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Active to be passive

A reasoned development of the Passivhaus standard for two different climates.

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Abstract— **In the era of "everything at once" the main objective seems to look for a standard, an adaptable prototype compliant with requirements on each situation. The architectural designing process has been affected by this phenomenon too, with the purpose of reaching the new european guidelines of high energy-efficient buildings, reducing energetic consumption and CO2 emissions and not taking into account the most important guideline ever: the environmental context.**

With this background, where even nature is under these rules, architects and designers should try to deconstruct the concept of standard itself, finding different solutions considering both the energetic and environmental issue, for specific locations. In order to fulfill this objective, the ancient teachings about solar energy and orientation have become the first steps to follow in the design process of a sustainable building.[1]

The aim of this study is to plan a scholastic building that respects EU limits in two different European countries, Italy and Germany, that present distinct climate conditions, history, formal solutions and aesthetic values, and to show how to compare its design if envisioned in the south of Italy or in Germany, both complying with the same energetic standard.

Passivhaus, the German voluntary energetic protocol chosen, is characterized by strict requirements, achieved through a reasoned diversification in technological solutions, materials and plant design, all declined to the needs of the location where it is applied.
This way, it is possible to develop further guidelines, within the standard, which make "creative" and suitable to every climate the entire process.
Starting from considerations about orientation and shape, following Vitruvio's statements, the building envelope becomes then the complex multi-functional filter between internal and external environment, and responds to structural and performance targets but also to energy efficiency.

This way, the Passivhaus building, wherever conceived, is developed as a "producer" of energy and not just as a "consumer" anymore, in order to be active in the leading process to sustainability.

Keywords—*Passivhaus, nZEB, sustainability, buildings, Mediterranean climate*

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I. Introduction

During the time of energetic and sources crisis, building construction is one of the most influential sectors: it is responsible, in fact, for 40% of total consumption of final energy and for 36% of CO_2 emissions in the European Union (from the US Department of Energy, "Annual Energy Review", 2006).
Sustainable development is "development that meets the needs of the present without compromising the ability of future generations to meet their own needs"[2] (WCED 1987).
A sustainable building satisfies performance and functional needs, thanks to the minimal environmental negative effect. This approach promotes economic, social and cultural improvement.
The need for change is necessary and configured as a duty to fulfill; it is an effective solution in the fight for the reduction of energy costs.
This is the priority objective of the European Union (EU).
With this background the following paper shows how to apply these concepts to architecture also through a German energy protocol, and how to adapt it to a different climate such as the Mediterranean.
Indeed, nowadays the topic has not been studied and applied enough: only few private buildings' owners invested into the realization of their *passivhauser*, while the public sector is still not ready to experiment. The methodology used provides two different results of the same building, comparing step by step the different solutions adopted and the output of the official energy certification software PHPP.

II. Legislative framework

In the last decade, European Community has produced a legislative framework in order to promote sustainability in the building sector, including the energy certification of buildings in order to reduce by 20% the annual energy consumption before 2020. European policy makers introduced goals for the year 2020 after the Kyoto Protocol. The 2020 energy goals are: 20% (or even 30%) reduction in CO2 emissions compared to 1990 levels; 20% of the energy, on the basis of consumption, coming from renewables; 20% increase in energy efficiency.
In chronological order, the main directives declared since 2002 are:

- 2002/91/EC Directive
- 2010/31/EU Directive
- 2012/27/EU Directive

Among them, 2010/31/EU Directive plays a leading role; it introduces for the first time the concept of nZEB, nearly Zero Energy Building, which refers to high energy-efficient buildings characterized by energy consumption and CO_2 emissions close to zero.

According to this request, numerous volunteer protocols were developed, including the Passivhaus standard, an example of excellence and "certified" success not only in Germany but also in the rest of Europe.

III. The standard Passivhaus

The standard Passivhaus was born in 1991 in Germanys from an idea of Wolfgang Feist and Bo Adamson.

Thousands of buildings were built according to this protocol since then; all of them have shown how the identified principles and methodology are effective.

Passivhaus deals with the evaluation of the conditions that reduce the energy consumption but especially takes care of the users' comfort.

A series of technical requirements must be necessarily verified to consider a building a Passivhaus: they express scientifically the indoor well-being.

The three fundamental principles of Passivhaus are:

• specific heating demand lower than 15 kWh/m^2yr;
• airtightness lower than 0,60 ac/h (n50, i.e. at outside pressure of 50 Pa);
• primary energy demand lower than 120 kWh/m^2yr.

These requirements can only be achieved by implementing a set of passive thermal control systems known as the "5 points" of Passivhaus:

- thermal insulation of all external components;
- thermal bridges free design;
- Passivhaus windows;
- high air tightness;
- mechanichal ventilation systems with heat recovery.

The tightness and insulation of building envelope are the fundamental requirements of a Passivhaus because, combined together, they allow to minimize energy losses to the outside; the general values of opaque elements transmittance are between 0,10 and 0,15 W/m^2K.

An interesting aspect of this standard is that there are no limits in the choice of the architectural type: it is possible to build a Passivhaus in any material, according to different needs and traditions, complying with thermal limitations.

The standard Passivhaus, therefore, can be considererd a viable perspective in the building sector since it combines comfort, ecology and architectural tradition.

IV. The implementation of the Standard: a reasoned development

The objective of "energy efficiency" especially affects public buildings: the Directive 2010/31 / EU, in fact, requires all the newly constructed public buildings to be nZEB since 31 December 2018.

For this reason, the European Union itself has provided regional funds.

In order to offer an effective response to the call of sustainability, this study faces the topic of a *Passivhaus* public building such as the elementary school, envisioned in two different climates: the German temperate climate and the Mediterranean south-Italian one.

After establishing a common starting point for both of them, the idea meets the standard and its requirements.

The Passivhaus bases its principles on the respect for the site and its climatic conditions, in order to derive as much benefits as possible for the building and its occupants.

This bioclimatic behaviour can be induced and created in the building through a series of design features and through the use of appropriate planimetric and formal configurations.

The shape and orientation of the building are absolutely necessary to be considered as priorities.

This paper shows how a scholastic building, designed from the same initial concept, changes according to the climatic needs to reach the same standard, the *Passivhaus*. Each case study underlines the main characteristics of the building about shape, envelope and systems developed in order to highlight the main differences between Continental climate and Mediterranean one.

> This reasoned development finds its origin in the traditional designing process: the study of materials, architectural technologies, typological forms of environmental context is the best guideline for the designer to draw a proper design, comparing tradition and innovation.

Case study 1: Dresden, Germany

- The shape and the orientation of functions

The thermal exchange between inside and outside takes place through the building envelope. This means that an energy efficient building should have a compact form in order to reduce the exchange area.

The compactness is expressed by the ratio of surface to volume (S/V); for *Passivhaus* building 0,6 m^{-1} is an optimal value.

In *Passivhaus* buildings, but generally in the buildings that follow the principles of bioclimatic architecture, functions are placed according to the time of stay: the functions that need more light during the day are south oriented, while services and technical areas are preferably north oriented, acting as a buffer space towards the cold side of the building.[3]

Figure 1 The school building in Dresden: compactness and high glass surface

- The building envelope

A well-designed building envelope is fundamental to achieve the requirements of the Standard Passivhaus.

Both the opaque components and the transparent ones have to satisfy technological functions (mainly high insulation requirements) and the respect of the following limits:

- Unitary thermal transmittance for walls, floors and roofs ≤ 0.15 W/m²K
- Unitary thermal transmittance for global window (frame+glass) ≤ 0.80 W/m²K

About the transparent elements, they must be certified by Passivhaus Institut.

A huge layer of insulation is the thing in common to all the opaque components: it is never less than 20 cm and reaches the highest value of 40 cm in the external walls (three layers: internal thermal coating, external thermal coating and in-between layer that englobes the pillars in order to avoid the problem of thermal bridges).

Wooden fiber is the main insulation because it has a series of advantages:

- suitable both for walls and roofs;
- permeable to air;
- good thermal and acoustic insulation;
- sustainability of the material.

In the first walking floor the problem of rising damp through the concrete slab has been solved with a sub-fundation made out of XPS insulation, highly resistant to compression and waterproof.

After the design process, it is necessary to verify that the building envelope is free of thermal bridges.

The most critical thermal bridges must have a value of the linear thermal transmittance lower than 0,01 W/mK, the limit value of the standard. Five thermal bridges were calculated and verified by the software Therm (Therm is a free software developed by Laurence Berkeley National Laboratory and studies the performance of 2d heat flow through building components).

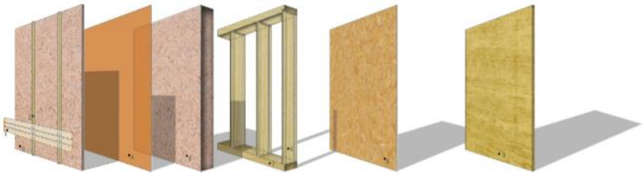

Figure 2 Platform frame and insulating layers

- The systems

In the building, a mechanical ventilation system has been planned in order to ensure the thermal comfort and air quality inside the rooms during the whole period of activity. The adopted solution allows to obtain a good thermal comfort and satisfactory indoor air quality with a single technology, saving space and costs.

The incoming air comes totally from outside but passes through a air-to-ground (heat recovery effectiveness of 80%) heat exchanger to reduce the energy consumption. After this first process, air goes through a second exchanger (air-to-air, heat recovery effectiveness of 80%), air-to-air, before reaching the rooms.

For German climate, especially during winter, this kind of solution is optimal because the heat exchangers reduce the difference of temperature between outside and inside. In this way the energy costs are lower.

During the most severe climatic conditions a geothermal heat pump completes the system. Geothermal energy is a free and renewable energy source, independent from external environmental conditions and is particularly suitable in cold climates.

The geothermal heat pump supports also the production of domestic hot water, together with the solar heating system (60 m^2) that is fully integrated in the roof. The scholastic building has an electricity demand of 53.6 kWh/m^2yr, due to a variety of services and devices as computers, office equipment, lighting.

In order to reduce this huge demand there are three kinds of photovoltaic systems:

- Structural photovoltaic glass (200 m^2);
- Semi-transparent solar glass (400 m^2);
- Photovoltaic sunshade blades (22,4 m^2).

In particular for the last one, different inclinations can be automatically selected, depending on the angle of incidence of solar rays and on the season.

The automatic system allows always to optimize the absorption of solar energy. [4]

- Results

After designing the building and verifying that the most critical thermal bridges are under control, the certification by the official software PHPP (Passive House Planning Package) takes place.

With 180 users and an internal temperature of 20°C, the main results of the certification are:

- Specific heating demand: 8 kWh/m^2yr;
- Specific Peak Load: 10 W/m2;
- Specific cooling demand: 15 kWh/m^2yr;
- Primary energy demand: 118 kWh/m^2yr.

So all the requirements of the standard have been fulfilled.

Case study 2: Naples, Italy

- Context

While the spread of *Passivhaus* buildings, characterized by highly insulated building envelope and heat recovery, continues and speeds up in the home countries, the demand for energy efficient and quality buildings starts to be relevant even in warmer countries. Therefore, it is urgent to adapt the building concept to ensure summer comfort with similar low level consumptions.

The main goal of a Mediterranean *Passivhaus* is to obtain a good thermal performance during summer is. It turns essentially into the building envelope ability to properly shade the indoor environment during daylight hours and in a system's ability to get rid overnight of the accumulated daytime heat in the walls.

For this purpose it is possible to identify three principles[5]:

1) Minimising the external and internal heat gains through thermal insulation, building form, solar

shading devices, building thermal inertia and the appropriate use of green;

2) Modulating and postponing heat gains during the day, adopting thermal attenuation and thermal lag strategies, moving them from day hours to night hours (cycles of thermal storage and unloading);
3) Remove the heat by natural means, through the sky, air or water as heat sinks.

In this regard, the Passive-On study was carried out from 2005 to 2007 about the adaptation of the German standard to Mediterranean climates.

Below the adaptation of the project of German *Passivhaus* in southern Italy is described, taking into account the guidelines Passive-on and the *genius loci*.

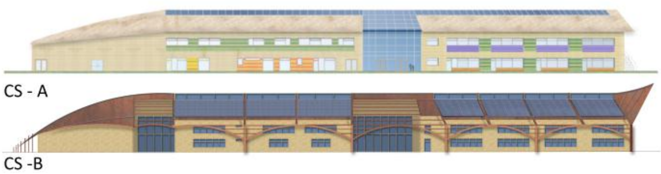

Figure 3 South facades, differences between the two case studies

- The shape and the orientation of functions

With the aim of optimizing solar gains and providing proper lighting, classrooms and offices have been southeast-oriented in this case too, while services and connective have been placed in the northern part.

Regarding the shape, in Mediterranean countries, the compactness is still an important parameter, but to be related to a good porosity, such as the building is characterized by patios, atriums and courtyards, creating shadows and natural ventilation: they, in fact, belong to the building tradition of the place.[6]

Nevertheless, a patio is a cooling element in summer and so it is during winter. This doesn’t help achieving the Passivhaus standard. That’s how the Mediterranean tradition meets the German innovation: the patio turns into a greenhouse in winter, with all the windows closed, a heating resource for the school.

Figure 4 The greenhouse patio from an outside view

- The building envelope

A significant aspect of the comparison between the German and Italian buildings is certainly the technological solutions.

The study of the building envelope has been relevant to make the school building a Mediterranean *Passivhaus*.

Taking into account Italian laws and the adaptations of the standard, the following requirements have to be respected:

- Opaque element transmittance lower than 0.30 W/m^{2}K[7];
- Wall thermal mass higher than 230 kg/m^2;
- periodic thermal transmittance lower than 0.12 W/m^{2}K;
- wall thermal lag between 10 and 12 hours;
- air tightness lower than 0.6 ac/h (n50).

The designed building envelope is based essentially, on the outside part, on a wood fiber coating (thickness 40 mm) and a ventilated wall to be achieved with panels of tufa stone, so long defined "the soul of Naples".

Inward instead, the stratigraphy provides rock wool, a panel plaster fiber and clay plaster.

The materials have been chosen with the aim to increase the thermal mass, already enhanced by the presence of the X-lam (cross laminated timber) instead of lightweight frame, valid in cold areas, and to preserve the bio-sustainability of the building, always preferring natural materials to synthetic ones.

The roof envelope is the main protection of the building from the weather. In pitched roofs, thermo-hygrometric benefits can be achieved even without specific heat-insulated functional layers, due to the shape of the roof itself (the attic acts as insulation if not affected by convective motions). In summer it is also possible that the hot air, which tends to rise upwards, goes out when an opening in the top is provided.

This system, designed for night ventilation, is part of a whole series of expedients for adjusting the internal microclimate entrusted to the coverage of the school building:

a) The roof as sun-shielding for x-lam ventilated walls, with a "porch" on which some tilting brise soleils are in charge of shading the entire south facade, exposed all day long to the solar path. This is even more important considering the cooling of the "thermal mass". Common practice of German *Passivhaus* is, in fact, to shade only the windows.

b) The roof as solar collection.

In a city like Naples, the values of solar radiation are high enough to choose the sun as a renewable energy source. The cover is in fact designed in order to place for its entire south-exposed length both solar heating system and photovoltaic panels. Solar heating systems are part of the winter work of the solar-assisted heat pump; moreover, they provide domestic hot water.

The inclination of the panels is a function of latitude and time of year when more energy is needed.

In the case of Naples the highest point of sun is at 73°. Considering both winter and summer requirements, a tilt angle of 28° has been chosen for the solar heating panels and photovoltaic panels.

Figure 5 The roof as solar shading: wooden porch and brise-soleil

- The system

Choosing a low consumption heating system is nowadays of great importance, especially in light of the Italian Legislative Decree 311/2006. The radiant floor heating panels follow the direction indicated by the European Union, allowing energy savings and thermal comfort. The air-conditioning system chosen is in fact radiant floor and primary air, so an appropriate area for the location of Air Handling Unit (AHU) has to be provided. The AHU includes the mechanical ventilation system requirement by the Passivhaus standard).

As heat generator, a solar-assisted heat pump is designed.

In order to increase the efficiency of the heat pump working in winter mode, it has been linked to solar collectors that rise up the temperature of the cold source so that the energy efficiency increases.

So a water-to-water heat pump has been chosen for the production of hot water, which is then sent to the heating distribution system inside the building.

Of course in summer conditions the solar collectors are used only for domestic hot water production.

The designated area for the photovoltaic plant for electricity production in the building is 276 m^2, south-exposed according to the optimum angle. In this way the limits imposed by Italian rules are respected (Decree num 28/2011).

- Results

According to the software output, regarding the heating energy demand, the building is effectively a *Passivhaus*, with a value of 13 kWh/m^2yr, lower than the mentioned limit of 15 kWh/m^2yr. The assessment of the summer thermal quality of the building can be made through the method based on the determination of parameters like the attenuation factor and the thermal lag [1] of the envelope. According to UNI EN ISO 13786 the stratigraphy provides “EXCELLENT” performance and the building is free of thermal bridges, as verified by means of the software THERM.

V. Conclusions and future developments

While designing a NZEB there are many variables that come into play.

Generally, during the design process, the respect of the limits on consumption and on energy parameters leads the designer to blindly follow various guidelines and standards without considering the context in which he operates.

The spread of the instruments, the deceptive simplicity of software, introduces us into a tunnel, where the final check of results is the ultimate goal of the design.

On the contrary, the results obtained in this study show that the *Passivhaus* feasibility is concrete and applicable even with boundary conditions different from the original ones and not only be configured as an ideal energy.

In the Mediterranean climate, the blind observance of a voluntary protocol as *Passivhaus* turns into a negative approach, misunderstanding principles, reasoning, but above all its purposes.

Its fulfilment requires compliance with certain limitations but it’s up to designers to understand how to adapt the standard to the case study. For example an appropriate adaptation of Passivhaus Mediterranean climates (Passive-on) has shown optimal results of one of the examined case studies.

This reasoned development finds its origin in the traditional designing process: the study of materials, architectural technologies, and typological forms of environmental context is the best guideline for the designer to draw a proper design, comparing tradition and innovation.

Once established the viability of the standard to the individual building, it might be experienced on entire Passivhaus neighbourhoods; these networks could produce clean energy in excess quantities than the needs, thus developing the city of the future.

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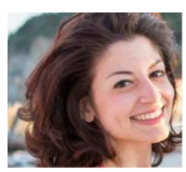

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