AAR4817 - Use and Operation of Zero Emission Buildings

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Passive house

Concept, good practices and lessons for Romania application

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SUMMARY

The report aims to investigate the Passive house concept and it’s application in Romania context.

The Kyoto Protocol and the Europe 2020 plan serve as a background for establishing targets for energy efficient buildings. Passive house has become the main expression of energy efficiency in temperate climates. Since their efficiency has been proven over the years, the paper will further focus on representative case study. Relevant case studies were chosen from similar climatic regions - looking at detached family houses that managed to comply with the technical requirements while presenting different architectural expressions. Beyond the technical facts, the houses were chosen for their strong and clear concept and architectural qualities they express.

It will further be shown what are the basic principles and how, by having the competence, the architects challenged the principles and wend beyond the image of the wooden “closed box” with small windows that is often visualised when mentioning a passive house. The forms and shapes go from one storey to two storeys, with flat or pitched roof; the orientation follows the south or west, glazing can adapt to follow the needs of daylight, view and solar gain, going to 7 m in height, can take the form of a clerestory window or roof window - all this while respecting the standard for comfort and energy parameters.

Having the competence and understanding the factors that influence the energy consumption, allows for a design to be free in expression as it will be shown in the report.

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1. INTRODUCTION

According to The European Directive 2010/31/EU on the energy performance of buildings, “Buildings account for 40% of total energy consumption in the Union. The sector is expanding, which is bound to increase its energy consumption. Therefor, reduction of energy consumption and the use of energy from renewable sources in the buildings sector constitute important measures needed to reduce the Union’s energy dependency and greenhouse gas emissions.”

As stated by Szokolay, Architecture is one of the professions that involve a considerable investment of resources, financial and material. Thus the professional responsibility it is oriented not only towards clients and society but also towards Sustainable development. (Szokolay,2004).

2. BACKGROUND

An important first step towards a truly global emission reduction regime that will stabilize GHG emissions is The Kyoto Protocol. The Kyoto Protocol, adopted in Kyoto, Japan, on 11 December 1997, is an international agreement linked to the United Nations Framework Convention on Climate Change, which commits its Parties by setting internationally binding emission reduction targets.

The Protocol shares the ultimate objective of the Convention - to stabilize atmospheric concentrations of GHGs at a level that will prevent dangerous interference with the climate system.

Following the protocol, the European Union set in 2010 a ten years old plan called "Europe 2020" which stipulates a reduction by 2020 of at least 20% overall greenhouse gas emissions, have at least 20% of energy from renewables and increase in energy efficiency of minimum 20%.

Due to the long life cycle of a building, this has an impact on long-term energy consumption. According to 2010/21/EU Directive, new and existing buildings that are subject to major renovation should meet minimum energy performance requirements adapted to the local climate.

Moreover, measures are needed to increase the number of buildings which go beyond current minimum energy performance requirements, towards nearly zero-energy buildings.(2010/21/EU),

EU MEMBER STATES AMBITIONS

The responsibility of states members, as stated in 2010/21/EU Directive, is to have minimum requirements for the energy performance of buildings, while achieving the cost-optimal balance of investment and energy cost saved through the lifecycle of the buildings.

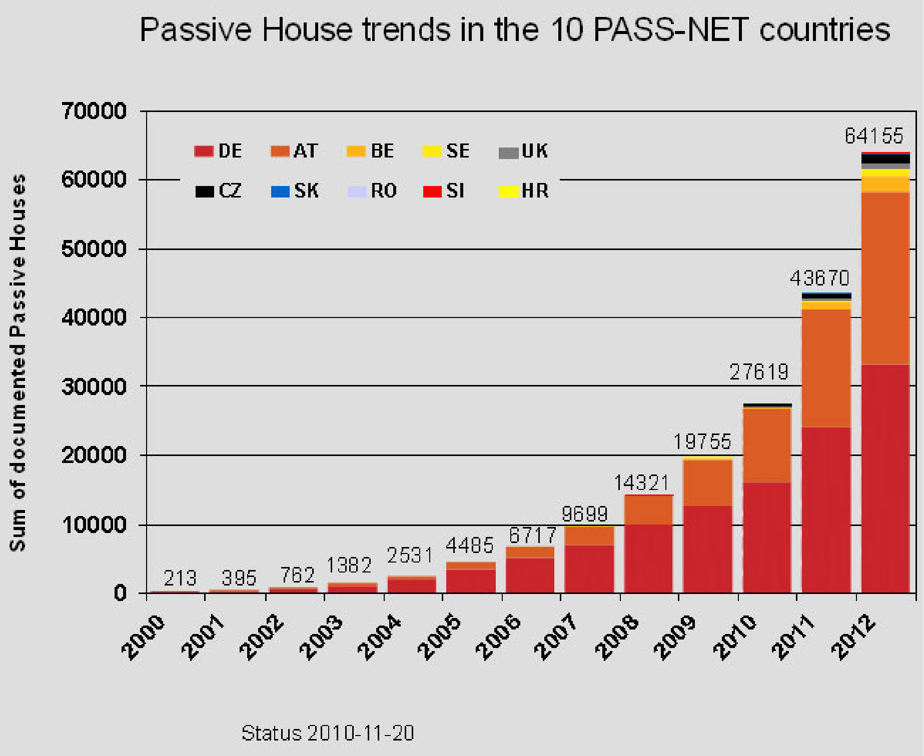
ROMANIA'S TARGET

On the 1st of January 2007 Romania adopted the appropriate measures for the transposition of the Energy Performance of Buildings Directive, through building codes with requirements for thermal performance indicators. There is no minimum Energy Performance requirement in terms of global indicator, neither for new buildings nor for renovations, except for residential buildings, where there is a maximum allowed head demand (per total heated volume), that varies between 15 kWH/m3.year to 37 kWH/m3.year, depending on the external area per volume ratio according to the report EPDB implementation in Romania at the end of 2012.

3. THEORY

In the research for a superior energy efficiency in buildings, Passive House Institute (PHI) and Dr. Wolfgang Feist played a very important role. From the first pilot project (Kranichstein Passive House, Darmstadt, Germany, 1990), the number of buildings grown exponentially.

According to Passive House Association, within the last several years, Passive House has gained rapidly in popularity, with over 50,000 residential and non-residential units in existence worldwide, and over 5,500 certified according to strict Passive House Institute certification criteria.



Passive House trends in the 10 PASS-NET countries

Status 2010-11-20

Fig.1 Passive house trends in Europe.

In the Press Release of PHI from 3 March 2014, a new category will be introduced, a concept to be presented at the 2014 International Passive House Conference.

"The efficiency of the clearly defined Passive House Standard has been proven with thousands of buildings – in order to also offer a reliable means of orientation regarding the additional use of renewables, the Passive House Institute now plans to introduce new categories. These will not only take energy demand into account, but also energy supply through, for example, solar panels. In this way, Passive House offers an attractive solution for the energy revolution while also serving as the basis for the "Nearly Zero Energy Building," mandatory for all new builds throughout the EU as of 2021."

4. RESEARCH QUESTION

Considering the progressive implementation of Passive house standard in Europe and around the world, it can be expected that Romania will follow this trend.

The research question will follow the WHY and IN WHICH WAY can we learn from previous similar experiences for having a competent response to a passive house in Romania.

5. METHOD

The method used in this research is case studies analysis. The four projects have been chosen from climates similar to Romania, are certified by PHI and have a clear concept.

As architecture being the "art and science of buildings" (Szokolay, vii), the study will follow the basic concepts around these case studies and what can be lessons learned for an architect that wants to implement the concept.

For each case study relevant technical data is presented as well as good design concepts.

The PHI through the internet platform passiv.de and PH Database passivhausprojekte.de offers updated and useful technical data. Also, the websites of the architecture offices as well as *Passive house* (Bere, 2013) also provided important information.

6. PASSIVE HOUSE REQUIREMENTS

According to the Passive House Institute, “for a building to be considered a Passive House, it must meet the following criteria:

1. The Space Heating Energy Demand is not to exceed 15 kWh per square meter of net living space (treated floor area) per year or 10 W per square meter peak demand.

2. The Primary Energy Demand, the total energy to be used for all domestic applications (heating, hot water and domestic electricity) must not exceed 120 kWh per square meter of treated floor area per year.

3. In terms of Airtightness, a maximum of 0.6 air changes per hour at 50 Pascals pressure (ACH50), as verified with an onsite pressure test (in both pressurized and depressurized states).

4. Thermal comfort must be met for all living areas during winter as well as in summer, with not more than 10 % of the hours in a given year over 25 °C.

Passive House buildings are planned, optimised and verified with the Passive House Planning Package (PHPP).

All of the above criteria are achieved through intelligent design and implementation of the 5 Passive House principles:

All opaque building components of the exterior envelope of the house must be very well-insulated. For most cool-temperate climates, this means a heat transfer coefficient (U-value) of 0.15 W/(m²K) at the most, i.e. a maximum of 0.15 watts per degree of temperature difference and per square metre of exterior surface are lost.

Passive House windows - The window frames must be well insulated and fitted with low-e glazing filled with argon or krypton to prevent heat transfer. For most cool-termperate climates, this means a U-value of 0.80 W/(m²K) or less, with g-values around 50% (g-value= total solar transmittance, proportion of the solar energy available for the room).

Ventilation heat recovery - Efficient heat recovery ventilation is key, allowing for a good indoor air quality and saving energy. In Passive House, at least 75% of the heat from the exhaust air is transferred to the fresh air again by means of a heat exchanger.

Airtightness of the building - Uncontrolled leakage through gaps must be smaller than 0.6 of the total house volume per hour during a pressure test at 50 Pascal (both pressurised and depressurised).

Absence of thermal bridges- All edges, corners, connections and penetrations must be planned and executed with great care, so that thermal bridges can be avoided. Thermal bridges which cannot be avoided must be minimised as far as possible."

For the accuracy of information, the entire section was replicated from the Passive House Institute official website.

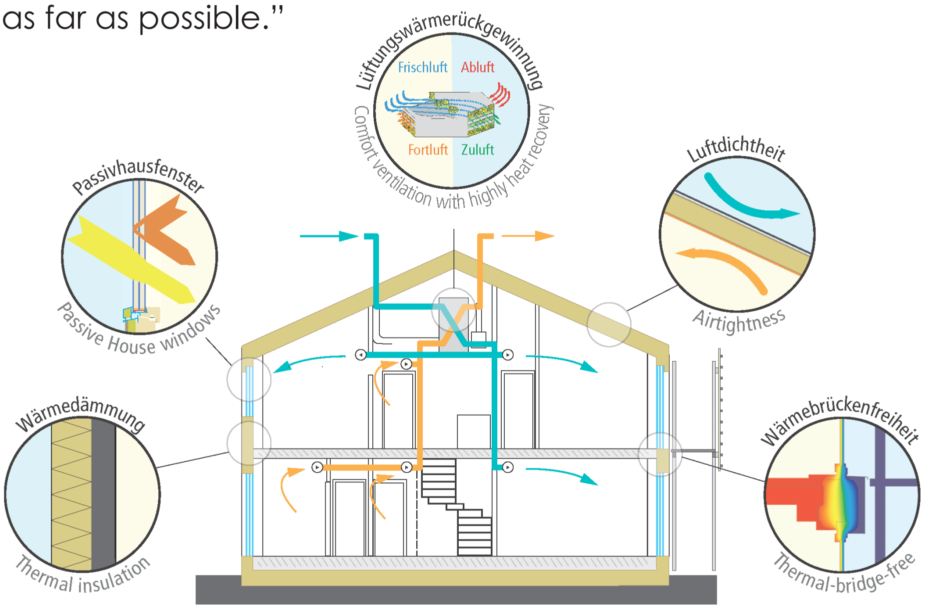


Fig.2 Basic principles that apply for the construction of Passive Houses.

7. CLIMATE IN ROMANIA

Because of its position on the southeastern portion of the European continent, Romania has a climate which ranges from temperate to continental.

Climatic conditions are modified by the country's varied topography, which goes from seaside to fields, plateau and mountains as to be seen in Annex 1 map.

According to Koeppen-Geiger climate classification, most regions have Dfb humid continental climate. Other areas have Cfa, Cfb Dfa influences.

CLIMATE REGIONS - GENERAL CONSIDERATIONS

Dfa, Dfb - humid continental climate, characterized by large seasonal temperature differences, with warm to hot (and often humid) summers and cold (sometimes severely cold) winters.

Cfb - oceanic climate (also known as marine) is the climate typical at the middle latitudes of most continents, and generally features warm (but not hot) summers and cool (but not cold) winters, with a relatively narrow annual temperature range.

Cfa - a humid subtropical climate is characterized by hot, humid summers and generally mild winters.

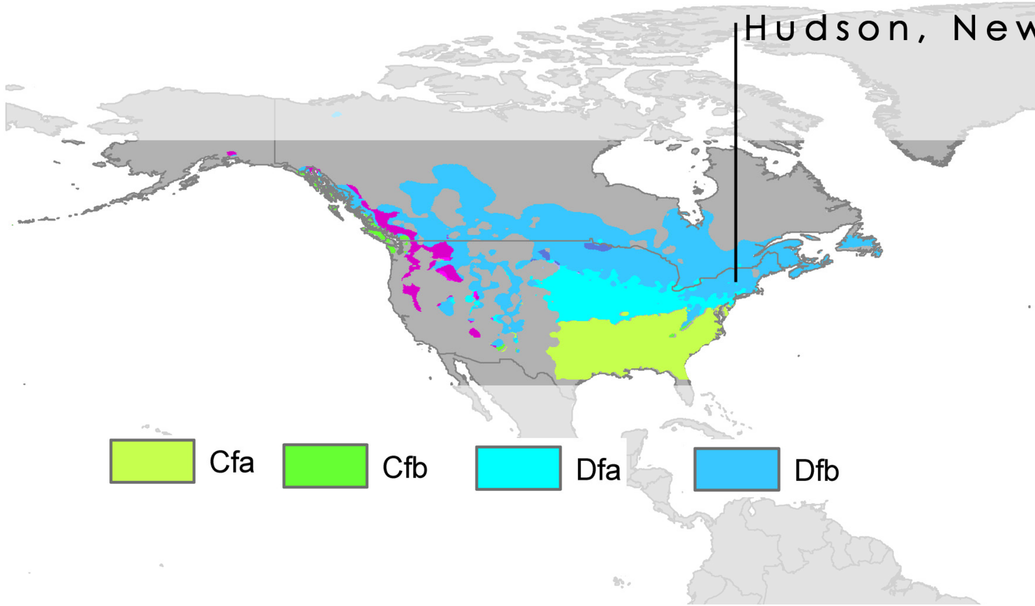


Fig.3 Köppen-Geiger climate classification -edited.

CHALLENGES

In appendix 1 are shown climate data extraction from Ecotect Weather tool. From there we can notice the seasonal variation between underheating and overheating, where none of the is severe but it makes more challenging the response to the seasonal behaviour of the buildings.

8. CASE STUDIES

The first criteria in choosing the case studies are the architectural qualities, the clarity of the concept and integration of strategies.

Secondly, all four of them are situated in regional climates that are present on the Romania's territory and had to response to similar challenges.

Thirdly, they are all certified as Passive house by Dr. Wolfgang Feist.

It is important to mention that the purpose is not to take the matching house from the similar climate but rather to learn the good principles of the case studies.

Technical data is taken from Passive House Database, Architecture office websites and *Passive House* (Bere, 2013).

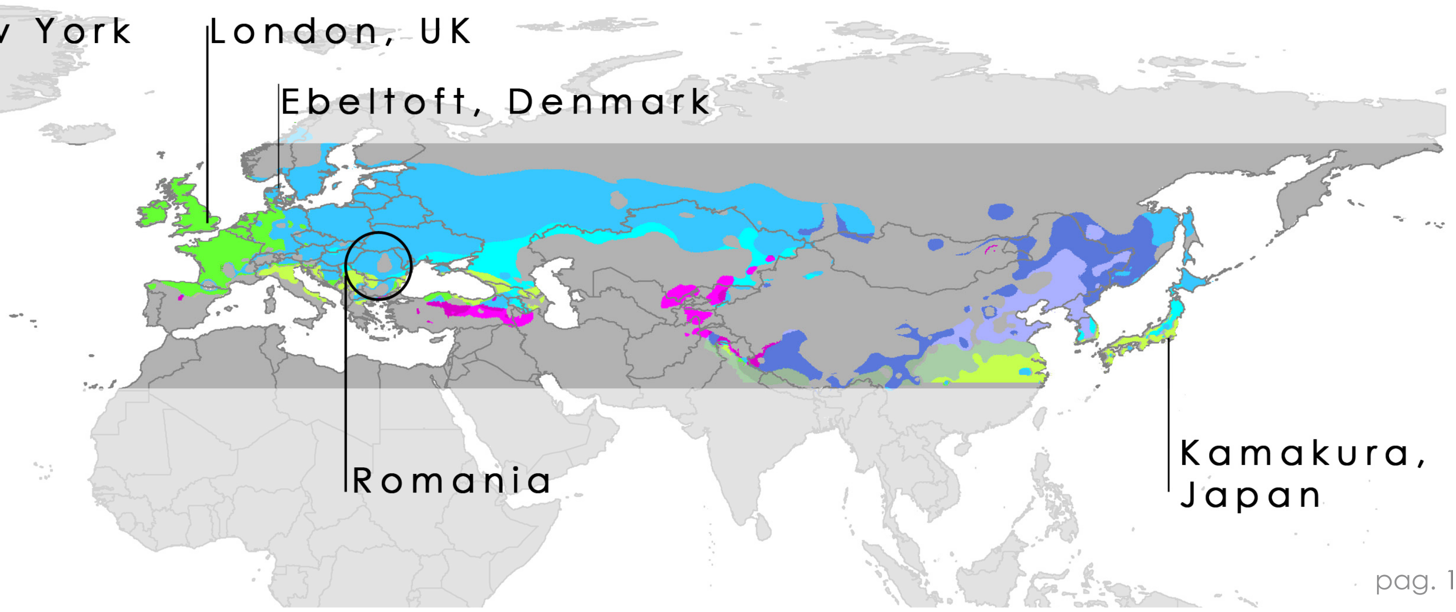
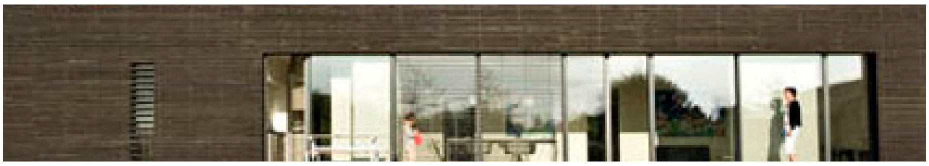


Fig.4 Villa Lagenkamp - West elevation



VILLA LANGENKAMP

Architecture: Olav Langenkamp, Architekt eth-maa

Location: Ebeltoft, Denmark.
Coordinates: 56.19° N, 10.67° E
Koeppen- Geiger climate classification: Dfb
Construction: 2008
Total area: 226 sqm
Gross area: 175 sqm (heated part)
Construction type: prefabricated timber construction
Hot water: provided by 8 sqm solar collectors on roof, backed by a heat pump.
Ventilation with air preheating in the ground.

First certified passive house in Denmark, the house has a rectangular compact geometry with two particularities:

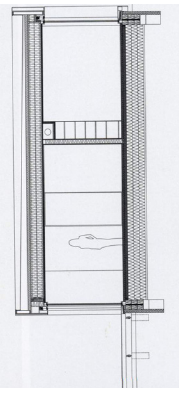
Firstly, despite the energy benefits of a compact form that usually translates in a two-storey house, all the functions of the house are integrated in one level.

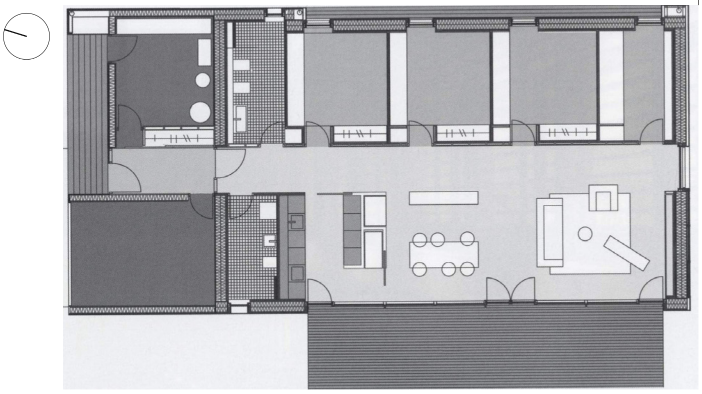
Secondly, the ideally orientation towards South (for a northern-hemisphere, to gain optimum benefit from the sun) was not chosen. Instead, the volume is oriented towards West to beneficiate from the best views.

On the south facade there is a red-coloured honeycomb-like pattern of card panels behind the wall of glass that allows the low winter sun to pass thought it and heat the interior, while the pattern provides shading from the high summer sun. The other glazing areas are shaded by retractable exterior blinds.

Fig.5 Villa Lagenkamp - Exterior perspective

Fig.6,7 Villa Lagenkamp - Cross Section and Plan.





Thermal envelope:

Component	Composition	U-value [W/m2K]
exterior wall	timber with insulation 356+60 mm	0.09
basement floor	Oak flooring and OSB, Insulation 60 mm, Concrete slab 100 mm, Polystyrene 600 mm	0.05
Roof	Roofing felt, Slope insulation, TJI construction with insulation 406 mm	0.05
Frame	fiberglass and wood	0.62
Glazing	triple glazing, g-value=51%	0.53

PHPP values:

Treated floor area according to PHPP: 147 sqm

Air tightness: n_{50}=0.6/h

Annual heating demand: 11 kWh /(m2a) acc. to PHPP

Heating load: 11 W/m2

Primary energy requirement: 105 kWh /(m2a) on heating installation, domestic hot water, household electricity and auxiliary electricity calculated acc. to PHPP.

Fig.8 Villa Lagenkamp - Interior image

HUDSON HOUSE

Architecture:
BarlisWedlick Arch.

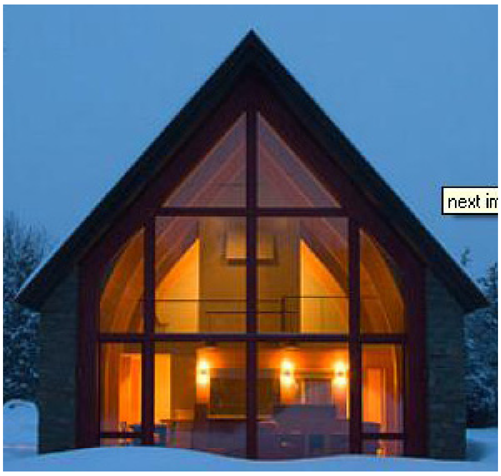


Fig.9 Hudson House - South elevation.

Location:
Hudson, New York
Coordinates:
42.22° N, 73.73° W
Koeppen- Geiger climate classification: Dfb
Construction: 2010
Total area: 150 sqm
Construction type: glulam timber construction
Hot water: electric tankless water heater
Ventilation with heat recovery unit and a summer bypass where the heat transfer is temporarily deactivated in warm months.
Heating installation: Heat pump system (air/air) with electric baseboard as backup system.

First certified passive house in New York, the house find inspiration in the historic rural structures in the area.

The project began as a research project to achieve highest energy conservation without the use of alternative energy technologies. It is now a demonstration house as well as a speculative development project.

The compact two storeys house has the glazing area oriented towards South. It's particularity is the orientation with the short side towards South, the pitched roof with a roof window and the 7m high living room as well as the large glass surface at the end of it that provides free solar gain during winter.

Fig.10 Hudson House - Exterior view.

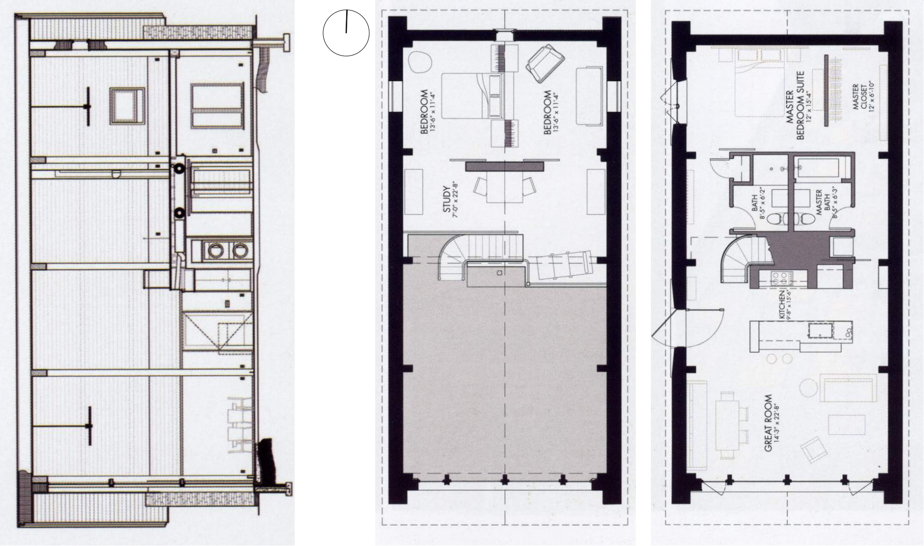


Fig.11,12,13 Hudson House - Longitudinal Section, First floor plan, Ground floor plan.

Thermal envelope:

Component	Composition	U-value [W/m2K]
exterior wall	Glulam support, beams Standard insulated panels 289 mm with stone veneer/wood	0.116
basement floor	Concrete slab EPS/XPS 305 mm under slab	0.094
Roof	Glulam support, beamsand Standard insulated panels EPS 289 mm	0.106
Frame	fiberglass roof windows- wood with Al	1.17
Glazing	suspended coated film glass roof window-triple glazed, low-e coating, g value=51%	1.02

PHPP values:

Treated floor area according to PHPP: 146 sqm

Air tightness: n_{50}=0.2/h

Annual heating demand: 12 kWh /(m2a) acc. to PHPP

Heating load: 14 W/m2

Primary energy requirement: 109 kWh /(m2a) on heating installation, domestic hot water, household electricity and auxiliary electricity calculated acc. to PHPP.

Fig.14 Hudson House - Interior view.

Fig.15 Kamakura House - South elevation.

KAMAKURA HOUSE

Architecture:
Key Architects

Location:
Kamakura, Japan
Coordinates:
35.31° N, 139.55° E

Koeppen- Geiger climate classification: Cfa
Construction: 2009
Construction type: timber construction
Hot water: heatpump
Ventilation with heat recovery and by-pass mode for summer operation.
Heating installation: Heat pump air-conditioner for heating/coolong/dehumidification.

The house is the first certified Passive House in Japan; the primary challenge was to assure comfort in a warm and humid summer climate where energy needed for dehumidification is as high as that required for cooling. It also had to be strong enough to resist earthquakes and termites.

The concept is deliberately simple - a two storey family unit on a small plot. Since the area is small for a family of four, the functions are carefully placed. The windows are placed to benefit from the views while keeping a good ratio of glass area. To overcome the lack of space in the garden, an exterior stair leads to the roof and gives the family an area of private open space and viewing platform to overlook the city.

Fig.16, 17, 18 Kamakura House - Exterior views.

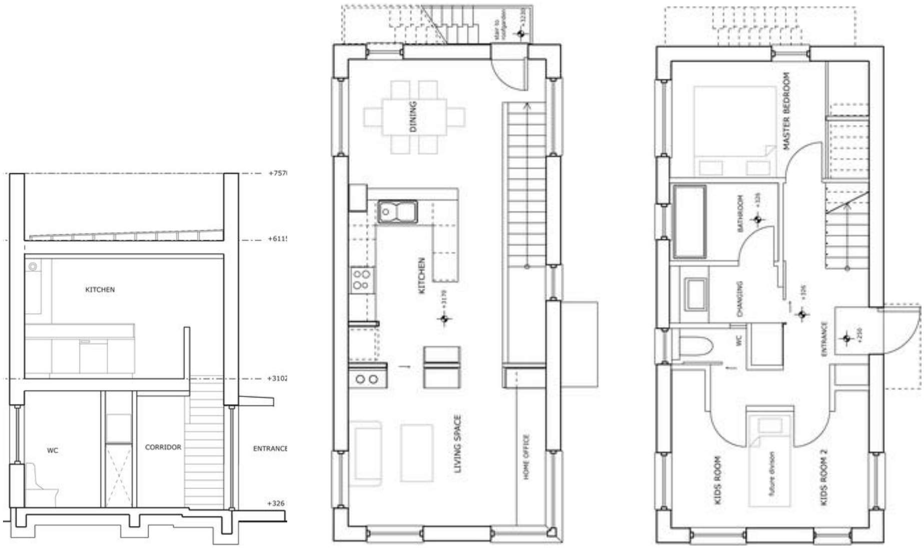


Fig.19 Kamakura House - Cross Section, First floor plan, Ground floor plan.

Thermal envelope:

Component	Composition	U-value [W/m2K]
exterior wall	15 mm plasterboard + 24 mm service cavity +140 mm wood fibre insulation within timber stud +13 mm wood board +12 mm wood board +100 mm wood fibre insulation + 11 mm rain screen, Cedar panel	0.16
basement floor	11 mm wood floor finish +165 mm reinforced concrete floor + 55 mm XPS insulation	0.217
Roof	15 mm plasterboard and render finish + 100 mm service cavity+ 286 mm wood fibre insulation within roof beam + 37 mm wood board+ 75 mm wood fibre insulation+ metal roofing system timber deck	0.101
Frame	wood-aluminium composit window, partly fixed glazing	1.71
Glazing	triple argon double low-e, g value=51%	0.64

PHPP values:

Treated floor area according to PHPP: 78 sqm

Air tightness: n_{50}=0.14/h

Annual heating demand: 15 kWh /(m2a) acc. to PHPP

Heating load: 18 W/m2

Primary energy requirement: 113 kWh /(m2a) on heating installation, domestic hot water, household electricity and auxiliary electricity calculated acc. to PHPP.

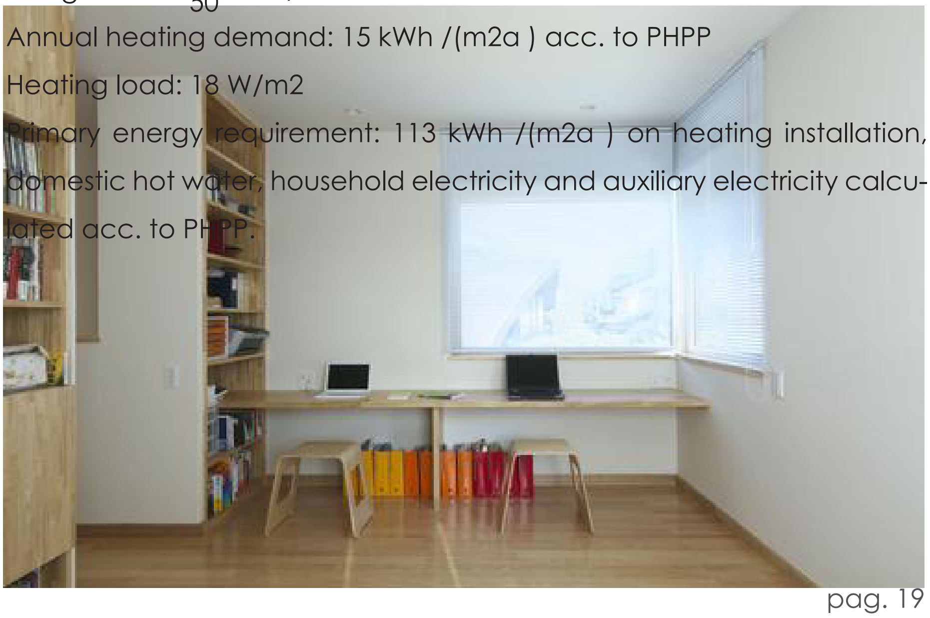


Fig.20 Kamakura House - Interior view.

CAMDEN HOUSE

Fig.21 Camden House - South elevation.

Architecture:
bere:architects

Location:
London, UK
Coordinates:
51.51° N, 0.13° W

Koeppen- Geiger climate classification: Cfb
Construction: 2010
Construction type: timber construction
Hot water: boiler with solar panels and 300 litre solar store.
Ventilation with heater battery and post heater.
Heating installation: Condensing gas boiler and air heating with towel rail backup.

The house is London's first certified Passive House. The client wanted to build a healthy "eco-house" for his daughter who suffers from asthma.

The design follows the narrow site, with a compact shape and ample glazing areas on the south facade. External retractable metal louvre blinds protect from the summer sun while assuring privacy. Clerestory windows bring south light into the back of the large room.

Ecological aspects: the superstructure is built with timber that has no chemical treatment, healthy air and water quality is prioritised by using non-toxic materials, rainwater is used for WCs, the use of solar thermal and green roof.

Fig.22 Camden House - Exterior view.

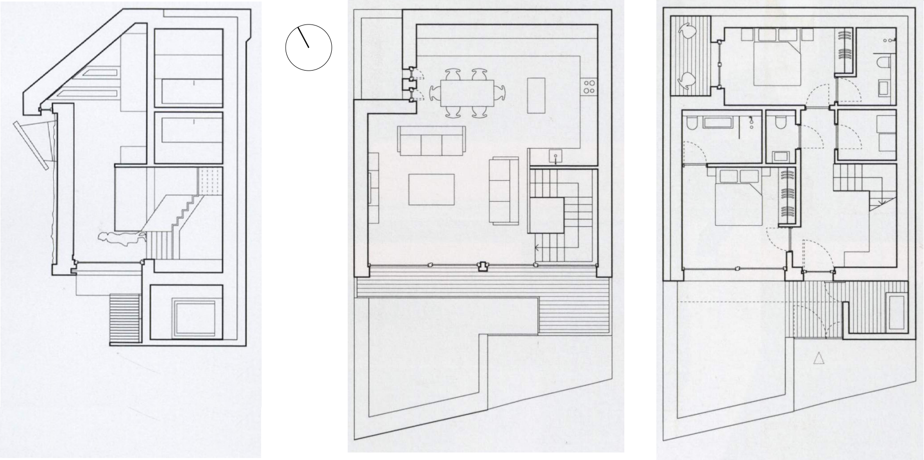


Fig.23,24,25 Camden House -
Longitudinal Section,
First floor plan,
Ground floor plan.

Thermal envelope:

Component	Composition	U-value [W/m2K]
exterior wall	15mm Plasterboard +100mm Insulation between studs +13mm OSB + 280mm Insulation between studs+ 13mm Fermacell + larch rainscreen	0.116
basement floor	32mm Floor finish (timber)+100mm Insulation between joists +140mm Insulation + 140mm Insulation + 20mm void+ 65mm screed + 300mm Conc slab	0.112
Roof	140mm solid timber deck + 280mm of insulation +120mm of Rockwool flexi + 25mm drainage layer + 80mm of earth	0.076
Frame	wood PU composite	0.76
Glazing	triple glazing, g value=48%	0.6

PHPP values:

Treated floor area according to PHPP: 102 sqm

Air tightness: n_{50}=0.44/h

Annual heating demand: 13 kWh /(m2a) acc. to PHPP

Primary energy requirement: 90 kWh /(m2a) on heating installation, domestic hot water, household electricity and auxiliary electricity calculated acc. to PHPP.

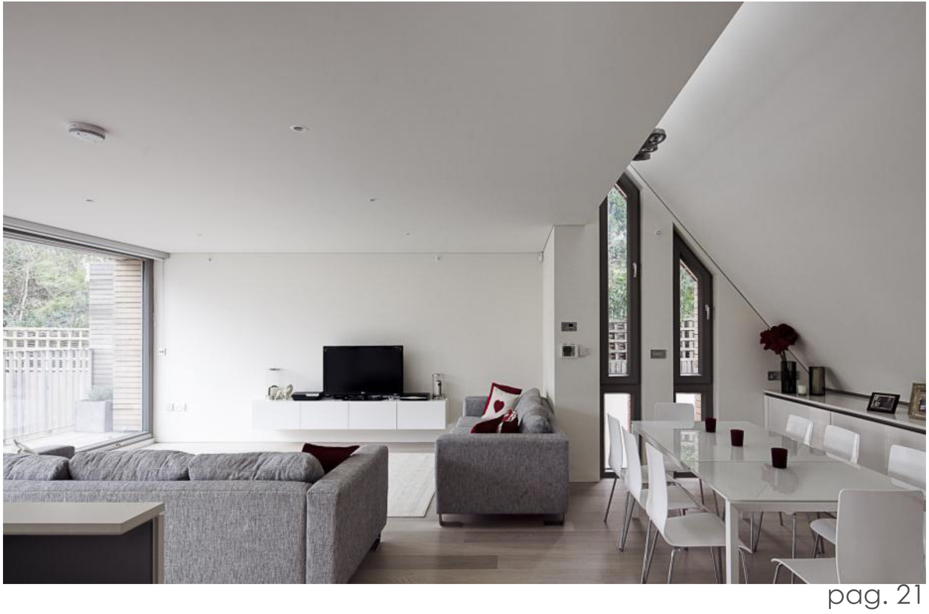


Fig.26 Camden House - Interior view.

9. DISCUSSION

The aim of this study was to provide an answer on why and in which way the design process has to change in Romania, to take into consideration lowering energy consumption.

Looking at the international and European context and understanding the implications of our design helps is a step further in building in a Sustainable manner.

The method used was case study analysis as a benchmark study is one of the first steps in a new design approach. The focus was on the response given by the Passive House concept for the program of a detached single family house looking on case studies that faced similar climatic conditions and have proven their efficiency for the past years.

The chosen case studies have started the path towards energy efficient houses in their countries, that means also a great responsibility and a long and detailed design process. They can provide useful information in the process of a passive house design in Romania.

All of them comply with the Passive house requirements; beyond that, the architectural expression varies to respond to particularities implied by each project.

Following there are some of the findings of these cases:

ORIENTATION

The best orientation is the one facing south, having also the largest glazed area. However, in Ebletoft house the orientation was given by the best view, in this case the west one.

FORM

A compact form is the most efficient in terms of energy balance which translates into a two storey building, as seen in the case studies in London, Kamakura and Hudson. However, the last one adapted the concept to the regional character and has a pitched roof. The Ebeltoft house is also challenging this by having a single floor.

MATERIALS

All the case studies use timber construction; wood is also used for exterior finishes which gives a common element of passive houses.

INTERIOR

Hudson house challenges the concept of the room height, which has to have an optimal value for energy efficiency. With the 7m high living room, it offers good architectural qualities of the space. White surfaces are preferred for light reflectance. Near south glazing, concrete floor is used as a thermal mass storage.

GLAZING

South orientated windows are preferred for the high solar gain in the winter and lower during the summer. In Kamakura house, assuring optimal daylight for each room was a priority while in Ebeltoft the best view shifted the large glazing area towards west. London house uses clerestory windows to bring the south light further into the volume. In Hudson house roof windows were also used.

SOLAR SHADING

Windows shading is essential during the warm months and is considered in the case studies design as exterior louvres. There is no information about this in the Hudson house and will create problems since the 7m height window is facing direct south; the large overhang and the vegetation present near the house will reduce the direct solar radiation of the height summer sun.

AIR QUALITY

The use of building physics allows for solution that keep the envelope dry which doesn't require chemical substance use for wood. As seen in the London house, the harmful substance concentration can be considerable reduced by using materials with low VOC substances, also measured by tests.

ACCESSIBILITY

Ebeltoft house has the merit of resolving all the functions in one level and proves that the Passive House standard can be achieved also with a single floor.

USE OF RENEWABLES

Both Ebeltoft house and London house use solar collectors for hot water demands.

Future development of the Passive house certification will include also the energy supply, going one step closer to Near Zero Energy Buildings.

OTHER STRATEGIES

The main passive strategy used is solar gain. Ebeltoft house uses a honey comb wall towards south to capture solar heat, the Hudson house uses the large glazing to heat the concrete floor. The London house is using the rainwater for WCs and has a green roof.

RELATION INTERIOR-EXTERIOR

Due to relatively strict sealing concept of a PH, the relation with the exterior of the house is almost missing, as seen in the case studies. There is a clear delimitation of the controlled space and the outside, and no in-between spaces, winter gardens or other buffer spaces are present. This is a negative aspect as they are beneficial for the environmental behaviour of the building as well as for the residents.

Looking at Romania, one of the first steps would be taking advantage of the potential regarding the renewable energy and passive strategies.

As seen in Appendix 1, Romania has a diverse landform and good potential in renewable energies.

In the Appendix 2 are presented the results of the climatic data files using Weather Tool from Ecotect. For Romania two climate regions are represented by the capital, Bucharest and Cluj-Napoca. The medium monthly temperature range goes from -5°C to 30°C in Bucharest and from -5°C to 30°C in Cluj Napoca.

As seen in the Annexes, the Psychrometric chart for Romania's cities show a big potential for using passive strategies in reaching comfort for half of the year.

Nevertheless, in order to properly design a passive house in Romania, the full context should be considered. In addition to climatic analysis, the regional character as well as local materials and living style should be studied.

For a house in Bucharest, where in most cases the land is not allowing a garden and the air is polluted, keeping a healthy indoor climate is essential.

On the opposite, the rural areas benefits from large gardens and from spring to autumn the boundaries between interior and exterior are blurred, the living space expanding to beneficiate from the optimal climate conditions and be closer to the nature.

Further work would be focused on finding a way to take advantage of this passive strategies while considering the seasonal behaviour when designing. It is in Romanian character to live with nature and in order to have a good response, the passive house concept should develop to respond to this behaviour.

10. CONCLUSION

The present work analyses the concept of a passive house and the international and local context that establishes the frame for its application in Romania.

It presents some of the best examples of Passive Houses in climates with seasonal variations, with design facing similar challenges as a passive house in Romania would have to respond to.

The conclusion is that Passive house does not translate into a single rigid design. Beyond the technical requirements and concepts like compact design, south face orientation, glazing predominant on the south facade - the case studies show a great variety of architectural expressions and spaces that can serve as an inspiration.

The architect has a major role in the success of a passive house since it has not only to comply with the numerical values but to offer a good response to the site and the owners needs. Only by having the competence in this domain the response can be a valid one.

Romania has a big potential in renewable energies and with proper measures can soon follow the trend of energy efficiency in buildings. Applying the concept of a passsive house will help Romania to comply with the target of reducing its CO_2 emissions while lowering the energy cost and give a comfortable home for it’s inhabitants.

The purpose of the report was not to establish the Passive house as being the best solution but rather to investigate what can be learned from the existing PH and in which direction should the concept develop more to be fully adapted to Romania’s context.

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Image sources:

Fig. 1 - [*Graph Passive House trends in the 10 PASS-NET countries]* nd [image online]. Available at <http://www.pass-net.net/situation/index.html> [Accesed at 7 May 2014].

Fig. 2 - [*Basic principles that apply for the construction of Passive Houses]* nd [image online]. Available at < http://passiv.de/en/02_informations/02_passive-house-requirements/02_passive-house-requirements.htm>. [Accesed at 7 May 2014].

Fig. 3 - *[Updated world map of the Köppen-Geiger climate classification] nd [image online]. Available at < http://en.wikipedia.org/wiki/File:Koppen_World_Map_(retouched_version).png>.* [Accesed at 7 May 2014].

Fig. 4-8 - Lagencamp Arch. *nd [image online]* Available at <http://www.langenkamp.dk Projects/?nav=p&pid=4&page=0>. [Accesed at

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Fig. 9- 14 - The Hudson Passive House project. *nd [image online]* Available at < http://hudsonpassiveproject.com/images.html>. [Accesed at 7 May 2014].

Fig. 15- 20 - Key Architects. *nd [image online]* Available at < http://www.key-architects.com/english/project/kamakura/>. [Accesed at 7 May 2014].

Fig. 21-26 - bere:architects. *nd [image online]* Available at < http://www.bere.co.uk/projects/camden-passivhaus/ranulf%20road>. [Accesed at 7 May 2014].

Appendix 1:

Fig. 27 - *[Romania geophysical map]* nd [image online]. Available at < http://www.hartaromaniei.co/harta-romaniei/>. [Accesed 17 May2014].

Fig. 28 - *[Renewable pottential in Romania]* nd [image online]. Available at < http://www.sunshinesolarenergy.com/romania_solar_potential.php>. [Accesed 17 May2014].

Fig. 29 - *[Romania solar Irradiation Map]* nd [image online]. Available at < http://www.sunshinesolarenergy.com/romania_solar_potential.php>. [Accesed 17 May2014].

Appendix 2:
Climatic data extraction using Weather Tool from Ecotect. Data from U.S. Department of Energy , *Weather Data. Available at < http://apps1.eere.energy.gov/buildings/energyplus/weatherdata_about.cfm?CFID*

=1130360&CFTOKEN=d150384de308d010-3E6CCB49-B7CE-E895-3A23A1F5F176A925&jsessionid=E31CA383B32D19EFB5D71FDB2F5229C0.eere>. [Accesed 17 May2014].

ANNEX 1

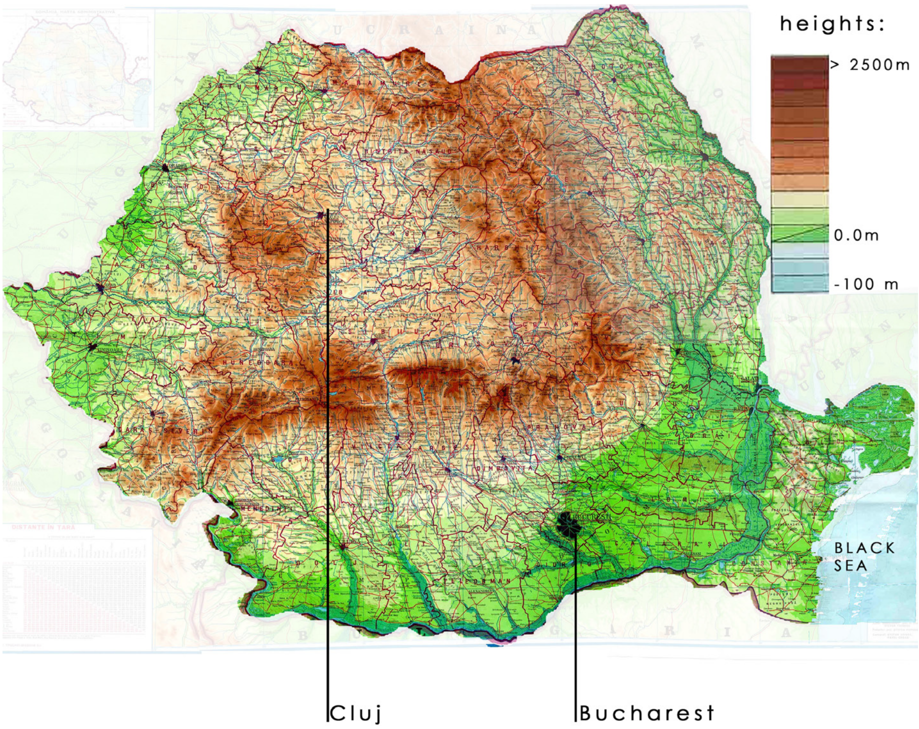


Fig.27 Geophysical map of Romania. Edited.

Fig.28 Renewable potential in Romania.

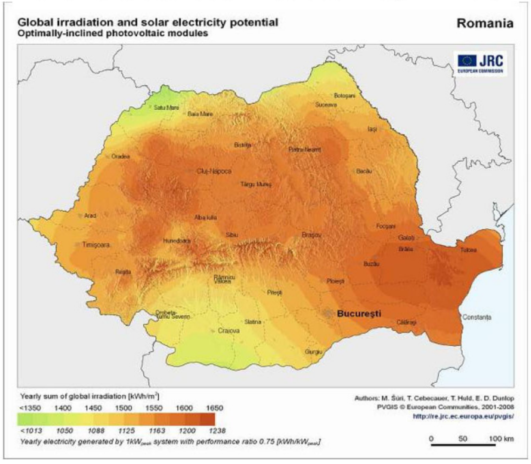
Renewable potential in Romania

Renewable focus

I. **Danubio area** – Solar
II. **Dobrogea** – Wind and Solar
III. **Moldova** – Micro Hydro, Wind, Biomass
IV. **Carpati** – Micro Hydro, Biomass
V. **Transilvania** – Micro Hydro
VI. **West Campia** – Geothermal
VII. **Subcarpati** – Solar, Biomass, Micro Hydro
VIII. **South Campia** – Biomass, Solar, Geothermal

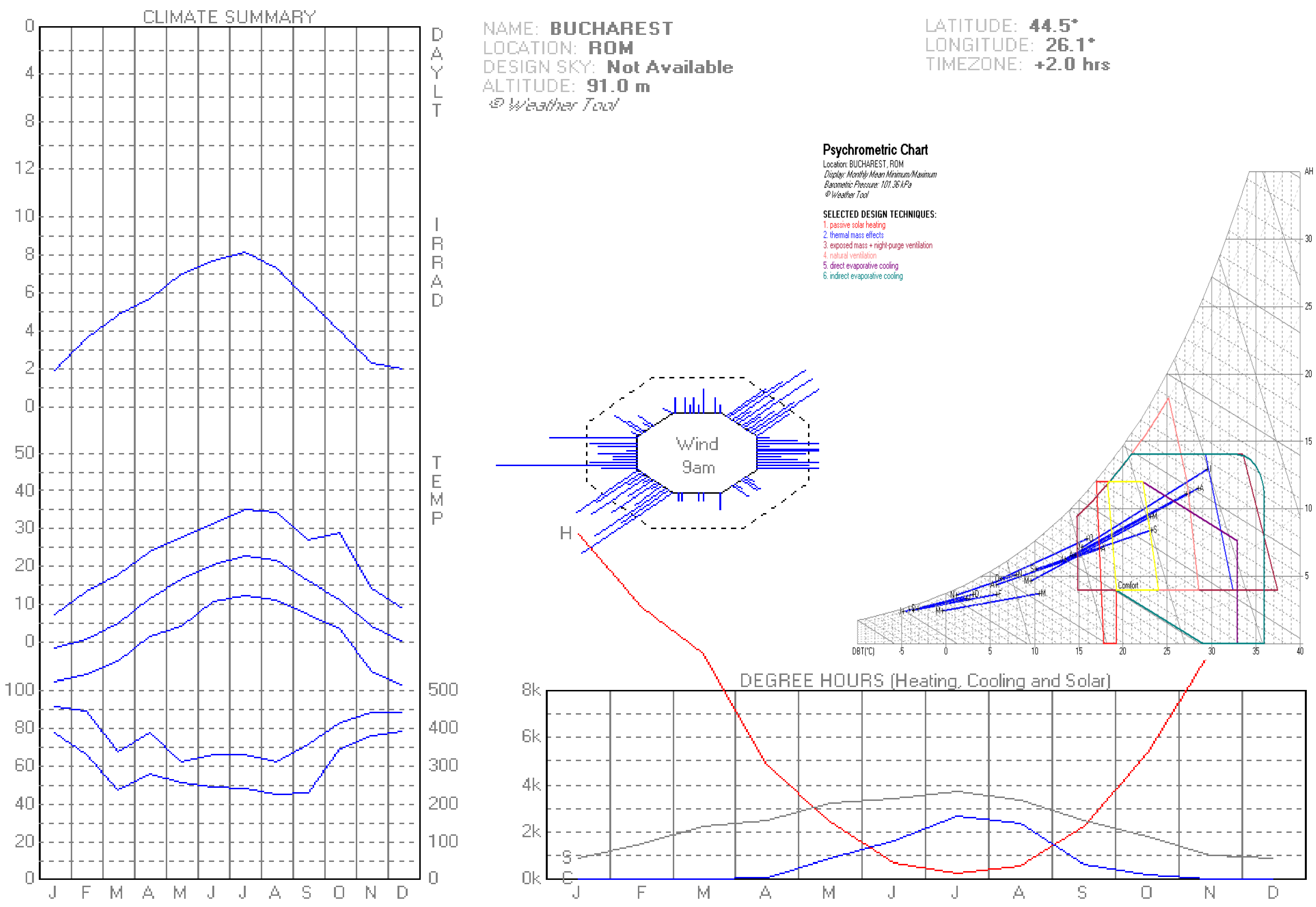
Fig.29 Romania Global Solar Irradiation Map.

Romania Global Solar Irradiation Map – PV GIS



- **Best locations** in terms of **solar irradiation** are in **South-East area**
- Peaks in **Dobrogea region** with **1650 kWh/m2** global irradiation
- **Bucarest** area (more than **1500 kWh/m2**) is also one of the **most promising** also thanks to a better developed **electricity infrastructure**

ANNEX 2

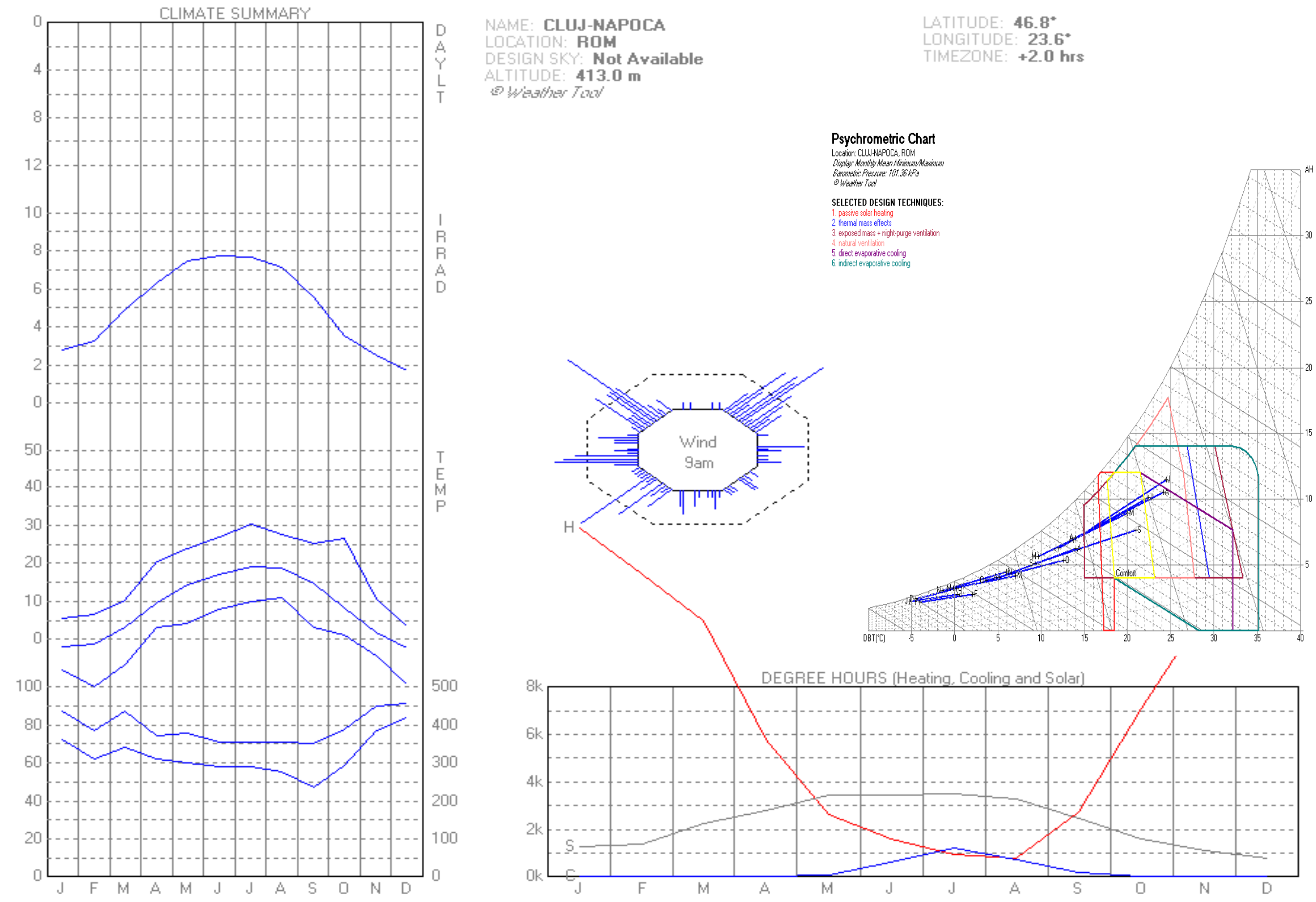


NAME: **BUCHAREST**
LOCATION: **ROM**
DESIGN SKY: **Not Available**
ALTITUDE: **91.0 m**
© Weather Tool

LATITUDE: **44.5°**
LONGITUDE: **26.1°**
TIMEZONE: **+2.0 hrs**

Psychrometric Chart
Location: BUCHAREST, ROM
Display: Monthly Mean Minimum/Maximum
Barometric Pressure: 101.36 kPa
© Weather Tool

SELECTED DESIGN TECHNIQUES:
1. passive solar heating
2. thermal mass effects
3. exposed mass + night-purge ventilation
4. natural ventilation
5. direct evaporative cooling
6. indirect evaporative cooling

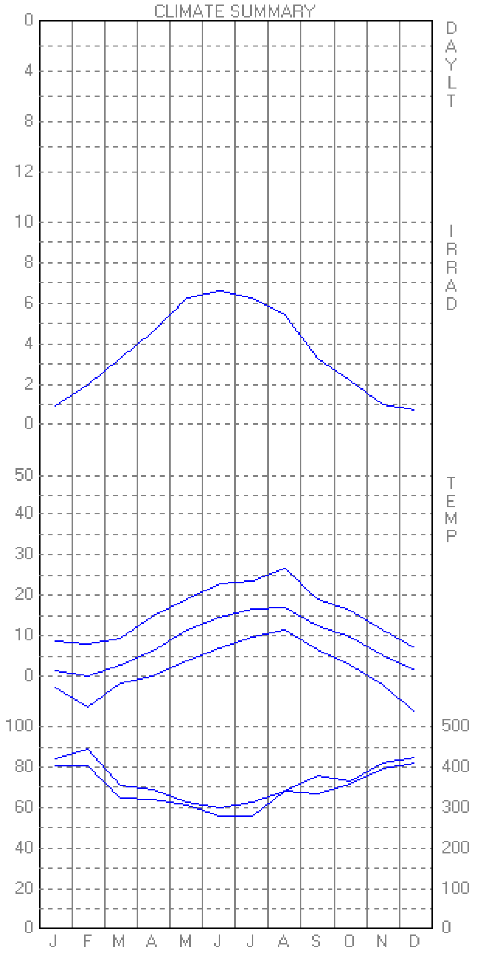


NAME: **CLUJ-NAPOCA**
LOCATION: **ROM**
DESIGN SKY: **Not Available**
ALTITUDE: **413.0 m**
© Weather Tool

LATITUDE: **46.8°**
LONGITUDE: **23.6°**
TIMEZONE: **+2.0 hrs**

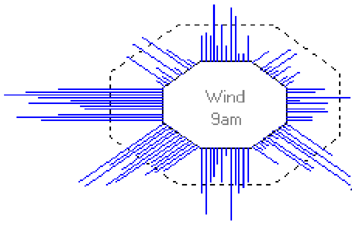
Psychrometric Chart
Location: CLUJ-NAPOCA, ROM
Display: Monthly Mean Minimum/Maximum
Barometric Pressure: 101.36 kPa
© Weather Tool

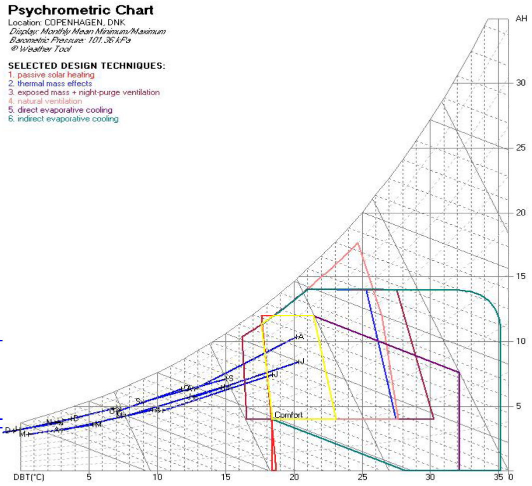
SELECTED DESIGN TECHNIQUES:
1. passive solar heating
2. thermal mass effects
3. exposed mass + night-purge ventilation
4. natural ventilation
5. direct evaporative cooling
6. indirect evaporative cooling

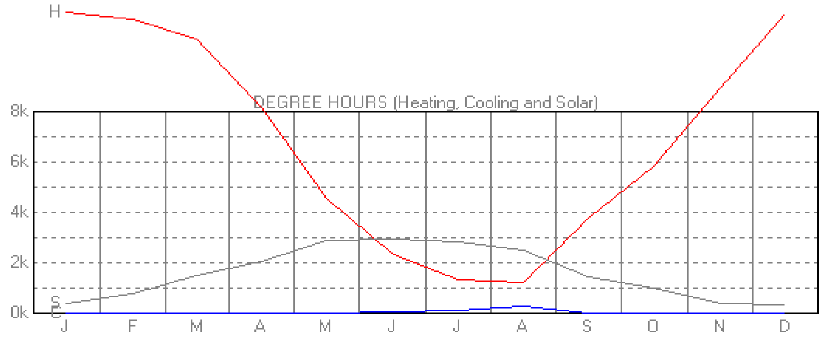


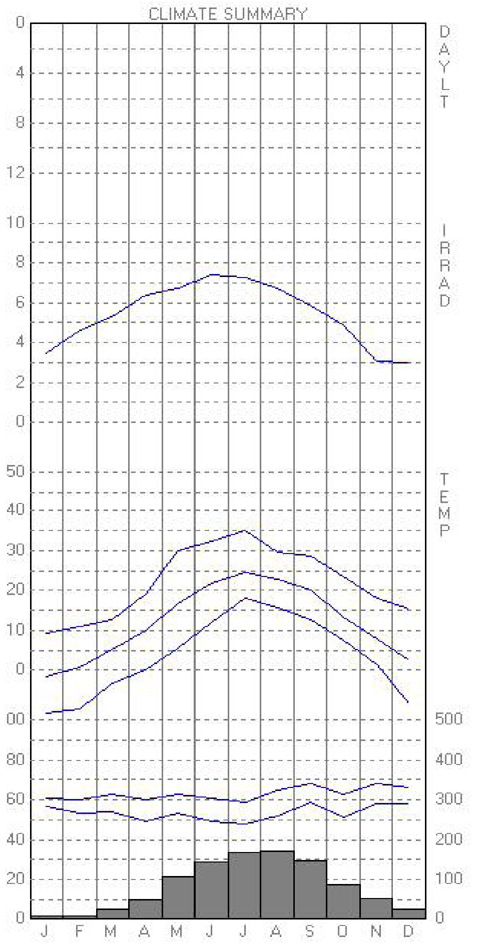
NAME: **COPENHAGEN**
LOCATION: **DNK**
DESIGN SKY: **Not Available**
ALTITUDE: **5.0 m**
© Weather Tool

LATITUDE: **55.6°**
LONGITUDE: **12.7°**
TIMEZONE: **+1.0 hrs**



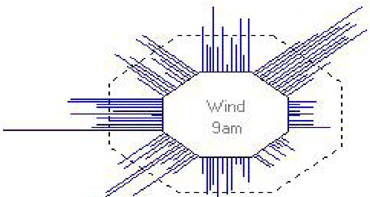


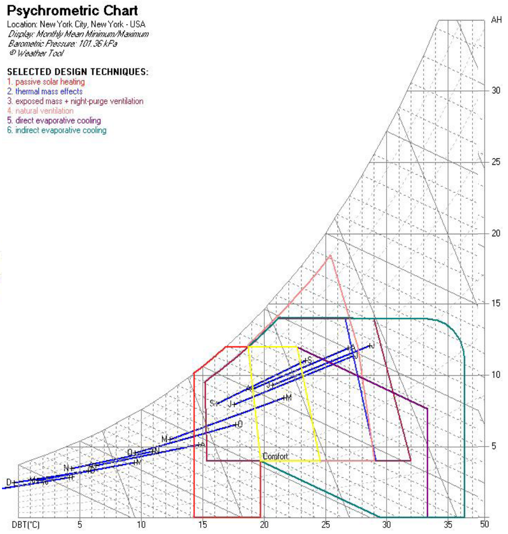


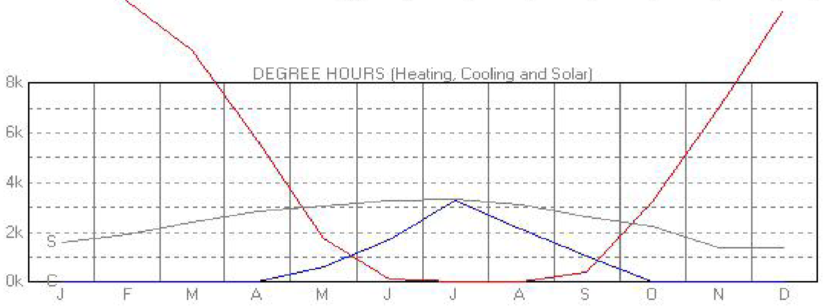


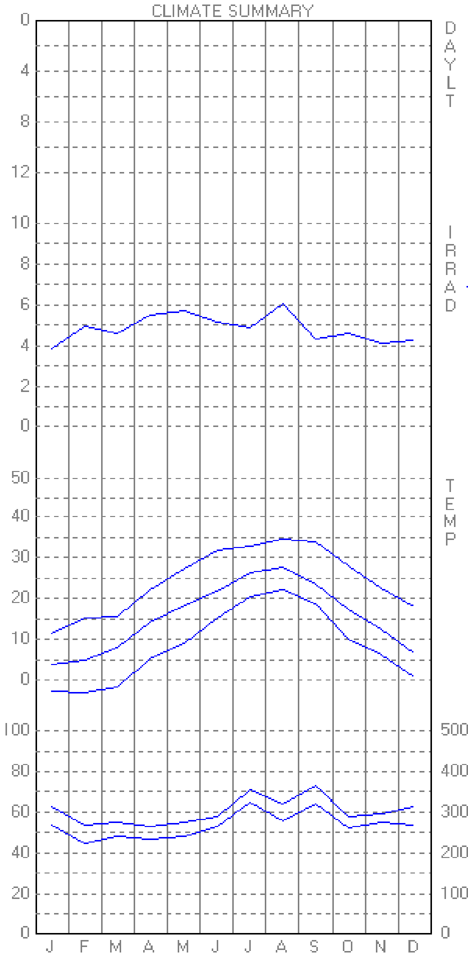
NAME: **New York City**
LOCATION: **New York - USA**
DESIGN SKY: **Not Available**
ALTITUDE: **57.0 m**
© Weather Tool

LATITUDE: **40.7°**
LONGITUDE: **-73.9°**
TIMEZONE: **-5.0 hrs**



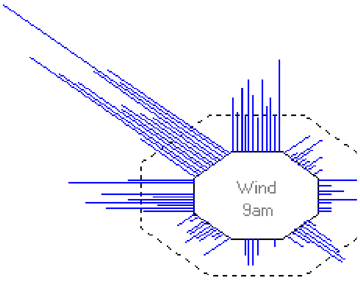


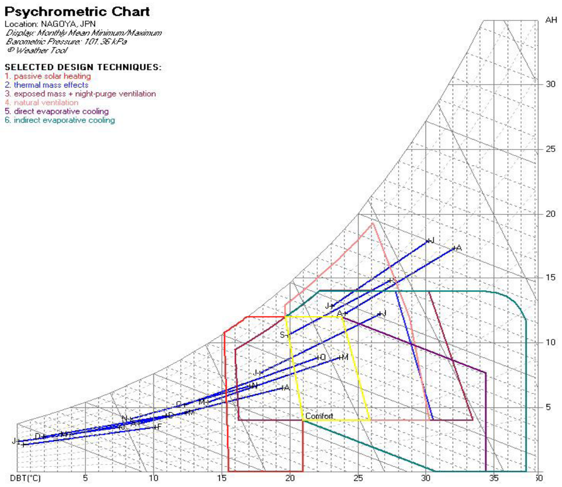


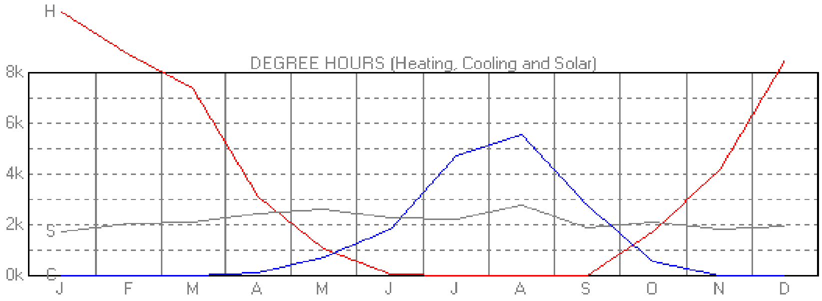


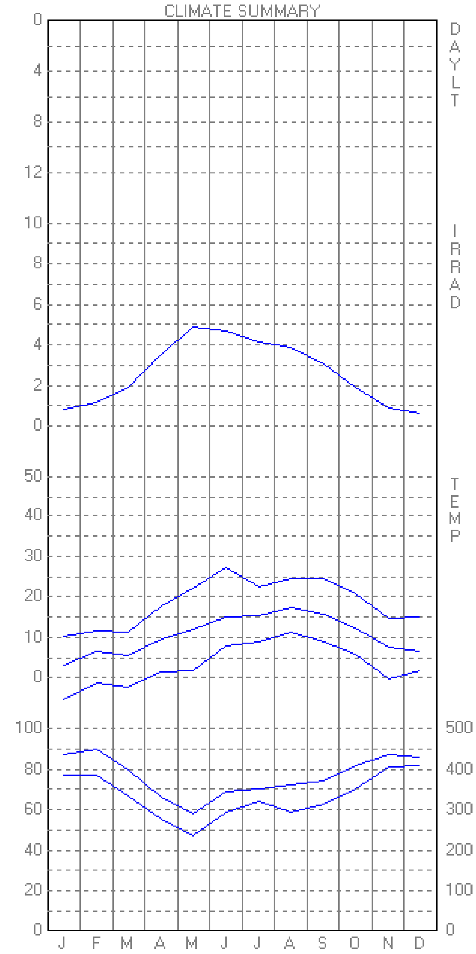
NAME: **NAGOYA**
LOCATION: **JPN**
DESIGN SKY: **Not Available**
ALTITUDE: **17.0 m**
© Weather Tool

LATITUDE: **35.2°**
LONGITUDE: **136.9°**
TIMEZONE: **+9.0 hrs**









NAME: **Heathrow**
LOCATION: **England - UK**
DESIGN SKY: **Not Available**
ALTITUDE: **12.8 m**
© Weather Tool

LATITUDE: **51.4°**
LONGITUDE: **-0.8°**
TIMEZONE: **-0.0 hrs**