MSc Program
Wood Based Building Design for Sustainable Urban Development

The wooden Passive Summer House

A Master Thesis submitted for the degree of
"Master of Science"

supervised by
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ABSTRACT

The project is launched to face the specific needs of the Mediterranean countries real estate, that is to study the summer cooling and the consequent issues connected to the correlation between energy saving and environmental comfort in relation to the wooden construction characterized by low thermal inertial mass properties.

In the specific, the aim is to study a pilot wooden residential building, in this specific case a single family house that is going to be build in the middle of the Italian plain named Pianura Padana, characterized by a Summer climate constantly hot and humid, which condition during the hot season should be analogue to the one during the winter period of the already tested northern Europe passive houses.

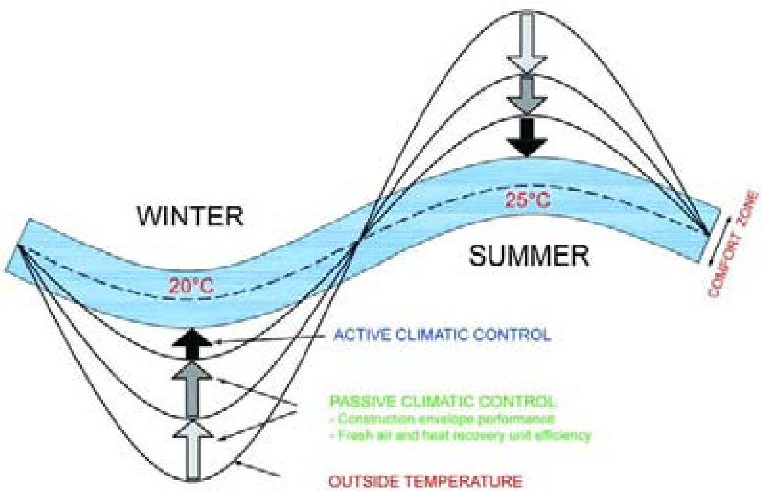
INTRODUCTORY PREFACE

The research project is focus on the study of the energy requirement index for the Summer air-conditioning that should be attested as a value, around 25 °C, at least equal to the one secured from a plant supplied, and this result has to be reach using a few energy with a limit equal to 15 kWh/(mq*year) that is the characteristic maximum value of energy consumption to heat a typical Passive House in the North Europe countries.

For the cooling demand could be used passive solutions such as the ventilation of inertial mass both mechanical and natural way (enlivened by chimney effect rather than by wind) and the indirect geothermic exchange, and innovative systems that are being tested at present, such as the thermal exchange through phase changing materials (PMC).

Otherwise a basic contribution to the reduction of air-conditioning needs will be achieved by a correct bioclimatic design, focus on a good shading system for glazed surfaces, connected to a right use of structural and finishing interior materials characterized by high proprieties to storage for many hours or days the overheating phenomena.

RANGE OF INDOOR COMFORT WINTER vs. SUMMER



PART I – STATE OF ART OF PASSIVE HOUSE BUILDINGS

TRADITIONAL PASSIVE HOUSE BUILDING GENERAL DEFINITION

(Bo Adamson 1987 and Wolfgang Feist 1988)

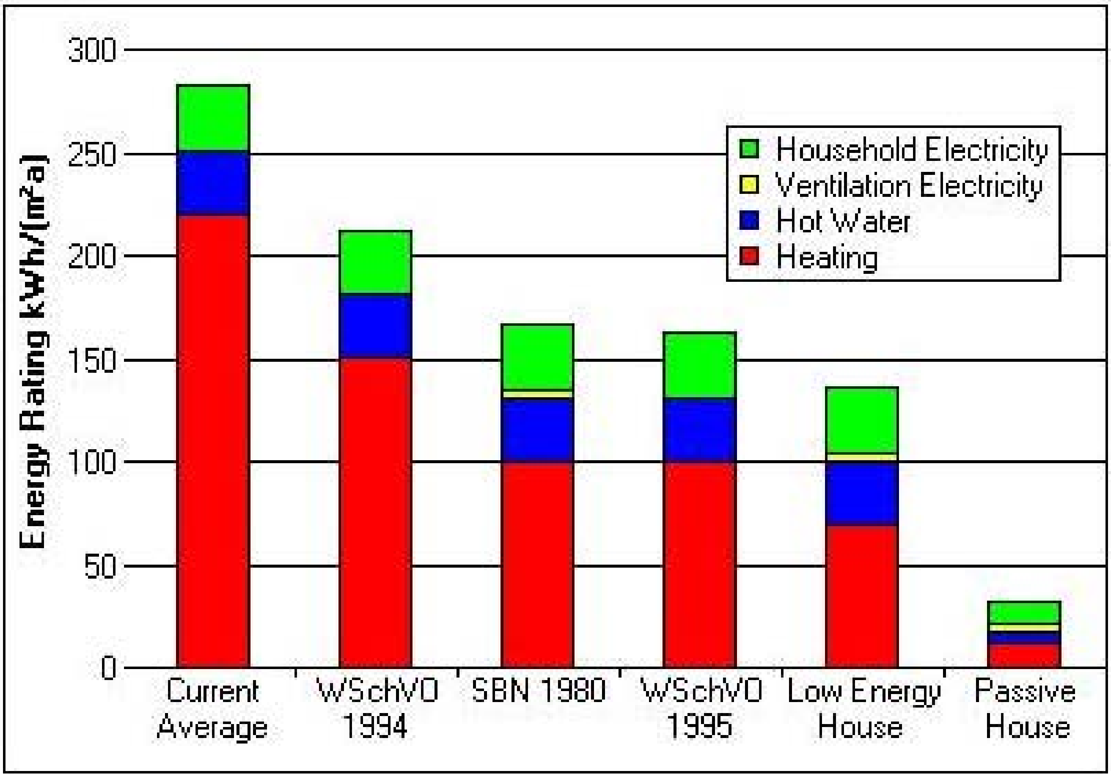
A passive house is a building in which a comfortable interior climate can be maintained without active heating and cooling systems so the house heats and cools itself, hence "passive".

For European passive construction, prerequisite to this capability is an annual heating requirement that is less than 15 kWh/(m²a) not to be attained at the cost of an increase in use of energy for other purposes (e.g., electricity).

Furthermore, the combined primary energy consumption of living area of a European passive house may not exceed 120 kWh/(m²a) for heat, hot water and household electricity.

With this as a starting point, additional energy requirements may be completely covered using renewable energy sources.

This means that the combined energy consumption of a passive house is less than the average new European home requires for household electricity and hot water alone and the combined end energy consumed by a passive house is therefore less than a quarter of the energy consumed by the average new construction that complies with applicable national energy regulations.



WSchVO = German Heat Protection Regulation   SBN = Swedish Construction Standard

Winter comparison of energy housing demand in North Europe area

SUMMER BEHAVIOUR REQUIREMENTS FOR PASSIVE HOUSE

To reach an extremely low energy demand for the indoor heating, the passive house projects have to respect a serial of parameter and constructive rules that allows to the building to be self energy efficient in relation to the indoor acclimatization comfort, and that depends of a combination of constructive and technical requirements.

A) *MAIN CONSTRUCTION REQUIREMENTS*

A1- Southern orientation and shade considerations:
Passive use of solar energy is a significant factor in passive house design.

A2.1- Compact form and good insulation:
All components of the exterior shell of the house are insulated to achieve a U-factor that does not exceed 0,15 W/(m²K).

A2.2- Energy-efficient window glazing and frames:
Windows (glazing and frames, combined) should have U-factors not exceeding 0,80 W/(m²K)
with solar heat-gain coefficients around g=50%.

A3- Building envelope air-tightness:
Air leakage through unsealed joints must be less than 0,6 times the house volume per hour.

B) *MAIN TECHNICAL IMPLANTS REQUIREMENTS*

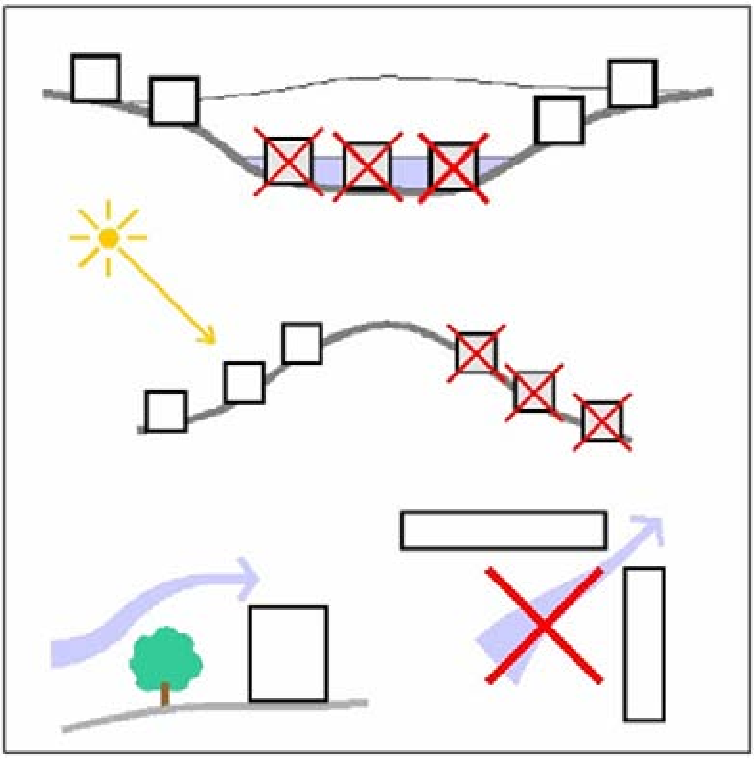
B1.1- Passive preheating of fresh air:
Fresh air may be brought into the house through underground ducts that exchange heat with the soil. This preheats fresh air to a temperature above 5°C, even on cold winter days.

B1.2- Highly efficient heat recovery from exhaust air using an air-to-air heat exchanger:
Most of the perceptible heat in the exhaust air is transferred to the incoming fresh air with an heat recovery rate over 80%.

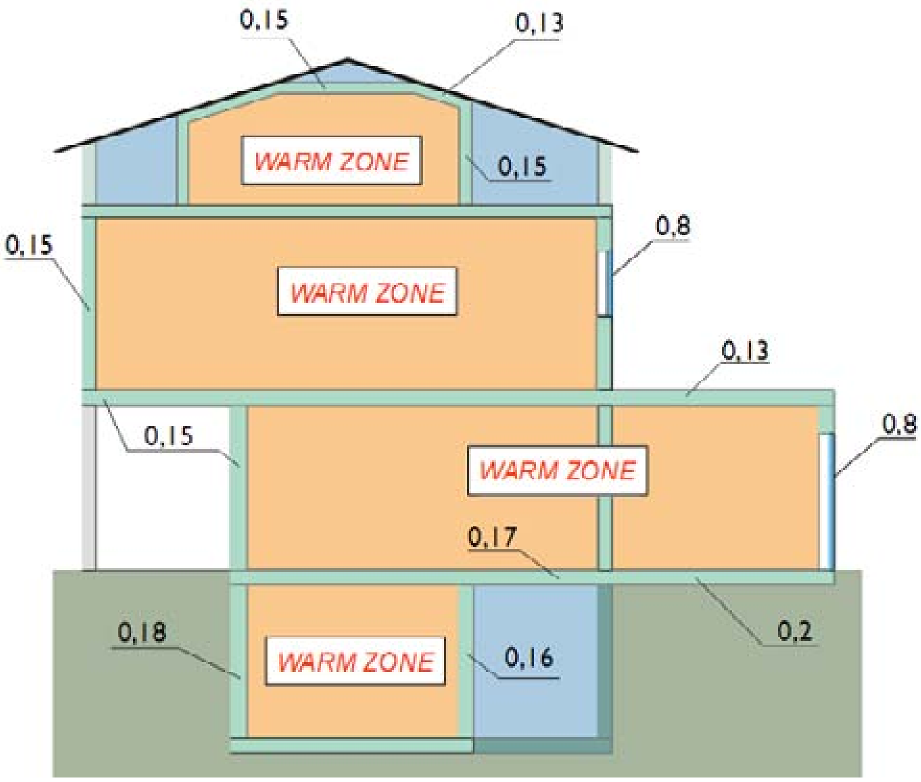
B2.1- Hot water supply using regenerative energy sources:
Solar collectors or heat pumps provide energy for hot water.

B2.2- Energy-saving household appliances:
Low energy refrigerators, stoves, freezers, lamps, washers, dryers, etc. are indispensable in a passive house.

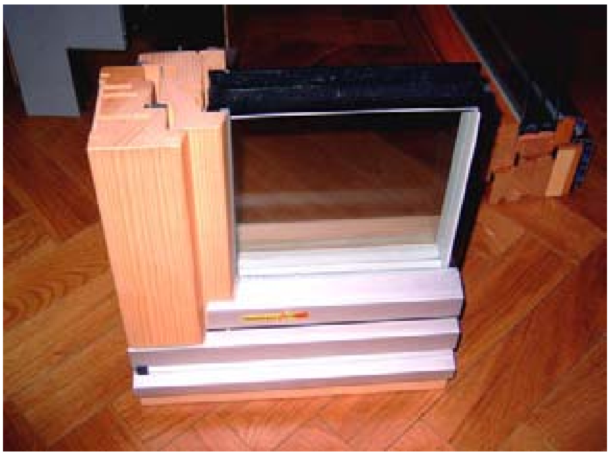
A1- GOOD SUNNY POSITION AND WIND SHELTERING GEOMETRY



A2.1- TYPICAL PASSIVE HOUSE CONSTRUCTION U VALUES



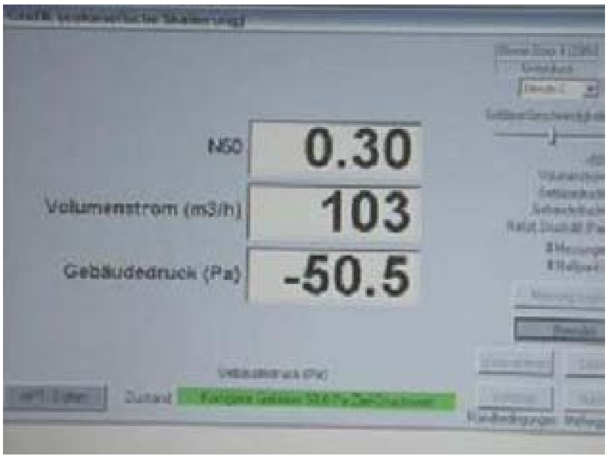
A2.2- TYPICAL PASSIVE HOUSE GLAZED WINDOW



$U_{frame} = 0{,}95\ (W/m^2K)$
$U_{glass} = 0{,}60\ (W/m^2K)$
$U_{window} < 0{,}80\ (W/m^2K)$

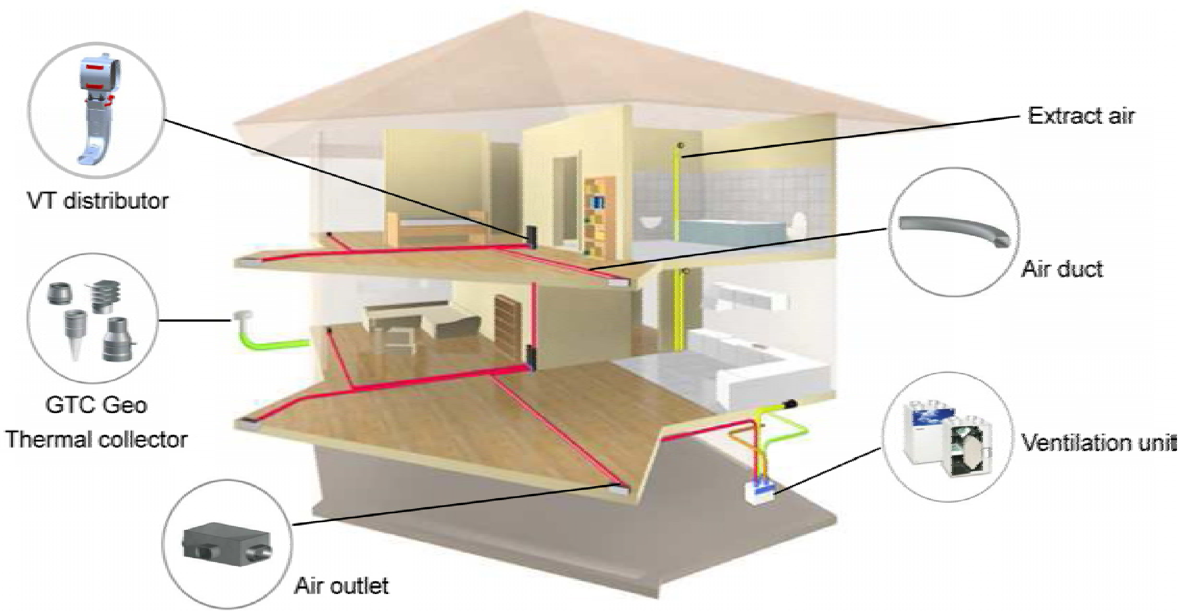
"Sigg-IV/98" Passive house window profile – Heiss Fenster Sarentino di Bolzano (Italy)

A3- AIR THIGTNESS VALUE $\leq 0.6\ h^{-1}$ *(N=+/-50 Pa)*



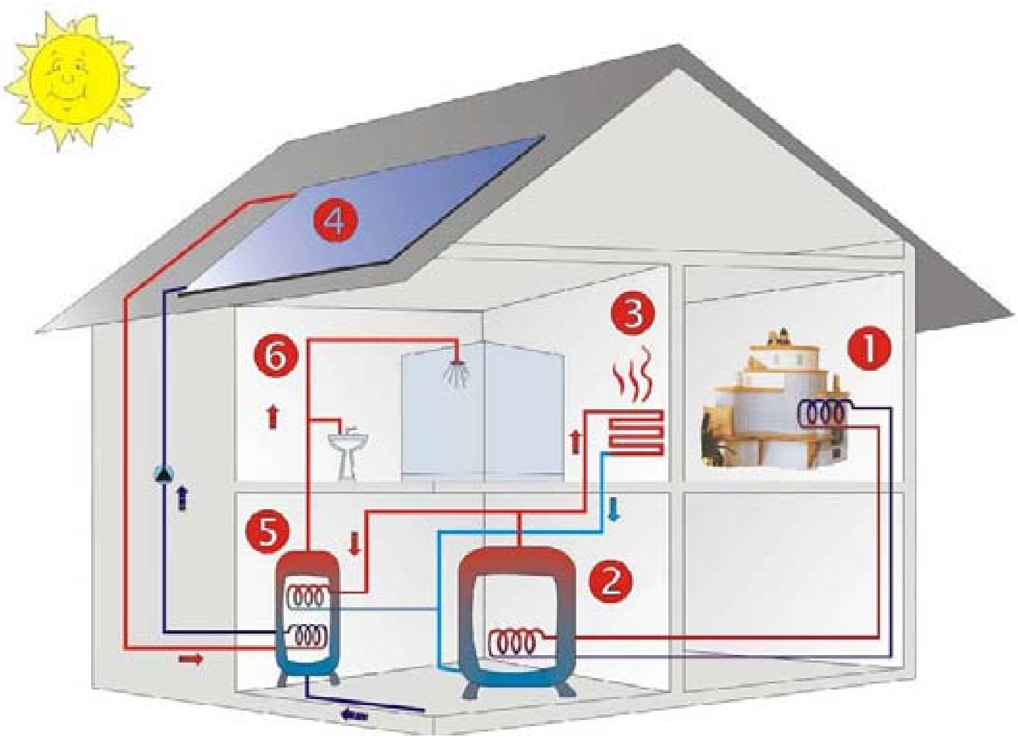
Blower door test by Gunther Gantioler-TBZ – Technisches Bauphysik Zentrum – Bolzano (Italy)

B1- AIR TO AIR HEAT RECOVERY SYSTEM EFFICIENCY > 80%



Example of mechanical ventilation system by Pluggit - Sweden

B2- HIGH RENEWABLE RESOURRCES USING



Example of combined solar and wood energy system

EXAMPLES OF NORTH EUROPE PASSIVE "WINTER" HOUSE

Wooden passive house in England and North of Germany

EXAMPLES OF AUSTRIAN WOODEN PASSIVE "WINTER" HOUSE

Wooden passive multi-storey house in Vienna and Salisburgo

EXAMPLES OF NORTH ITALY WOODEN PASSIVE "WINTER" HOUSE

Wooden passive house in the Italian Alps mountains (TBZ certification)

SUMMER BEHAVIOUR OF PASSIVE HOUSE IN SOUTH EUROPE

In relation of the indoor performance of the Passive House during the winter season, there thousand of buildings (more than 8000 in Germany and 3000 in Austria) that prove that this construction system works really well mostly in Central-North Europe.

On the other hand right now the Passive House technology is develop in areas where are not so high the problems of Summer overheating, but if we should transfer *"tout court"* this knowledge in the Mediterranean countries, we should have really high problems in relation to the indoor comfort.

In fact in these areas is primary important during almost half of the year have a building that can face the sun irradiation related to high external temperature in some case also during the night especially inside the cities, and these problems are more sensible in case of lightweight construction system as the wooden one characterized by low thermal mass efficiency.

CLIMATIC CHARACTERISATION AND APPLICABILITY

Energy demand for heating and cooling a building depends on the climate and the thermal characteristics of the building envelope.

The climate parameters with main influence on building's energy demand are the outdoor temperature and the solar radiation.

Potentially the heating and cooling demand can be assessed on the basis of 'degree-days' but this only takes temperatures into account and does not account for the influence of solar radiation.

Thus, in order to compare two different climates we should compare both the outdoor temperature and the solar radiation.

This means that it is possible to extrapolate the use of a passive technique/design strategy from one location to another when both have similar outdoor temperature and similar levels of solar radiation.

CLIMATIC SEVERITY INDEX – WCS/SCS

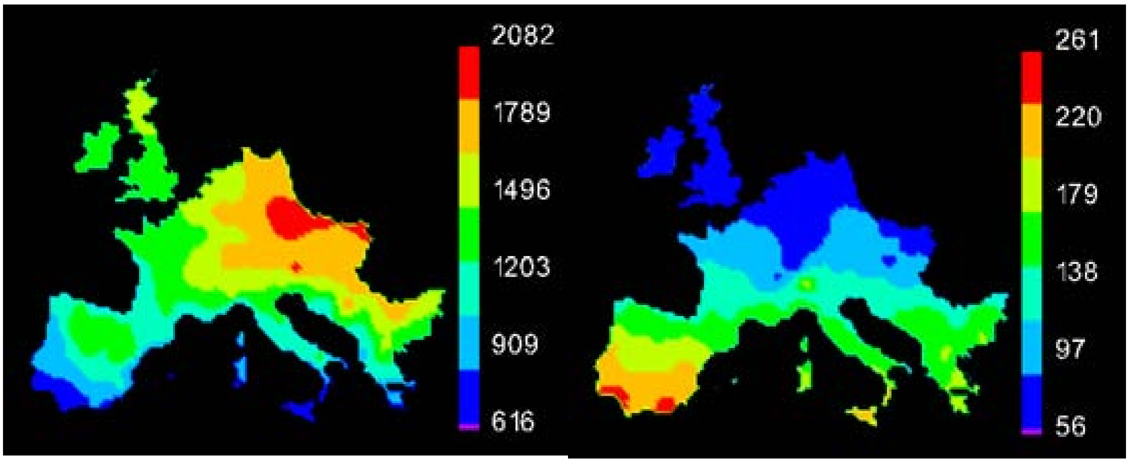
The degree-days approach does not account for the influence of either solar radiation or the thermal characteristics of a particular building so is more realistic use the ***Climate Severity Index*** (CSI) that has been developed in the 1984 to allow the characterization of climate in relation to a building of known envelope characteristics.

The CSI, that is a single number on a dimensionless scale, is specific for each building and location, and accounts for both temperature and solar radiation.

The CSI is calculated separately to represent summer and winter conditions, so two different winter climatic conditions can be considered identical if the heating demand is the same in a certain building, under both climatic conditions.

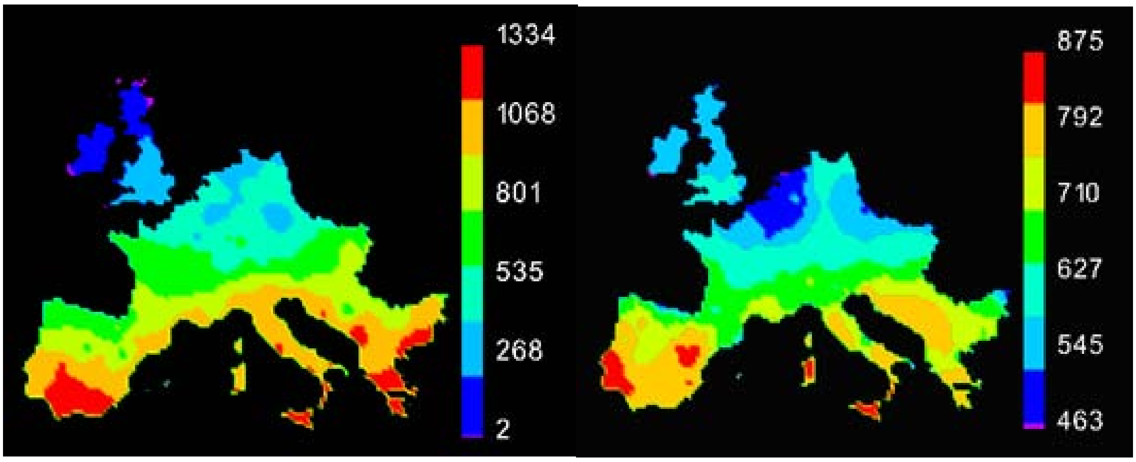
In this case, we can say that both winter climatic conditions have the same Winter Climatic Severity (WCS) and the same definition is valid for cooling demand and the term used would be Summer Climatic Severity (SCS).

TEMPERATURES MAP – DEGREE-DAYS



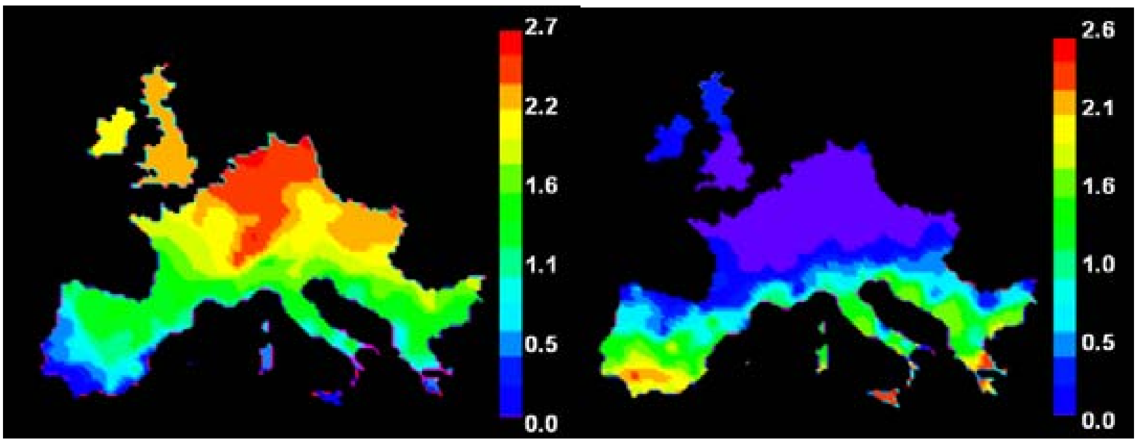
WINTER *vs* *SUMMER*

RADIATION MAP – (kW/m2)



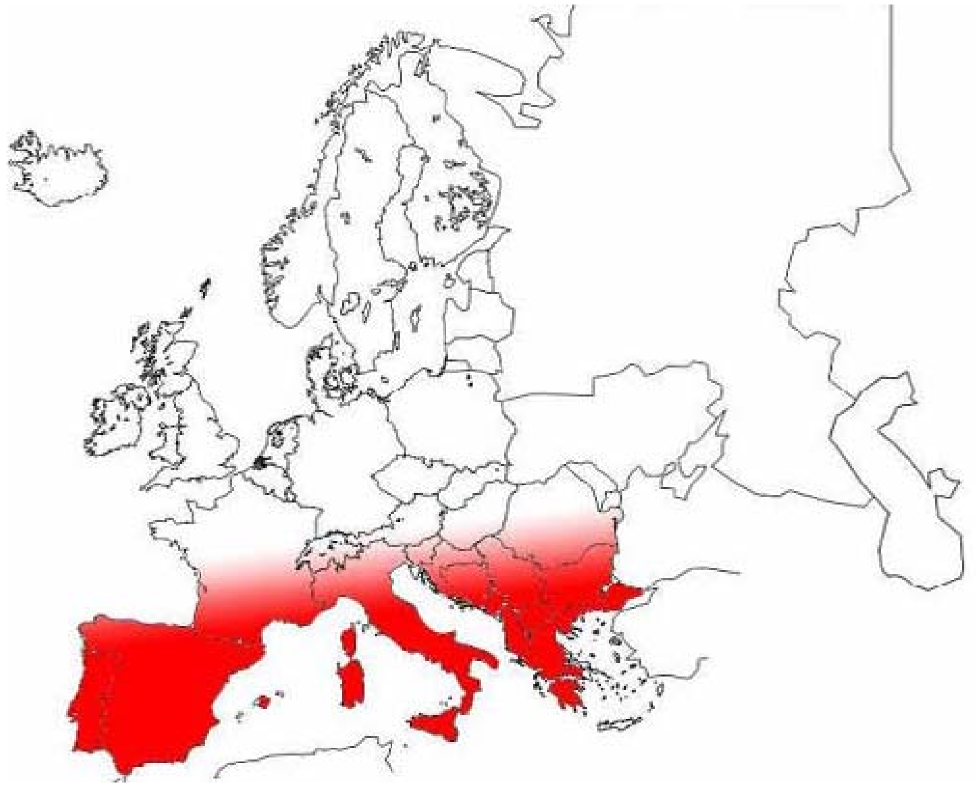
WINTER *vs* *SUMMER*

CLIMATIC SEVERITY INDEX MAP – WCS/SCS



WINTER *vs* *SUMMER*

EUROPEAN AREAS OF SUMMER OVERHEATING PROBLEMS



CLIMATIC SEVERITY INDEX FOR LOCATIONS REPORTED TO MADRID

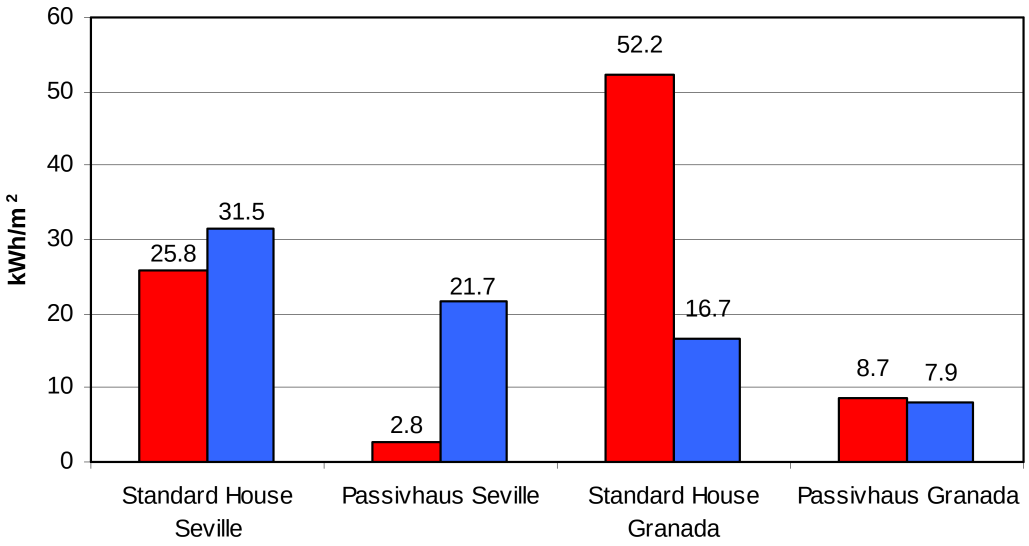
LOCATION	WINTER *(WCS)*	SUMMER *(SCS)*
Germany (Dresden)	**3.31**	**0.00**
Germany (Braunschweig)	2.56	0.05
Germany (Freiburg)	2.14	0.10
United Kingdom (Glasgow)	2.59	0.00
United Kingdom (London)	2.22	0.01
United Kingdom (Newcastle)	2.59	0.00
France (Agen)	1.44	0.19
France (Carcassonne)	1.24	0.37
Italy (Milan)	1.81	0.46
Italy (Rome)	0.83	1.19
Italy (Trapani)	0.32	1.87
Portugal (Lisbon)	0.37	1.05
Spain (Seville)	**0.32**	**2.56**
Spain (Madrid)	***1.00***	***1.00***
Spain (Granada)	0.81	1.11
Spain (Burgos)	1.96	0.05

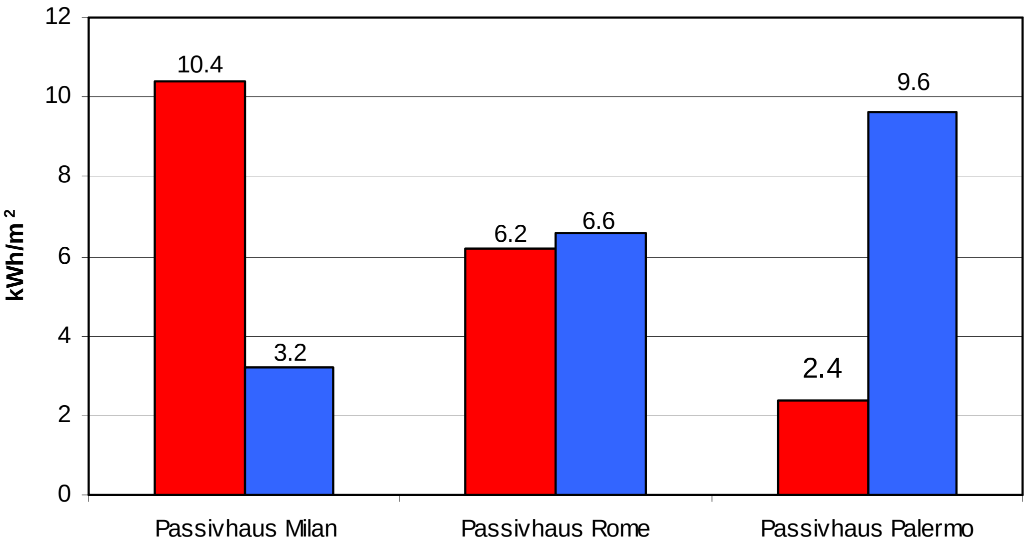
Statistics by Passive On research project

ENERGY DEMAND FOR COOLING IN SOUTH EUROPE

The Climate Severity Index (CSI) approach allow the characterization of climate in relation to a building of known envelope characteristics, in this case one located in the city of Madrid in the middle of Spain, and it's related to the radiation and the degree-days of a precise area.

So, as it's possible to see from the diagrams above, is possible the fact that two cities in the same area, for instance Seville and Granada in the middle of the Spanish region of Andalusia, should have different energy demand level in relation to the Winter and Summer acclimatization.

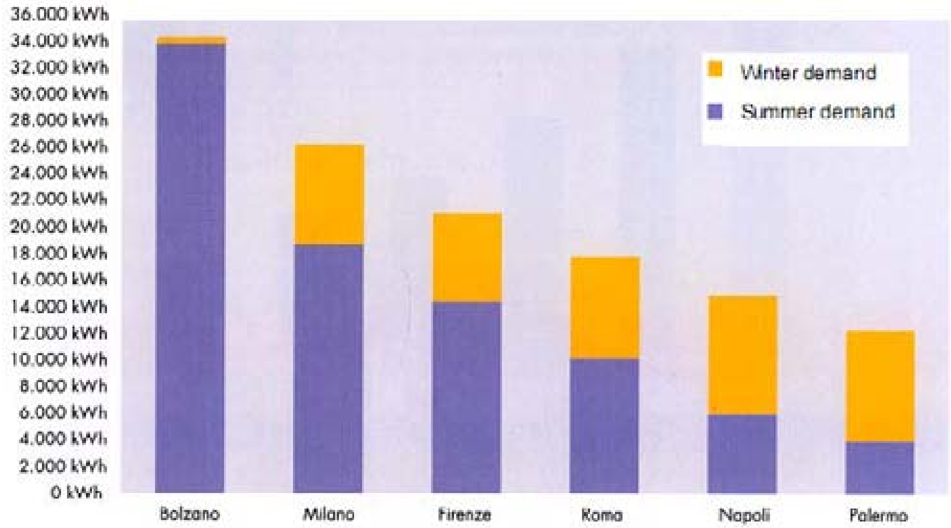




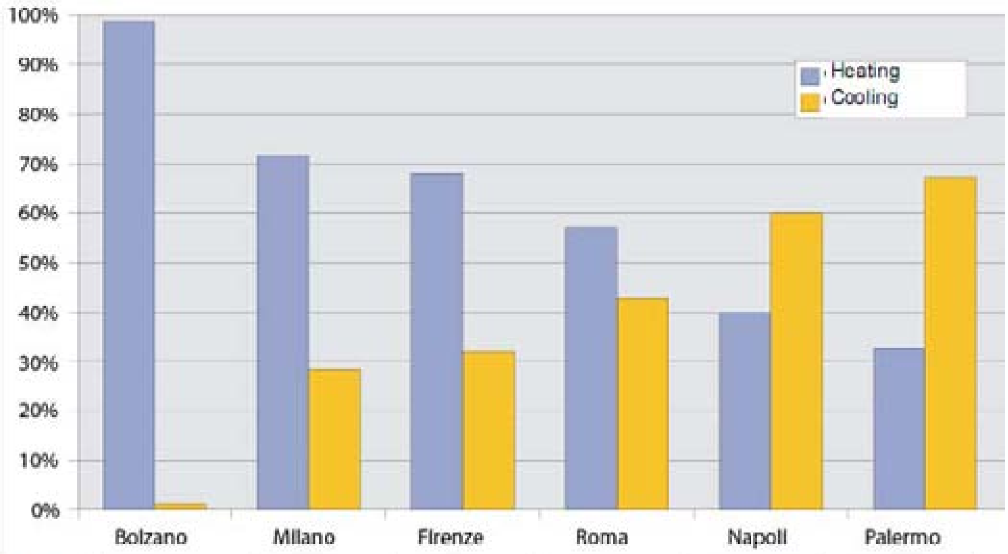
Statistics by Passive On research project

ENERGY DEMAND FOR THE ITALIANS CLIMATE – WINTER vs SUMMER

In the same way to the Climate Severity Index approach, the Institute of Building Physic *"TBZ - Technisces Bauphysik Zentrum"* located in Bolzano (Italy) has simulated the different behaviour of a typical Italian massive house in relation to the different regional climate from the North to the South of Italy, to show how relevant is the cooling energy demand in relation to the heating one.



Heating energy index	159 kWh/m²	88 kWh/m²	68 kWh/m²	48 kWh/m²	28 kWh/m²	19 kWh/m²
Cooling energy index	2 kWh/m²	35 kWh/m²	32 kWh/m²	36 kWh/m²	42 kWh/m²	39 kWh/m²
Global energy index	161 kWh/m²	123 kWh/m²	100 kWh/m²	84 kWh/m²	70 kWh/m²	58 kWh/m²



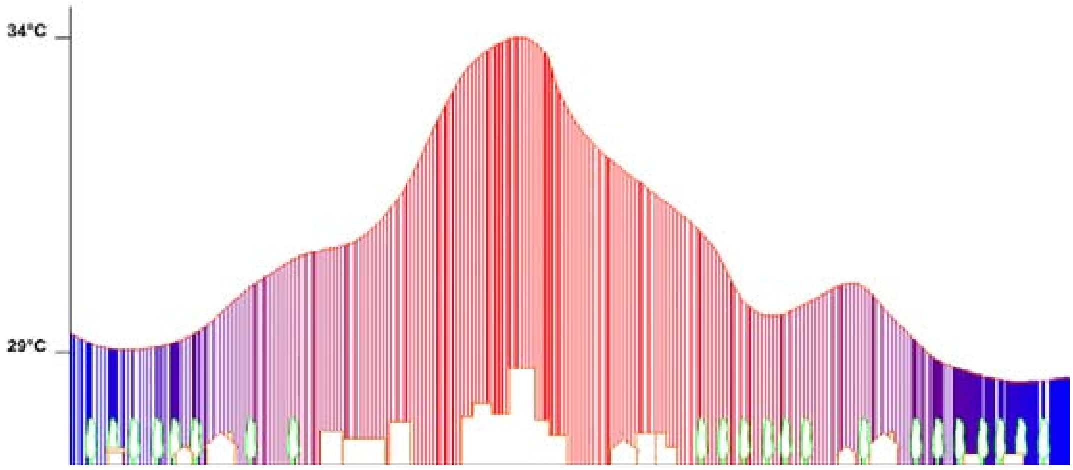
WINTER	99%	72%	68%	57%	40%	33%
SUMMER	1%	28%	32%	43%	60%	67%

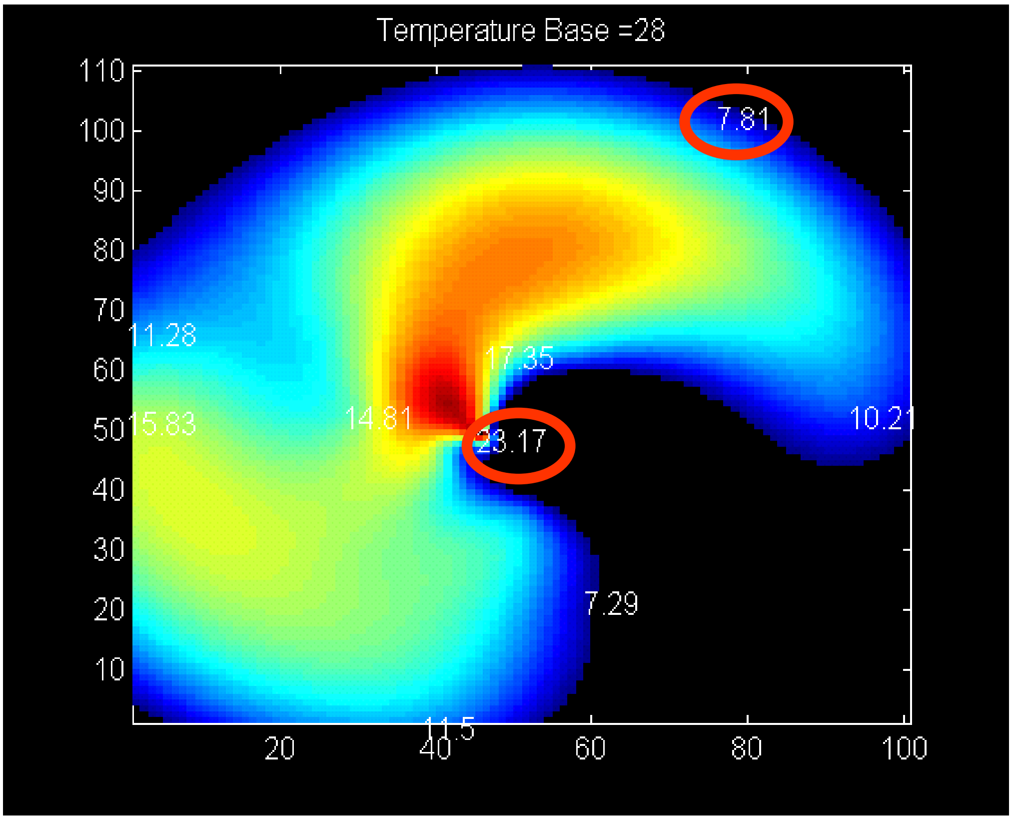
Analysis by Gunter Gantioler-TBZ – Technisches Bauphysik Zentrum – Bolzano (Italy)

OVERHEATING PHENOMENA OF "WARM URBAN ISLAND"

In the middle of the urban areas respect to the suburbs and the landscape' there is a increase of the temperature due the fact there are a lot of energy gains from human activities, vehicles, etc.

This aspect is really relevant not only in South Europe, but it seems bigger in Central Europe with a top of 6° C of difference in relation to the country side, as is possible to see in the analysis by Prof. Matheos Santamouris of the University of Athens.





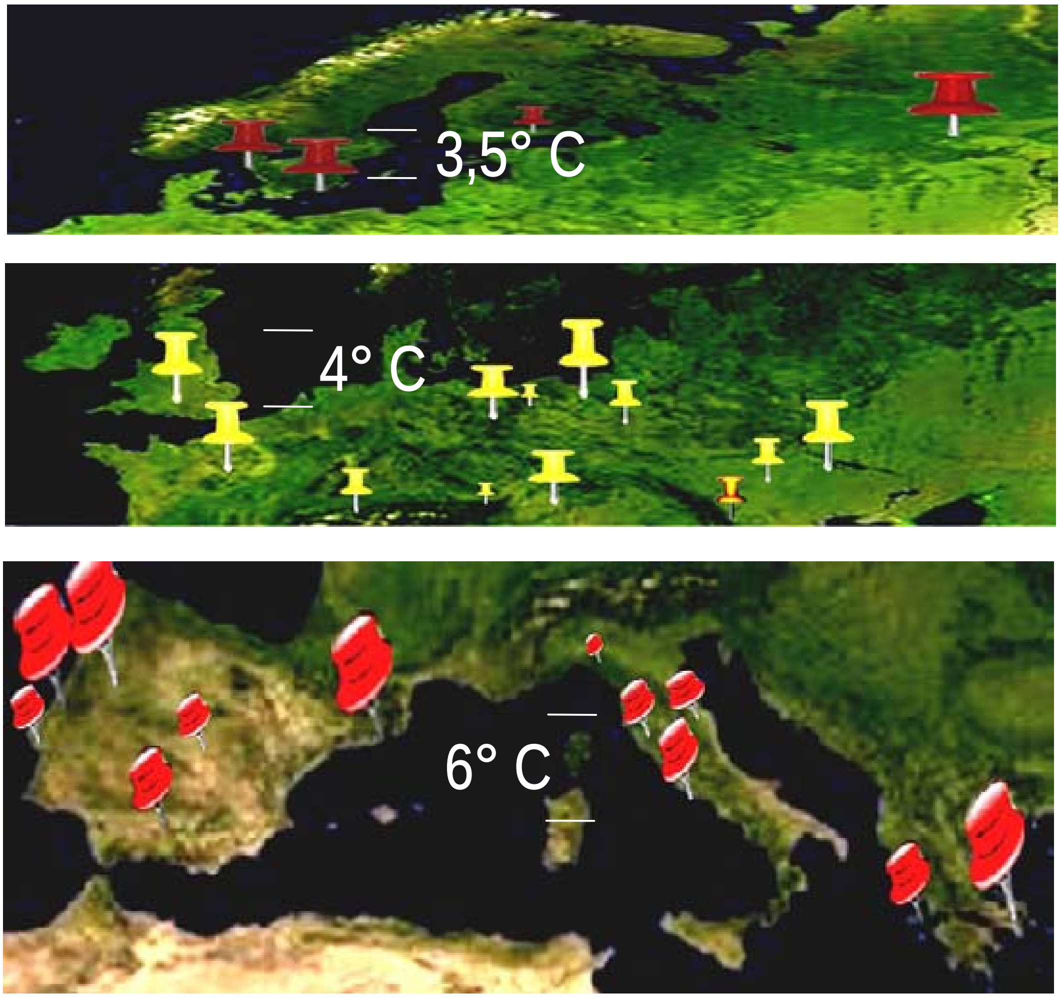
Analysis of cooling energy demand (Kwh) in the city of Athens – Prof. Matheos Santamouris

SUMMER BEHAVIOUR OF NORTH EUROPE WOODEN PASSIVE HOUSE

The *Passivhaus* standard was born to face only to the requirements of relatively cold central Europe climate, but in southern Europe the need to be warm in winter is accompanied by a need to ensure comfort in summer, which at times can be the predominate issue.

Sometimes in relation to the geometry of the building, to the indoor material and to the technical installations calculated and designed to face only the winter climate, it could happen that in the Summer also some buildings located in Central-North Europe could have some overheating problems and these are a lot of relevant in the case of lightweight constructions and it’s higher in the case of urban localizations.

So it appears really important the fact to have to design in the right way especially those buildings that are characterized by a few indoor thermal mass and in the same time with a high insulation behavior and the most dangerous combination seems to be that one of the passive houses built in a wood light structure without massive indoor elements.



Analysis of the overheating problems for the Europe urban areas – Prof. Matheos Santamouris

OVERHEATING PROBLEMS IN A WOODEN PASSIVE MULTI-STOREY HOUSE

The real demonstration of this kind of overheating problems in relation to the lightweight construction system is evident in the case of a multi storey passive house complex located in the city of Vienna during the hottest week of the 2007 Summer.

In this case the outdoor temperature at 5:30 p.m. of the 19th July 2007 was 36,7°C, but the indoor one in the ground floor was 31,8°C and in the mansard roof of 35,0°C.

South elevation and attic level view of a multi storey passive house – Vienna 19th July 2007 - 36,7°C

WOODEN CONSTRUCTION SYSTEM FOR PASSIVE MULTI-STOREY HOUSE

The multi storey complex is completely built with wooden cross-lam panels within all the installations and the floor system is characterized by an acoustic overload of calcareous gravel.

These pictures are related to a multi storey passive house under construction in Vienna, having the same characteristics of the complete one with overheating problems.

Wooden panel structure of a multi storey passive house – Vienna 19th July 2007 - 36,7°C

INDOOR TEMPERATURE FOR A PASSIVE MULTI-STOREY HOUSE

GROUND LEVEL - SOUTH WEST SIDE: 31,8°C

ATTIC LEVEL - SOUTH WEST SIDE : 35,0°C

Indoor overheating problems in a multi storey passive house – Vienna 19th July 2007 - 36,7°C

MAIN STRATEGIES FOR A PASSIVE INDOOR COOLING

To ensure a good summer indoor climate without adopting active air-conditioning systems, there are some general rules to follow both for passive or traditional constructions and they can be resume in four main points:

1- Building orientation, geometry and shading:
Shading avoids solar radiation to impinge on external surfaces of buildings, with particular relevance for windows in relation also to their orientation.

2- Thermal mass efficiency:
Materials within a building which have a high thermal capacitance can provide a ‘flywheel’ effect, smoothing out the variation in temperature within the building, and reducing the swing in temperature on a diurnal and potentially longer term basis.

3- Natural and night ventilation:
The cool air can be drawn into the house to flush out any residual heat from the day and to pre-cool the internal fabric for the following day taking advantage of the internal mass.

4- Subsoil heat exchanger and recovery system:
Subsoil heat exchanger can generally reduce use of active heating as incoming fresh air is pre-heated so active cooling demand and power may be reduced or even eliminated.

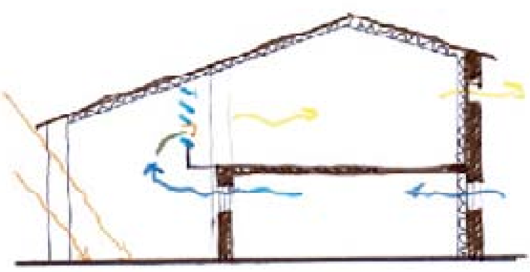
First worldwide Summer Passive House certificated – Office building A.S.S.A., Pisa (Italy)

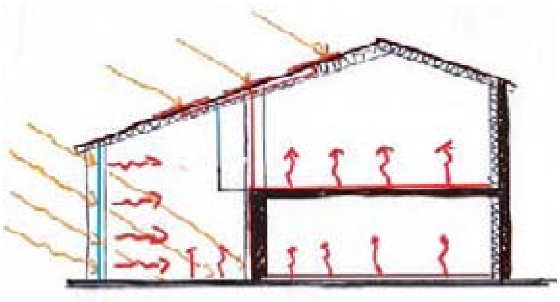
1- BUILDING ORIENTATION, GEOMETRY AND SHADING

A dwelling with a correct orientation should have a high level of heat loss area oriented to the south, with a high percentage of glazing, but for the summer conditions this measure requires a well designed system of solar control because in other case the building will be overheated.

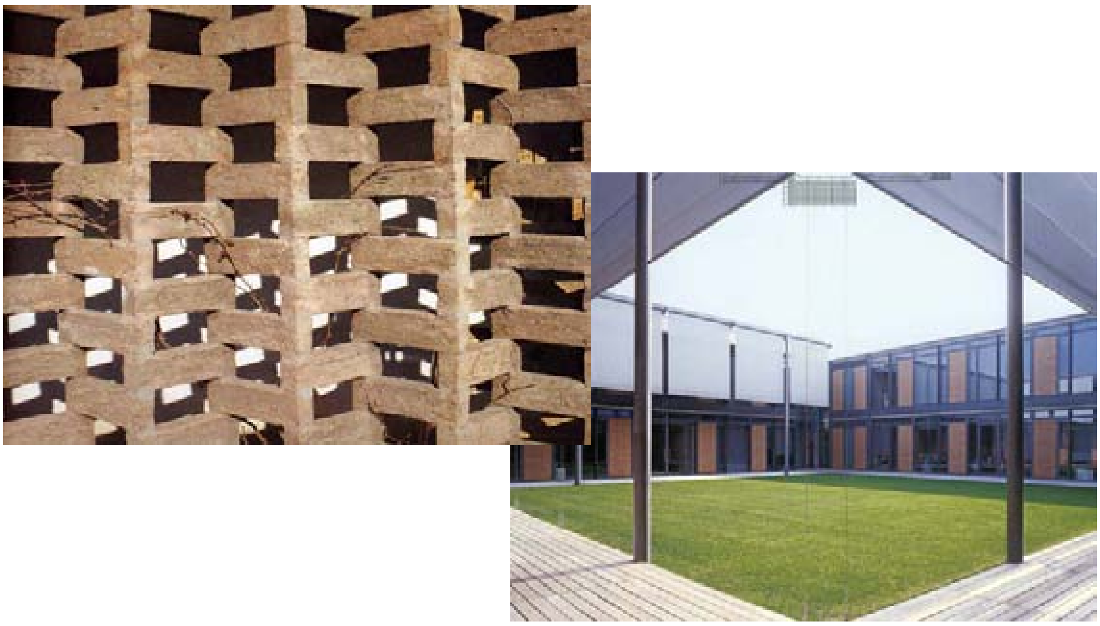
East and west orientation are avoided because the level of radiation in these ones is very low in winter, and in summer solar control is much more complicated than in south orientation.

Solar shading devices have to be designed in a selective way, as they should allow radiation to reach the building in winter and but block the radiation in summer and in general they can be divided in three groups: own shading due to the building surfaces over themselves, an other for obstacles like overhangs or Venetian blinds, and shading due to far obstacles like other buildings in the surroundings or natural or designed vegetation.





Shadow protection against the sun during Summer *vs.* *Glazing surface no shaded during Winter*

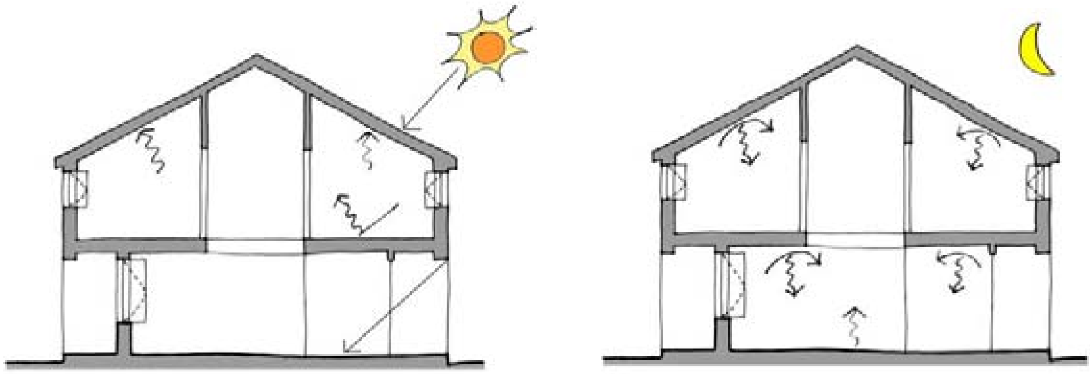


Traditional rural static sheltering *vs.* *Modern flexible sheltering – Max Mara headquarter (Italy)*

2- THERMAL MASS EFFICIENCY

Thermal mass (Joules/kg) is the term used to describe materials of high thermal capacitance to absorb and store large quantities of heat and they can be in the form of masonry walls, exposed concrete soffits to intermediate floors, or possibly embedded phase change materials.

In summer this behavior is useful to limits the upper daytime temperature and thereby reduce the need for cooling and this effect can be enhanced by coupling the high capacitance material with night time convection to pre-cool the thermal mass for the following day.



Heat storing effect of thermal mass during the day vs. Heat stored in the mass is released at night

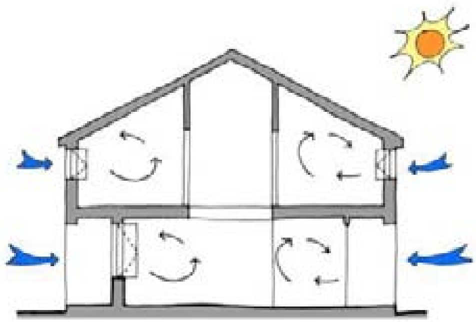
Masonry passive house in Zoppola di Pordenone (Italy) – Biodomus by Claudio Botter

3- NATURAL AND NIGHT VENTILATION

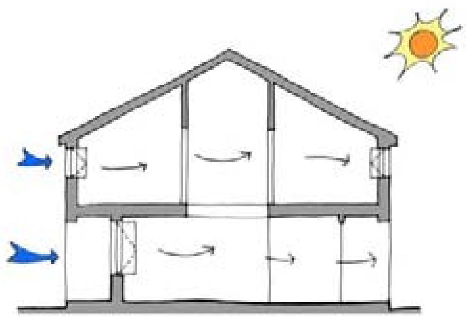
Wind driven ventilation is induced by the pressure differences arising due to the change in momentum when the air is deflected or when the air speed is reduced and typically a difference in wind pressure arises between the windward and the leeward sides of a building, and can drive air through the building to achieve simple cross ventilation.

Otherwise the thermal buoyancy (stack) occurs when pressure differences arising from differences in temperature between inside and outside of the building create a flow of air between inside and outside, being the flow normally from low level to high level, through openings provided to exploit this.

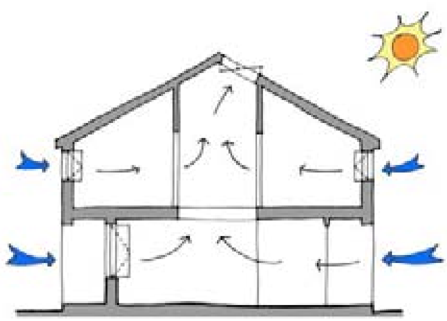
Three factors determine the rate of air movement due to thermal buoyancy: the pressure difference, the area of openings in the building and the height difference between the openings.



Single side ventilation



Cross ventilation

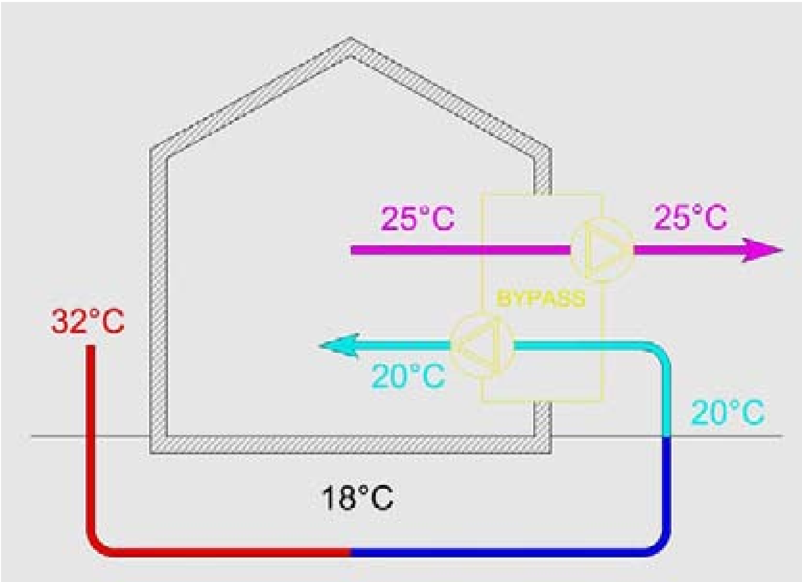


Stack ventilation

4- SUBSOIL HEAT EXCHANGER AND RECOVERY SYSTEM

Ground at 2-3 m deep has an almost constant temperature, equal to the average air temperature over the year, which in Europe depending on locality means 10 – 20°C, so the ground temperature can be significantly above (in winter) or significantly below (in summer) the local outside air temperature, it provides a potential for heating or cooling a building with very little energy input.

This cooling and heating potential is usually accessed by installing a sub soil heat exchanger (typically constructed in smooth-walled, rigid or semi-rigid plastic or metal pipes of 100 to 450 mm diameter) under or close to the building.



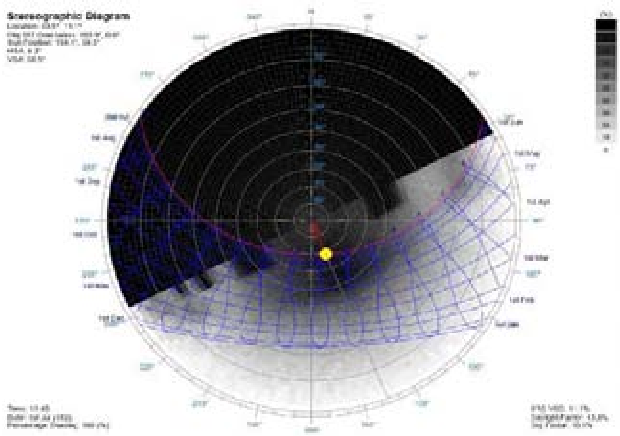
Subsoil heat exchanger system during summer time

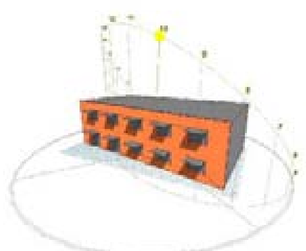
Air-to-air subsoil Winter heat exchanger vs. Liquid-to-air subsoil heat exchanger for Summer cooling

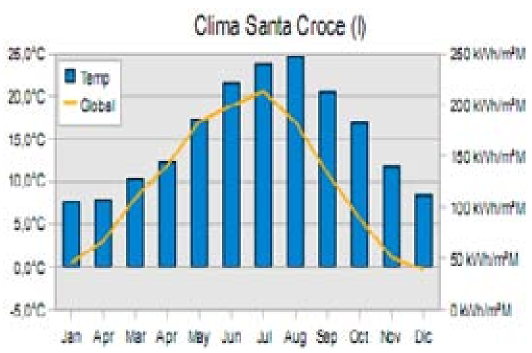
MEDITERRANEAN STATE OF ART OF SUMMER PASSIVE HOUSE

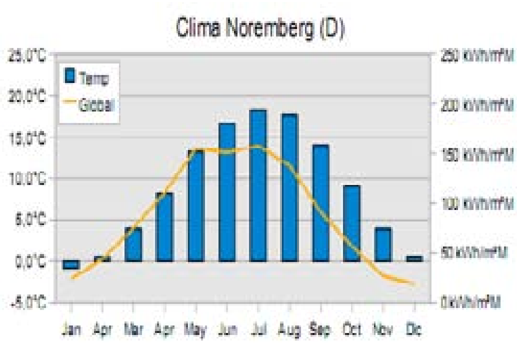
Right now there aren't many profound studies about this problematic and the reason is that the realization of high insulated buildings has been develop mostly in the North Europe to face the Winter climate problems, and in this case the wooden buildings have proved their high performances in terms of insulation against the cold, but in the same time this technology doesn't appear indicate to solve the problems due to the summer overheating.

In fact right now all around Europe there is only one certificated Passive Summer Building, the A.S.S.A. Headquarters in Pisa (Italy) by arch. Silvia Mazetti, built in a traditional way using a massive masonry internal structure combined with an extremely high insulated envelopment.









Energy project by Gunter Gantioler-TBZ – Technisches Bauphysik Zentrum – Bolzano (Italy)

PART II – THE WOODEN SUMMER PASSIVE HOUSE

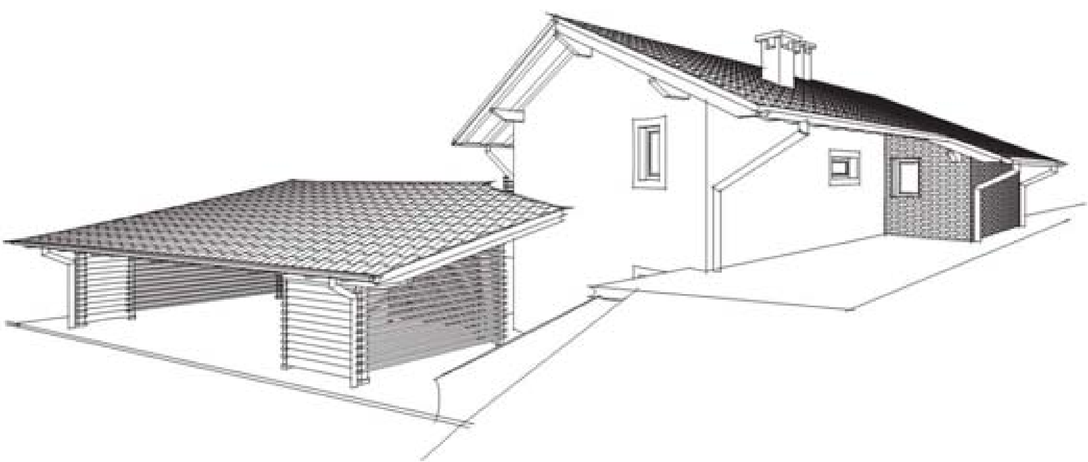
STUDIO CASE OF A SINGLE FAMILY PASSIVE HOUSE IN NORTH ITALY

Consequently this considerations, the aim of this research project is that to study the right combination of wooden cross-lam building structures with massive inertial materials to ensure high living indoor performances in the most natural way, taking advantage of the specific physics behaviour of each material.

In the specific, it will be analyzed a single two stores family house that is going to be realized close to the city of Udine (North East of Italy) with a wooden cross-lam panels structure combined with a masonry core, functional to absorb the overheating energy during the summer days and then release this during the night, using a combination of mechanical and natural air flow.

SOUTH WEST VIEW

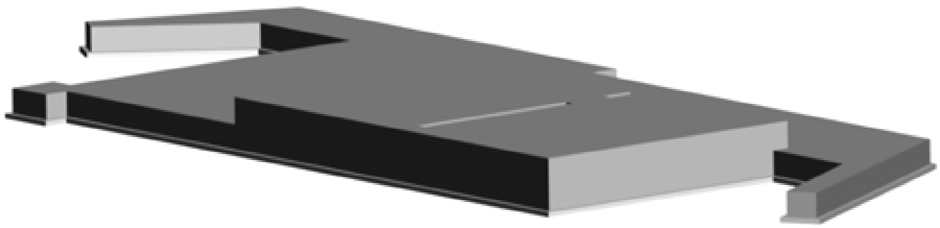
NORTH EAST VIEW



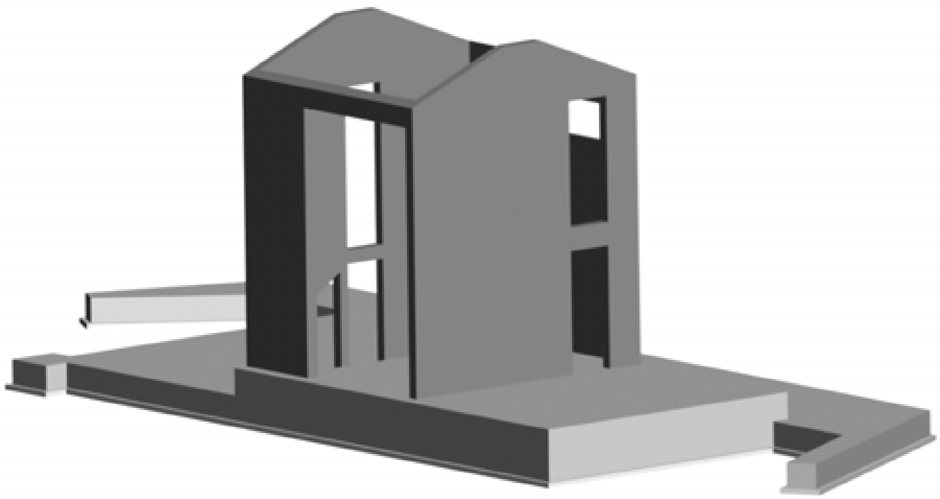
Project design, structural engineering and energy demand calculation – arch. Andrea Boz

STRUCTURAL CONSTRUCTIVE SEQUENCES

STEP 1 – View of the concrete foundation system



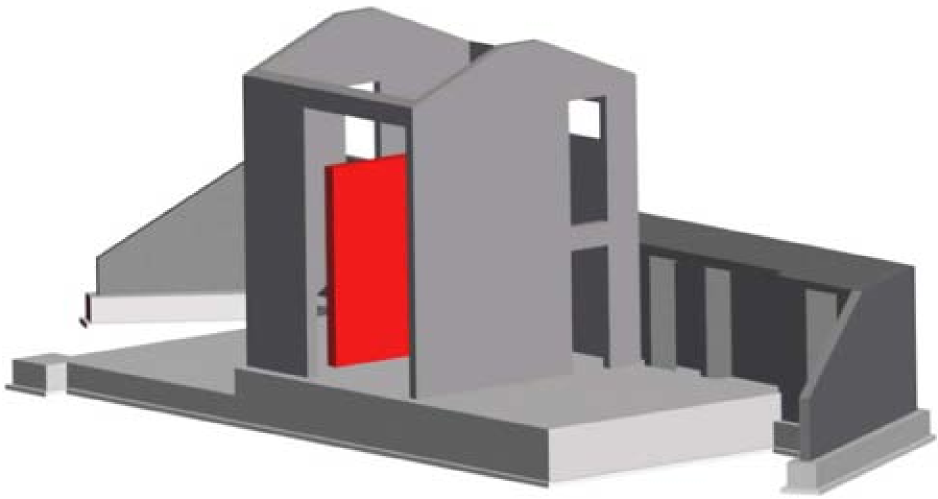
STEP 2 – View of the inertial mass core system



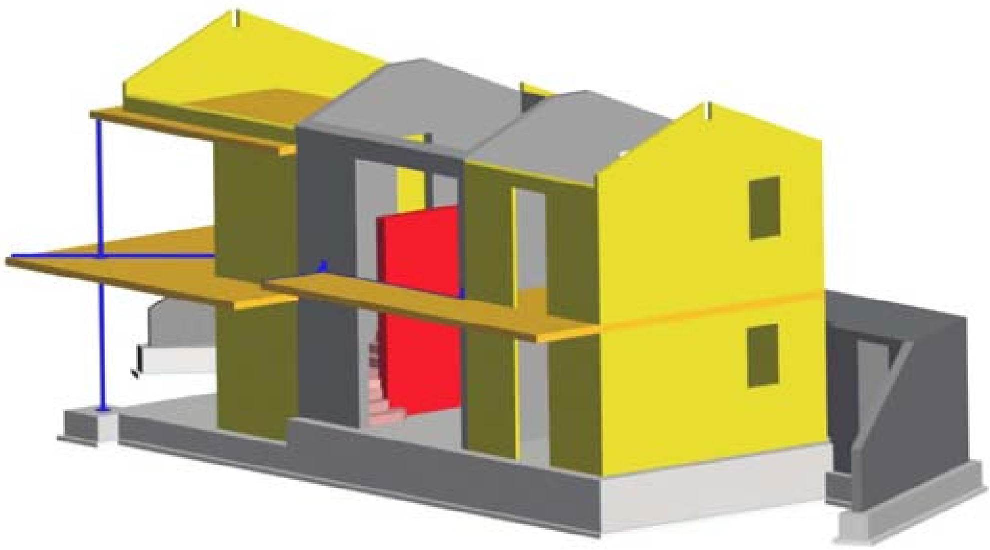
Project design, structural engineering and energy demand calculation – arch. Andrea Boz

STRUCTURAL CONSTRUCTIVE SEQUENCES

STEP 3 – View of the massive wall system



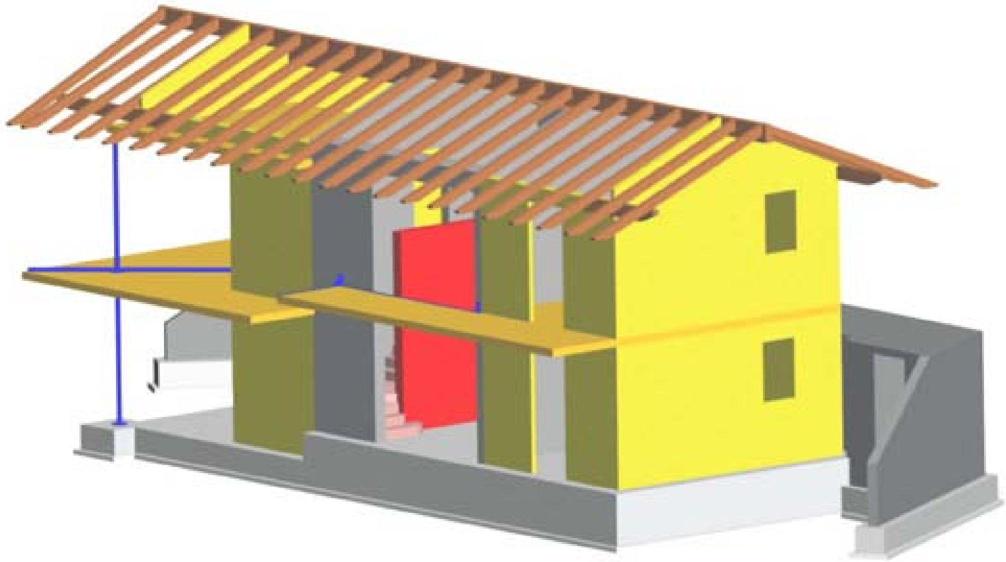
STEP 4 – View of the cross-lam wooden panels system



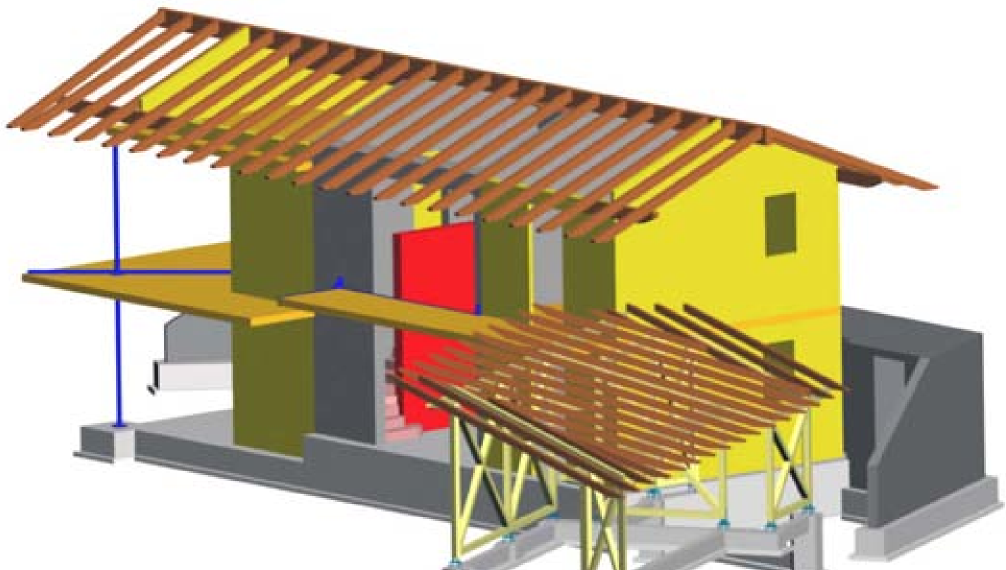
Project design, structural engineering and energy demand calculation – arch. Andrea Boz

STRUCTURAL CONSTRUCTIVE SEQUENCES

STEP 5 – View of the house structural system



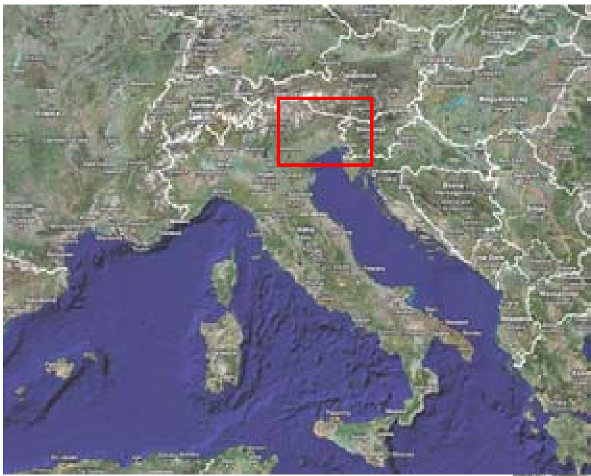
STEP 6 – View of the complete structural system



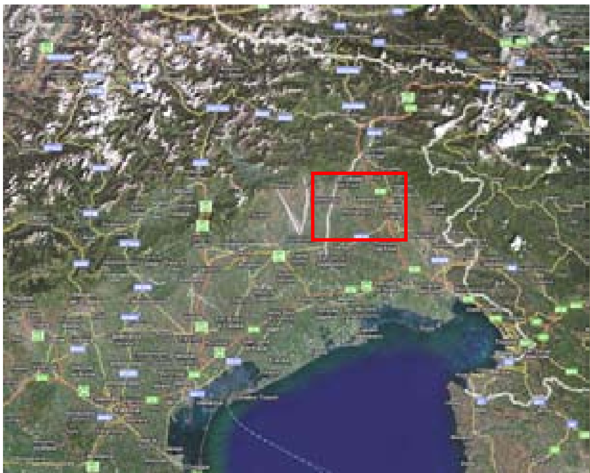
Project design, structural engineering and energy demand calculation – arch. Andrea Boz

GEOGRAPHYCAL AND CLIMATIC LOCALIZATION – FRIULI – ITALY

The project that is going to be built from September 2008 is located in the municipality of Fagagna in the Udine Province of the Friuli region, 130 km North-East from Venice, 90 km North-West from Trieste, 40 km East from Slovenia and 100 km South from Austria.



Latitude *46,11° N*
Longitude *-13,09°*
Altitude *+177 m.a.s.l.*



Climatic zone *E*
Degrees-Days *2428 DD*
Solar radiation *1272 kWh/m^2*

Municipality of Fagagna – Province of Udine – Region of Friuli Venezia Giulia - Italy

TEMPERATURES DURING LAST 10 YEARS OF FRIULI HILL AREAS

For the energy demand calculations are taking in account the average outdoor temperatures and in consideration of the Summer period has been choose the average temperature of 23,5°C with a daily difference of 10,9°C, both for the dynamic analysis, using the GEBA software, and for the static one with PHPP.

MONTH	Faedis			FAGAGNA			Udine			Talmassons		
	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max
January	4.4	0.5	8.3	3.9	0.2	7.7	3.8	-0.4	8.0	3.9	-0.1	8.0
February	5.2	0.4	9.9	4.8	0.3	9.3	4.4	-0.8	9.6	4.6	-0.8	10.0
March	9.0	4.1	13.9	8.7	3.9	13.6	8.6	3.2	14.0	8.5	2.6	14.5
April	11.9	7.0	16.9	11.8	7.1	16.6	12.1	6.9	17.3	12.0	6.5	17.6
May	17.3	11.8	22.7	17.6	12.6	22.6	17.6	12.2	23.0	17.7	11.9	23.6
June	20.5	14.9	26.1	20.9	15.8	26.1	20.7	15.2	26.2	21.1	15.0	27.2
July	22.3	16.5	28.2	22.7	17.5	27.9	22.4	16.4	28.4	22.9	16.4	29.4
August	23.2	17.1	29.3	**23.5**	**18.1**	**29.0**	23.1	16.7	29.5	23.2	16.5	30.0
September	18.0	12.7	23.4	18.2	13.2	23.1	17.8	12.0	23.6	18.3	12.1	24.4
October	13.8	9.3	18.4	13.5	9.2	17.9	13.5	8.6	18.3	13.9	8.9	19.1
November	8.9	5.1	12.8	8.6	5.0	12.3	8.5	4.3	12.7	8.9	4.7	13.2
December	4.9	1.2	8.5	4.5	1.1	8.0	4.3	0.4	8.3	4.5	0.6	8.4
YEAR	**13.3**	**8.4**	**18.2**	**13.3**	**8.7**	**17.9**	**13.2**	**8.0**	**18.4**	**13.3**	**7.9**	**18.8**

Data by ERSA FVG – Ente Regionale per la Salvaguardia dell' Agricoltura – Friuli Venezia Giulia

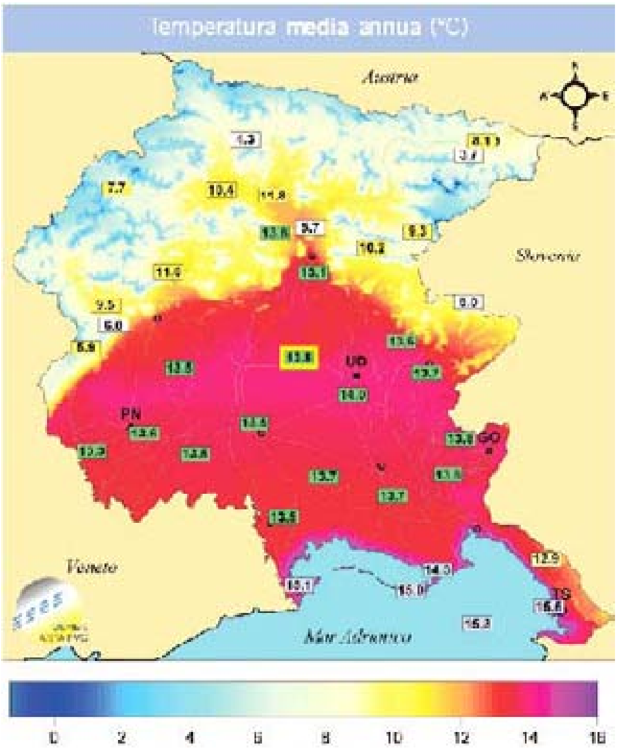
HOTTEST PERIOD: AUGUST

23.5	18.1	29.0

Mounth	1	2	3	4	5	6	7	8	9	10	11	12	Solar radiation		
Udine IT	geogr, Breite	46,07	geogr, Länge	13,23	Höhe über NN (m)	98			tägliche Temperaturschwankung Sommer (K)	10,9	Strahlungsdaten:	kWh/(m²*Monat)	Strahlung: W/m²		W/m²
Außentemp	3,6	4,5	8,7	12,3	17,9	21,8	23,1	23,5	18,3	14	8,9	4,6	-1,5	7,4	27,5
Nord	12	15	26	31	43	48	49	40	28	20	13	9	14	10	57
East	28	38	55	73	94	96	115	95	69	45	27	20	31	13	133
Süd	75	88	86	89	81	82	91	102	96	94	61	49	48	24	124
West	28	40	56	77	83	87	93	90	70	52	26	20	23	14	110
Global	40	58	91	125	150	164	178	156	108	75	42	27	36	23	192
Taupunkt	-0,5	-1,3	2,4	6,2	11,5	14,9	16,2	16,8	12,7	9,9	5	0,4			
Himmelstemp	-8,6	-8,8	-3,9	0,5	6,4	10,9	11,6	12,4	7,3	4,5	-1	-7,1			

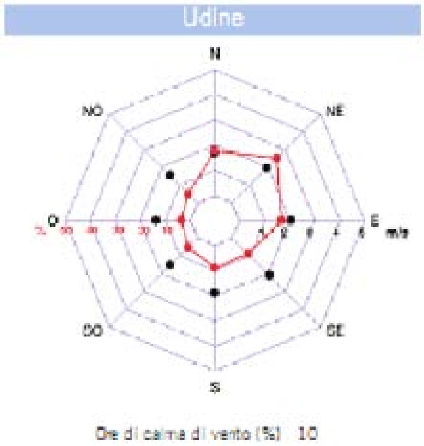
Data by Meteonorm - Meteotest software and global meteorological database – Bern (Switzerland)

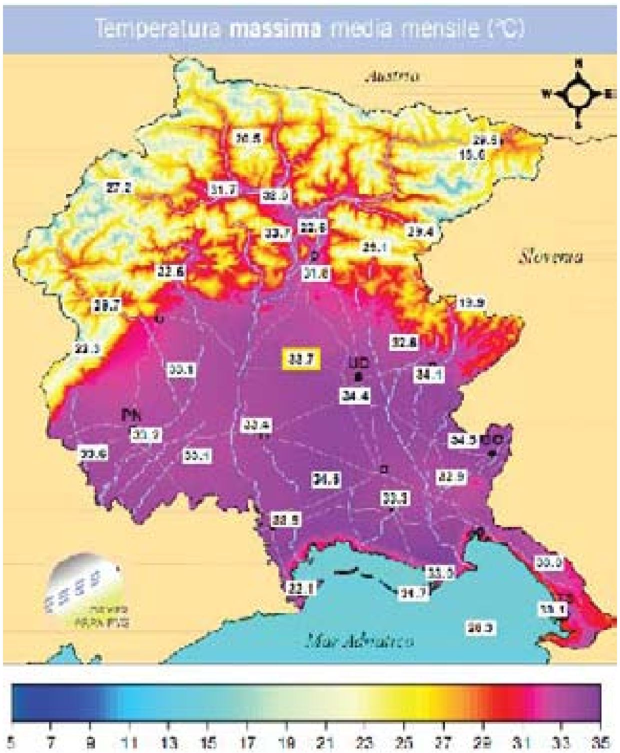
ANNUAL AND SUMMER REPORT TEMPERATURES IN FRIULI REGION – 2006



ANNUAL TEMPERATURES

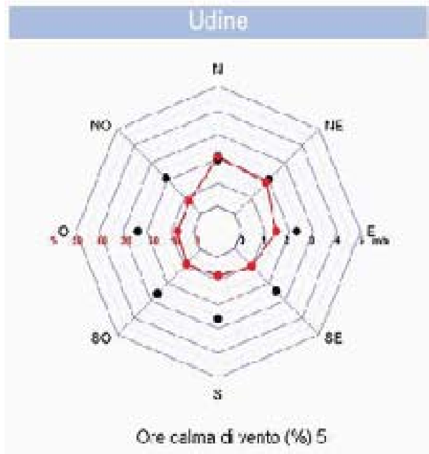
Ave.	13,8°
Min.	-9,5° - 25/01
Max.	38,9° - 21/07
Ground	13,9° Average





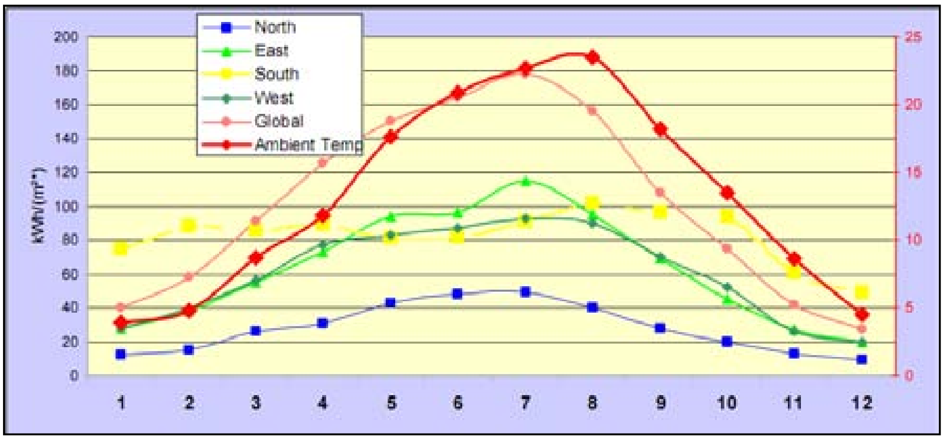
SUMMER TEMPERATURES

Ave.	26,6°
Min.	16,4° - 17/07
Max.	38,9° - 21/07
Ground	28,9° Average



Data by ERSA FVG – Ente Regionale per la Salvaguardia dell' Agricoltura – Friuli Venezia Giulia

FAGAGNA CLIMATIC DATA BY PHPP – PASSIVE HOUSE PLANNING PACKAGE



Temperatures and radiation map – Meteonorm by Meteotest, Bern (Switzerland)

WINTER EXTREME CLIMATIC CONDITIONS

	Design Temperature		Radiation: North	East	South	West	Horizontal	
Weather Condition 1:	-2,6	°C	14	31	48	23	36	W/m²
Weather Condition 2:	2,2	°C	10	13	24	14	23	W/m²

	Design Temperature		North	East	South	West	Horizontal	
Weather Condition 1:	-2,6	°C	14	31	48	23	36	W/m²
Weather Condition 2:	2,2	°C	10	13	24	14	23	W/m²
Ground Design Temp:	13,0	°C						

1 Cold, clear day
2 Moderate, overcast day

	Building Element	Temperature Zone	Area m²		U-Value W/(m²K)		Factor Always 1 (except "X")		TempDiff 1 K		TempDiff 2 K		P_T 1 W		P_T 2 W
1	Exterior Wall - Ambient	A	181,0	*	0,121	*	1,00	*	22,6	or	17,8	=	495	or	390
2	Exterior Wall - Ground	B		*		*	1,00	*	7,0	or	7,0	=		or	
3	Roof/Ceiling - Ambient	A	110,5	*	0,132	*	1,00	*	22,6	or	17,8	=	330	or	260
4	Floor Slab	B		*		*	1,00	*	7,0	or	7,0	=		or	
5	Elementi verso cantine	X	41,9	*	0,217	*	0,50	*	22,6	or	17,8	=	103	or	81
6	Pavimenti su vespaio	X	92,8	*	0,113	*	0,50	*	22,6	or	17,8	=	119	or	93
7		X		*		*	0,50	*	22,6	or	17,8	=		or	
8	Fenster	A	39,4	*	0,884	*	1,00	*	22,6	or	17,8	=	787	or	620
9	Exterior Door	A		*		*	1,00	*	22,6	or	17,8	=		or	
10	Thermal Bridges Ambient	A		*		*	1,00	*	22,6	or	17,8	=		or	
11	Perimeter Thermal Bridges	P		*		*	1,00	*	7,0	or	7,0	=		or	
12	Thermal Bridges Floor Slab	B	5,4	*	0,068	*	1,00	*	7,0	or	7,0	=	3	or	3
13	Haus/Wohnungstrennwand	I		*		*	1,00	*	3,0	or	3,0	=		or	
	Transmission Heat Losses PT P_T										Total	=	1837	or	1447

SUMMER EXTREME CLIMATIC CONDITIONS

	Ambient Air		Sky		Ground	
Design Temperature	28,0	°C	20,0	°C	20,2	°C

Radiation	North	East	South	West	Horizontal	
	57	133	124	110	192	W/m²

	Building Elements	Temperature Zone	m²		W/(m²K)		Always 1 (except "X")		K		W
1	Exterior Wall - Ambien	A	181,0	*	0,121	*	1,00	*	3,0	=	66
2	Exterior Wall - Ground	B		*		*	1,00	*	-4,8	=	
3	Roof/Ceiling - Ambient	A	110,5	*	0,132	*	1,00	*	3,0	=	44
4	Floor Slab	B		*		*	1,00	*	-4,8	=	
5	Elementi verso cantine	X	41,9	*	0,217	*	0,50	*	3,0	=	14
6	Pavimenti su vespaio	X	92,8	*	0,113	*	0,50	*	3,0	=	16
7		X		*		*	0,50	*	3,0	=	
8	Fenster	A	39,4	*	0,884	*	1,00	*	3,0	=	104
9	Exterior Door	A		*		*	1,00	*	3,0	=	
10	Thermal Bridges Ambient	A		*		*	1,00	*	3,0	=	
11	Perimeter Thermal Bridges	P		*		*	1,00	*	-4,8	=	
12	Thermal Bridges Floor Slab	B	5,4	*	0,068	*	1,00	*	-4,8	=	-2
13	House/DU Partition Wall	I		*		*	1,00	*	3,0	=	
			Lambient W/K		TempDiff K		LSky W/K		TempDiff K		
14	Radiation Correction		-2,0	*	3,0	+	1,9	*	-5,0	=	-16
	Transmission Heat Losses	P_T							Total	=	226

Winter vs. Summer energy demand by PHPP 2007 – Passive House Planning Package

CRAWL SPACE FOR AIR VENTILATED GROUND FLOOR

A particular condition for the right calculation of the indoor temperature and related energy demand in case of buildings build up respecting the Italians rules, is due to the fact that is not allow have a direct contact between living spaces and the ground.

The Friuli regional health regulations prescribe a ventilated space of at least 20cm in between the rooms and the ground, so during the Summer the risk is that to lose the benefit of this usual direct contact in relation to a good cooling natural process and in the Winter the ground doesn't give the effect of "lake of warm" under the foundation, typical of the passive house after some years they are built.

Standard Italians Polypropilene elements for crawl space – Pontarolo engineering Pordenone (Italy)

Design Ground Temperature for Heat Load Sheet — 10,6

Steady-State Transmittance	L_s	28,17 W/K	Periodic Heat Flow	Φ_{harm}	87,0 W
Exterior Periodic Transmittance	L_{pe}	20,41 W/K	Heat Losses During Heating Period	Q_{tot}	1218 kWh

for Cooling Load Sheet — 22,3

Monthly Average Ground Temperatures for Monthly Method

Month	1	2	3	4	5	6	7	8	9	10	11	12	Average Value
Winter	11,7	10,6	10,9	12,5	15,0	17,7	19,9	21,0	20,7	19,1	16,6	13,9	15,8
Summer	13,0	11,9	12,2	13,8	16,3	19,0	21,2	22,3	22,0	20,4	17,9	15,2	17,1

For Suspended Floor

U-Value Crawl Space	U Crawl	0,130	W/(m²K)
Height of Crawl Space Wall	h	0,20	m
U-Value Crawl Space Wall	U_W	1,000	W/(m²K)
Area of Ventilation Openings	εP	0,10	m²
Wind Velocity at 10 m Height	v	25,0	m/s
Wind Shield factor	f_W	0,05	-

Ground crawl space temperature calculated by PHPP 2007 – Passive House Planning Package

GENERAL VENTILATION REPORT ENTIRE HOUSE

The heat recover system is an essential part of the central European Passive House, and allows homes to be built without conventional heating systems by using a low powered (200-300 W) electronically commuted DC motors and in warm climates the heat recover system is used to pre-cool incoming warm air.

For an healthy and comfortable indoor climate the average air change flow has to be included between 0,3 and 0,5 volume/hour for the entire building, but each room has to have a specific value in relation to his volume and function, and so it has to be calculate the different air flow of each room.

Treated Floor Area	A_{EB}	m²	123	(Areas worksheet)
Room Height h		m	2,5	(Annual Heat Demand worksheet)
Room Ventilation Volume	$(A_{EB}{*}h) = V_V$	m³	306	(Annual Heat Demand worksheet)

Ventilation System Design - Standard Operation

Occupancy	m²/P	35				
Number of Occupants	P	3,5				
Supply Air per Person	m³/(P*h)	30				
Supply Air Requirement	m³/h	105				
Extract Air Rooms		Kitchen	Bathroom	Shower	WC	
Quantity		1	1	1	0	
Extract Air Requirement per Room	m³/h	60	40	20	20	
Total Extract Air Requirement	m³/h	120				

Design Air Flow Rate (Maximum) m³/h 200 — **ENTIRE HOUSE AIR FLOW (m³/h)**

Average Air Change Rate Calculation

Type of Operation	Daily Operation Duration (h/d)	Factors Referenced to Maximum	Air Flow Rate (m³/h)	Air Change Rate (1/h)
Maximum	2,0	1,00	200	0,65
Standard	4,0	0,77	154	0,50
Basic	18,0	0,54	108	0,35
Minimum	0,0	0,40	80	0,26
x Residential Building	Average value	0,62	Average Air Flow Rate (m³/h): 123	Average Air Change Rate (1/h): 0,40

VENTILATION FLOW BASE REQUIREMENT

Minimum extract air requirement for kitchen room: ***60 m³/h***

Minimum extract air requirement for single room area: ***3 m³/h*m²***

Minimum extract air requirement for person for entire house: ***30 m³/h***

1- VENTILATION FLOW KITCHEN ROOM

Kitchen area: 30 m² - *Minimum air requirement for area: 90 m³/h*
Kitchen volume: 75 m³

SPECIFIC AIR FLOW RATIO FOR KITCHEN ROOM: 1,2 1/h

2- VENTILATION FLOW LIVING ROOM

Living room area: 25 m² - *Minimum air requirement for area or persons: 75/90 m³/h*
Living room volume: 125 m³

SPECIFIC AIR FLOW RATIO FOR LIVING ROOM: 0,6/0,7 1/h

CALCULATION OF THE SPECIFIC AIR CHANGE RATE FOR ROOM

The heat recover system can work with different speed in relation to the use or crowd level of the house, so it's suppose that for a couple of hour it's having the maximum air flow ratio, for six ones a standard flow and for the rest of the time a basic one.

Type of Operation	h/d		m³/h	1/h
Maximum	2,0	1,00	200	0,65
Standard	6,0	0,77	154	0,50
Basic	16,0	0,54	108	0,35

AIR CHANGE RATE KITCHEN ROOM

Maximum *1,2 1/h * 0,65 = 0,8 1/h = 60 m³/h*
(12:00; 20:00)

Standard *1,2 1/h * 0,50 = 0,6 1/h = 45 m³/h*
(07:00 - 08:00; 11:00; 13:00; 19:00; 21:00)

Basic *1,2 1/h * 0,35 = 0,4 1/h = 30 m³/h*
(22:00 - 06:00; 09:00 - 10:00; 14:00 - 18:00)

AIR CHANGE RATE LIVING ROOM

Persons: Maximum *0,6 1/h * 0,65 = 0,4 1/h = 50 m³/h*
Floor area: Maximum *0,7 1/h * 0,65 = 0,45 1/h = 55 m³/h*
(12:00; 20:00)

Persons: Standard *0,6 1/h * 0,50 = 0,3 1/h = 40 m³/h*
Floor area: Standard *0,7 1/h * 0,50 = 0,35 1/h = 45 m³/h*
(07:00 - 08:00; 11:00; 13:00; 19:00; 21:00)

Persons: Basic *0,6 1/h * 0,35 = 0,2 1/h = 25 m³/h*
Floor area: Basic *0,7 1/h * 0,35 = 0,25 1/h = 30 m³/h*
(22:00 - 06:00; 09:00 - 10:00; 14:00 - 18:00)

MECHANICAL AIR FLOW RATIO COMBINED WITH NATURAL ONE

In addition to the mechanical air flow ratio is possible combine the natural one due the fact that in some hours, preferably during the night time, is possible increase the air flow opening windows and taking away the Summer overheating thermal load.

In this case there can be four different levels of air flow exchange:

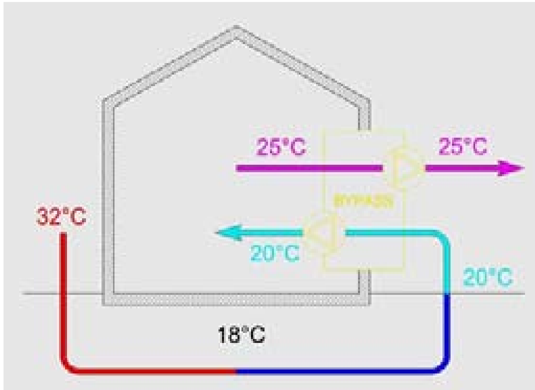
A- Basic heat recover system + Close windows

B- Basic heat recover system + Transom opening windows

C- Standard heat recover system + Half opening windows

D- Maximum heat recover system + Total opening windows

A- AIR CHANGE SYSTEM + CLOSE WINDOW: ***<u>0% – n=0 (1/h)</u>***

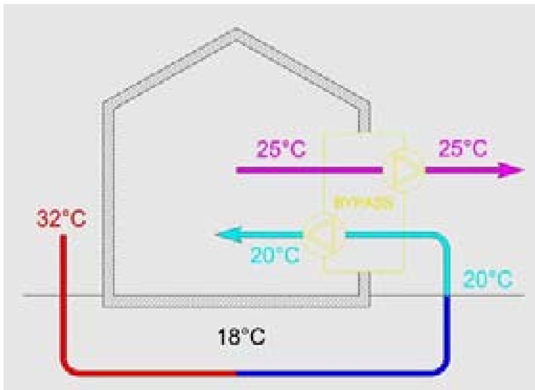


MAX: *(0,8 +0,0) = 0,8 1/h = 100%*
(0,45 +0,0) = 0,45 1/h = 100%

STAN: *(0,6 +0,0) = 0,6 1/h = 75%*
(0,35 +0,0) = 0,35 1/h = 77%

BASE: *(0,4 +0,0) = 0,4 1/h = 50%*
(0,25 +0,0) = 0,25 1/h = 55%

B- AIR CHANGE SYSTEM + TRANSOM-WINDOW: ***<u>13% – n=0,4 (1/h)</u>***

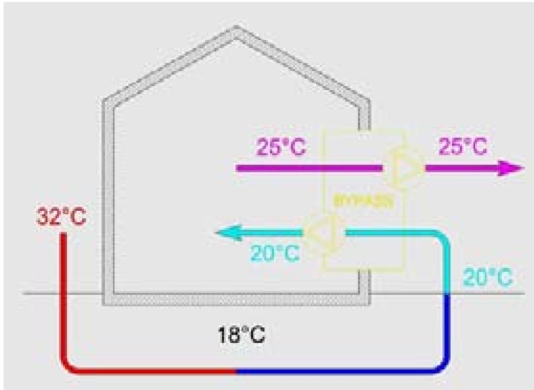


MAX: *(0,8 +0,4) = 1,2 1/h = 100%*
(0,45 +0,4) = 0,95 1/h = 100%

STAN: *(0,6 +0,4) = 1,0 1/h = 83%*
(0,35 +0,4) = 0,75 1/h = 79%

BASE: *(0,4 +0,4) = 0,8 1/h = 66%*
(0,25 +0,4) = 0,65 1/h = 68%

C- AIR CHANGE SYSTEM + HALF OPEN WINDOW: ***<u>50% – n=1,5 (1/h)</u>***

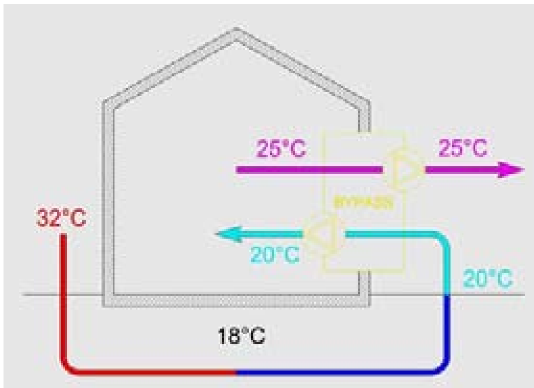


MAX: *(0,8 +1,5) = 2,3 1/h = 100%*
(0,45 +1,5) = 1,95 1/h = 100%

STAN: *(0,6 +1,5) = 2,1 1/h = 91%*
(0,35 +1,5) = 1,85 1/h = 95%

BASE: *(0,4 +1,5) = 1,9 1/h = 83%*
(0,25 +1,5) = 1,75 1/h = 90%

D- AIR CHANGE SYSTEM + TOTAL OPEN WINDOW: ***<u>100% – n=3,0 (1/h)</u>***



MAX: *(0,8 +3,0) = 3,8 1/h = 100%*
(0,45 +3,0) = 3,45 1/h = 100%

STAN: *(0,6 +3,0) = 3,6 1/h = 95%*
(0,35 +3,0) = 3,35 1/h = 97%

BASE: *(0,4 +3,0) = 3,4 1/h = 90%*
(0,25 +3,0) = 3,25 1/h = 94%

AIR CHANGE COMBINATION RATE FOR NORMAL USE ROOMS

For the calculation of the more realistic indoor Summer ventilation of the entire house, it has been suppose the fact that during the morning for two hours there is a medium high flow due to the combination of the standard mechanical rate and the half open windows, during the day for nine hours the lowest one with all the windows close, during the evening for three hours the highest one for the combination of the maximum mechanical rate and the total open windows and during all the night a low flow due to the basic mechanical rate added to the transom opening windows.

KITCHEN ROOM

COMBINATIONS		A- Close		B- Transom		C- Half		D- Total		Average	
AIR FLOW RATE		*1/h*	*%*	*1/h*	*%*	*1/h*	*%*	*1/h*	*%*	*1/h*	*%*
1-	MAXIMUM	0,8	21%	1,2	32%	2,3	61%	**3,8**	100%	2,03	53%
2-	STANDARD	0,6	17%	1,0	28%	**2,1**	58%	3,6	100%	1,83	51%
3-	BASIC	**0,4**	12%	**0,8**	24%	1,9	56%	3,4	100%	1,63	48%
AVERAGES		***0,6***	***16%***	***1,0***	***28%***	***2,1***	***58%***	***3,6***	***100%***	***1,83***	***51%***

19 HOUR OF LOW AIR FLOW

Basic + Close window
0,4 1/h – 10% - (10:00 - 18:00)

Basic + Transom window
0,8 1/h – 20% - (22:00 - 07:00)

5 HOUR OF HIGH AIR FLOW

Standard + Half open window
2,1 1/h – 55% - (07:00 - 08:00)

Maximum + Total open window
3,8 1/h – 100% - (19:00; 22:00)

LIVING ROOM

COMBINATIONS		A- Close		B- Transom		C- Half		D- Total		Average	
AIR FLOW RATE		*1/h*	*%*	*1/h*	*%*	*1/h*	*%*	*1/h*	*%*	*1/h*	*%*
1-	MAXIMUM	0,45	13%	0,95	27%	1,95	57%	**3,45**	100%	1,70	49%
2-	STANDARD	0,35	10%	0,75	23%	**1,85**	55%	3,35	100%	1,58	47%
3-	BASIC	**0,25**	7%	**0,65**	20%	1,75	54%	3,25	100%	1,48	45%
AVERAGES		***0,35***	***10%***	***0,78***	***23%***	***1,85***	***55%***	***3,35***	***100%***	***1,58***	***47%***

19 HOUR OF LOW AIR FLOW

Basic + Close window
0,25 1/h – 7% - (10:00 - 18:00)

Basic + Transom window
0,65 1/h – 20% - (22:00 - 07:00)

5 HOUR OF HIGH AIR FLOW

Standard + Half open window
1,85 1/h – 55% - (07:00 - 08:00)

Maximum + Total open window
3,45 1/h – 100% - (19:00; 22:00)

PART III – DYNAMIC ANALYSIS OF THE THERMAL MASS INFLUENCE FOR THE COOLING DEMAND

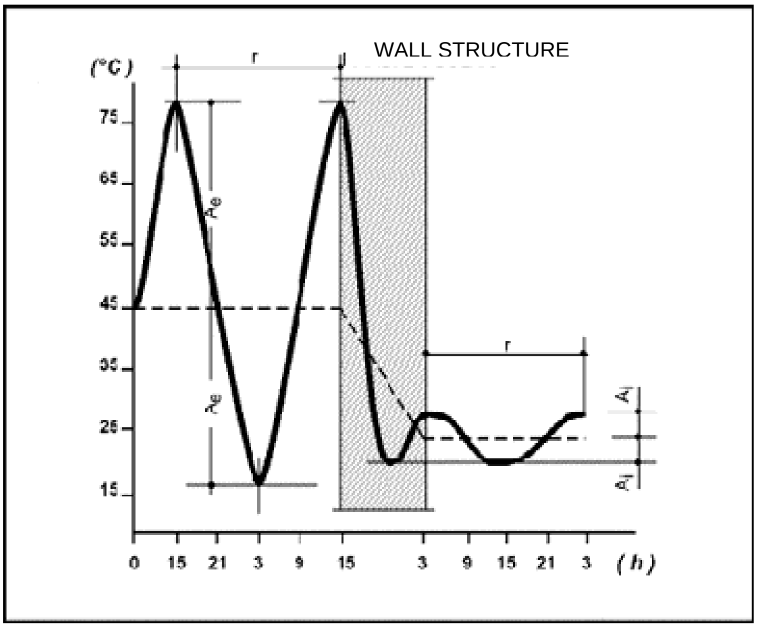
STORAGE HEAT CAPACITY OF DIFFERENT MATERIALS

The aim of this research project is that to investigate the thermal influence of the mass in relation to the cooling demand during Summer in the South European area, especially in the case of lightweight constructions elements.

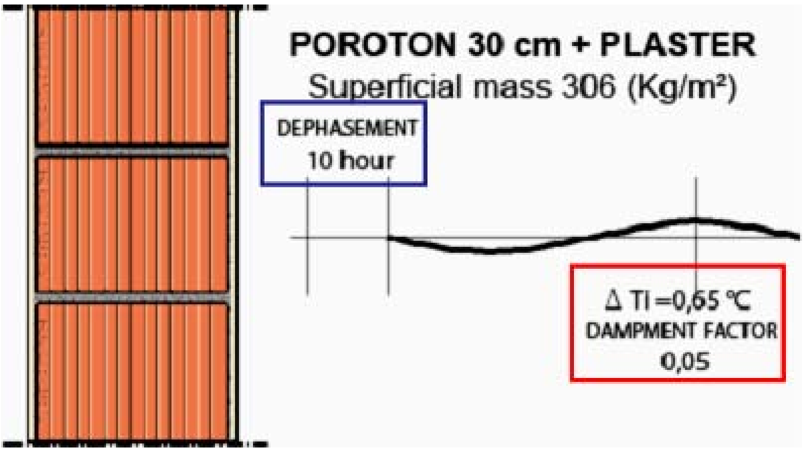
For this reason there are taking in consideration four different kinds of constructive typology from the lightweight, to the massive and the mix ones in relation to the same geometry, location and climate of the house in Fagagna as a basic studio case.

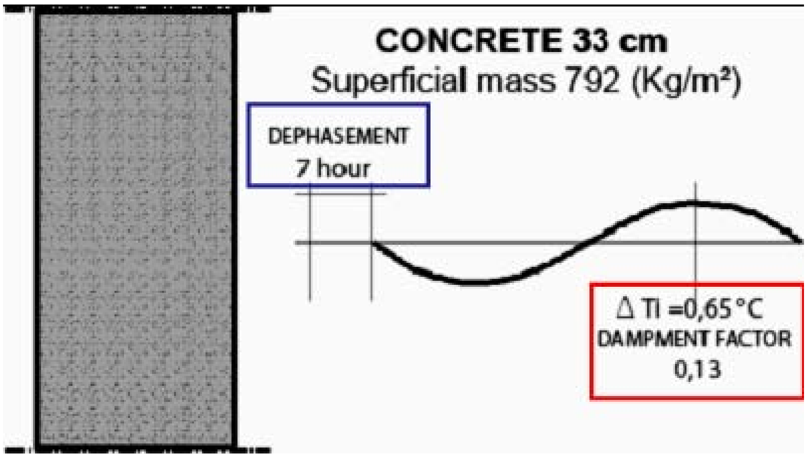
MATERIAL	C [J /kgK]	ρ [kg/m³]	ρ x c [kJ /m³K]
WATER	4190	1000	4190
CONCRETE	900	2400	2160
WOOD	2100	600	1260
FB WOOD	2100	180	380
POLYSTIRENE	1440	30	40

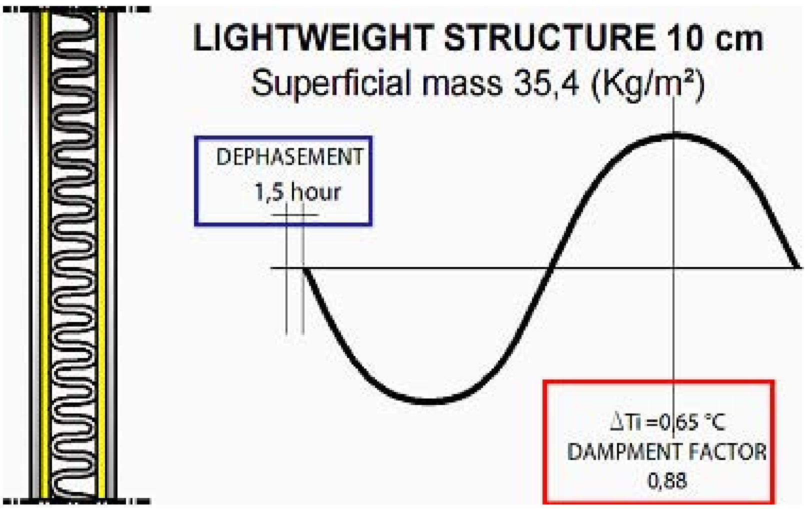
DEPHASEMENT AND DAMPMENT BEHAVIOUR OF MASSIVE STRUCTURES



DEPHASEMENT AND DAMPMENT BEHAVIOUR OF DIFFERENT STRUCTURES







Analysis by Laterificio Pugliese S.p.a – Terlizzi di Bari (Italy)

DEPHASEMENT AND DAMPMENT WALL BEHAVIOUR FOR PASSIVE HOUSE

Thermal mass is the term used to describe materials of high thermal capacitance, for istance materials which can absorb and store large quantities of heat and the materials within a building which have a high thermal capacitance can provide a ‘flywheel’ effect, smoothing out the variation in temperature within the building, and reducing the swing in temperature on a diurnal and potentially longer term basis.

Thermal mass may be in the form of masonry walls, exposed concrete soffits to intermediate floors, or possibly embedded phase change materials and it can be of considerable advantage both in the summer and winter.

In summer it can limits the upper daytime temperature and thereby reduce the need for cooling and this effect can be enhanced by coupling the high capacitance material with night time convection to pre-cool the thermal mass for the following day, otherwise in winter the mass can absorb heat gains which build up during the day, for release into the space at night, thus potentially reduce heating demand.

In this case the analysis point the focus about the characteristics of three different constructive systems to check their dephasement and dampment different behavior.

1A- WOODEN LIGHTWEIGHT STRUCTURES

2,5cm Osb/Gypsum fibre board
30cm Rockwool
2,5cm Osb/Gypsum fibre board

Global superficial inertial mass: *50 kg/m² - 10%*
Indoor heat capacity mass (10cm): *15 kg/m² - 6%*

1B- WOODEN MASSIVE STRUCTURES

10cm X-Lam wood panel
30cm Wooden insulation FB

Superficial inertial mass: *100 kg/m² - 20%*
Indoor heat capacity mass (10cm): *50 kg/m² - 20%*

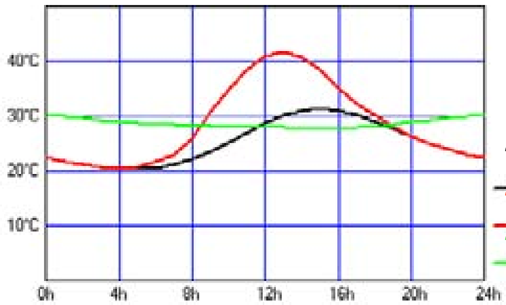
2- MASONRY MASSIVE STRUCTURES

20cm Reinforced concrete
30cm Polystyrene insulation panel

Superficial inertial mass: *500 kg/m² - 100%*
Indoor heat capacity mass (10cm): *250 kg/m² - 100%*

1A- WOODEN LIGHTWEIGHT PASSIVE HOUSE SOUTH SIDE WALL

GENERAL CHARACTERISTICS	
Thickness:	0,350 m
Superficial mass (>200):	61,50 kg/m²
Thermal resistence:	7,908 m²K/W
Global U value (<0,15):	0,126 W/m²K *OK*
DYNAMIC PARAMETER	
Reduction factor *(<0,1)*:	0,658 – 0,341 *KO!*
Dampment hours *(>10)*:	06h 49' *KO!*

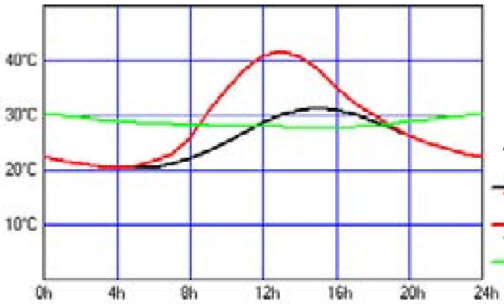


Te air Δ_{max}=10,9°C
Te wall Δ_{max}=21,1°C
Ti wall Δ_{max}=13,9°C - No scheltered
Δ_{min}= 7,2°C - Sheltered

Hour	Te air [°C]	Rad. [W/m²]	Te wall [°C] No shelter vs. Shelter	Ti wall [°C] No shelter vs. Shelter
01	21,8	0	21,83 – 21,83	29,68 – 27,76
02	21,3	0	21,28 – 21,28	28,17 – 26,82
03	20,8	0	20,84 – 20,84	27,06 – 25,88
04	20,5	0	20,51 – 20,51	26,27 – 25,08
05	20,4	11	20,64 – 20,40	25,54 – 24,36
06	20,6	50	21,73 – 20,62	24,96 – 23,78
07	21,2	86	23,08 – 21,17	24,53 – 23,35
08	22,2	177	26,09 – 22,16	24,17 – 22,98
09	23,6	321	30,72 – 23,59	23,81 – 22,62
10	25,2	439	35,00 – 25,24	23,52 – 22,33
11	27,1	515	38,55 – 27,11	23,30 – 22,12
12	28,9	541	40,89 – 28,87	23,39 – 22,04
13	30,2	515	41,63 – 30,19	24,10 – 22,19
14	31,1	439	40,83 – 31,07	24,99 – 22,55
15	31,4	321	38,53 – 31,40	26,97 – 23,20
16	31,1	177	35,00 – 31,07	30,02 – 24,14
17	30,3	86	32,21 – 30,30	32,83 – 25,23
18	29,1	50	30,20 – 29,09	35,18 – 26,46
19	27,7	11	27,90 – 27,66	36,71 – 27,62
20	26,2	0	26,23 – 26,23	37,20 – 28,49
21	25,0	0	25,02 – 25,02	36,67 – 29,07
22	23,9	0	23,92 – 23,92	35,16 – 29,28
23	23,0	0	23,04 – 23,04	32,84 – 29,07
24	22,4	0	22,38 – 22,38	31,00 – 28,56

1B- WOODEN MASSIVE PASSIVE HOUSE SOUTH SIDE WALL

GENERAL CHARACTERISTICS	
Thickness:	0,400 m
Superficial mass (>200):	88,20 kg/m²
Thermal resistence:	8,108 m²K/W
Global U value (<0,15):	0,123 W/m²K OK
DYNAMIC PARAMETER	
Reduction factor *(<0,1):*	0,016 – 0,008 OK
Dampment hours *(>10):*	24h 16' OK

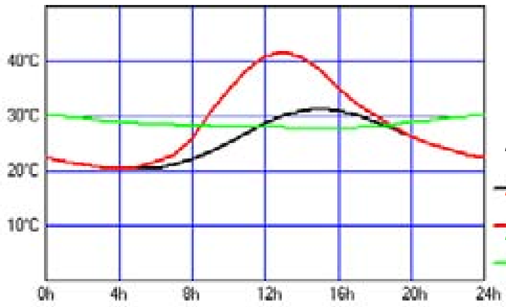


Te air Δ_{max}=10,9°C
Te wall Δ_{max}=21,1°C
Ti wall Δ_{max}=0,4°C - No scheltered
Δ_{min}= 0,2°C - Sheltered

Hour	Te air [°C]	Rad. [W/m²]	Te wall [°C] No shelter vs. Shelter	Ti wall [°C] No shelter vs. Shelter
01	21,8	0	21,83 – 21,83	28,56 – 25,15
02	21,3	0	21,28 – 21,28	28,55 – 25,14
03	20,8	0	20,84 – 20,84	28,54 – 25,13
04	20,5	0	20,51 – 20,51	28,53 – 25,13
05	20,4	11	20,64 – 20,40	28,54 – 25,13
06	20,6	50	21,73 – 20,62	28,55 – 25,13
07	21,2	86	23,08 – 21,17	28,58 – 25,14
08	22,2	177	26,09 – 22,16	28,63 – 25,16
09	23,6	321	30,72 – 23,59	28,70 – 25,18
10	25,2	439	35,00 – 25,24	28,78 – 25,21
11	27,1	515	38,55 – 27,11	28,84 – 25,24
12	28,9	541	40,89 – 28,87	28,87 – 25,27
13	30,2	515	41,63 – 30,19	28,89 – 25,29
14	31,1	439	40,83 – 31,07	28,87 – 25,31
15	31,4	321	38,53 – 31,40	28,84 – 25,31
16	31,1	177	35,00 – 31,07	28,78 – 25,31
17	30,3	86	32,21 – 30,30	28,73 – 25,29
18	29,1	50	30,20 – 29,09	28,70 – 25,27
19	27,7	11	27,90 – 27,66	28,66 – 25,25
20	26,2	0	26,23 – 26,23	28,63 – 25,23
21	25,0	0	25,02 – 25,02	28,61 – 25,20
22	23,9	0	23,92 – 23,92	28,59 – 25,19
23	23,0	0	23,04 – 23,04	28,56 – 25,17
24	22,4	0	22,38 – 22,38	28,55 – 25,16

2- MASONRY MASSIVE PASSIVE HOUSE SOUTH SIDE WALL

GENERAL CHARACTERISTICS	
Thickness:	0,500 m
Superficial mass (>200):	487,50 kg/m²
Thermal resistence:	7,774 m²K/W
Global U value (<0,15):	0,128 W/m²K *OK*
DYNAMIC PARAMETER	
Reduction factor *(<0,1):*	0,107 – 0,058 *OK*
Dampment hours *(>10):*	10h 34' *OK*



Te air *Δmax=10,9°C*
Te wall *Δmax=21,1°C*
Ti wall *Δmax=2,3°C - No scheltered*
Δmin= 1,2°C - Sheltered

Hour	Te air [°C]	Rad. [W/m²]	Te wall [°C] No shelter vs. Shelter	Ti wall [°C] No shelter vs. Shelter
01	21,8	0	21,83 – 21,83	29,97 – 25,83
02	21,3	0	21,28 – 21,28	29,72 – 25,87
03	20,8	0	20,84 – 20,84	29,35 – 25,83
04	20,5	0	20,51 – 20,51	29,05 – 25,75
05	20,4	11	20,64 – 20,40	28,83 – 25,62
06	20,6	50	21,73 – 20,62	28,59 – 25,47
07	21,2	86	23,08 – 21,17	28,40 – 25,32
08	22,2	177	26,09 – 22,16	28,28 – 25,19
09	23,6	321	30,72 – 23,59	28,16 – 25,07
10	25,2	439	35,00 – 25,24	28,07 – 24,98
11	27,1	515	38,55 – 27,11	28,00 – 24,91
12	28,9	541	40,89 – 28,87	27,94 – 24,85
13	30,2	515	41,63 – 30,19	27,88 – 24,79
14	31,1	439	40,83 – 31,07	27,83 – 24,74
15	31,4	321	38,53 – 31,40	27,80 – 24,71
16	31,1	177	35,00 – 31,07	27,81 – 24,70
17	30,3	86	32,21 – 30,30	27,93 – 24,72
18	29,1	50	30,20 – 29,09	28,07 – 24,78
19	27,7	11	27,90 – 27,66	28,39 – 24,88
20	26,2	0	26,23 – 26,23	28,89 – 25,04
21	25,0	0	25,02 – 25,02	29,35 – 25,21
22	23,9	0	23,92 – 23,92	29,73 – 25,41
23	23,0	0	23,04 – 23,04	29,98 – 25,60
24	22,4	0	22,38 – 22,38	30,06 – 25,74

INDOOR WALL TEMPERATURE COMPARISON

1A- WOODEN LIGHTWEIGHT PASSIVE HOUSE SOUTH SIDE WALL

GENERAL CHARACTERISTICS	
Thickness:	0,350 m
Superficial mass (>200):	61,50 kg/m²
Thermal resistence:	7,908 m²K/W
Global U value (<0,15):	0,126 W/m²K *OK*
DYNAMIC PARAMETER	
Reduction factor *(<0,1):*	0,658 – 0,341 *KO!*
Dampment hours *(>10):*	06h 49' *KO!*

Hour	Te air [°C]	Rad. [W/m²]	Te wall [°C] No shelter	Ti wall [°C] No shelter vs. Shelter
04	20,5	0	**20,51**	26,27
05	**20,4**	11	20,64	25,54
11 – 12	27,1	515	38,55	**23,30 – 22,04**
13	30,2	515	**41,63**	24,10
15	**31,4**	321	38,53	26,97
20 – 22	26,2	0	26,23	**37,20 – 29,28**

Δmax=10,9°C ***Δmax=21,1°C*** ***ΔTi= 13,9 – 7,2°C***

Average= 30,2 – 25,6°C

1B- WOODEN MASSIVE PASSIVE HOUSE SOUTH SIDE WALL

GENERAL CHARACTERISTICS	
Thickness:	0,400 m
Superficial mass (>200):	88,20 kg/m²
Thermal resistence:	8,108 m²K/W
Global U value (<0,15):	0,123 W/m²K *OK*
DYNAMIC PARAMETER	
Reduction factor *(<0,1):*	0,016 – 0,008 *OK*
Dampment hours *(>10):*	24h 16' *OK*

Hour	Te air [°C]	Rad. [W/m²]	Te wall [°C] No shelter	Ti wall [°C] No shelter vs. Shelter
04 – 05	20,5	0	**20,51**	**28,53 – 25,13**
05	**20,4**	11	20,64	28,54
13 – 15	30,2	515	**41,63**	**28,89 – 25,31**
15	**31,4**	321	38,53	28,84

Δmax=10,9°C ***Δmax=21,1°C*** ***ΔTi= 0,4 – 0,2°C***

Average= 28,7 – 25,2°C

2- MASONRY MASSIVE PASSIVE HOUSE SOUTH SIDE WALL

GENERAL CHARACTERISTICS	
Thickness:	0,500 m
Superficial mass (>200):	487,50 kg/m²
Thermal resistence:	7,774 m²K/W
Global U value (<0,15):	0,128 W/m²K *OK*
DYNAMIC PARAMETER	
Reduction factor *(<0,1):*	0,107 – 0,058 *OK*
Dampment hours *(>10):*	10h 34' *OK*

Hour	Te air [°C]	Rad. [W/m²]	Te wall [°C] No shelter	Ti wall [°C] No shelter vs. Shelter
04	20,5	0	**20,51**	29,05
05	**20,4**	11	20,64	28,83
13	30,2	515	**41,63**	27,88
15 – 16	**31,4**	321	38,53	**27,80 – 24,70**
24 – 02	22,4	0	22,38	**30,06 – 25,87**

∆max=10,9°C ***∆max=21,1°C*** ***∆Ti= 2,3 – 1,2°C***
Average= 28,9 – 25,3°C

As it has been previously describe, the thermal mass effect is suitable to avoid the indoor overheating due to the high temperature of the interior surface as the walls that have a good performance in the case of daily costant superficial temperature.

In this analysis is clear the fact that the best performance is related to the wooden massive structure compound of 10cm cross-lam wood panel protected by 30cm of wooden insulation fibre board with a swing temperature of 0,2-0,4°C.

This performance is also better than the masonry massive one, characterized by a swing value of 1,2-2,3°C, that is close to the limit for a good comfort calculated in a daily temperature difference of 2-3°C.

Instead from this point of view the performance of the lightweight structure is disastrous, characterized by a swing value of 7,2-13,9°C and this effect can create a bad indoor comfort sensation to the habitants mainly in the late afternoon and in the evening.

So it's appear so important remark the fact that is important to consider the daily temperature swing and not only the average one that in this case is almost the same for the three structures especially in the sheltered situation.

1A- WOODEN LIGHTWEIGHT:	***∆Ti= 7,2 – 13,9°C***	***Average= 30,2 – 25,6°C***
1B- WOODEN MASSIVE:	***∆Ti= 0,2 – 0,4°C***	***Average= 28,7 – 25,2°C***
2- MANSORY MASSIVE:	***∆Ti= 1,2 – 2,3°C***	***Average= 28,9 – 25,3°C***

INDOOR SUMMER CLIMATE COMPARISON FOR DIFFERENTS STRUCTURES

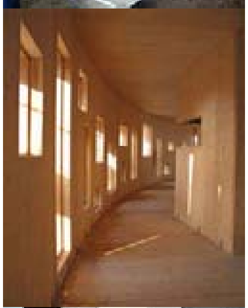
As it has been previously analyzed and remarked, the influence of the mass is really important in the case of warm Summer condition to avoid a high swing of the indoor operative temperature, calculated as the average of the air and the surface's elements one.

In base to this considerations the research topic is that to compare the different performance of this three analyzed construction typology and than focus the attention to a new fourth one characterized by a wooden massive external structure combined with a internal masonry massive core useful to storage the overheating energy.

1A- WOODEN LIGHTWEIGHT STRUCTURES

2,5cm Osb/Gypsum fibre board
30cm (Passive) / 15cm (Class B) Rockwool
2,5cm Osb/Gypsum fibre board

Normal storage heat capacity: ***60 Wh/(m^3/K)***



1B- WOODEN MASSIVE STRUCTURES

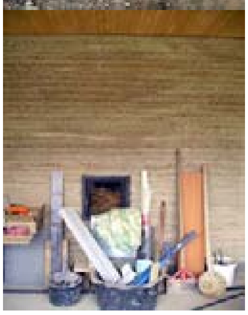
10cm Cross-Lam wood panel
30cm (Passive) – 12 cm (Class B) Wooden insulation FB

Normal storage heat capacity: ***90 Wh/(m^3/K)***

2- MASONRY MASSIVE STRUCTURES

20cm Reinforced concrete
30cm (Passive) – 15 cm (Class B) Polystyrene panel

Normal storage heat capacity: ***204 Wh/(m^3/K)***

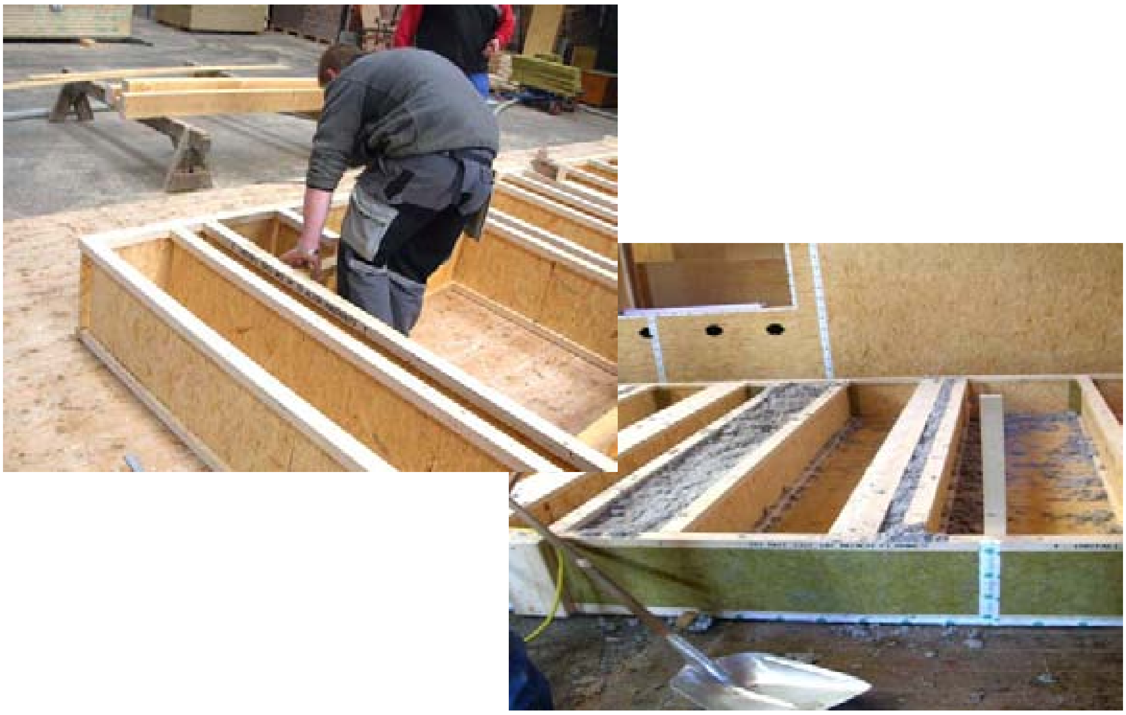


3- MIXED WOODEN EXTERNAL WALLS MASONRY INNER CORE STRUCTURES

10cm Cross-Lam wood panel
30cm (Passive) – 12 cm (Class B) Wooden insulation FB
20cm Reinforced concrete inner wall

Normal storage heat capacity: ***132 Wh/(m^3/K)***

1A- WOODEN LIGHTWEIGHT STRUCTURES



Wooden frame construction system – Weissenser Holz-System-Bau GmbH, Oberdorf (Austria)

1B- WOODEN MASSIVE STRUCTURES

Headquarters of Banca Etica, Padova (Italy) –R. Pantaleo-TAM Associati, F. Steffinlongo-4AD (Italy)

2- MASONRY/CONCRETE MASSIVE STRUCTURES

Private passive house in San Daniele del Friuli (Italy) – eng. Sergio Fistarol, Udine (Italy)

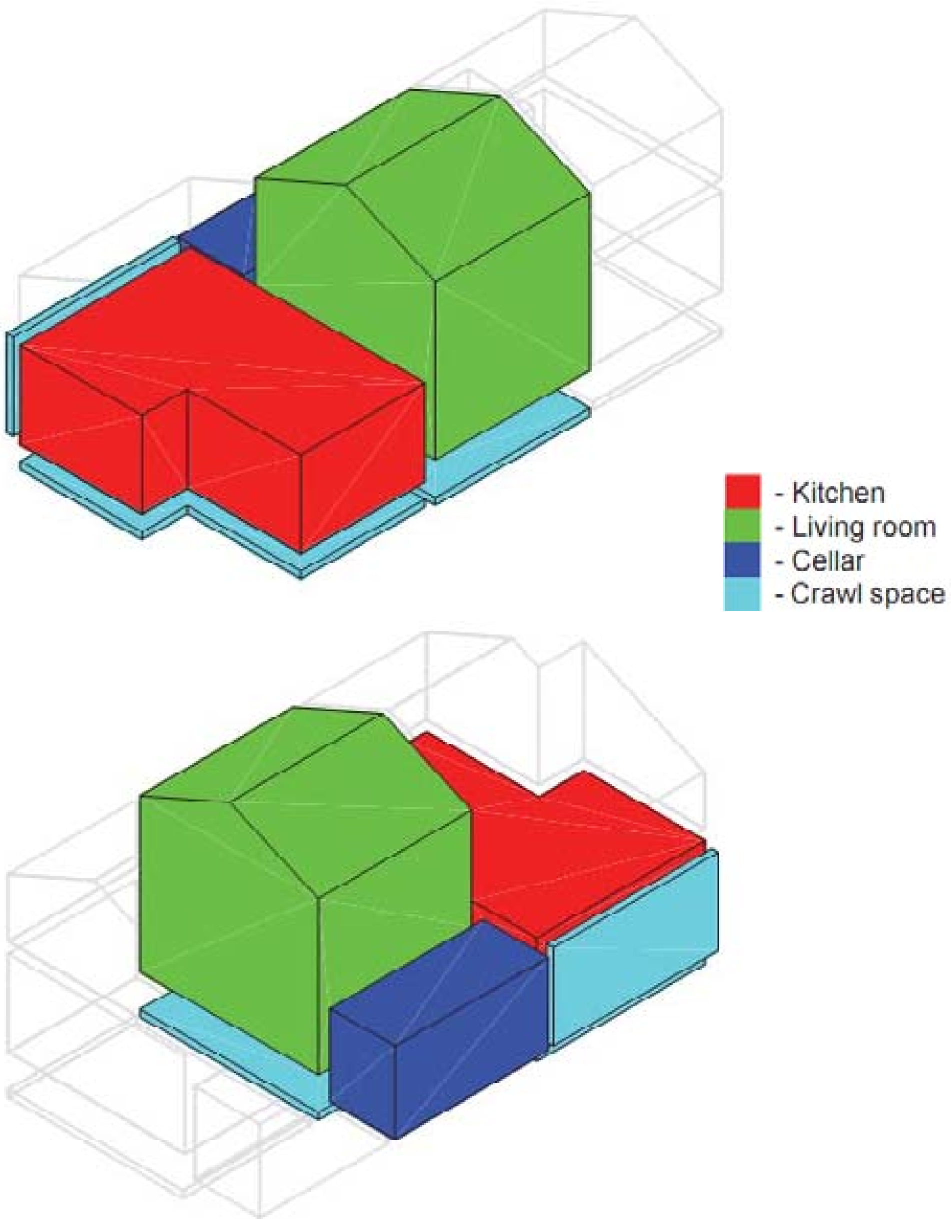
3- MIXED WOODEN WALLS + MASONRY CORE STRUCTURES

Ecological wooden house, Vorarlberg (Austria) – Christian Walch GbmH, Ludesh (Austria)

DYNAMIC ANALYSIS OF THE STUDIO CASE HOUSE

To analyze the indoor temperature of the entire house in relation to the four different constructive systems, there are choose the two more important and stressed rooms: the kitchen in South West position and the double high space of the living room in an inner position with a big window toward South.

The first serial of dynamic analysis are referred to investigate the maximum and minimum temperature and their daily swing gap of the two separated rooms, in relation of a different insulation level from a passive house to a simple one.



arch. Andrea Boz and Dl. Michaela Gruber Dynamic analysis with GEBA –TUW Vienna

COMPARISON INDOOR BEHAVIOUR FOR DIFFERENT STRUCTURES

1A- WOODEN LIGHTWEIGHT STRUCTURES

2,5cm Osb/Gypsum fiber board + 30/15 cm Rockwool + 2,5cm Osb/Gypsum fiber board

LOCATION	KITCHEN ROOM						LIVING ROOM					
COMBINATION	NO GLASS SHELTERED			GLASS SHELTERED			NO GLASS SHELTERED			GLASS SHELTERED		
WALL STRUCTURES	Aver. °C	Min. °C	Max. °C	Aver. °C	Min. °C	Max. °C	Aver. °C	Min. °C	Max. °C	Aver. °C	Min. °C	Max. °C
A- PASSIVE HOUSE	31,5	28,7	**34,9**	27,1	25,5	28,3	31,8	28,1	**36,3**	27,2	25,1	**29,1**
B- CLASS B HOUSE	31,3	28,6	34,4	26,9	25,4	28,1	31,3	27,7	35,6	27,1	24,9	28,9
C- NO INSULAT. HOUSE	30,9	**27,7**	34,7	26,8	**24,8**	**28,4**	31,0	**26,9**	36,0	26,9	**24,5**	**29,1**
AVERAGE Ti	*31,2*	*28,3*	*34,7*	*26,9*	*25,2*	*28,3*	*31,3*	*27,5*	*35,9*	*27,0*	*24,8*	*29,0*
A- Min/Max GAP DT:	*6,2*			*2,8*			*8,2*			*4,0*		
B- Min/Max GAP DT:	*5,8*			*2,7*			*7,9*			*4,0*		
C- Min/Max GAP DT:	***7,0***			***3,6***			***9,1***			***4,6***		

- *No glass sheltered solution:* **Tmax.= 36,3°C – ΔTmax.= 9,1°C**
- *Glass sheltered solution:* **Tmax.= 29,1°C – ΔTmax.= 4,6°C**

1B- WOODEN MASSIVE STRUCTURES

10cm X-Lam wood panel + 30cm (Passive) – 12 cm (ClassB) Wooden insulation FB

LOCATION	KITCHEN ROOM						LIVING ROOM					
COMBINATION	NO GLASS SHELTERED			GLASS SHELTERED			NO GLASS SHELTERED			GLASS SHELTERED		
WALL STRUCTURES	Aver. °C	Min. °C	Max. °C	Aver. °C	Min. °C	Max. °C	Aver. °C	Min. °C	Max. °C	Aver. °C	Min. °C	Max. °C
A- PASSIVE HOUSE	31,7	29,1	**35,0**	27,1	25,6	**28,3**	31,9	29,1	**35,4**	27,3	25,5	**28,8**
B- CLASS B HOUSE	31,2	28,6	34,4	26,9	25,4	28,0	31,3	28,5	34,7	27,1	25,3	28,5
C- NO INSULAT. HOUSE	29,0	**26,6**	31,8	26,3	**24,7**	27,5	29,6	**26,9**	32,8	26,3	**24,6**	27,6
AVERAGE Ti	*30,6*	*28,1*	*33,7*	*26,8*	*25,2*	*27,9*	*30,9*	*28,2*	*34,3*	*26,9*	*25,1*	*28,3*
A- Min/Max GAP DT:	***5,9***			*2,7*			***6,3***			***3,3***		
B- Min/Max GAP DT:	*5,8*			*2,6*			*6,2*			*3,2*		
C- Min/Max GAP DT:	*5,2*			***2,8***			*5,9*			*3,0*		

- *No glass sheltered solution:* **Tmax.= 35,4°C – ΔTmax.= 6,3°C**
- *Glass sheltered solution:* **Tmax.= 28,8°C – ΔTmax.= 3,3°C**

Dynamic analysis results by software GEBA – Prof. Dr. Klaus Kreck TUWien

COMPARISON INDOOR BEHAVIOUR FOR DIFFERENT STRUCTURES

2- MASONRY MASSIVE STRUCTURES

20cm Reinforced concrete + 30cm (Passive) – 15 cm (Class B) Polystyrene panel

LOCATION	***KITCHEN ROOM***						***LIVING ROOM***					
COMBINATION	*NO GLASS SHELTERED*			*GLASS SHELTERED*			*NO GLASS SHELTERED*			*GLASS SHELTERED*		
WALL STRUCTURES	Aver. °C	Min. °C	Max. °C	Aver. °C	Min. °C	Max. °C	Aver. °C	Min. °C	Max. °C	Aver. °C	Min. °C	Max. °C
A- PASSIVE HOUSE	31,8	30,2	***33,7***	27,1	26,1	***27,9***	31,9	30,1	***33,7***	27,3	26,3	***28,2***
B- CLASS B HOUSE	31,8	30,2	***33,7***	27,0	26,0	27,7	31,4	29,8	33,3	27,1	26,1	28,1
C- NO INSULAT. HOUSE	27,0	**25,0**	29,2	26,3	**24,9**	27,4	27,2	**25,6**	29,0	25,3	**24,1**	26,2
AVERAGE Ti	*30,2*	*28,5*	*32,2*	*26,8*	*25,7*	*27,7*	*30,2*	*28,5*	*32,0*	*26,6*	*25,5*	*27,5*
A- Min/Max GAP DT:		*3,5*			*1,8*			***3,6***			*1,9*	
B- Min/Max GAP DT:		*3,5*			*1,7*			*3,5*			*2,0*	
C- Min/Max GAP DT:		***4,2***			***2,5***			*3,4*			***2,1***	

- *No glass sheltered solution:* **Tmax.= 33,7°C – ΔTmax.= 4,2°C**
- *Glass sheltered solution:* **Tmax.= 28,2°C – ΔTmax.= 2,5°C**

3- MIXED WOODEN WALLS + MASONRY CORE STRUCTURES

10cm X-Lam wood panel + 30cm (Passive) – 12 cm (ClassB) Wooden insulation FB + 20cm Concrete

LOCATION	***KITCHEN ROOM***						***LIVING ROOM***					
COMBINATION	*NO GLASS SHELTERED*			*GLASS SHELTERED*			*NO GLASS SHELTERED*			*GLASS SHELTERED*		
WALL STRUCTURES	Aver. °C	Min. °C	Max. °C	Aver. °C	Min. °C	Max. °C	Aver. °C	Min. °C	Max. °C	Aver. °C	Min. °C	Max. °C
A- PASSIVE HOUSE	31,7	29,5	***34,4***	27,0	25,7	28,0	31,8	30,3	***33,9***	27,2	26,2	***28,1***
B- CLASS B HOUSE	31,2	29,0	33,9	27,0	25,7	***28,1***	31,3	29,6	33,0	27,1	25,9	28,0
C- NO INSULAT. HOUSE	29,1	**26,9**	31,5	25,7	**24,2**	27,3	29,7	**27,8**	31,9	26,3	**25,1**	27,2
AVERAGE Ti	*30,7*	*28,5*	*33,3*	*26,6*	*25,2*	*27,8*	*30,9*	*29,2*	*32,9*	*26,9*	*25,7*	*27,8*
A- Min/Max GAP DT:		*4,9*			*2,3*			*3,6*			*1,9*	
B- Min/Max GAP DT:		***4,9***			*2,4*			*3,4*			*2,1*	
C- Min/Max GAP DT:		*4,6*			***3,1***			***4,1***			***2,1***	

- *No glass sheltered solution:* **Tmax.= 35,4°C – ΔTmax.= 4,9°C**
- *Glass sheltered solution:* **Tmax.= 28,8°C – ΔTmax.= 3,1°C**

Dynamic analysis results by software GEBA – Prof. Dr. Klaus Kreck TUWien

COMPARISON INDOOR BEHAVIOUR RELATED TO THE INSULATION

A- PASSIVE HOUSE (EI<15 Kwh/m²year) - INDOOR CLIMATE CONDITIONS

LOCATION	***KITCHEN ROOM***						***LIVING ROOM***					
COMBINATION	*NO GLASS SHELTERED*			*GLASS SHELTERED*			*NO GLASS SHELTERED*			*GLASS SHELTERED*		
WALL STRUCTURES	Aver. °C	Min. °C	Max. °C	Aver. °C	Min. °C	Max. °C	Aver. °C	Min. °C	Max. °C	Aver. °C	Min. °C	Max. °C
1A- WOODEN LIHGTWEIGHT	31,5	**28,7**	34,9	27,1	**25,5**	28,3	31,8	**28,1**	**36,3**	27,2	**25,1**	**29,1**
1B- WOODEN MASSIVE	31,7	29,1	**35,0**	27,1	25,6	**28,3**	31,9	29,1	35,4	27,3	25,5	28,8
2- MASONRY MASSIVE	31,8	30,2	33,7	27,1	26,1	27,9	31,9	30,1	33,7	27,3	26,3	28,2
3- MIX WOODEN-MASONRY	31,7	29,5	34,4	27,0	25,7	28,0	31,8	30,3	33,9	27,2	26,2	28,1
AVERAGES Ti	***31,7***	***29,4***	***34,5***	***27,1***	***25,7***	***28,1***	***31,9***	***29,4***	***34,8***	***27,3***	***25,8***	***28,6***
ΔT MAX.:	***0,3***	***1,5***	***1,3***	***0,1***	***0,6***	***0,4***	***0,1***	***2,2***	***2,4***	***0,1***	***1,2***	***1,0***
AVER. GAP ΔT:		***4,8***			***2,3***			***5,9***			***2,9***	
MAX. GAP ΔT:		***6,2***			***2,8***			***8,2***			***4,0***	
MIN. GAP ΔT:		***3,5***			***1,8***			***3,6***			***1,9***	
3- MIX W-M ΔT:		***4,5***			***2,3***			***3,6***			***1,9***	

B- CLASS B HOUSE (EI<50Kwh/m²year) - INDOOR CLIMATE CONDITIONS

LOCATION	***KITCHEN ROOM***						***LIVING ROOM***					
COMBINATION	*NO GLASS SHELTERED*			*GLASS SHELTERED*			*NO GLASS SHELTERED*			*GLASS SHELTERED*		
WALL STRUCTURES	Aver. °C	Min. °C	Max. °C	Aver. °C	Min. °C	Max. °C	Aver. °C	Min. °C	Max. °C	Aver. °C	Min. °C	Max. °C
1A- WOODEN LIHGTWEIGHT	31,3	**28,6**	**34,4**	26,9	**25,4**	**28,1**	31,3	**27,7**	**35,6**	27,1	**24,9**	**28,9**
1B- WOODEN MASSIVE	31,2	**28,6**	**34,4**	26,9	**25,4**	28,0	31,3	28,5	34,7	27,1	25,3	28,5
2- MASONRY MASSIVE	31,8	30,2	33,7	27,0	26,0	27,7	31,4	29,8	33,3	27,1	26,1	28,1
3- MIX WOODEN-MASONRY	31,2	29,0	33,9	27,0	25,7	28,1	31,3	29,6	33,0	27,1	25,9	28,0
AVERAGES Ti	***31,4***	***29,1***	***34,1***	***27,0***	***25,6***	***28,0***	***31,3***	***28,9***	***34,2***	***27,1***	***25,6***	***28,4***
ΔT MAX.:	***0,6***	***1,6***	***1,8***	***0,1***	***0,6***	***0,4***	***0,1***	***2,1***	***2,6***	***0***	***1,2***	***0,9***
AVER. GAP ΔT:		***5,0***			***2,4***			***5,3***			***2,8***	
MAX. GAP ΔT:		***5,8***			***2,7***			***7,9***			***4,0***	
MIN. GAP ΔT:		***3,5***			***1,7***			***3,4***			***2,0***	
3- MIX W-M ΔT:		***4,9***			***2,4***			***3,4***			***2,1***	

Dynamic analysis results by software GEBA – Prof. Dr. Klaus Kreck TUWien

C- NO INSULATED HOUSE (EI>250 Kwh/m²year) - INDOOR CLIMATE CONDITIONS

LOCATION	***KITCHEN ROOM***						***LIVING ROOM***					
COMBINATION	*NO GLASS SHELTERED*			*GLASS SHELTERED*			*NO GLASS SHELTERED*			*GLASS SHELTERED*		
WALL STRUCTURES	Aver. °C	Min. °C	Max. °C	Aver. °C	Min. °C	Max. °C	Aver. °C	Min. °C	Max. °C	Aver. °C	Min. °C	Max. °C
1A- WOODEN LIHGTWEIGHT	30,9	27,7	***34,7***	26,8	24,8	***28,4***	31,0	26,9	***36,0***	26,9	24,5	***29,1***
1B- WOODEN MASSIVE	29,0	26,6	31,8	26,3	24,7	27,5	29,6	26,9	32,8	26,3	24,6	27,6
2- MASONRY MASSIVE	27,1	***25,0***	29,2	26,3	24,9	27,4	27,2	***25,6***	29,0	25,3	***24,1***	26,2
3- MIX WOODEN-MASONRY	29,1	26,9	31,5	25,7	***24,2***	27,3	29,7	27,8	31,9	26,3	25,1	27,2
AVERAGES Ti	***29,0***	***26,6***	***31,8***	***26,3***	***24,7***	***27,7***	***29,4***	***26,8***	***32,4***	***26,2***	***24,6***	***27,5***
ΔT MAX.:	***3,9***	***2,7***	***5,4***	***1,1***	***0,7***	***1,1***	***3,8***	***2,2***	***7,0***	***1,6***	***1,0***	***2,9***
AVER. GAP ΔT:		***5,2***			***3,0***			***5,6***			***2,9***	
MAX. GAP ΔT:		***7,0***			***3,6***			***9,1***			***4,6***	
MIN. GAP ΔT:		***4,2***			***2,5***			***3,4***			***1,9***	
3- MIX W-M ΔT:		***4,6***			***3,1***			***4,1***			***2,1***	

A- PASSIVE HOUSE (EI<15 Kwh/m²year)

- *No glass sheltered solution:* **Tmax.= 36,3°C – ΔTmax.= 8,2°C**

  Mix structures: **Tmax.= 34,4°C – ΔTmax.= 4,5°C**

- *Glass sheltered solution:* **Tmax.= 29,1°C – ΔTmax.= 4,0°C**

  Mix structures: **Tmax.= 28,1°C – ΔTmax.= 2,3°C**

B- CLASS B HOUSE (EI<50Kwh/m²year)

- *No glass sheltered solution:* **Tmax.= 35,6°C – ΔTmax.= 7,9°C**

  Mix structures: **Tmax.= 33,9°C – ΔTmax.= 4,9°C**

- *Glass sheltered solution:* **Tmax.= 29,1°C – ΔTmax.= 4,0°C**

  Mix structures: **Tmax.= 28,1°C – ΔTmax.= 2,4°C**

C- NO INSULATED HOUSE (EI>250 Kwh/m²year)

- *No glass sheltered solution:* **Tmax.= 36,0°C – ΔTmax.= 9,1°C**

  Mix structures: **Tmax.= 31,9°C – ΔTmax.= 4,6°C**

- *Glass sheltered solution:* **Tmax.= 29,1°C – ΔTmax.= 4,6°C**

  Mix structures: **Tmax.= 27,3°C – ΔTmax.= 3,1°C**

Dynamic analysis results by software GEBA – Prof. Dr. Klaus Kreck TUWien

FIRST PARTIAL RESULTS CONSIDERATIONS

The first serials of dynamic analysis about the entire room allow to confirm the results studied in relation to simple constructive elements, and the main conclusion are firstly that the glass areas has to be appropriately sheltered to have a lower indoor temperature and in the second place that there should be some massive elements able to stabilize and in the same time to limit the indoor temperature.

A- PASSIVE HOUSE (EI<15 Kwh/m²year)

- *Lightweight - No sheltered Vs. sheltered:* **Tmax.= 36,3°C – Tmax.= 29,1°C**
  ΔTmax.= 8,2°C – ΔTmax.= 4,0°C
- *Masonry - No sheltered Vs. sheltered:* **Tmax.= 33,7°C – Tmax.= 28,2°C**
  ΔTmax.= 3,6°C – ΔTmax.= 1,9°C
- *Mix structure - No sheltered Vs. sheltered:* **Tmax.= 34,4°C – Tmax.= 28,1°C**
  ΔTmax.= 4,5°C – ΔTmax.= 2,3°C

B- *CLASS B HOUSE (EI<50Kwh/m²year)*

- *Lightweight - No sheltered Vs. sheltered:* **Tmax.= 35,6°C – Tmax.= 29,1°C**
  ΔTmax.= 7,9°C – ΔTmax.= 4,0°C
- *Masonry - No sheltered Vs. sheltered:* **Tmax.= 33,7°C – Tmax.= 28,1°C**
  ΔTmax.= 3,5°C – ΔTmax.= 2,0°C
- *Mix structure - No sheltered Vs. sheltered:* **Tmax.= 33,9°C – Tmax.= 28,1°C**
  ΔTmax.= 4,9°C – ΔTmax.= 2,4°C

C- *NO INSULATED HOUSE (EI>250 Kwh/m²year)*

- *Lightweight - No sheltered Vs. sheltered:* **Tmax.= 36,0°C – Tmax.= 29,1°C**
  ΔTmax.= 9,1°C – ΔTmax.= 4,6°C
- *Masonry - No sheltered Vs. sheltered:* **Tmax.= 29,2°C – Tmax.= 27,4°C**
  ΔTmax.= 4,2°C – ΔTmax.= 2,5°C
- *Mix structure - No sheltered Vs. sheltered:* **Tmax.= 31,9°C – Tmax.= 27,3°C**
  ΔTmax.= 4,5°C – ΔTmax.= 3,1°C

In consideration of these results it seems obviously the fact that is necessary shelter the glass surface and than have at least an minimum of external insulation and an indoor mass to storage the overheating energy and in this case is enough for a wooden cross-lam construction have one inner concrete wall of 500x300x20cm to reach almost an equal performance respect an entire masonry construction.

INDOOR CLIMATE BEHAVIOUR FOR DIFFERENT LEVELS

Until now the analysis are done taking in consideration the two separated rooms, but in the reality there is a medium indoor climate due the fact these spaces are directly connected and so the final temperature is the average of both the volumes.

From an other point of view the real use of the house can have some differences in relation to the owners' habits and these elements can have a big influence in the calculation of the real ventilation that could flow through the house.

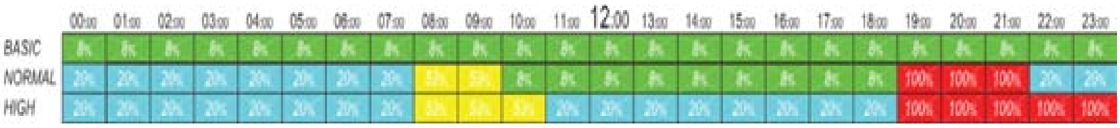
Finally an other important characteristic to valuate the overheating problems is related to the fact that the single one or two stories house can benefit of the direct contact with the ground, using this high mass to minimize the Summer climate problems.

So it make more sense to investigate also the behaviour of upper level with the same construction characteristics of the studio case ones, but loosing the beneficial contact with ground and cellar, and in all of the case the analysis has to be done for different use of the house, divided in this three mainly situation:

A. *BASIC* – Holidays time: only the basic air flow + all close windows

B. *NORMAL* – Working days: medium air flow + medium opening windows

C. *HIGH* – Weekends: medium air flow + medium opening windows



I - COMPARISON INDOOR CLIMATE BEHAVIOUR GROUND LEVEL

COMBINATION		***BASIC AIR FLOW***			***NORMAL AIR FLOW***			***HIGH AIR FLOW***		
WALL STRUCTURES		Aver.°C	Min.°C	Max.°C	Aver.°C	Min.°C	Max.°C	Aver.°C	Min.°C	Max.°C
1A-	**WOODEN LIHGTWEIGHT**	29,9	***28,8***	***30,9***	27,1	***25,8***	***28,4***	26,7	***25,4***	***28,0***
1B-	**WOODEN MASSIVE**	29,9	28,9	***30,9***	27,1	25,9	***28,4***	26,7	25,5	***28,0***
2-	**MASONRY MASSIVE**	29,8	29,4	30,3	27,3	26,7	27,9	26,8	26,4	27,4
3-	**MIX WOODEN-MASONRY**	29,7	***28,8***	30,5	27,2	26,1	28,2	26,7	25,6	27,7
AVERAGES Ti:		***29,8***	***29,0***	***30,7***	***27,2***	***26,1***	***28,2***	***26,7***	***25,7***	***27,8***
1A-	***Min/Max GAP ΔT:***	29,9	***2,1***		27,1	***2,6***		26,7	***2,6***	
1B-	***Min/Max GAP ΔT:***	29,9	***2,0***		27,1	***2,5***		26,7	***2,5***	
2-	***Min/Max GAP ΔT:***	29,8	***0,9***		27,3	***1,2***		26,8	***1,0***	
3-	***Min/Max GAP ΔT:***	29,7	***1,7***		27,2	***2,1***		26,7	***2,1***	

Dynamic analysis results by software GEBA – Prof. Dr. Klaus Kreck TUWien

II - COMPARISON INDOOR CLIMATE BEHAVIOUR MEDIUM LEVEL

COMBINATION	*BASIC AIR FLOW*			*NORMAL AIR FLOW*			*HIGH AIR FLOW*		
WALL STRUCTURES	Aver.°C	Min.°C	Max.°C	Aver.°C	Min.°C	Max.°C	Aver.°C	Min.°C	Max.°C
1A- WOODEN LIHGTWEIGHT	31,0	**29,6**	**32,4**	27,5	**25,7**	**29,3**	26,9	**25,2**	**28,7**
1B- WOODEN MASSIVE	31,0	30,0	31,9	27,6	26,4	28,8	27,1	25,9	28,2
2- MASONRY MASSIVE	30,9	30,5	31,3	27,8	27,2	28,3	27,1	26,6	27,6
3- MIX WOODEN-MASONRY	31,0	30,1	31,8	27,8	26,7	28,7	27,1	26,1	28,1
AVERAGES Ti:	***31,0***	***30,1***	***31,9***	***27,7***	***26,5***	***28,8***	***27,1***	***26,0***	***28,2***
1A- *Min/Max GAP ΔT:*	31,0	***2,8***		27,5	***3,6***		26,9	***3,5***	
1B- *Min/Max GAP ΔT:*	31,0	***1,9***		27,6	***2,4***		27,1	***2,3***	
2- *Min/Max GAP ΔT:*	30,9	***0,8***		27,8	***1,1***		27,1	***1,0***	
3- *Min/Max GAP ΔT:*	31,0	***1,7***		27,8	***2,0***		27,1	***2,0***	

III - COMPARISON INDOOR CLIMATE BEHAVIOUR ROOF LEVEL

COMBINATION	*BASIC AIR FLOW*			*NORMAL AIR FLOW*			*HIGH AIR FLOW*		
WALL STRUCTURES	Aver.°C	Min.°C	Max.°C	Aver.°C	Min.°C	Max.°C	Aver.°C	Min.°C	Max.°C
1A- WOODEN LIHGTWEIGHT	31,1	**30,0**	**32,2**	28,0	**26,6**	29,3	27,3	**25,9**	28,7
1B- WOODEN MASSIVE	31,1	**30,0**	32,1	28,1	26,8	**29,4**	27,4	26,2	**28,8**
2- MASONRY MASSIVE	31,0	30,7	31,4	28,1	27,6	28,6	27,4	26,9	27,9
3- MIX WOODEN-MASONRY	31,1	30,2	32,0	28,1	27,0	29,2	27,4	26,3	28,5
AVERAGES Ti:	***31,1***	***30,2***	***31,9***	***28,1***	***27,0***	***29,1***	***27,4***	***26,3***	***28,5***
1A- *Min/Max GAP ΔT:*	31,1	***2,2***		28,0	***2,7***		27,3	***2,8***	
1B- *Min/Max GAP ΔT:*	31,1	***2,1***		28,1	***2,6***		27,4	***2,6***	
2- *Min/Max GAP ΔT:*	31,0	***0,7***		28,1	***1,0***		27,4	***1,0***	
3- *Min/Max GAP ΔT:*	31,1	***1,8***		28,1	***2,2***		27,4	***2,2***	

Also this analysis confirms that the performances of the masonry and the mix wooden walls – mass core structure are extremely better in the sense of limit the daily temperature swing, but in the same time it appears clear the fact that the rooms not ground connected are characterized by higher temperatures, losing the suitable benefit due to the influence of the hearth mass connection.

COMPARISON OF TEMPERATURE GAP BETWEEN DIFFERENT LEVELS

COMBINATION	BASIC AIR FLOW		NORMAL AIR FLOW		HIGH AIR FLOW		Average GAP
GROUND LEVEL	Aver.°C	ΔT °C	Aver.°C	ΔT °C	Aver.°C	ΔT °C	ΔT °C
1A-Min/Max GAP ΔT:	29,9	2,1	27,1	2,6	26,7	2,6	2,4
1B-Min/Max GAP ΔT:	29,9	2,0	27,1	2,5	26,7	2,5	2,3
2-Min/Max GAP ΔT:	29,8	0,9	27,3	1,2	26,8	1,0	1,0
3-Min/Max GAP ΔT:	29,7	1,7	27,2	2,1	26,7	2,1	1,9
MEDIUM LEVEL	Aver.°C	ΔT °C	Aver.°C	ΔT °C	Aver.°C	ΔT °C	ΔT °C
1A-Min/Max GAP ΔT:	31,0	2,8	27,5	3,6	26,9	3,5	3,3
1B-Min/Max GAP ΔT:	31,0	1,9	27,6	2,4	27,1	2,3	2,2
2-Min/Max GAP ΔT:	30,9	0,8	27,8	1,1	27,1	1,0	1,0
3-Min/Max GAP ΔT:	31,0	1,7	27,8	2,0	27,1	2,0	1,9
ROOF LEVEL	Aver.°C	ΔT °C	Aver.°C	ΔT °C	Aver.°C	ΔT °C	ΔT °C
1A-Min/Max GAP ΔT:	31,1	2,2	28,0	2,7	27,3	2,5	2,5
1B-Min/Max GAP ΔT:	31,1	2,1	28,1	2,6	27,4	2,4	2,4
2-Min/Max GAP ΔT:	31,0	0,7	28,1	1,0	27,4	0,9	0,9
3-Min/Max GAP ΔT:	31,1	1,8	28,1	2,2	27,4	2,0	2,0

CLIMATE BEHAVIOUR FOR "ADOBE" TYPOLOGY WALL STRUCTURES

To complete the serial of thermal mass influence and comfort benefit analysis, it has been investigate the indoor climate behaviour of a serial of different combination of construction systems based on clay or "adobe" building typology.

2- MASONRY MASSIVE STRUCTURES + MASONRY INNER CORE 20 cm
20cm Reinforced concrete + 30cm Polystyrene panel

3- MIXED WOODEN WALLS + MASONRY INNER CORE 20 cm
10cm Cross-Lam wood panel + 30cm Wooden insulation FB

4- MASONRY EXTERNAL STRUCTURES + INNER ADOBE WALL 15 cm
20cm Reinforced concrete + 30cm Polystyrene panel

5- MIXED WOODEN EXTERNAL WALLS + INNER ADOBE WALL 15 cm
10cm X-Lam wood panel + 30cm Wooden insulation FB

6- ADOBE EXTERNAL WALLS + MASONRY INNER CORE 20 cm
15 cm Adobe wall + 30cm Wooden insulation FB

7- ADOBE EXTERNAL WALLS + INNER ADOBE WALL 15 cm
15 cm Adobe wall + 30cm Wooden insulation FB

INDOOR CLIMATE BEHAVIOUR FOR MASSIVE TYPOLOGY STRUCTURES

COMBINATION		*BASIC AIR FLOW*			*NORMAL AIR FLOW*			*HIGH AIR FLOW*		
WALL STRUCTURES		Aver. °C	Min. °C	Max. °C	Aver. °C	Min. °C	Max. °C	Aver. °C	Min. °C	Max. °C
1A-	**WOODEN LIHGTWEIGHT**	**29,9**	***28,8***	***30,9***	**27,1**	***25,8***	***28,4***	**26,7**	***25,4***	***28,0***
1B-	**WOODEN MASSIVE**	**29,9**	**28,9**	***30,9***	**27,1**	**25,9**	***28,4***	**26,7**	**25,5**	***28,0***
2-	**MASONRY MASSIVE**	**29,8**	**29,4**	**30,3**	**27,3**	**26,7**	**27,9**	**26,8**	**26,4**	**27,4**
3-	**MIX WOODEN-MASONRY**	**29,7**	***28,8***	**30,5**	**27,2**	**26,1**	**28,2**	**26,7**	**25,6**	**27,7**
4-	**MIX MANSORY-ADOBE**	**29,8**	**29,3**	**30,3**	**27,3**	**26,7**	**27,9**	**26,8**	**26,2**	**27,4**
5-	**MIX WOODEN-ADOBE**	**29,8**	**29,1**	**30,5**	**27,3**	**26,4**	**28,1**	**26,7**	**25,9**	**27,6**
6-	**MIX ADOBE-MASONRY**	**29,8**	**29,3**	**30,3**	**27,3**	**26,6**	**27,9**	**26,8**	**26,1**	**27,4**
7-	**TOTAL ADOBE WALLS**	**29,9**	**29,3**	**30,4**	**27,3**	**26,6**	**27,9**	**26,8**	**26,1**	**27,4**
AVERAGES Ti:		***29,8***	***29,1***	***30,6***	***27,3***	***26,3***	***28,1***	***26,7***	***25,9***	***27,6***

FIRST GENERAL CONCLUSION

THERE IS NO REAL BENEFIT IN A PASSIVE HOUSE TO USE ALL MASSIVE ELEMENTS TO REDUCE THE INDOOR AIR TEMPERATURE, BUT ONLY TO UNIFORM IT AND IT'S ENOUGH THE PRESENCE OF ONLY SOME INNER MASSIVE ELEMENTS TO REACH THE SAME PERFORMANCE AND COMFORT BENEFIT .

OTHERWISE IN THE CASE OF WOODEN BUILDINGS, THIS IS TRUE IN RELATION TO A CONSTRUCTION TYPOLOGY CHARACTERIZED BY MASSIVE SOLID WOOD OR CROSS-LAM PANELS WITH AN HIGH THERMAL CAPACITY, BUT ABSOLUTELY NOT FOR THE LIGHTWEIGHT SYSTEMS THAT THEY HAVE TO BE AVOID IN THE WARM CLIMATE AREAS.

PART IV – STATIC ANALYSIS OF PASSIVE HOUSE ENERGY DEMAND

WOODEN CONSTRUCTION TYPOLOGY

1A - WOODEN LIGHTWEIGHT STRUCTURES

2,5cm Osb/Gypsum fibre board + 30cm Rockwool + 2,5cm Osb/Gypsum fibre board

Global superficial inertial mass: *50 kg/m²*
Indoor heat capacity mass (10cm): *15 kg/m²*

Normal storage heat capacity: *60 Wh/(m³/K)*

Specific Demands with Reference to the Treated Floor Area

	Applied:	yearly calculation		PH Certificate:
Treated Floor Area:	122,5	m^2		
Specific Space Heat Demand:	14	$kWh/(m^2a)$		15 $kWh/(m^2a)$
Pressurization Test Result:	0,6	h^{-1}		0,6 h^{-1}
Specific Primary Energy Demand (DHW, Heating, Cooling, Auxiliary and Household Electricity):	109	$kWh/(m^2a)$		120 $kWh/(m^2a)$
Specific Primary Energy Demand (DHW, Heating and Auxiliary Electricity):	64	$kWh/(m^2a)$		
Specific Primary Energy Demand Energy Conservation by Solar Electricity:	56	$kWh/(m^2a)$		
Heating Load:	15	W/m^2		
Frequency of Overheating:	9	%	over 25 °C	
Specific Useful Cooling Energy Demand:		$kWh/(m^2a)$		15 $kWh/(m^2a)$
Cooling Load:	5	W/m^2		

1B- WOODEN MASSIVE STRUCTURES

10cm Cross-Lam wood panel + 30cm Wooden insulation fibre board

Superficial inertial mass: *100 kg/m²*
Indoor heat capacity mass (10cm): *50 kg/m²*

Normal storage heat capacity: *90 Wh/(m³/K)*

Specific Demands with Reference to the Treated Floor Area

	Applied:	yearly calculation		PH Certificate:
Treated Floor Area:	122,5	m^2		
Specific Space Heat Demand:	13	$kWh/(m^2a)$		15 $kWh/(m^2a)$
Pressurization Test Result:	0,6	h^{-1}		0,6 h^{-1}
Specific Primary Energy Demand (DHW, Heating, Cooling, Auxiliary and Household Electricity):	108	$kWh/(m^2a)$		120 $kWh/(m^2a)$
Specific Primary Energy Demand (DHW, Heating and Auxiliary Electricity):	62	$kWh/(m^2a)$		
Specific Primary Energy Demand Energy Conservation by Solar Electricity:	56	$kWh/(m^2a)$		
Heating Load:	15	W/m^2		
Frequency of Overheating:	8	%	over 25 °C	
Specific Useful Cooling Energy Demand:		$kWh/(m^2a)$		15 $kWh/(m^2a)$
Cooling Load:	5	W/m^2		

Energy demand calculation with software PHPP 2007 – Passive House Planning Package

MASSIVE AND MIX CONSTRUCTION TYPOLOGY

2- MASONRY MASSIVE STRUCTURES

20cm Reinforced concrete + 30cm Polystyrene insulation panel

Superficial inertial mass: *500 kg/m²*
Indoor heat capacity mass (10cm): *250 kg/m²*

Normal storage heat capacity: *204 Wh/(m³/K)*

Specific Demands with Reference to the Treated Floor Area

	Applied:	yearly calculation	PH Certificate:
Treated Floor Area:	122,5	m²	
Specific Space Heat Demand:	12	kWh/(m²a)	15 kWh/(m²a)
Pressurization Test Result:	0,6	h⁻¹	0,6 h⁻¹
Specific Primary Energy Demand (DHW, Heating, Cooling, Auxiliary and Household Electricity):	107	kWh/(m²a)	120 kWh/(m²a)
Specific Primary Energy Demand (DHW, Heating and Auxiliary Electricity):	62	kWh/(m²a)	
Specific Primary Energy Demand Energy Conservation by Solar Electricity:	56	kWh/(m²a)	
Heating Load:	15	W/m²	
Frequency of Overheating:	7	%	over 25 °C
Specific Useful Cooling Energy Demand:		kWh/(m²a)	15 kWh/(m²a)
Cooling Load:	5	W/m²	

3- MIXED WOODEN WALLS + MASONRY CORE STRUCTURES

Cross-Lam wood panel + 30cm Wooden insulation fibre board
+ 20cm Reinforced concrete core

Superficial inertial mass: *250 kg/m²*
Indoor heat capacity mass (10cm): *125 kg/m²*

Normal storage heat capacity: *132 Wh/(m³/K)*

Specific Demands with Reference to the Treated Floor Area

	Applied:	yearly calculation	PH Certificate:
Treated Floor Area:	122,5	m²	
Specific Space Heat Demand:	12	kWh/(m²a)	15 kWh/(m²a)
Pressurization Test Result:	0,6	h⁻¹	0,6 h⁻¹
Specific Primary Energy Demand (DHW, Heating, Cooling, Auxiliary and Household Electricity):	107	kWh/(m²a)	120 kWh/(m²a)
Specific Primary Energy Demand (DHW, Heating and Auxiliary Electricity):	62	kWh/(m²a)	
Specific Primary Energy Demand Energy Conservation by Solar Electricity:	56	kWh/(m²a)	
Heating Load:	15	W/m²	
Frequency of Overheating:	7	%	over 25 °C
Specific Useful Cooling Energy Demand:		kWh/(m²a)	15 kWh/(m²a)
Cooling Load:	5	W/m²	

Energy demand calculation with software PHPP 2007 – Passive House Planning Package

PASSIVE HOUSE SUMMER COOLING DEMAND CALCULATION

10cm Cross-Lam wood panel + 30cm Wooden insulation FB+ 20cm Reinforced concrete core

Spec. Capacity: 132 Wh/K pro m² TFA

Overheating Limit: 25 °C

	Building Element	Temperature Zone	Area m²		U-Value W/(m²K)		Red. Factor f T,Summer		H Summer Heat Conductance
1.	Exterior Wall - Ambie	A	181,0	*	0,121	*	1,00	=	21,9
2.	Exterior Wall - Groun	B		*		*	1,00	=	
3.	Roof/Ceiling - Ambien	A	110,5	*	0,132	*	1,00	=	14,6
4.	Floor Slab	B		*		*	1,00	=	
5.	Elementi verso cantin	X	41,9	*	0,217	*	0,50	=	4,5
6.	Pavimenti su vespaio	X	92,8	*	0,113	*	0,50	=	5,2
7.		X		*		*	0,50	=	
8.	Fenster	A	39,4	*	0,884	*	1,00	=	34,8
9.	Exterior Door	A		*		*	1,00	=	
10.	Thermal Bridges Ambie	A		*		*	1,00	=	
11.	Perimeter Thermal Bri	P		*		*	1,00	=	
12.	Thermal Bridges Floor	B	5,4	*	0,068	*	1,00	=	0,4

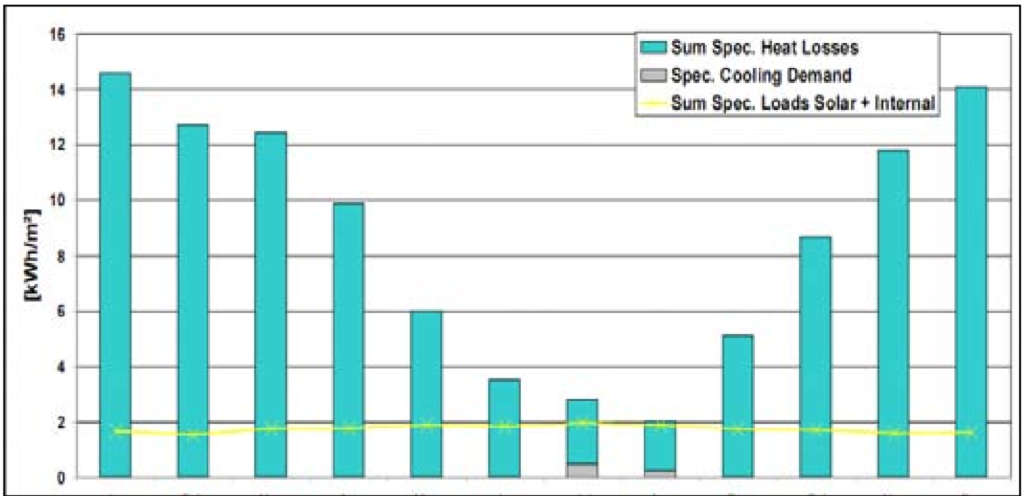
Exterior Thermal Transmittance $H_{T,e}$ 81,2 W/K

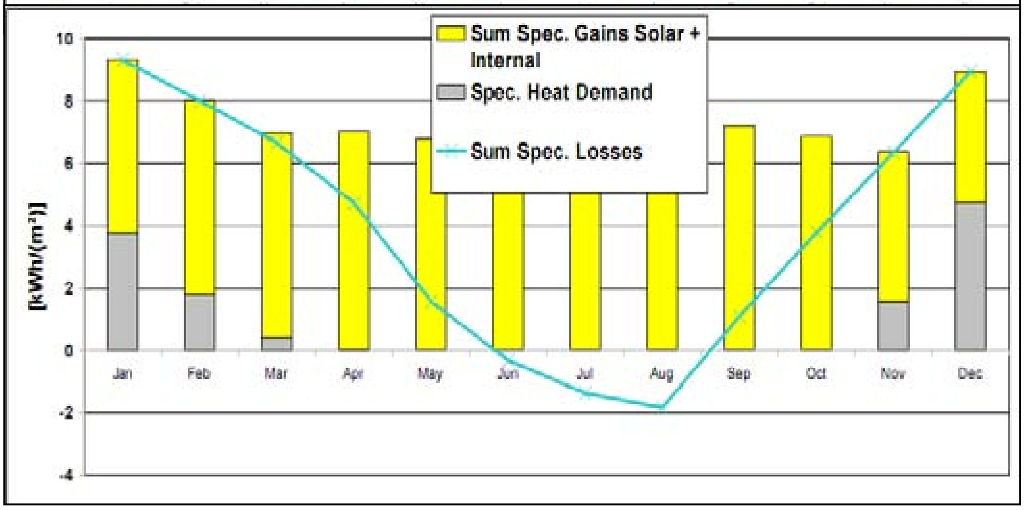
Ground Thermal Transmittance $H_{T,g}$ 0,4 W/K

Frequency of Overheating $h_{\theta \geq \theta max}$ **6,6%** **at the overheating limit θmax = 25 °C**

If the "frequency over 25°C" exceeds 10%, additional measures to protect against summer heat waves are necessary.

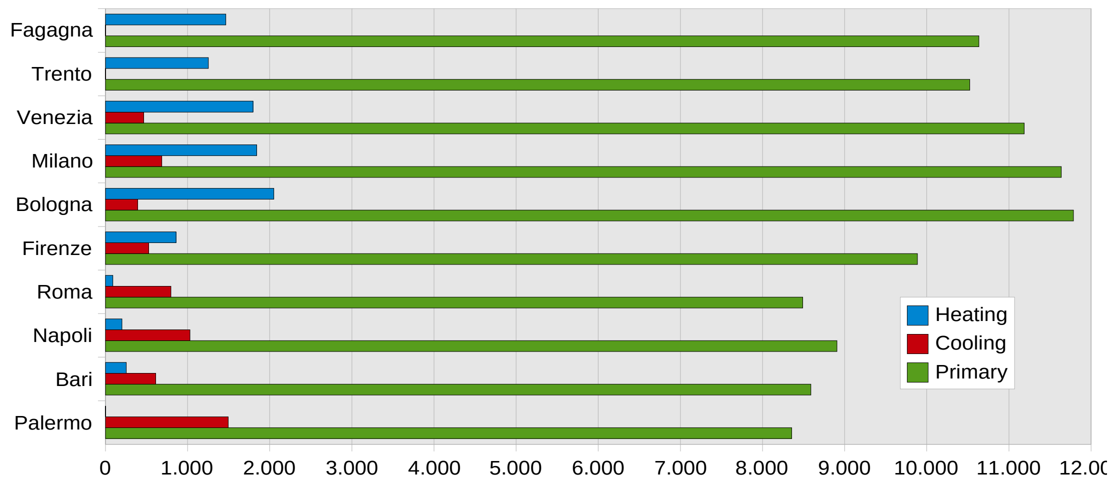
COOLING Vs. HEATING ENERGY DEMAND





Energy demand calculation with software PHPP 2007 – Passive House Planning Package

DIFFERENT LOCATION FOR MIXED WOODEN WALLS + MASONRY CORE



Studio case building	IE-Heating	IE-Cooling	IE-Primary
Location	kWh/m²*year	kWh/m²*year	kWh/m²*year
Fagagna (Udine)	12,0	0,0	86,8
Trento	10,2	0	85,9
Venezia	14,7	3,8	91,3
Milano	15,0	5,6	95,0
Bologna	16,7	3,2	96,2
Firenze	7,0	4,3	80,7
Roma	0,7	6,5	69,3
Napoli	1,6	8,4	72,7
Bari	2,1	5,0	70,1
Palermo	0,0	12,2	68,2

Studio case building	Heating	Cooling	Primary
Location	kWh/year	kWh/year	kWh/year
Fagagna (Udine)	1.465	0	10.633
Trento	1.252	0	10.523
Venezia	1.796	466	11.184
Milano	1.841	686	11.638
Bologna	2.050	392	11.785
Firenze	859	527	9.886
Roma	89	796	8.489
Napoli	202	1.029	8.906
Bari	253	613	8.587
Palermo	1	1.495	8.355

Analysis by Gunter Gantioler-TBZ – Technisches Bauphysik Zentrum – Bolzano (Italy)

PART V – GENERAL CONCLUSIONS

GENERAL FINAL CONSIDERATIONS

1- Building orientation, geometry and shading:
Shading avoids solar radiation to impinge on external surfaces of buildings, with particular relevance for windows in relation also to their orientation and "g" glass value.

In the specific analysis the overheating phenomena are really higher in the case of lightweight wooden construction, but it's lower for the simple massive wood one, with indoor temperature values similar to the massive construction system and to the mix one.

Furthermore for the Summer climate the problem is higher for the well insulated buildings and it becomes terrible in the case of bad sun sheltering construction and/or building orientation.

Otherwise it seems that the benefit of massive internal walls elements is not so relevant in consideration of the fact that the typology of the two storey house are characterized by large massive ground floor surfaces in relation to the perimetric walls, and so this high heating mass capacity is enough to modulate the indoor air temperature.

In any case in relation to this consideration, it's important to notice that the value of the operative temperature, that is the media of the indoor surface ones, is almost the same of the air indoor one, but the specific internal surface temperature should be really high in the case of lightweight construction systems with a bad living comfort effect.

2- Thermal mass efficiency:
Materials within a building which have a high thermal capacitance can provide a 'flywheel' effect, smoothing out the variation in temperature within the building, and reducing the swing in temperature on a diurnal and potentially longer term basis, to have a constant operative indoor temperature balanced for each construction element.

Otherwise this phenomena can give a really good benefit if is correlate to an adequate indoor ventilation flow especially during the night time, taking away the overheat thermal load storage in the massive construction elements during the day time.

3- Natural and night ventilation:
The cool air can be drawn into the house to flush out any residual heat from the day and to pre-cool the internal fabric for the following day taking advantage of the internal mass as vertical walls and/or the ground floor and the intermediate ones.

The only problems for this natural acclimatization system is that seems difficult to provide in a safe living way to a right night window opening above all in the modern urban areas, so it become important maximize this useful effect during the evening and the morning when the people is still in the house and awake and the sun has still to penetrate inside the house or it can be sheltered by using a normal curtains system to stop the radiation rays.

PROBLEMS IDENTIFICATION

1- Building orientation, geometry and shading:
Shading solar systems are strongly recommended in case of glazed elements and mainly if they are East or West orientated and they need to be completely sheltered adopting also moving or sliding elements and suitable horizontal projections.

2- Thermal mass efficiency:
The wooden lightweight construction are not suitable in general for a warm climate as the Mediterranean one, especially in the case of wooden multistory buildings, because they lack the high thermal mass capacity and relative benefit due to the ground floor connection and to the intermediate traditional large massive floors and roof elements good to stabilize the temperature.

3- Natural and night ventilation:
The ventilation is strictly necessary and it should be during the daytime only the mechanical one, but it has to be increased by the natural one especially during the evening and the night time.

4- Subsoil heat exchanger and recovery system:
If the first three previous main rules are respected, a subsoil heat exchanger can generally reduce the use of an active heating system as incoming fresh air is pre-heated, so active cooling demand and power may be reduced or even eliminated.

THERMAL MASS ELEMENTS AND FINAL CONCLUSION

Finally the analysis of this studio case project characterized by a wooden cross-lam construction typology, show the fact that is enough the presence of a inner concrete wall of 500x300x20cm of dimension in a middle building position between two rooms to reduce the global temperature swing of the house and also the daily maximum value, and from this point of view the indoor performance is similar to a complete masonry building.

IN GENERAL FOR TRADITIONAL BUILDINGS AND IN THE SPECIFIC FOR THE PASSIVE HOUSE TYPOLOGY, THE USE OF MASSIVE ELEMENTS ALLOWS TO STORAGE THE HEAT GAINS AND ALSO TO UNIFORM THE INDOOR TEMPERATURE FOR MANY HOURS.

FOR THIS REASON IT'S REALLY IMPORTANT HAVE AN INDOOR MASS EFFECT BOTH IN THE WINTER TIME AND IN THE SUMMER SEASON, BUT IT'S ENOUGH THE PRESENCE OF ONLY SOME INNER MASSIVE ELEMENTS TO REACH THE SAME INDOOR CLIMATIC PERFORMANCE OF A TRADITIONAL MASSIVE CONSTRUCTION SYSTEM.

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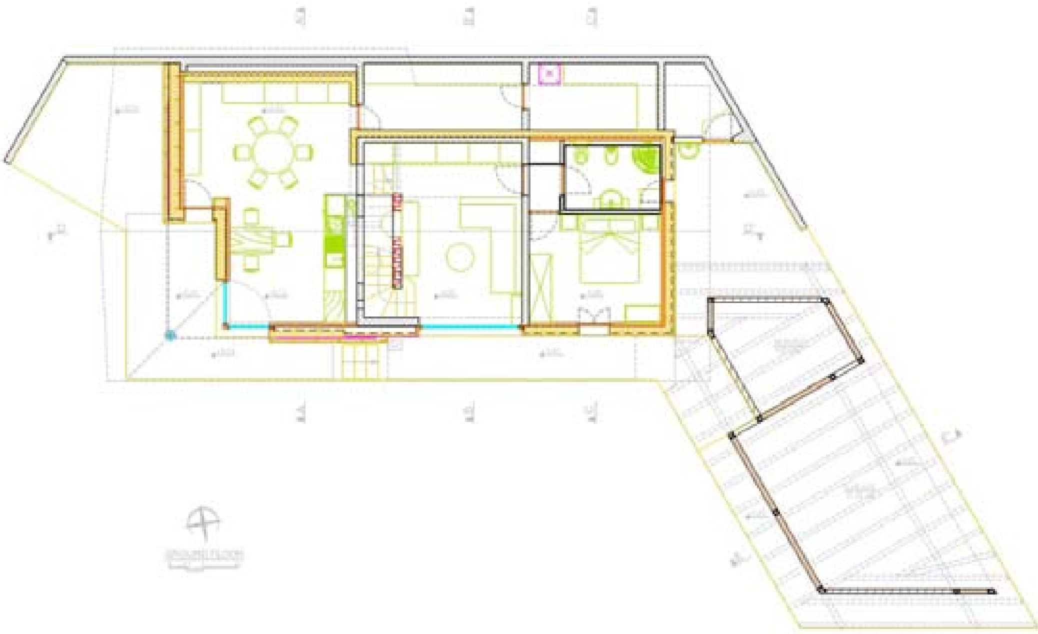
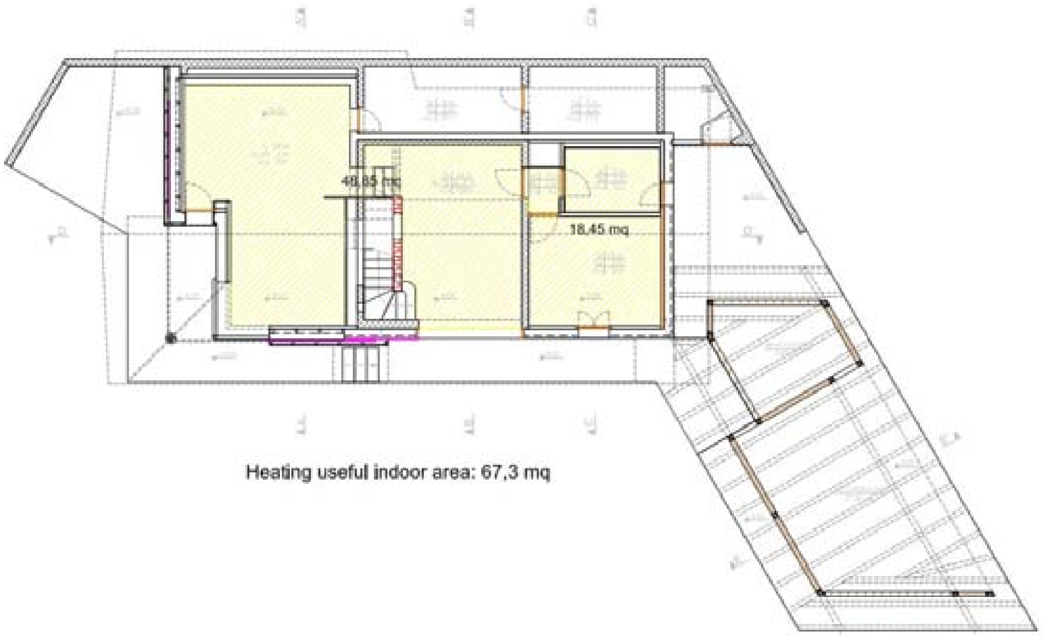
APPENDIX A – PROJECT DRAWINGS

GROUND FLOOR SITE PLAN



Calculation indoor area for PHPP



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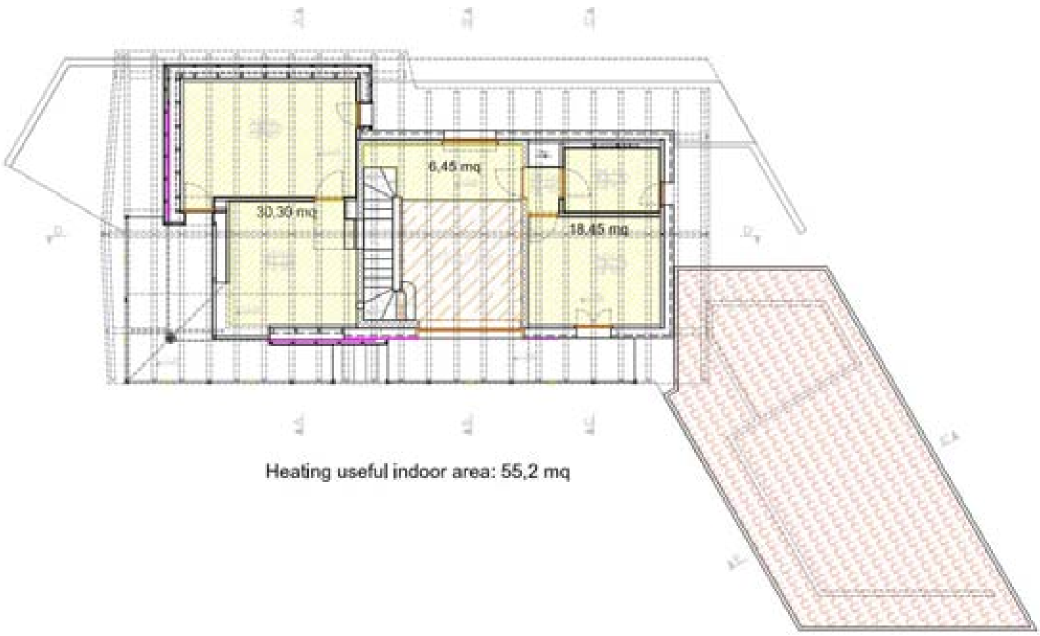
FIRST FLOOR SITE PLAN

Calculation indoor area for PHPP



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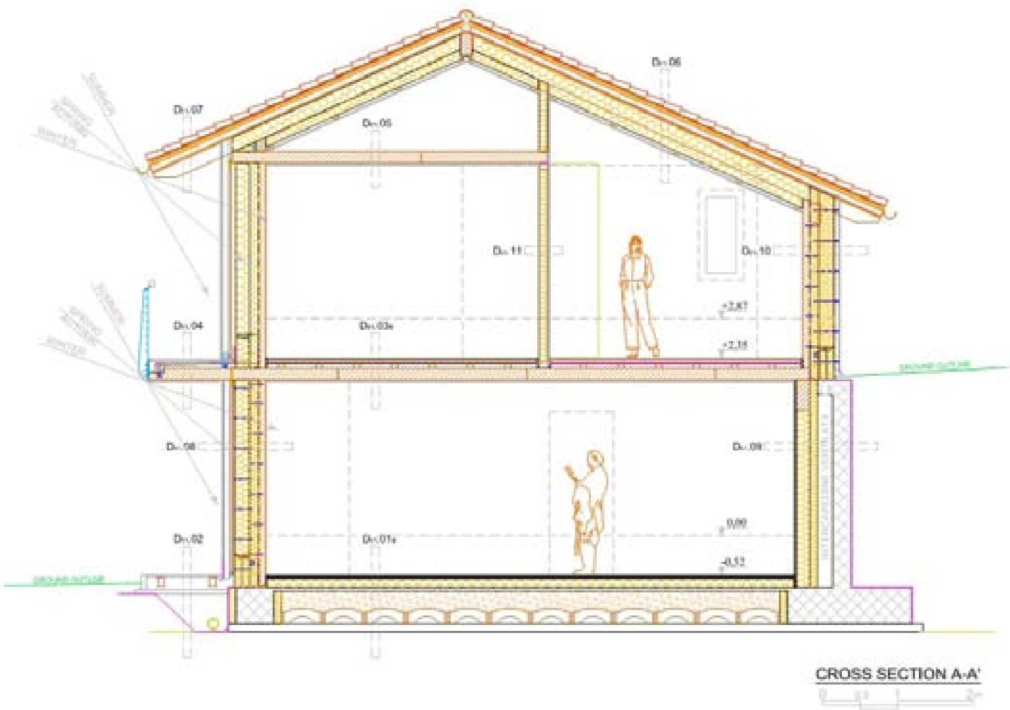
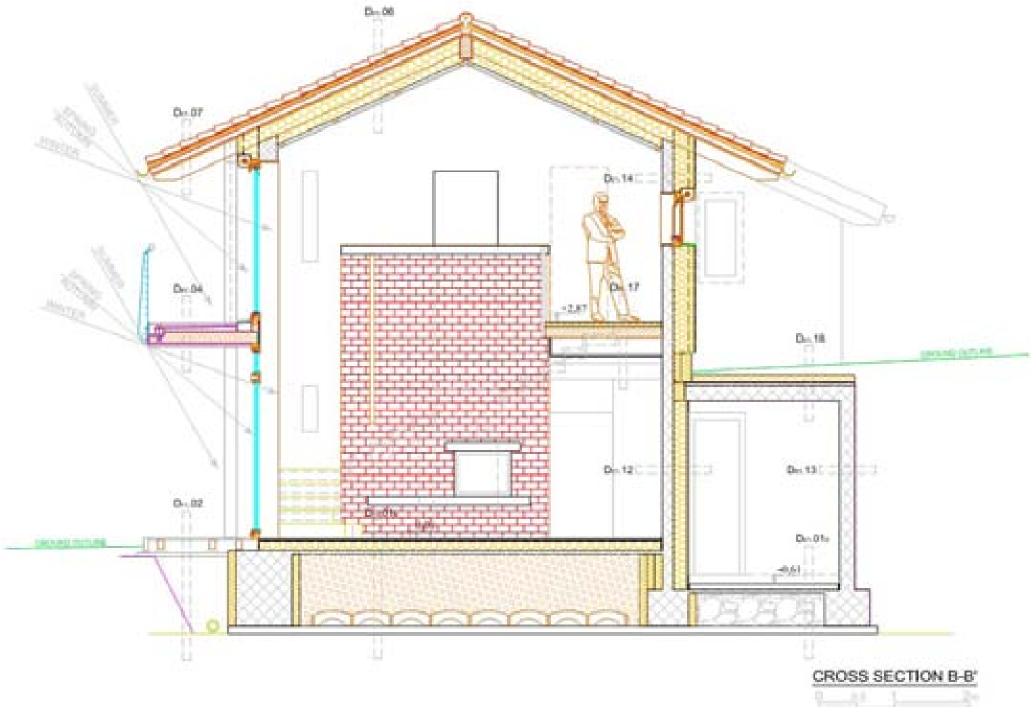
CROSS SECTIONS A-A' AND B-B'





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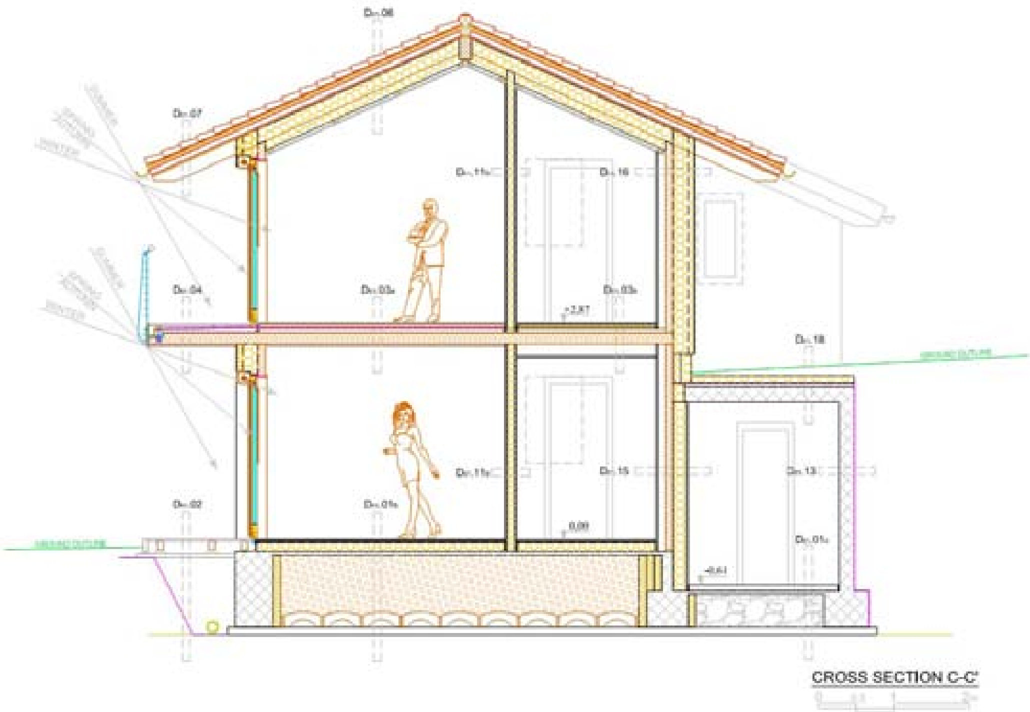
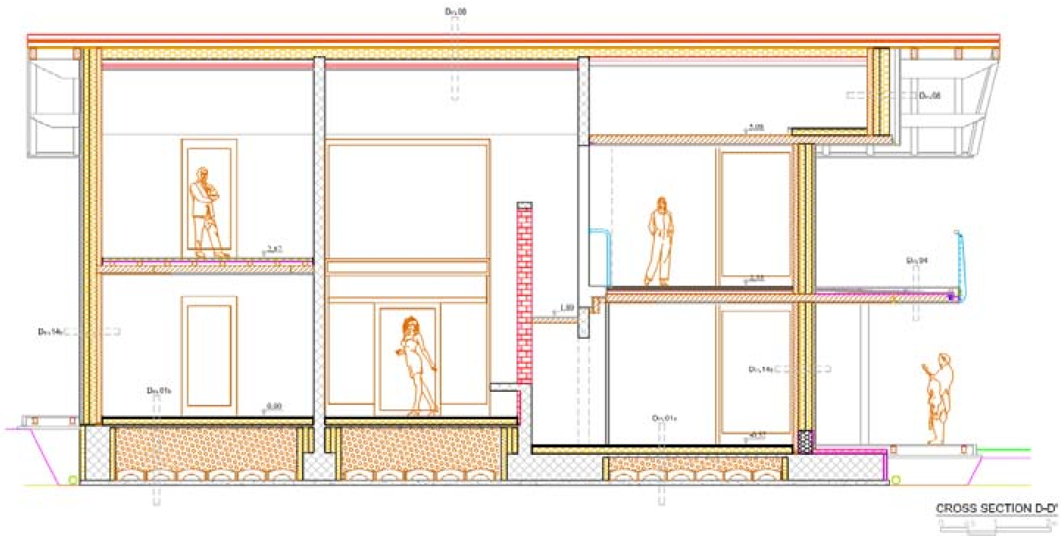
CROSS SECTIONS C-C' AND D-D'





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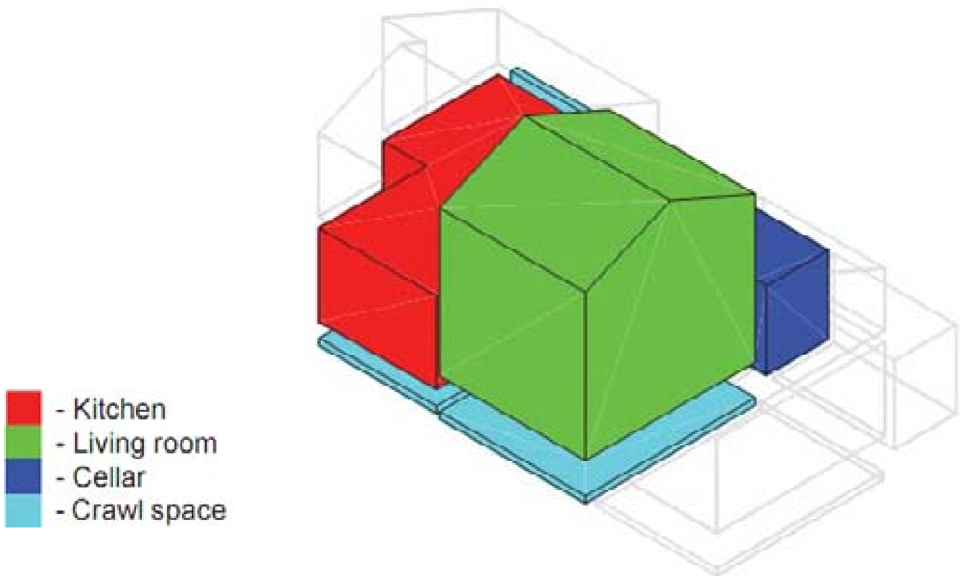
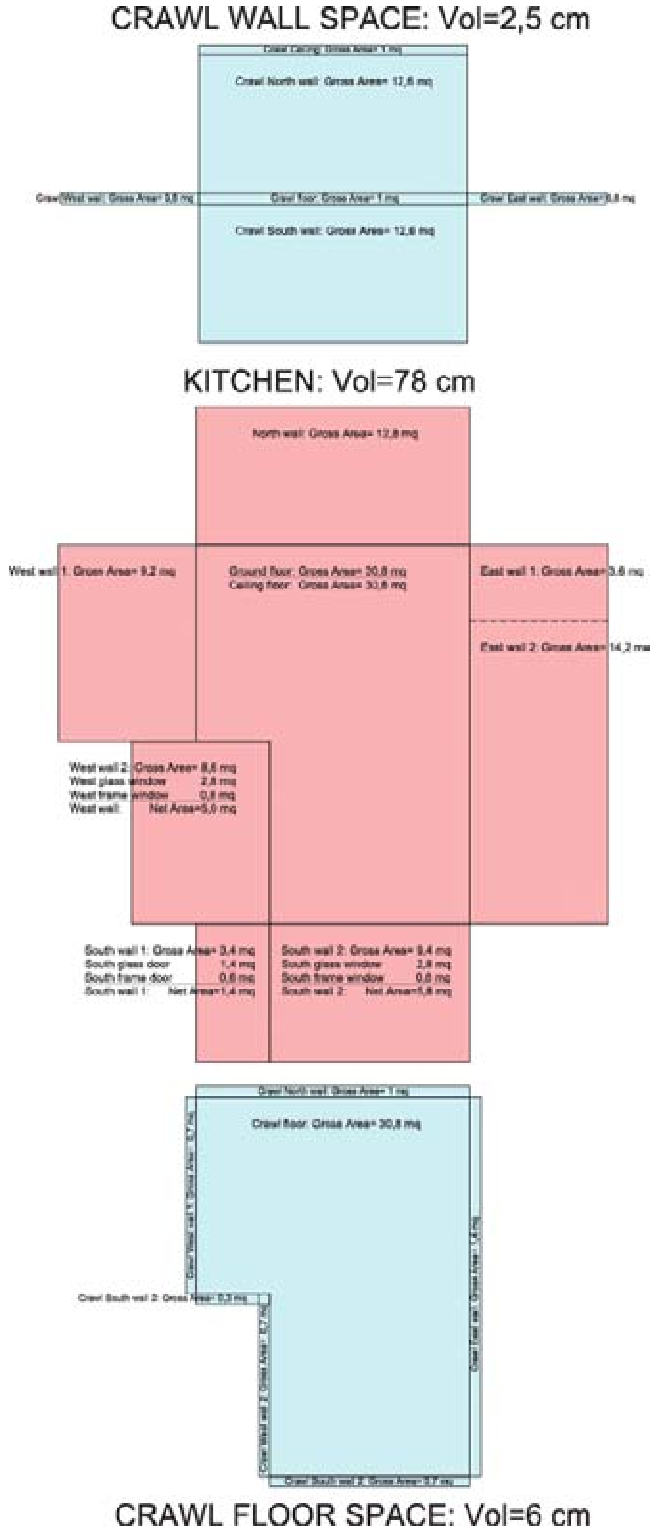
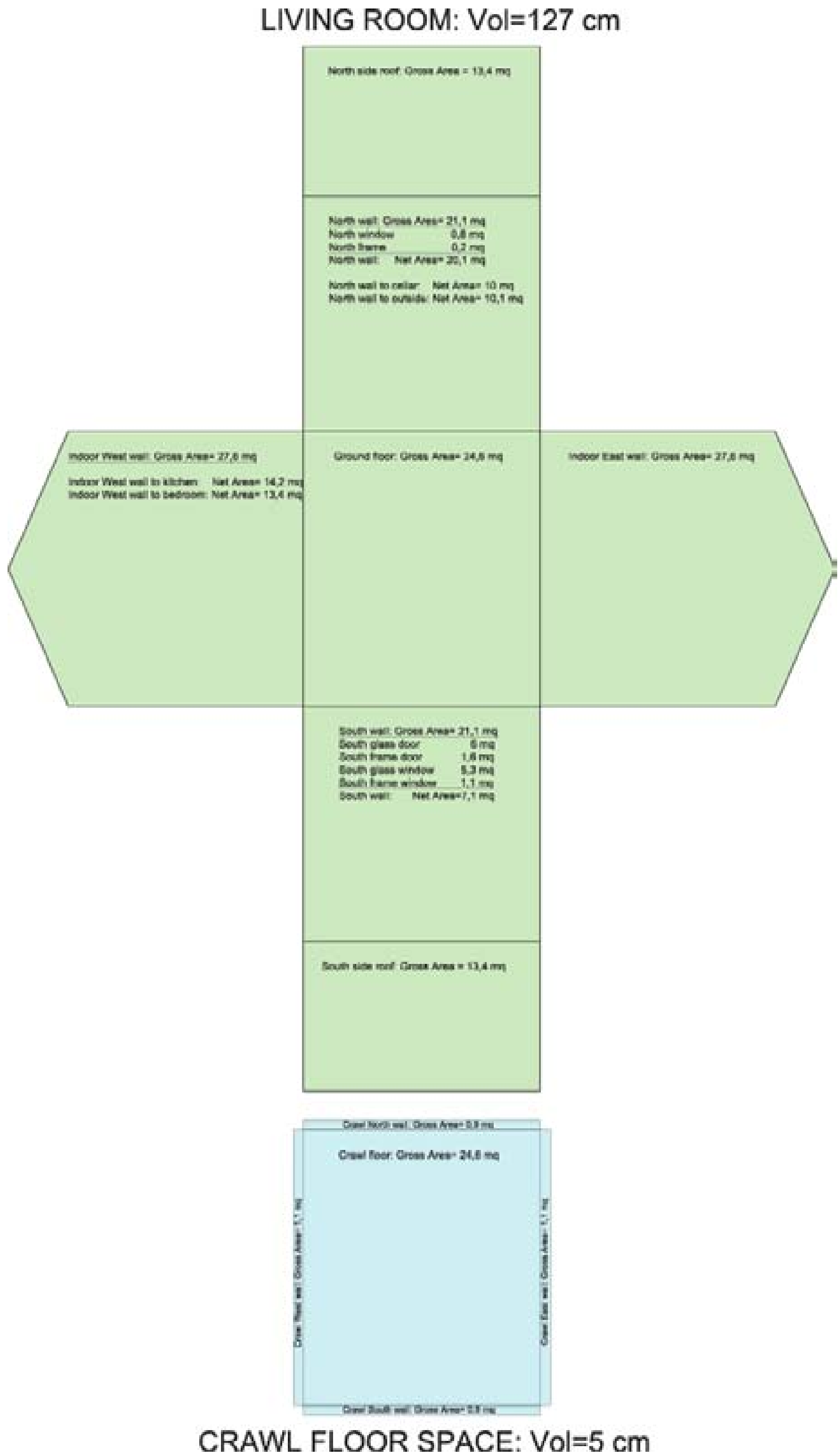
APPENDIX B – ROOM SPECIFICATIONS FOR DYNAMIC ANALYSIS



KITCHEN ROOM		LIVING ROOM	
Construction elements	Area	Construction elements	Area
Ground floor: Gross Area	30,8	Ground floor: Gross Area	24,6
Ceiling floor: Gross Area	30,8	North side roof: Gross Area	13,4
		South side roof: Gross Area	13,4
North wall: Gross Area	12,8		
		North wall: Gross Area	21,1
East wall 1: Gross Area	3,6	North window	0,8
		North frame	0,2
East wall 2: Gross Area	14,2	North wall: Net Area	20,1
South wall 1: Gross Area	3,4	North wall to cellar: Net Area	10,0
South glass door	1,4	North wall to outside: Net Area	10,1
South frame door	0,6		
South wall 1: Net Area	1,4	Indoor East wall: Gross Area	27,6
South wall 2: Gross Area	9,4	South wall: Gross Area	21,1
South glass window	2,8	South glass door	6,0
South frame window	0,8	South frame door	1,6
South wall 2: Net Area	5,8	South glass window	5,3
West wall 1: Gross Area	9,2	South frame window	1,1
		South wall: Net Area	7,1
West wall 2: Gross Area	8,6	Indoor West wall: Gross Area	27,6
West glass window	2,8		
West frame window	0,8	Indoor West wall to kitchen:	14,2
West wall: Net Area	5,0	Indoor West wall to bedroom:	13,4



arch. Andrea Boz and Dl. Michaela Gruber Dynamic analysis with GEBA –TUW Vienna



arch. Andrea Boz and Dl. Michaela Gruber Dynamic analysis with GEBA –TUW Vienna

APPENDIX C – DETAIL CONSTRUCTION SYSTEMS

DETAIL 01a
- Ceramic stoneware tiles - 1 cm
- Gypsum fibre board - 20 mm
- Dry granular aerated concrete levelling (0,09) - 1,5-2 cm
- Rigid wooden fibreboard insulation panel (0,038) - 12 cm
- Radon and air-stop barrier - 4 mm
- Structural reinforced Polypropylene mesh
- Concrete slab - 5 cm
- Polyethylene protective membrane
- Granular expanded clay (0,09) 8/20 - 23 cm
- Crawl space in Polypropylene structural dome - 20 cm
- Concrete lean mix - 10 cm

DETAIL 01b
- Ceramic stoneware tiles - 1 cm
- Gypsum fibre board - 20 mm
- Dry granular aerated concrete levelling (0,09) - 1,5-2 cm
- Rigid wooden fibreboard insulation panel (0,038) - 12 cm
- Radon and air-stop barrier - 4 mm
- Structural reinforced Polypropylene mesh
- Concrete slab - 5 cm
- Polyethylene protective membrane
- Granular expanded clay (0,09) 8/20 - 75 cm
- Crawl space in Polypropylene structural dome - 20 cm
- Concrete lean mix - 10 cm

DETAIL 02
- Larch board sidewalk - 3 cm
- Soundproof strip in EPDM with closed cell - 5 mm
- Larch load bearing stringhers - 8x12 cm
- Concrete edge trim - 6x20 cm
- Draining layer in compaction fine gravel and sand - 20 cm
- Draining layer in compaction crushed gravel - 35 cm
- Protective layer in Polypropylene unwoven material
- Draining micro drilling pipe - Dia=125 mm

DETAIL 03a
- Floating floor in larch linseed oil planking - 20 mm
- Combined wooden stringhers and fibreboard insulation panel (0,039) – 4 cm
- Standard gypsum fibre board - 12,5 mm
- Soundproof linen felt - 5 mm
- Dry soundproof ballast with fine calcareous stone grit - 6 cm
- Deck stiffened with wooden stringhers (span 25 cm) - 8x6 cm
- Structural spruce cross-laminated timber deck - 14/15 cm
- Finishing spruce plywood panels milled with 25 mm of span - 32 mm

DETAIL 03b
- Ceramic stoneware tiles - 1 cm
- Waterproof gypsum fibre board - 22 mm
- Rigid wooden fibreboard insulation panel (0,038) - 4 cm
- Soundproof linen felt - 5 mm
- Dry soundproof ballast with fine calcareous stone grit - 6 cm
- Deck stiffened with wooden stringhers (span 25 cm) - 8x6 cm
- Structural spruce cross-laminated timber deck - 14/15 cm
- Horizontal service hollow space - 15 cm
- False ceiling in waterproof gypsum plaster board - 25 mm

DETAIL 04
- Movable larch board panel floor - 3 cm
- Wooden floor bearing stringhers with different cross-section (span 60 cm)
- Soundproof strip in EPDM with closed cell - 5 mm
- Non-woven Polypropylene waterproof fibre reinforced membrane - 4 mm
- OSB-Oriented strand board panel for draining graded layer 2% - 15 mm
- Deck stiffened with wooden stringhers (span 25 cm) - 8x6 cm
- Air-stop retarder (Sd_{max} 3) in non-woven Polypropylene membrane - 5 mm
- Structural spruce cross-laminated timber deck - 14/15 cm
- Finishing spruce plywood panels milled with 25 mm of span - 32 mm

DETAIL 05a
- Structural spruce cross-laminated timber deck - 14/15 cm
- Finishing spruce plywood panels milled with 25 mm of span - 32 mm

DETAIL 05b
- Rough wooden boarding in spruce - 25 mm
- Rigid wooden fibreboard insulation panel (0,038) - 12 cm
- Structural spruce cross-laminated timber deck - 14/15 cm
- Finishing spruce plywood panels milled with 25 mm of span - 32 mm

DETAIL 06
- Brick roofing pantile
- Wooden roofing pantile stringhers - 4x2 + 6x4 cm
- Non-woven Polypropylene waterproof fibre reinforced membrane - 4 mm
- OSB-Oriented strand board panel for air roof ventilated space - 20 mm
- Air roof ventilated space - 8 cm
- Air space wooden stringhers (span 80 cm) - 6x8 cm
- Watertight transpiring and reflecting membrane (Sd 0,2) as *Dorken-Delta Maxx*
- Rough wooden boarding in spruce - 25 mm
- Flexible wooden fibreboard insulation panel (0,038) - 18 cm
- Wooden rafter in duo beam spruce (span 80 cm) - 12x18 cm
- Rigid wooden fibreboard insulation panel (0,038) - 12 cm
- Air-stop retarder (Sd_{max} 3) in non-woven Polypropylene membrane
- False ceiling spruce stringhers (span 100 cm) - 4x2 cm
- False ceiling in spruce plywood panels - 20 mm

DETAIL 07
- Brick roofing pantile
- Wooden roofing pantile stringhers - 4x2 + 6x4 cm
- Non-woven Polypropylene waterproof fibre reinforced membrane - 4 mm
- OSB-Oriented strand board panel for air roof ventilated space - 20 mm
- Air roof ventilated space - 8 cm
- Air space wooden stringhers (span 80 cm) - 6x8 cm
- Watertight transpiring and reflecting membrane (Sd 0,2) as *Dorken-Delta Maxx*
- Rough wooden boarding in spruce - 25 mm
- Wooden rafter in duo beam spruce (span 80 cm) - 12x18 cm

DETAIL 08
- Structural spruce cross-laminated timber wall - 9/10 cm
- Air-stop retarder (Sd_{max} 3) in non-woven Polypropylene membrane - 5 mm
- Vertical spruce stringhers for insulation panel (span 70 cm) - 7,5x12 cm
- Flexible wooden fibreboard insulation panel (0,038) - 12 cm
- Rigid wooden fibreboard insulation panel (0,038) - 20 cm
- Watertight transpiring and reflecting membrane (Sd 0,2) as *Dorken-Delta*
- Air roof ventilated space - 8 cm
- Air space wooden stringhers (span 80 cm) - 6x8 cm
- Wooden sliding sun shade in spruce - 3 cm
- External wood panelling in larch board - 2 cm

DETAIL 09
- Standard gypsum fibre board plastered - 12,5 mm
- Air-stop retarder (Sd_{max} 3) in non-woven Polypropylene membrane - 5 mm
- Glue laminar wood 16x40 cm
- Framework in spruce stringhers for insulation panel (span 70 cm) - 7,5x12 cm
- Flexible wooden fibreboard insulation panel (0,038) - 12 cm
- Plaster baseboard in wooden fibreboard insulation panel (0,045) - 6 cm
- Transpiring silicates plaster as watertight transpiring function
- EPS-Polystyrene insulation panel (0,036) - 10 cm
- Vertical air ventilated space - 20 cm
- Structural walls in reinforced normal concrete - 25 cm
- Damp proofing Polypropylene studded membrane - 5 mm
- Protective layer in Polypropylene unwoven material
- Draining micro drilling pipe - Dia=125 mm
- Draining layer in compaction crushed gravel

DETAIL 10
- Structural spruce cross-laminated timber wall - 9/10 cm
- Air-stop retarder (Sd_{max} 3) in non-woven Polypropylene membrane - 5 mm
- Vertical spruce stringhers for insulation panel (span 70 cm) - 7,5x12 cm
- Flexible wooden fibreboard insulation panel (0,038) - 12 cm
- Rigid wooden fibreboard insulation panel (0,038) - 20 cm
- Watertight transpiring and reflecting membrane (Sd 0,2) as *Dorken-Delta*
- Air roof ventilated space - 8 cm
- Air space wooden stringhers (span 70 cm) - 6x8 cm
- External wood panelling in larch board - 2 cm

DETAIL 11a
- Surface wood panelling in spruce board - 25 mm
- Framework in spruce stringhers for insulation panel (span 70 cm) - 6x10 cm
- Flexible wooden fibreboard insulation panel (0,038) - 10 cm
- Pannelli in fibre di legno flessibili (0,038) - 10 cm
- Surface wood panelling in spruce board - 25 mm

DETAIL 11b
- Waterproof gypsum fibre board - 22 mm
- Metal structural framework for insulation panel (span 60 cm)
- Flexible wooden fibreboard insulation panel (0,038) - 10 cm
- Standard gypsum fibre board plastered - 12,5 mm

DETAIL 12
- Structural walls in reinforced white concrete - 15 cm
- Vertical spruce stringhers for insulation panel (span 70 cm) - 7,5x12 cm
- Flexible wooden fibreboard insulation panel (0,038) - 12 cm
- Plaster baseboard in wooden fibreboard insulation panel (0,045) - 6 cm
- Transpiring silicates coloured plaster

DETAIL 13
- Structural walls in reinforced normal concrete - 20 cm
- Damp proofing Polypropylene studded membrane - 5 mm
- Protective layer in Polypropylene unwoven material
- Draining micro drilling pipe - Dia=125 mm
- Draining layer in compaction crushed gravel

DETAIL 14a
- Structural walls in reinforced white concrete - 15 cm
- Vertical spruce stringhers for insulation panel (span 70 cm) - 7,5x12 cm
- Flexible wooden fibreboard insulation panel (0,038) - 12 cm
- Rigid wooden fibreboard insulation panel (0,038) - 12 cm
- Plaster baseboard in wooden fibreboard insulation panel (0,045) - 6 cm
- Transpiring silicates coloured plaster

DETAIL 14b
- Structural spruce cross-laminated timber wall - 9/10 cm
- Air-stop retarder (Sd_{max} 3) in non-woven Polypropylene membrane - 5 mm
- Vertical spruce stringhers for insulation panel (span 70 cm) - 7,5x12 cm
- Flexible wooden fibreboard insulation panel (0,038) - 12 cm
- Rigid wooden fibreboard insulation panel (0,038) - 12 cm
- Plaster baseboard in wooden fibreboard insulation panel (0,045) - 6 cm
- Transpiring silicates coloured plaster

DETAIL 15
- Covering layer in ceramic stoneware tiles - 10 mm
- Waterproof gypsum fibre board - 22 mm
- Vertical service hollow space - 10 cm
- Structural spruce cross-laminated timber wall - 9/10 cm
- Air-stop retarder (Sd_{max} 3) in non-woven Polypropylene membrane - 5 mm
- Vertical spruce stringhers for insulation panel (span 70 cm) - 7,5x12 cm
- Rigid wooden fibreboard insulation panel (0,038) - 12 cm
- Plaster baseboard in wooden fibreboard insulation panel (0,045) - 6 cm
- Transpiring silicates coloured plaster

DETAIL 16
- Covering layer in ceramic stoneware tiles - 10 mm
- Waterproof gypsum fibre board - 22 mm - 22 mm
- Vertical service hollow space - 10 cm
- Structural spruce cross-laminated timber wall - 9/10 cm
- Air-stop retarder (Sd_{max} 3) in non-woven Polypropylene membrane - 5 mm
- Vertical spruce stringhers for insulation panel (span 70 cm) - 7,5x12 cm
- Flexible wooden fibreboard insulation panel (0,038) - 12 cm
- Rigid wooden fibreboard insulation panel (0,038) - 12 cm
- Plaster baseboard in wooden fibreboard insulation panel (0,045) - 6 cm
- Transpiring silicates coloured plaster

DETAIL 17
- Floating floor in larch linseed oil planking - 20 mm
- Combined wooden stringhers and fibreboard insulation panel (0,039) - 4 cm
- Soundproof linen felt - 5 mm
- Structural spruce cross-laminated timber deck - 14/15 cm
- Service hollow space - 15 cm
- False ceiling in standard gypsum plaster board - 12,5 mm

DETAIL 18
- Draining layer in compaction fine gravel - 10 cm
- Protective layer in Polypropylene unwoven material
- EPS-Polystyrene insulation panel (0,036) - 10 cm
- Damp proofing Polypropylene studded membrane - 5 mm
- Brick-concrete slab with lattice flitch girder - 20+5 cm
- Inside transpiring silicates and lime plaster - 15 mm

APPENDIX D –CONSTRUCTION SYSTEMS THERMAL BEHAVIOUR

Assembly No.	Building Assembly Description
1	Det 01a - Ground floor up granular expanded clay 23 cm

Heat Transfer Resistance [m²K/W] interior Rsi: 0,17 exterior Rse: 0,04

	Area Section 1	l [W/(mK)]	Area Section 2 (optional)	λ [W/(mK)]	Area Section 3 (optional)	λ [W/(mK)]	Total Width Thickness [mm]
1.	Ceramic stoneware tile:	1,200					15
2.	Gypsum fibre board	0,320					20
3.	Dry granular leveling :	0,090					20
4.	Wooden fibreboard insu:	0,038					120
5.	Radon and air-stop bar:	0,200					5
6.	Concrete slab	2,300					40
7.	Granular expanded clay	0,090					250
8.							
			Percentage of Sec. 2		Percentage of Sec. 3		Total 47,0 cm

U-Value: 0,154 W/(m²K)

Assembly No.	Building Assembly Description
2	Det 01b - Ground floor up granular expanded clay 75 cm

Heat Transfer Resistance [m²K/W] interior Rsi: 0,17 exterior Rse: 0,04

	Area Section 1	l [W/(mK)]	Area Section 2 (optional)	λ [W/(mK)]	Area Section 3 (optional)	λ [W/(mK)]	Total Width Thickness [mm]
1.	Ceramic stoneware tile:	1,200					15
2.	Gypsum fibre board	0,320					20
3.	Dry granular leveling :	0,090					20
4.	Wooden fibreboard insu:	0,038					120
5.	Radon and air-stop bar:	0,200					5
6.	Concrete slab	2,300					40
7.	Granular expanded clay	0,090					750
8.							
			Percentage of Sec. 2		Percentage of Sec. 3		Total 97,0 cm

U-Value: 0,083 W/(m²K)

Assembly No.	Building Assembly Description
8	Det 06 - Wooden roof

Heat Transfer Resistance [m²K/W] interior Rsi: 0,10 exterior Rse: 0,10

	Area Section 1	l [W/(mK)]	Area Section 2 (optional)	λ [W/(mK)]	Area Section 3 (optional)	λ [W/(mK)]	Total Width Thickness [mm]
1.	Plywood false cealing	0,130					20
2.	Air space	0,120	Stringhers 4x2 x Int	0,130			20
3.	Wooden fibreboard insu:	0,038					120
4.	Wooden fibreboard insu:	0,038			Rafter 12x18 x Int 80 c	0,130	180
5.	Wooden spruce boarding	0,130					20
6.	Air space	0,000					80
7.	Wooden spruce boarding	0,130					0
8.							
			Percentage of Sec. 2	3,0%	Percentage of Sec. 3	15,0%	Total 44,0 cm

U-Value: 0,132 W/(m²K)

Thermal U-value analysis by PHPP 2007 – Passive House Planning Package

Assembly No.	Building Assembly Description
4	Det 08 - Cross-laminated timber wall with insulation+plaster

Heat Transfer Resistance [m²K/W] interior Rsi : 0,13 exterior Rse : 0,04

	Area Section 1	λ [W/(mK)]	Area Section 2 (optional)	λ [W/(mK)]	Area Section 3 (optional)	λ [W/(mK)]	Total Width Thickness [mm]
1.	Cross-laminated timber	0,130					95
2.	Wooden fibreboard insu	0,038	Stringhers 7,5x12 x 1	0,130			120
3.	Wooden fibreboard insu	0,038					180
4.	Air space	0,000					100
5.	Wood paneling larch bo	0,130					0
6.							
7.							
8.							

Percentage of Sec. 2: 11,0% Percentage of Sec. 3: Total: 49,5 cm

U-Value: 0,120 W/(m²K)

Assembly No.	Building Assembly Description
11	Det 08b - Basement cross-laminated timber wall with insulation+plaster

Heat Transfer Resistance [m²K/W] interior Rsi : 0,13 exterior Rse : 0,04

	Area Section 1	λ [W/(mK)]	Area Section 2 (optional)	λ [W/(mK)]	Area Section 3 (optional)	λ [W/(mK)]	Total Width Thickness [mm]
1.	Cross-laminated timber	0,130					95
2.	Polystyrene insulation	0,036					100
3.	Polystyrene insulation	0,036	Stringhers 7,5x12 x 1	0,130			180
4.	Air space	0,000					100
5.	Wooden spruce boarding	0,130					0
6.							
7.							
8.							

Percentage of Sec. 2: 10,0% Percentage of Sec. 3: Total: 47,5 cm

U-Value: 0,127 W/(m²K)

Assembly No.	Building Assembly Description
5	Det 09 - Concrete insulated wall against ground

Heat Transfer Resistance [m²K/W] interior Rsi : 0,13 exterior Rse : 0,12

	Area Section 1	λ [W/(mK)]	Area Section 2 (optional)	λ [W/(mK)]	Area Section 3 (optional)	λ [W/(mK)]	Total Width Thickness [mm]
1.	Gypsum fibre board	0,320					15
2.	Wooden fibreboard insu	0,038	Stringhers 7,5x12 x 1	0,130			120
3.	Wooden fibreboard insu	0,043					60
4.	Cement-lime plaster	1,400					5
5.	Polystyrene insulation	0,035					100
6.							
7.							
8.							

Percentage of Sec. 2: 11,0% Percentage of Sec. 3: Total: 30,0 cm

U-Value: 0,139 W/(m²K)

Thermal U-value analysis by PHPP 2007 – Passive House Planning Package

Assembly No.	Building Assembly Description
6	Det 12 - Concrete insulated wall against cellar

Heat Transfer Resistance [m²K/W] interior Rsi: 0,13 exterior Rse: 0,12

	Area Section 1	λ [W/(mK)]	Area Section 2 (optional)	λ [W/(mK)]	Area Section 3 (optional)	λ [W/(mK)]	Total Width Thickness [mm]
1.	Reinforced concrete wa	2,300					150
2.	Wooden fibreboard insu	0,038	Stringhers 7,5x12 x 1	0,130			120
3.	Wooden fibreboard insu	0,043					60
4.							
5.							
6.							
7.							
8.							

Percentage of Sec. 2: 11,0% Percentage of Sec. 3: Total: 33,0 cm

U-Value: 0,231 W/(m²K)

Assembly No.	Building Assembly Description
10	Det 14 - Concrete exterior insulated wall

Heat Transfer Resistance [m²K/W] interior Rsi: 0,13 exterior Rse: 0,04

	Area Section 1	λ [W/(mK)]	Area Section 2 (optional)	λ [W/(mK)]	Area Section 3 (optional)	λ [W/(mK)]	Total Width Thickness [mm]
1.	Reinforced concrete wa	2,300					150
2.	Wooden fibreboard insu	0,038	Stringhers 7,5x12 x 1	0,130			120
3.	Wooden fibreboard insu	0,038					120
4.	Wooden fibreboard insu	0,043					60
5.							
6.							
7.							
8.							

Percentage of Sec. 2: 11,0% Percentage of Sec. 3: Total: 45,0 cm

U-Value: 0,134 W/(m²K)

Assembly No.	Building Assembly Description
9	Det 15b - Wooden insulated bathroom wall against cellar

Heat Transfer Resistance [m²K/W] interior Rsi: 0,13 exterior Rse: 0,04

	Area Section 1	λ [W/(mK)]	Area Section 2 (optional)	λ [W/(mK)]	Area Section 3 (optional)	λ [W/(mK)]	Total Width Thickness [mm]
1.	Cross-laminated timber	0,130					95
2.	Wooden fibreboard insu	0,038	Stringhers 7,5x12 x 1	0,130			120
3.	Wooden fibreboard insu	0,043					60
4.							
5.							
6.							
7.							
8.							

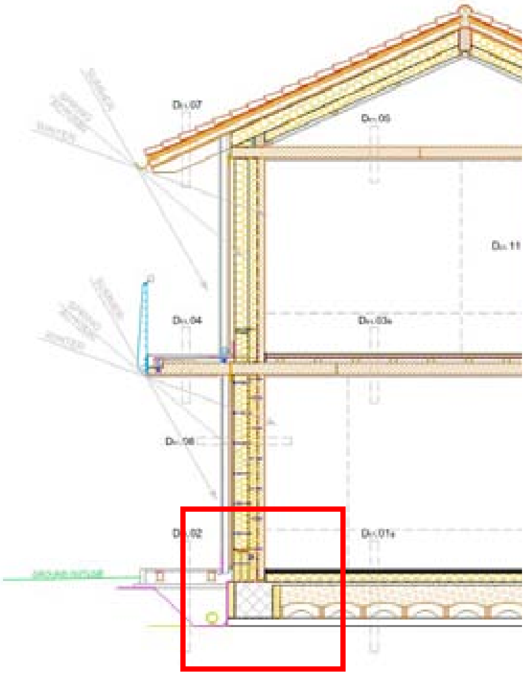
Percentage of Sec. 2: 11,0% Percentage of Sec. 3: Total: 27,5 cm

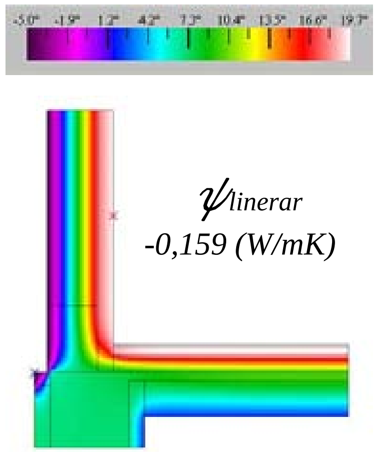
U-Value: 0,203 W/(m²K)

Thermal U-value analysis by PHPP 2007 – Passive House Planning Package

APPENDIX E – THERMAL BRIDGES CALCULATION

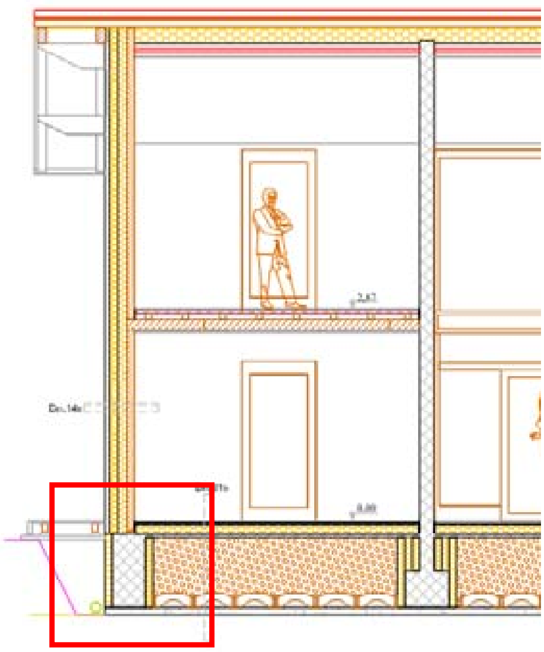
Concrete foundation 50cm – Wooden wall 10cm

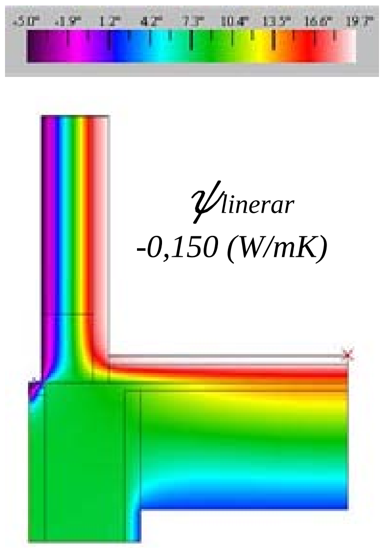




ψlinerar
-0,159 (W/mK)

Concrete foundation 100cm – Wooden wall 10cm

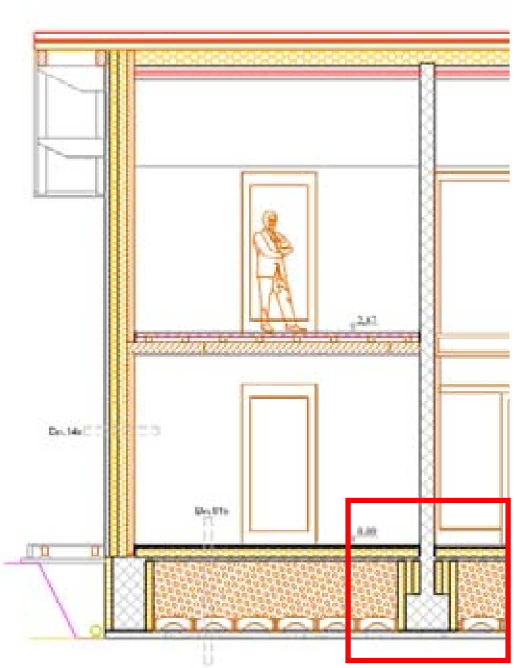




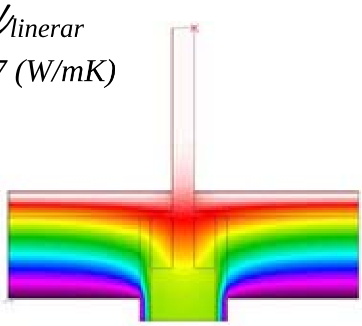
ψlinerar
-0,150 (W/mK)

Thermal bridge finite elements analysis with software THERM 5.0 – University of California

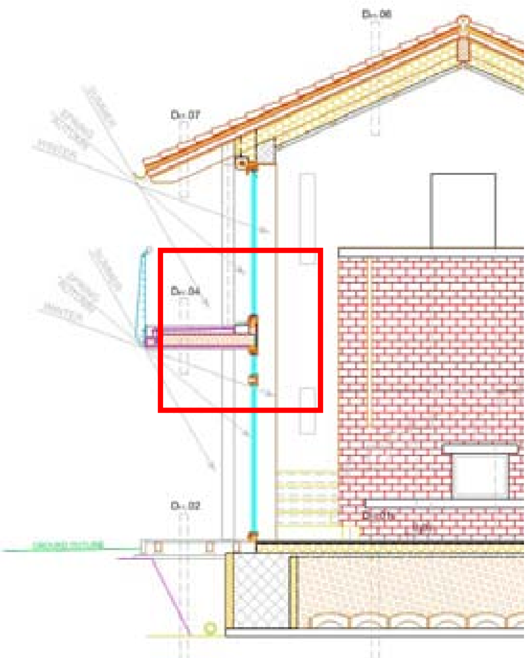
Concrete foundation 100cm – Concrete wall 20cm

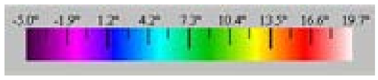


ψlinerar
0,067 (W/mK)

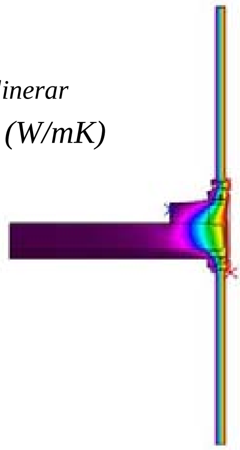


Wooden slab 15cm – Wooden passive window





ψlinerar
-0,343 (W/mK)



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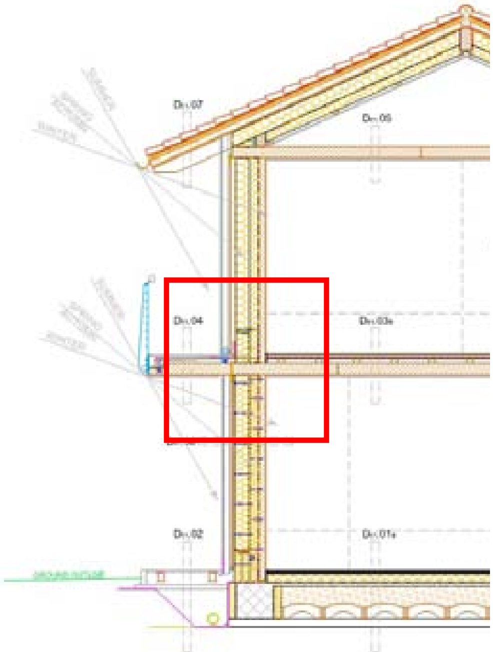
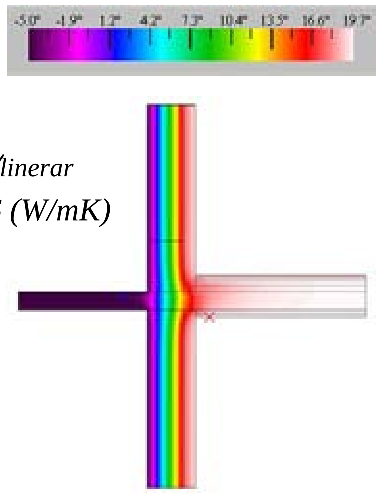
<u>Wooden slab 15cm – Wooden wall 10cm</u>

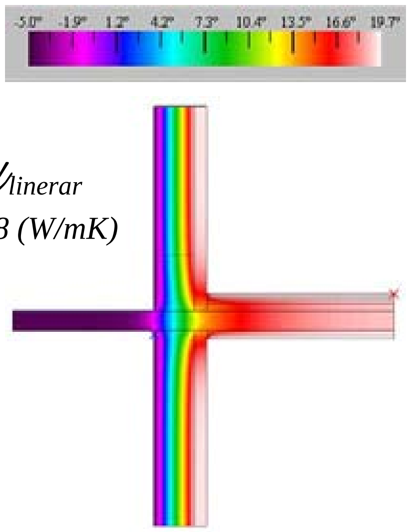




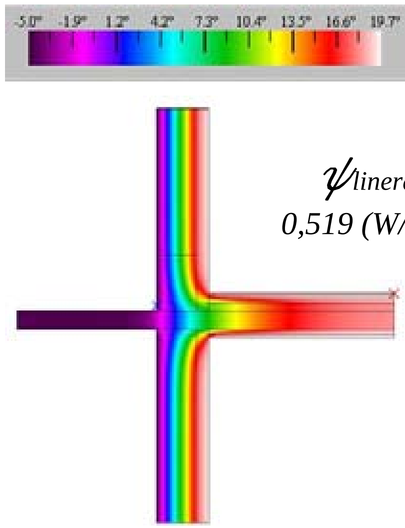
ψlinerar
-0,006 (W/mK)

Versus

<u>Concrete slab 15cm – Wood wall 10cm</u> *or* *<u>Concrete slab 15cm – Concrete wall 10cm</u>*



ψlinerar
0,338 (W/mK)



ψlinerar
0,519 (W/mK)

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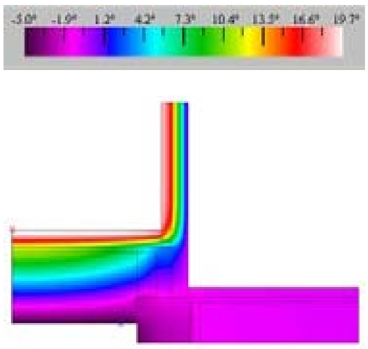
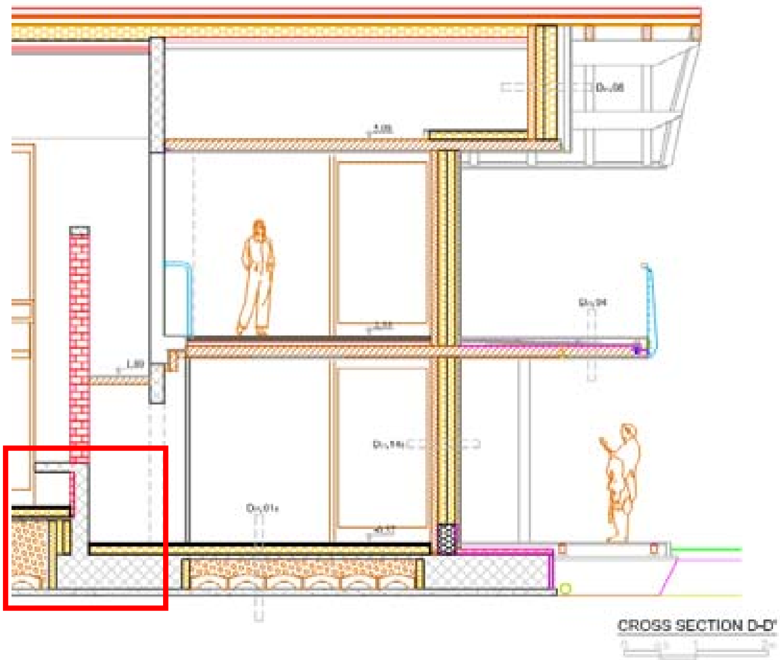
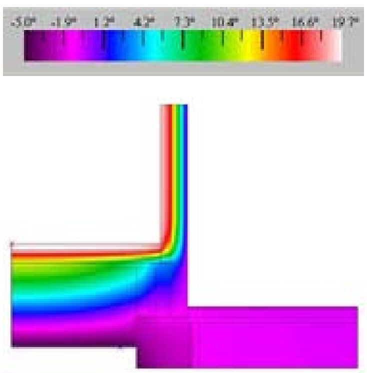
Concrete foundation 50cm – Brick wall 25cm



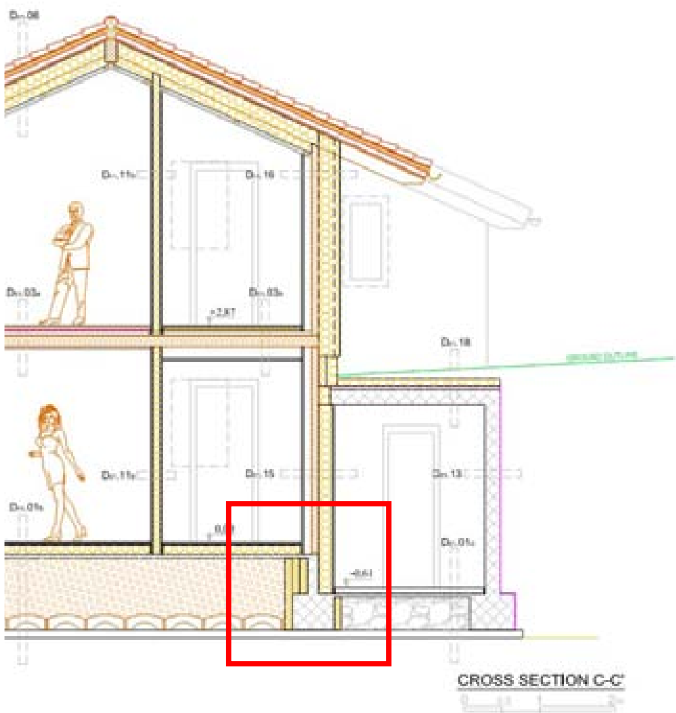
ψlinerar
-0,387 (W/mK)



Concrete foundation 50cm – Wooden wall 10cm



ψlinerar
-0,128 (W/mK)



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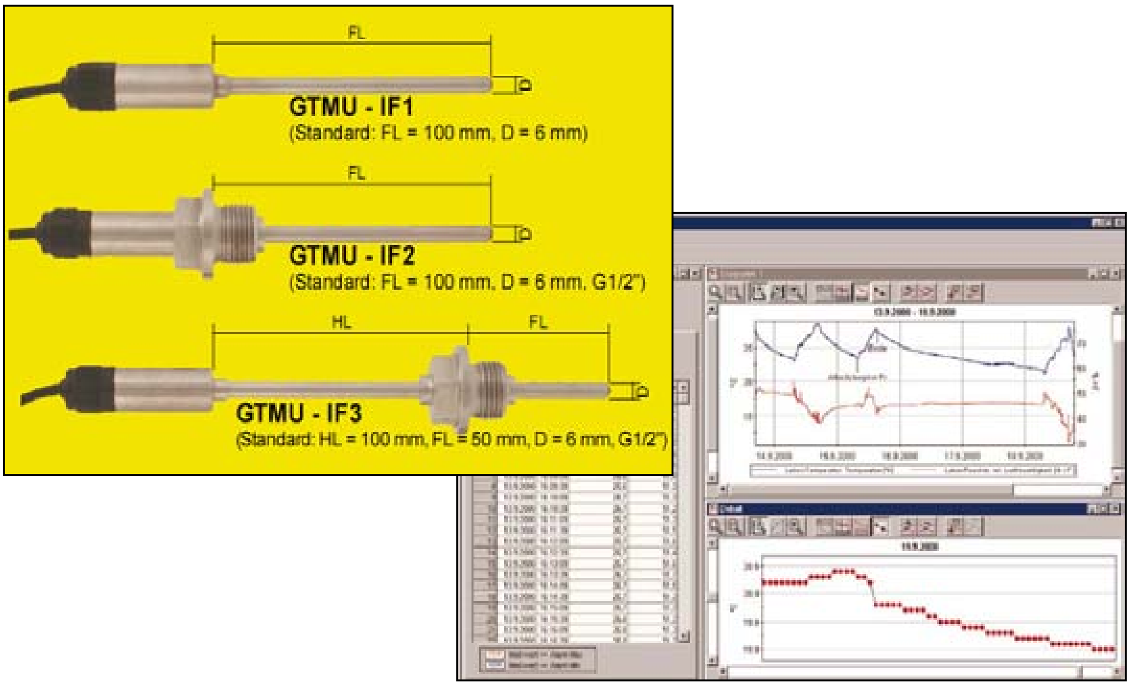
APPENDIX F – MONITORING SYSTEM FOR THE STUDY CASE



Product systems by Greisinger Electronic GmbH – Regenstauf (Germany)

Main organization by Gunter Gantioler-TBZ – Technisches Bauphysik Zentrum – Bolzano (Italy)