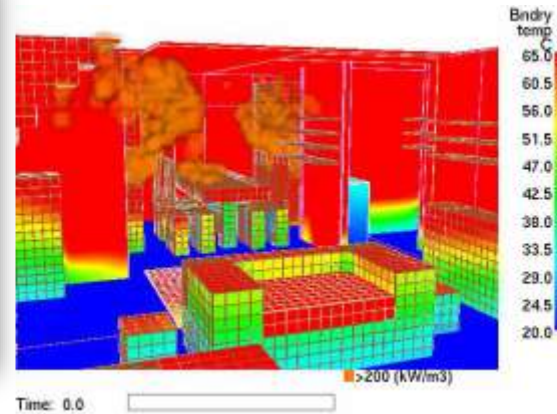
Amfilochia Demo House

FIRE DYNAMIC SIMULATION OF THE FULL-SCALE HOUSE (NTUA)



- Fire Scenario: A 300kW oil fire in the kitchen room - Corresponds to a corn oil fire in a 10” pot (NIST, 2007)





- Fire Protection Engineering: Prediction and visualization of fire & smoke movement
- Building Architectural Design: Prediction of fire behaviour to estimate the optimal place for fire exits or sprinkler placement and operation
- Building Re-design: Predictions of fire behaviour to reduce the fire hazard and reinforce the structural behavior of existing building
- Fire Safety Directives: Support to the development of performance-based codes and directives

Amfilochia Demo House

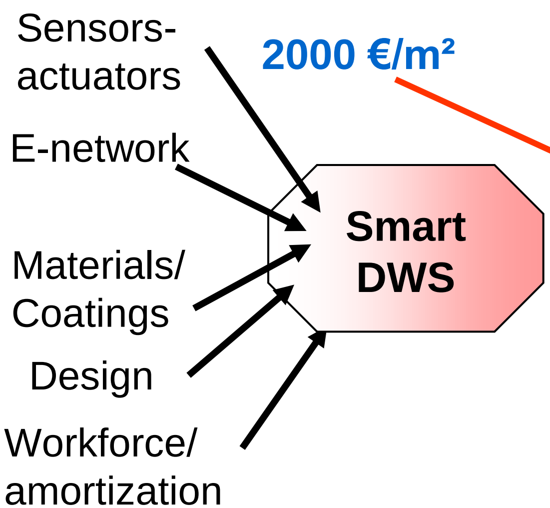
ASSESSMENT (I-SSB)

Anticipated market impact

2007	2015	2020

Estimation of cost for demo house of 100 sqm

Estimation of I-SSB unit cost per sqm (square meter)



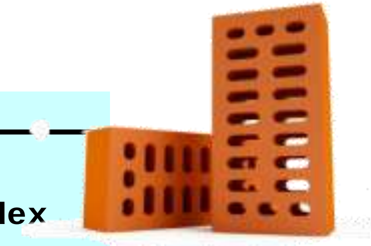
2000 €/m² → **1400 €/m²** → **1000 €/m²**

Achieving cost target
1000 €/sqm in 2020 seems realistic

Production size No. of units	**Post-Demo**	**12500**	**32500**
Production/ sqm year	**300**	**1500 Mil.**	**4000 Mil.**

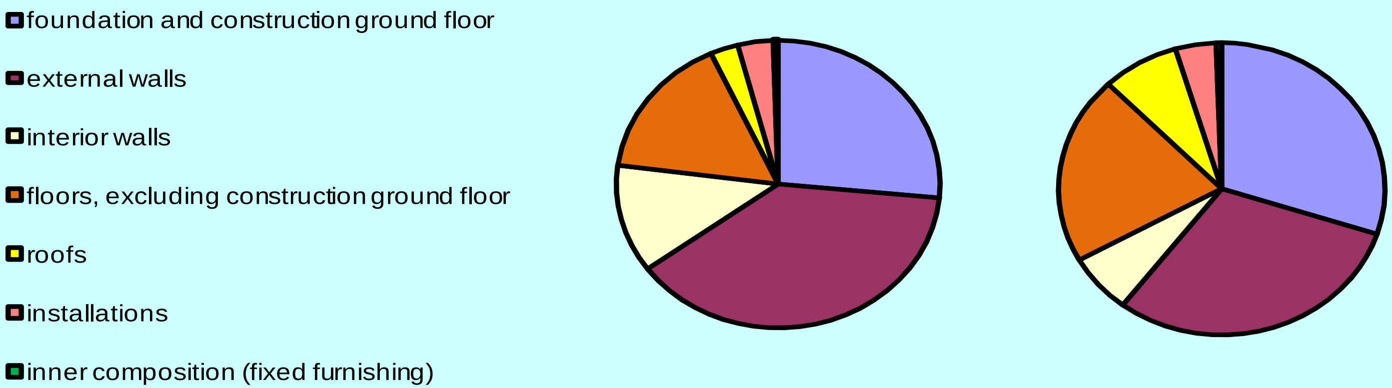
Environmental Assessment results

ASSESSMENT (I-SSB)



Materials

structure	Hidden environmental costs draft		Hidden environmental costs traditional		index
foundation and construction ground floor	€	147,08	€	147,08	
external walls	€	213,64	€	148,85	
interior walls	€	66,95	€	31,94	
floors, excluding construction ground floor	€	88,99	€	102,11	
roofs	€	15,63	€	37,58	
installations	€	19,78	€	19,78	
inner composition (fixed furnishing)	€	2,73	€	2,73	
total	**€**	**554,80**	**€**	**490,07**	**88**



Environmental Assessment results

ASSESSMENT (I-SSB)

Materials - details

environmental impact category	Hidden environmental costs draft	Hidden environmental costs traditional	Environmental impacts as equivalents	draft	traditional
Emissions	**€ 448,97**	**€ 376,90**			
global warming (GWP100)	€ 282,55	€ 229,22	kg CO2	3,1E+03	2,5E+03
ozone layer depletion (ODP)	€ 2,80	€ 1,62	kg CFC-11	4,9E-04	2,8E-04
human toxicity	€ 37,69	€ 40,92	kg 1,4 DB	7,8E+02	8,5E+02
aquatic toxicity fresh water	€ 1,99	€ 1,78	kg 1,4 DB	4,1E+01	3,7E+01
terrestrial toxicity	€ 0,27	€ 0,15	kg 1,4 DB	5,6E+00	3,1E+00
photochemical oxidation	€ 5,88	€ 4,06	kg C2H4	1,3E+00	9,2E-01
acidification	€ 37,98	€ 28,25	kg SO2	1,4E+01	1,0E+01
eutrophication	€ 79,81	€ 70,91	kg PO4	1,5E+00	1,3E+00
Exhaust resources	**€ 33,86**	**€ 27,93**			
biotic	€ 0,06	€ 1,67	points	1,3E+00	4,0E+01
abiotic	€ 27,71	€ 21,50	kg Sb	6,6E+02	5,1E+02
energy carriers	€ 6,09	€ 4,75	kg Sb	1,4E+02	1,1E+02
Landuse	**€ 59,29**	**€ 75,81**			
Eco99 EQ Landuse	€ 59,29	€ 75,81	PDF.m2.yr	2,9E+02	3,7E+02
Annoyance	**€ 11,91**	**€ 9,43**			
malodorous air	€ 2,01	€ 0,82	OTV m3	8,6E+07	3,5E+07
roadnoise	€ 1,94	€ 2,29	DALY	6,0E-03	7,1E-03
noise	€ 0,02	€ 0,02	points	1,4E+04	1,4E+04
light	€ 4,15	€ 3,49	points	1,7E+02	1,5E+02
calamitys	€ 3,78	€ 2,80	points	1,6E+02	1,2E+02
total	**€ 554,03**	**€ 490,07**			

Assessment results

ASSESSMENT (I-SSB)

- Materials with highest environmental

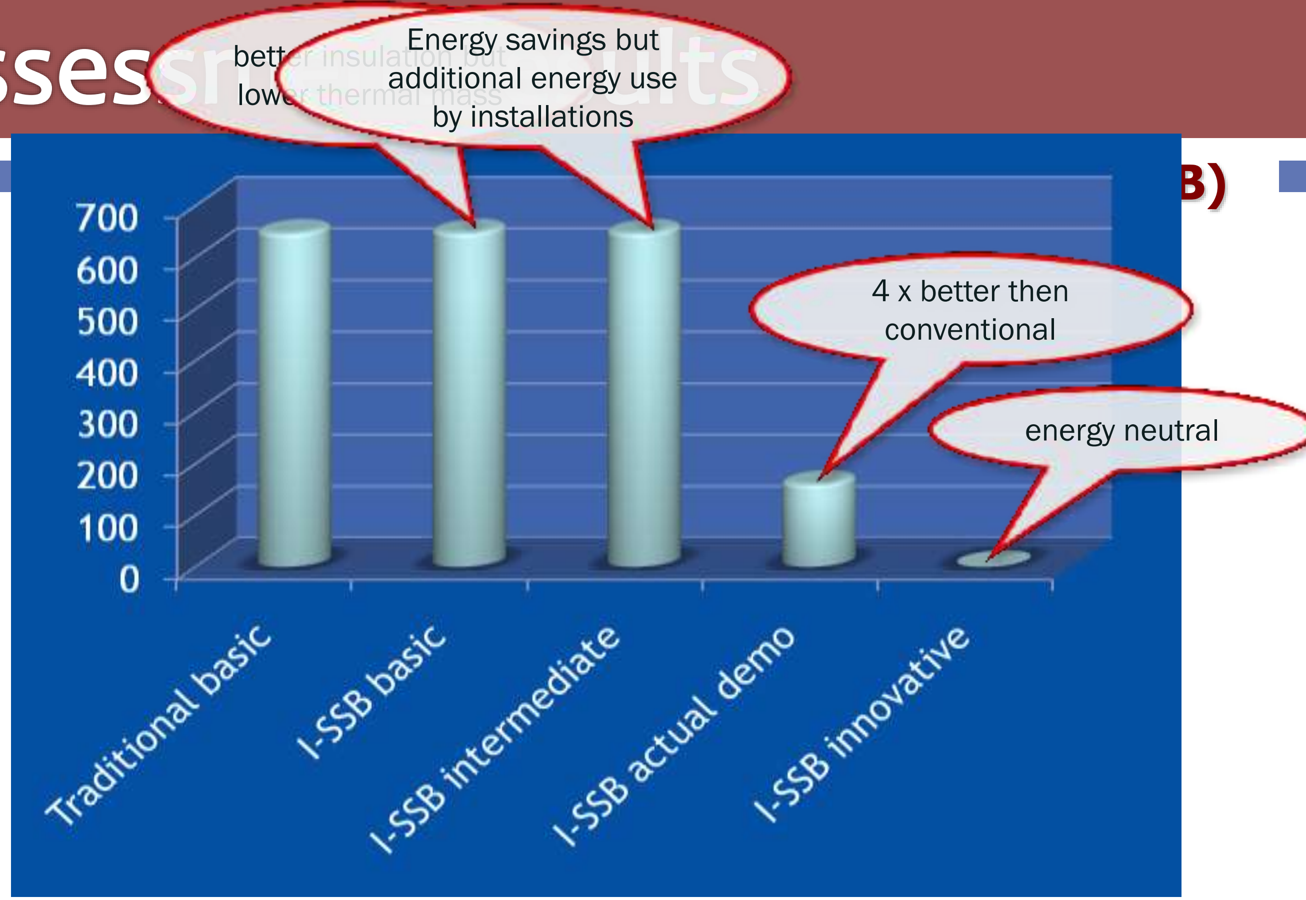
Same as traditional house

38% by steel

Material	Construction part	Env. Costs	%
500 mm reinforced concrete foundation (0% debris granulate)	foundation + ground floor	€ 110,47	20%
steel profiles: UW 100x40x0,6 and CW 100x50x0,6	external + internal walls	€ 104,27	19%
wall construction steel profiles, incl. FLB floor beams	interior walls	€ 55,39	10%
ceiling steel profiles first floor and roof; L.28.27.0,6 and C 60.27.0,6	floors, excluding ground floor	€ 51,66	9%
aluminium windows and sunshades	external windows incl sunshades	€ 39,52	7%
Knauf Gypsum board type A	external + internal walls, ceilings	€ 32,74	6%
Knauf SM700 natur weiß mineral plaster	mineral plaster	€ 39,52	5%
100mm tamped concrete (0% debris granulate)	foundation + ground floor	€ 21,95	4%
aquapanel outdoor/indoor	external and indoor panelling	€ 20,57	4%
rest		€ 93,22	17%
	Total	€ 554,80	100%

Asses… …ults … B)

- Energy index



traditional house 'basic' conventional (1)		I-SSB 'basic' conventional (1)		I-SSB intermediate 'natural gas' (2)		I-SSB actual demo house 'all electric' (3)		I-SSB innovative' energy neutral (4)	
hidden annual environ-mental costs	EI Environ-mental Index	hidden annual environ-mental costs	EI Environ-mental Index	hidden annual environ-mental costs	EI Environ-mental Index	hidden annual environ-mental costs	EI Environ-mental Index	hidden annual environ-mental costs	EI Environ-mental Index
€ 647,29	100	€ 648,00	100	€ 647,69	100	€ 160,34	404	€ 0,95	68.257

Assessment results

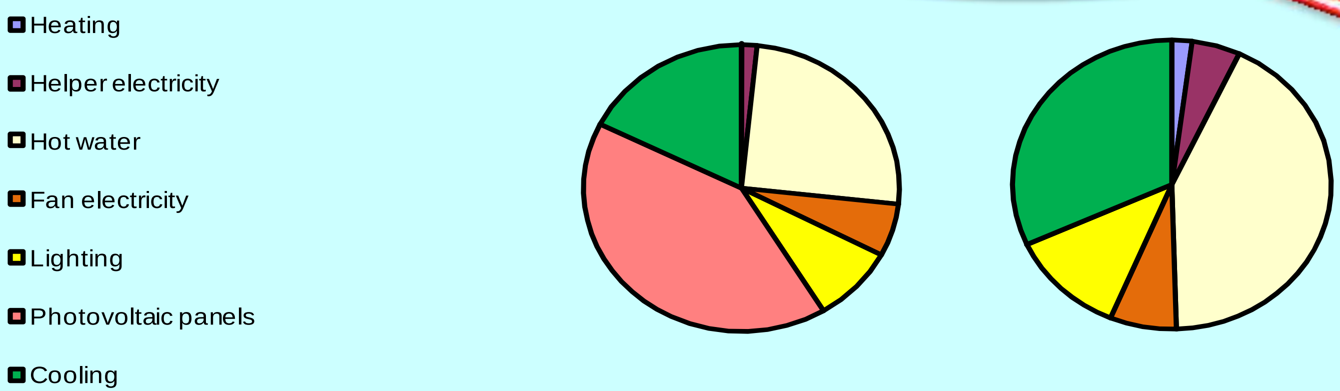
ASSESSMENT (I-SSB)

Energy use of installation components (actual demo house = energy concept 3)

Energy

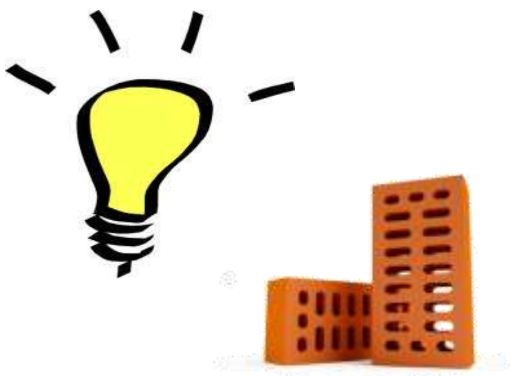
primairy energy usage	draft	traditional	
Heating	35	1.194	MJ primairy
Helper electricity	1.248	2.882	MJ primairy
Hot water	20.309	24.776	MJ primairy
Fan electricity	4.765	3.971	MJ primairy
Lighting	6.933	6.933	MJ primairy
Photovoltaic panels	-33.119	0	MJ primairy
Cooling	14.279	18.490	MJ primairy
total	14.449	58.245	MJ primairy

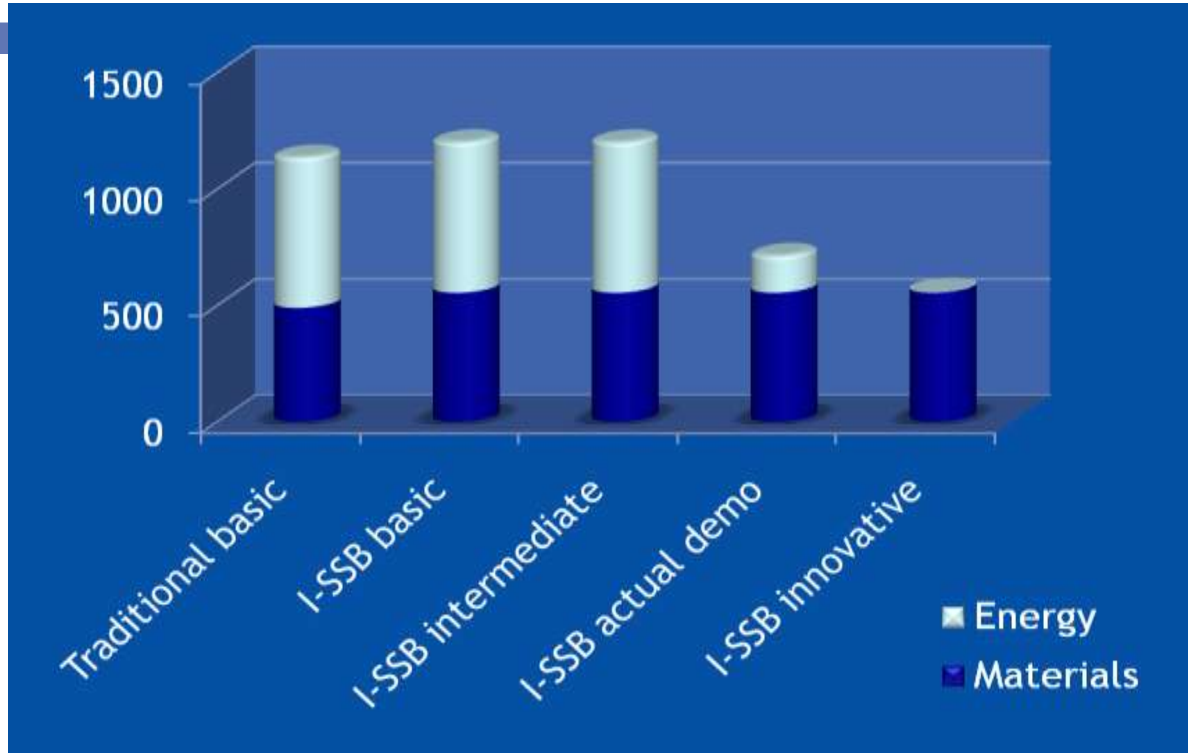
Energy index 404



Assessment results

- Total index
  (environmental costs)



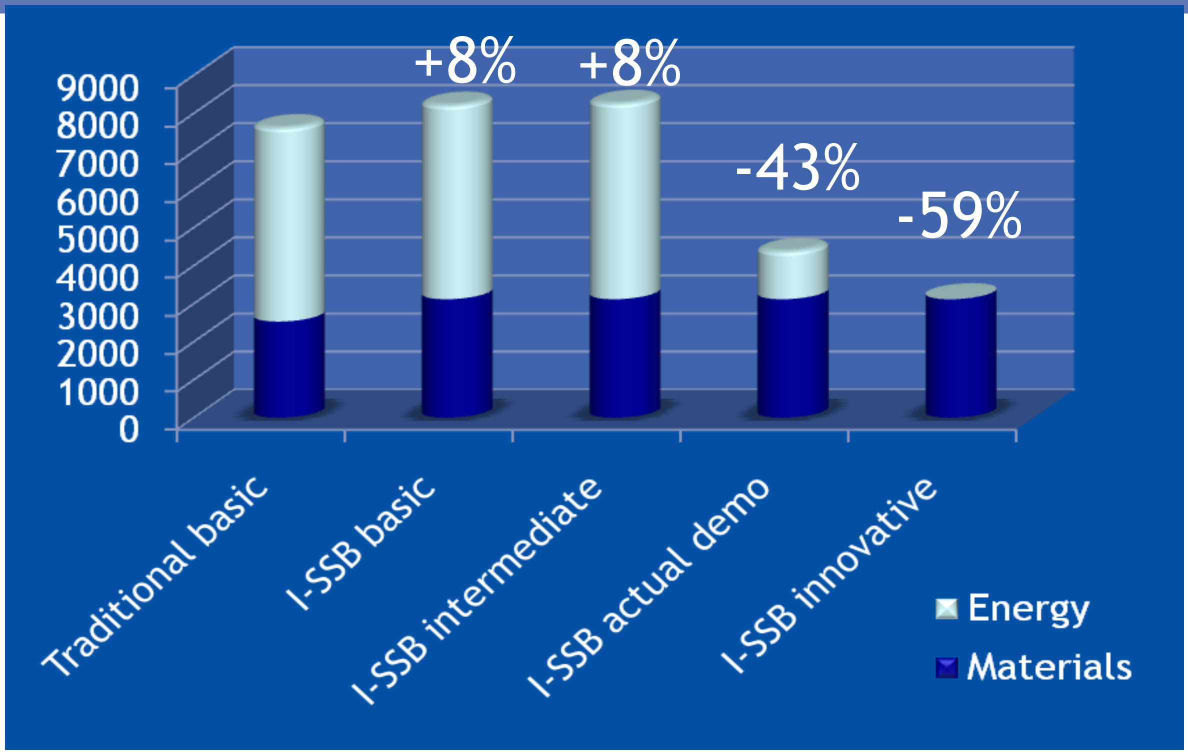


	traditional house 'basic' conventional (1)		I-SSB 'basic' conventional (1)		I-SSB intermediate 'natural gas' (2)		I-SSB actual demo house 'all electric' (3)		I-SSB innovative' energy neutral (4)	
	hidden annual environ-mental costs	EI Environ-mental Index	hidden annual environ-mental costs	EI Environ-mental Index	hidden annual environ-mental costs	EI Environ-mental Index	hidden annual environ-mental costs	EI Environ-mental Index	hidden annual environ-mental costs	EI Environ-mental Index
materials	€ 490,07	100	€ 554,80	88	€ 554,80	88	€ 554,80	88	€ 554,80	88
energy	€ 647,29	100	€ 648,00	100	€ 647,69	100	€ 160,34	404	€ 0,95	68.257
total	€ 1.137,35	100	€ 1.202,80	95	€ 1.202,48	95	€ 715,14	159	€ 555,75	205

Assessment results

- CO_2- emissions

kg CO_2eq/year



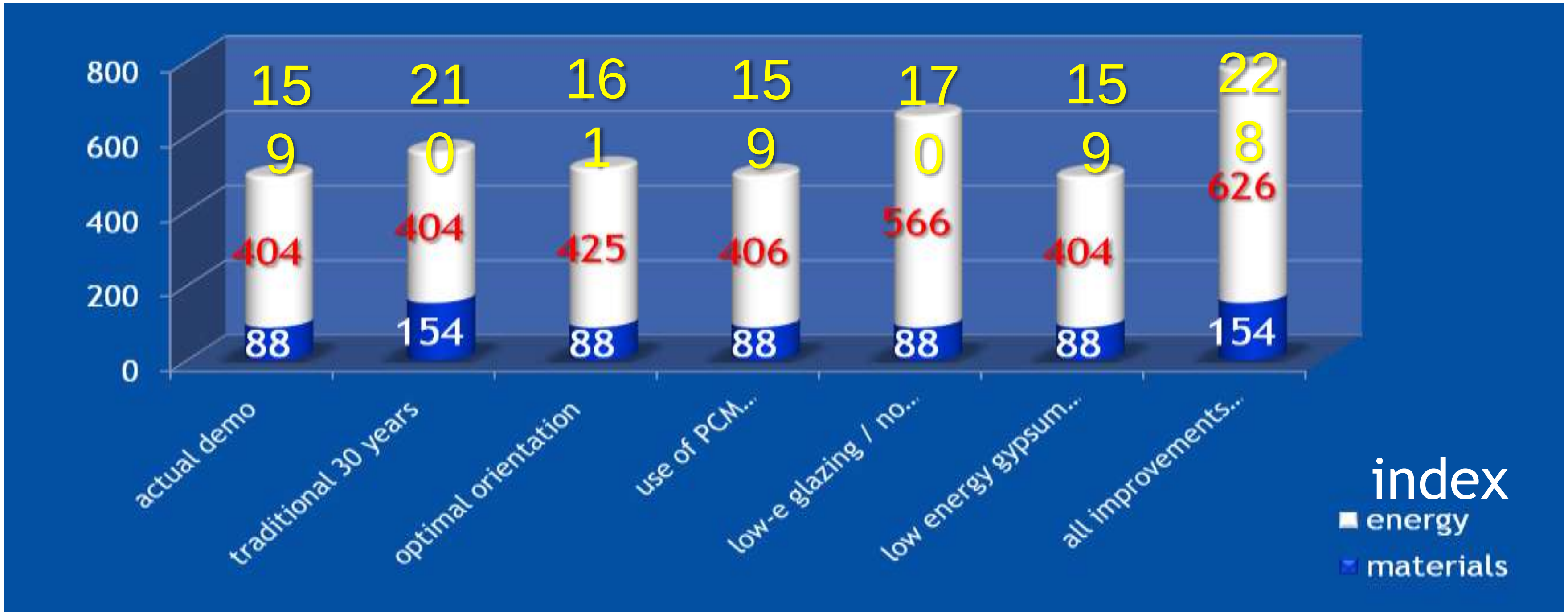
CO_2 emissions [kg eq CO_2/yr]	traditional house 'basic' conventional (1)	I-SSB 'basic' conventional (1)	I-SSB intermediate 'natural gas' (2)	I-SSB actual demo house 'all electric' (3)	I-SSB innovative' energy neutral (4)
materials	2.526	3.113	3.113	3.113	3.113
energy	5.092	5.098	5.145	1.258	7
total	**7.618**	**8.211**	**8.258**	**4.372**	**3.121**

Assessment results

Energy - details

environmental impact category	draft	traditional	as equivalents	draft	traditional
Emissions	**€ 146,98**	**€ 594,42**			
global warming (GWP100)	€ 114,21	€ 462,15	kg CO2	1,3E+03	5,1E+03
ozone layer depletion (ODP)	€ 0,36	€ 1,51	kg CFC-11	6,3E-05	2,6E-04
human toxicity	€ 12,47	€ 49,91	kg 1,4 DB	2,6E+02	1,0E+03
aquatic toxicity fresh water	€ 0,14	€ 0,66	kg 1,4 DB	3,0E+00	1,4E+01
terrestrial toxicity	€ 0,06	€ 0,23	kg 1,4 DB	1,2E+00	4,8E+00
photochemical oxidation	€ 0,42	€ 1,69	kg C2H4	9,5E-02	3,8E-01
acidification	€ 6,01	€ 24,53	kg SO2	2,2E+00	9,0E+00
eutrophication	€ 13,31	€ 53,74	kg PO4	2,4E-01	9,9E-01
Exhaust resources	**€ 2,41**	**€ 9,53**			
biotic	€ -	€ -	points	0,0E+00	0,0E+00
abiotic	€ 0,05	€ 0,19	kg Sb	1,1E+00	4,5E+00
energy carriers	€ 2,36	€ 9,34	kg Sb	5,6E+01	2,2E+02
Landuse	**€ 8,47**	**€ 33,52**			
Eco99 EQ Landuse	€ 8,47	€ 33,52	PDF.m2.yr	4,1E+01	1,6E+02
Annoyance	**€ 2,48**	**€ 9,82**			
malodorous air	€ 0,02	€ 0,07	OTV m3	7,1E+05	2,8E+06
roadnoise	€ -	€ -	DALY	0,0E+00	0,0E+00
noise	€ 0,00	€ 0,00	points	7,3E+02	2,9E+03
light	€ 1,24	€ 4,90	points	5,2E+01	2,0E+02
calamitys	€ 1,23	€ 4,85	points	5,1E+01	2,0E+02
total	**€ 160,34**	**€ 647,29**			

Assessment results – fine tuning



	(A) Actual demo house (energy concept 3)	(A) plus: adjusted life expectancy	(A) plus: optimal orientation of the house	(A) plus: use of PCM Smartboard	(A) plus: low-e glazing instead of sunscreens	(A) plus: low energy gypsum boards
Materials index	88	154	88	88	88	88
Energy index	404	404	425	406	566	404
Environmental index	159	210	161	159	170	159

Assessment results – Conclusions

ASSESSMENT (I-SSB)

1. Materials index demo house = 88
   - ✓ environmental costs of I-SSB house 13% higher than traditional house
   - ✓ large amounts of steel in exterior and interior walls, aluminium windows and sunshades, and gypsum boards.
2. Energy index of demo house = 404
   - ✓ four times better energy performance
   - ✓ with traditional energy concepts the energy performance is similar to the traditional house
   - ✓ innovative energy concept -> demo house = energy neutral
3. Overall environmental index of demo house = 159
   - ✓ with innovative energy concept -> 205
4. Demo house produces 43% less CO_2 emissions than traditional
   - ✓ with innovative energy concept -> 59%
5. With average life of traditional house of 30 years:
   - ✓ materials index from 88 -> 154
   - ✓ total environmental index from 159 -> 210

Assessment results – Conclusions

6. Optimal orientation demo house to the sun:
   - ✓ energy index from 404 -> 425
   - ✓ total environmental index from 159 -> 161
7. Use of PCM smart board instead of standard gypsum boards:
   - ✓ energy index from 404 -> 406
   - ✓ total environmental index: no effect
8. Low-e glazing instead of sunscreens:
   - ✓ energy index from 404 -> 566
   - ✓ total environmental index from 159 -> 170
9. Low energy gypsum board through plasticizers:
   - ✓ no effect on the environmental index
10. Combined improvements:
    - ✓ materials index from 88 -> 154
    - ✓ energy index from 404 -> 626
    - ✓ total environmental index from 159 -> 228

Thank you for your attention!