# Coming Back to Sustainability: Technological Solutions for an nZEB

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## ABSTRACT

When man needed the first time to find a shelter, he conformed himself to environmental context, finding in it resources and benefits. Then progress brought man to see Nature as a servant rather than as a valuable ally. The abuse of natural resources has revealed how critical the concept of renewability is and forced man to review his actions.

In the last decade sustainability in building design stopped being just an ideal and turned into a duty to fulfill. In order to reduce energetic consumption and CO2 emissions, according to the new European directives, a sustainable building must satisfy performance and functional needs, with the minimal environmental negative effect.

Rely on technology is not enough: a valid architectural solution depends strictly on the study of materials, architectural technologies, typological forms of environmental context, which becomes again the best guideline for the designer to draw a proper design, comparing tradition and innovation.

For this reason, numerous energy volunteer protocols were developed to meet the demand for high energy-efficient buildings, the nZEB.

This study shows how the German Passivhaus is applied to a scholastic building. The strict requirements of the standard are achieved thanks to a reasoned development, which leads to tailored technological, material and plant design solutions of the location where it is applied.

After considerations about form and orientation, the building envelope is the main part to focus on: it has to be conceived as a complex multi-functional filter between internal and external environment, responding to structural and performance targets but also to energy efficiency.

Man has to cooperate with nature to design energy efficient buildings and environmentally friendly with the users, but mostly to meet new needs for environmental compatibility.

***Keywords:*** *nZEB, Sustainability, Building envelope, Technology*

## INTRODUCTION

The relationship between man and Nature has not been always the same: it changed depending on the needs, the improvement and the acquired knowledge by mankind. From the beginning, Nature has been a precious ally able to provide items for defense and sources for the sustenance and development. The cave was the first safe place; fire and water were the first elements that enabled the start of progress. First building materials were provided by local nature according to the modern principle of “km 0” and the energetic performances were obtained thanks to the climatic environmental sources.

For this reason, the selection of the site was fundamental in the research of a shelter, regarding the nature of soil, materials and position compared to the environmental context. The delimitation of the earliest settlements started the process of anthropization of the natural environment [1].

The new sedentary lifestyle inspired intelligence and led to new needs that changed completely the concept of settlement, aimed to reduce the additional energy requirements compared to the natural one, according to a model of anthropization in harmony with the context.

Each settlement took different features according to the different demands: the populations devoted to farming and agricolture preferred flat and fertile areas while the ones devoted to fishing set themselves next to lakes and rivers. Then the need for protection from enemies led to the founding of settlements on high ground to have a 360° visibility of the surrounding areas. These first considerations were strictly related to the physical resources of the territory.

The use of natural resources became field of study and implemented the considerations on of the complex building constructions: shape, distances, exposure and colours started to be fundamental design elements to increase internal comfort thanks by using passive systems.

Vitruvius in *De Re architectura* underlined the importance of astrology thanks to which is possible to know "*the cardinal points, equinox, solstice and the right face of the sky*" everytime and everywhere; these were essential elements for the proper arrangement of the buildings; functions were placed according to their intended use and time of stay, ensuring the "natural decorum" typical of the architectural works [2].

Concerning this, the example of the Roman "domus" was emblematic as a perfect model of an almost zero energy building.

The development of the "domus" was horizontal: it had different rooms with different functions: **vestibulum e fauces** (the atrium entrance and the central room immediately after the entry); the bedrooms (**cubicula**); the lateral rooms (**alae**); **tablinum** (the living room). The **peristylium** was a garden surrounded on each side by the **Porticus**. The rooms on the street were rented (**tabernae**). In the back of the house the **hortus** (vegetable garden) was placed.

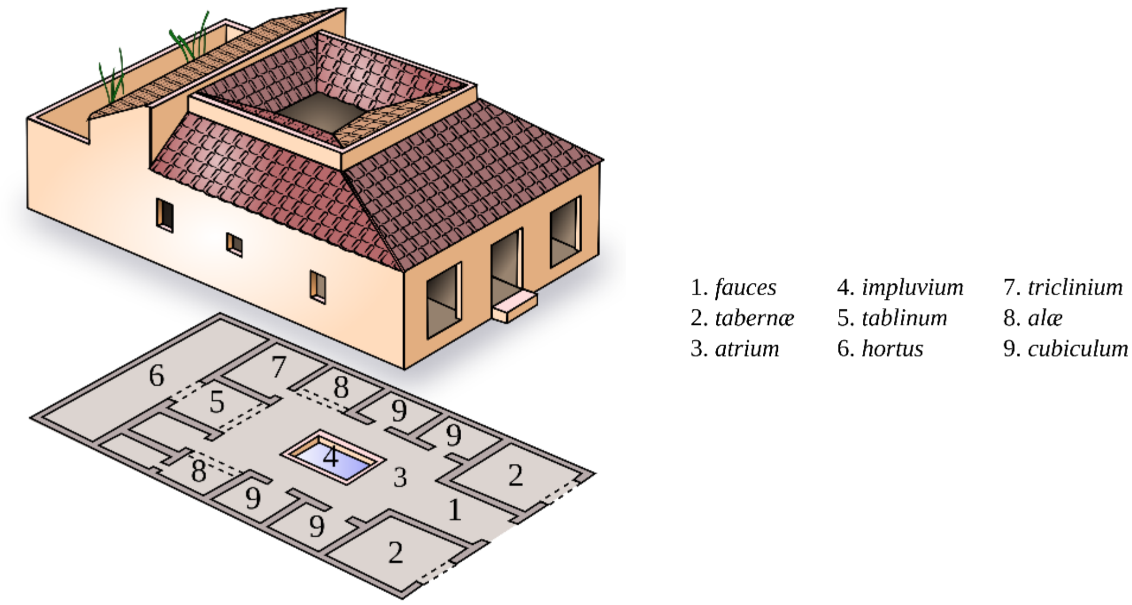


Figure 2 Roman "domus"

The courtyard was a strategic element in Mediterranean areas, both from the bioclimatic point of view and the functional one: it guaranteed the internal natural enlightenment; at the same time, it facilitated the shading and regulated the natural ventilation, optimising the relationship with the environmental context. In addition, the courtyard also collected the rainwater through a bath or central tank called **impluvium.**

On the contrary in cold climates, the building shape was compact and with limited openings in order to minimize heat dispersions.
Man succeeded in improving his own home; the use of more solid materials led to a high level of civilization both from the technological and energetic point of view.

The increased human trust in building materials, the development of technologies and the availability of energy resources, considered inexhaustible, turned the environmental context just into a background in the process of urbanization and Nature into a restriction to the free use of the territory. The new "ultra-resistant" materials and systems were the main causes of a detached built from the environmental context. Man developed globalized solutions, forgetting the basic principles of a sustainable design: all the places take on the same features; each context is indifferent to the technologies to adopt. Everything becomes possible for the "ruling" man and Nature gets something "extraneous" to design process. The harmony that characterized the relationship between man and nature for centuries breaks up and an uncontrolled waste of non-renewable energy resources takes place: this situation brought to a lot of cases of "unsustainable" settlements where the negligence towards the context and the historical memory was disastrous.

Nature initially sustained the imposed alterations finding new balances and producing the energy resources needed by humankind. It had been possible until when Nature itself consumed its regenerating capacities: this changed the environmental parameters, putting at risk the stability of mankind on Earth and declaring the failure of the speculative settlement model developed by man.

## THE ENERGETIC CRISIS

In the last decade, the resources crisis and the unsustainable use of them have become very delicate topics of discussion.

Building construction, responsible for 40% of total consumption of final energy and for 36% of $CO_2$ emissions in the European Union [3], is one of the most involved sectors on sustainability topic.

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).

Humankind needs to take a step back to his primitive reasonings and behaviour towards environmental context, in order to reach these objectives.

## NZEB and energetic Protocols

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.

2010/31/EU Directive 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 [4].

Integrated design process, referred in particular to the integration between design and environmental context is the key-instrument to obtain these high standards. The illusory confidence in inextinguishable energetic sources privileged the development of air conditioning systems instead of the technological qualities of building envelope. The adoption of the climate as basic element of design process becomes fundamental in terms of sustainability.

For this reasons numerous volunteer protocols were developed to reach the European objectives on energy efficiency, such as LEED, ITACA, BREEAM and PASSIVHAUS.

They highlight the importance to use the natural sources of the site and to have an accurate consciousness of it, in order to map out instruments and technologies adapted to the different climatic conditions. They are the basis of bioclimatic architecture, which is the whole of design solutions that allow in-house comfort keeping, using as little as possible systems that requires the consumption of exhaustible natural resources.

A so characterized building should be able to establish a close relationship with the environmental context, not losing heat when it is cold, gaining solar energy during the day especially during winter in order to keep it at need and expelling it outside during warmer times. This bioclimatic behaviour can be obtained in the building through a series of design measures on shape and orientation.

## Shape and orientation

The shape of a building is a very important influence factor in energy demand; it defined itself in the course of time according to a set of complex items closely dependent on the environmental, climatic and historical features of the site. A universally valid architectural response satisfying any demand for comfort cannot exist and the same can be said for the "perfect" shape of a building: according to climatic factors, it should be defined in accordance with the solar radiation and air temperature, which have the greatest impact on internal heat balance.

A high energy-efficient building should have a compact shape because the heat exchange realizes through its surface: the space must be keep as much as possible inside the thermal envelope. On the energy side, the sun-air impact mainly influences the building shape.

The optimal shape of a building is not definable in an absolute way but it is strictly dependent on the environmental and climatic reality of a place [5].

On the basis of these considerations, it is possible to compile a reference grid that summarizes the genaral criteria to define, at first instance, the shape of a building. For this reason, Victor Olgyay examined the effects produced by climatic factors (sun and air temperature) in four different macroclimatic zones.

In the cold area, the winter low temperature prevents the building to be arranged along the East-West direction because it is more convenient to use a compact shape and a plant as square as possible.

In the temperate area, where the outside temperature values allow to design buildings with more articulated and flexible plants, the elongated shape is generally recommended with the a development of the main views along the East-West direction.

In the hot-dry area, thanks to the favorable winter conditions, the building could develop with an elongated plant; however, the heavy summer stresses force to adopt a compact and nearly square shape.

In the hot-humid area, sun affects mainly the roof and the East and West extremities of the building, which takes on a tight and elongated shape, facilitating ventilation. It is also possible to design free plant buildings, providing shading and screening systems.

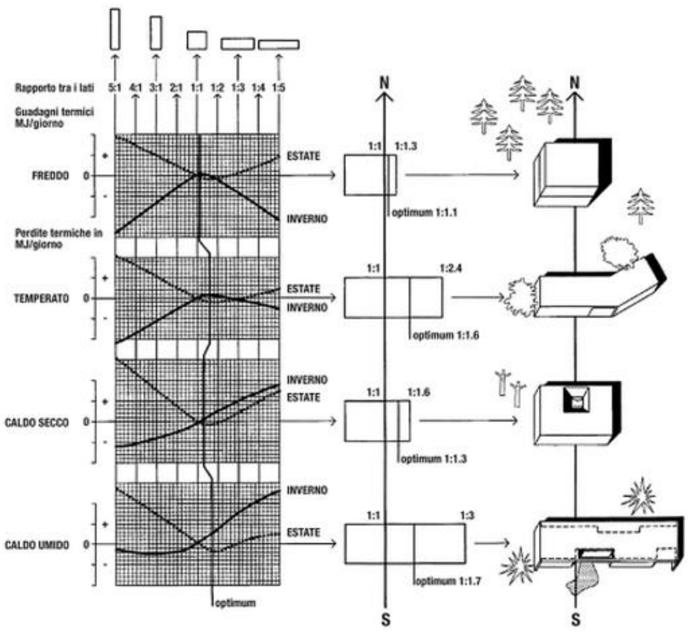


Figure 2 Olgiay's grid on building shape

Although the analysis carried out by Olgyay refers to a particular building type (single-family house), it is still possible to make general considerations.

Regarding the orientation, it does not refer only to the position of the building in the context but also to the distribution of functions inside of it, according to the time of stay and the end of use. These teachings have been preserved through the ages and declined for the new building types [6].

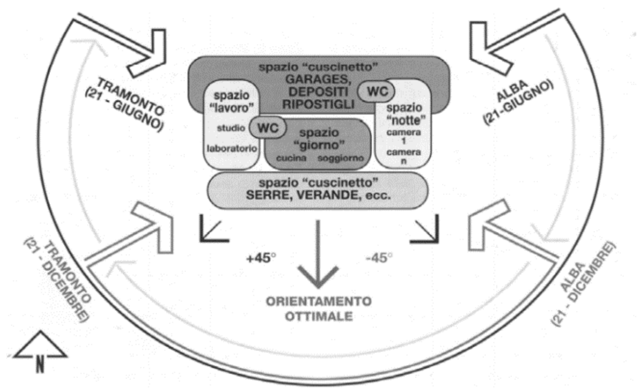


Figure 3 Optimal distribution of functions according to the time of stay

## THE CASE STUDY

Among the volunteer protocols that adopted the principles of bioclimatic architecture to reach energy efficiency, Passivhaus, a german protocol, gives useful advices on design process and not just requirements to respect. In order to reach the standard succesfully, in fact, Passivhaus provides important indication on the shape and the orientation of a building.

With this background, the following paper shows how this standard had been applied on a scholastic building in Dresden (DE), focusing in particular on the architectural choices.

The faithful application of the standard is made possible by the choice of a place similar to the climatic features for which the standard was born.

Figure 4 Case study

- **THE SHAPE**

The building under investigation is characterized by a longitudinal development, 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 the case study the reached value is 0,4.

The building is similar to a leaf to emphasize the analogy between nature and an energy efficient building, able to produce energy for itself thanks to the use of natural sources: efficiency of nature is used for an anthropic purpose as building design.

- **THE ORIENTATION**

Respect to the previous considerations on the orientation, the building is placed in the lot in compliance with the regulations relating to distances and surfaces, along the East-West direction, in order to increase as much as possible the free contributions by solar radiation.

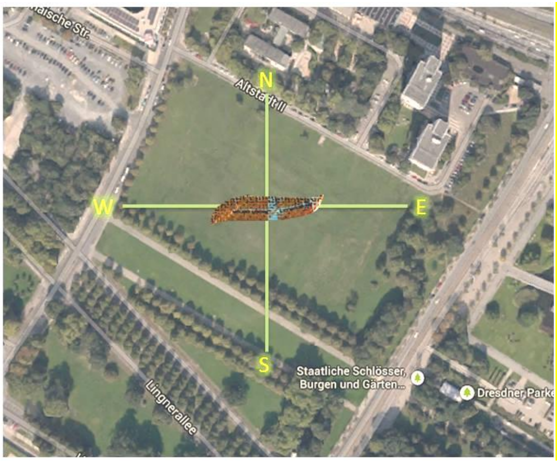


Figure 5 Orientation of the building

Glass surfaces are maximized on the main South facade while they are limited on the North one.

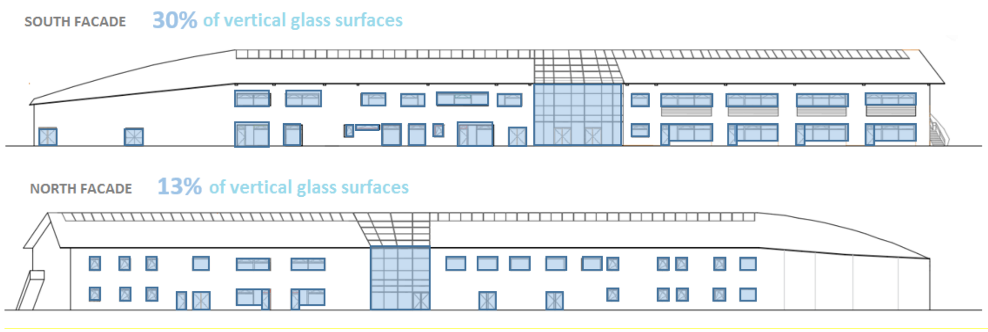


Figure 6 Glass vertical surfaces of the main facades

Regarding to the functions, the ones 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.

- 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 $\leq 0.15$ W/m²K;
- Unitary thermal transmittance for global window (frame+glass) $\leq 0.80$ W/m²K [7].

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).

Table 2 Reached U values

| COMPONENTS | W/m$^2$K |
|---|---|
| First floor plate | 0,10 |
| External wall | 0,10 |
| Roof | 0,14 |
| Window | 0,56 |

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 $\psi$ lower than 0,01 W/mK, the limit value of the standard.

Four 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).

Boundary conditons

Inside: 20 °C, $R_{Üi}$= 0,13 m$^2$K/W
Outside: -5 °C, $R_{Üe}$= 0,08 m$^2$K/W
Ground: 10 °C, $R_{Üi}$= 0,0 m$^2$K/W

$$\Psi = \frac{\left(\sum_{i=1}^{N} b_i \cdot U_i \cdot \Delta T_i - \sum_{k=1}^{K} b_k \cdot U_k \cdot \Delta T_k\right)}{\Delta T_{\max}} \tag{1}$$

where:

- $\sum_{i=1}^{N} b_i \cdot U_i \cdot \Delta T_i$ is the calculated value by Therm
- $\sum_{k=1}^{K} b_k \cdot U_k \cdot \Delta T_k$ is the value of the undisturbed sections

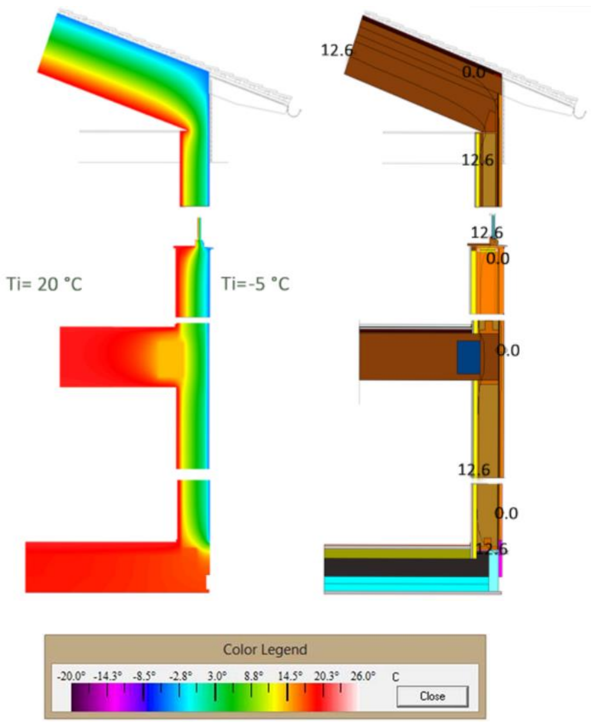


Figure 7 Simulation of thermal bridges by Therm that shows temperatures trend with colors and isotherms

Particular attention is given to the isotherms of 0.00° C and 12.6°C because of the risk of ice and mold respectively.

Table 3 ψ calculated values

| THERMAL BRIDGES | W/mK |
|---|---|
| Base plate connection | -0,20 |
| Ceilling connection | -0,003 |
| Window connection | -0,07 |
| Roof connection | -0,09 |

## CONCLUSIONS

The mistake made by man in the developing settlement process that produced an unsustainable model and the awareness of having to come back to the environmental coherence, led to the rise of volunteer energetic protocols: they represent a good starting point to find the elements to focus on in order to obtain energy-efficient buildings. The parameters of protocols need to be stricly defined according to environmental features of the context in which they operate.

The globalization of the protocols would be a further mistake and would lead to the implementation of energy-inefficient products; if Passivhaus is very efficient in cold climates, the same parameters applied, for example, in the Mediterranean climate, turn into a negative approach, misunderstanding principles, reasoning, but above all its purposes.

It's up to designers to understand how to adapt a standard to a particular case study. 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 [8].

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