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The historical evolution of the energy efficient buildings



Constantin Ionescu*, Tudor Baracu, Gabriela-Elena Vlad, Horia Necula, Adrian Badea

University Politehnica of Bucharest, Power Engineering Faculty, Department of Energy Production and Use, Spl. Independentei 313, S6, Bucharest, Romania

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ABSTRACT

The today energy efficient buildings are mainly related only to the available standards when their performances are described. This approach is correct just in terms of formal qualification to meet the requirements of the statutory rules and give people confidence. Beyond these facts, today's energy efficient buildings have to be known not only in the context of the existing technology, but also in the evolution of the equipment and the design concept used in synchronization with the contemporaneity of the science. In this paper, a historical laborious presentation of the techniques and concepts evolution that lead to energy efficient buildings as we know them today, is presented. An overview of the modern approach for the design of the main elements of such type of buildings is also presented. The paper realizes a review of the current state of the energy efficient buildings, in terms of definitions and characteristics.

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1. Introduction

Nowadays in Europe, the building sector is responsible for about 40% of the total primary energy consumption [1] and there is a significant potential in the energy consumption reduction. In this respect, highly topical analyses and interventions are related to energy savings while ensuring adequate comfort conditions. This is called energy efficiency of building. It accomplishes two important goals of sustainable development while reducing energy demand, namely, primary resources economy and reducing emissions to the environment.

In order to develop new technologies and strategies for improving energy efficiency in buildings, their evolution throughout history is important to be known. Only based on previous experiences and

knowing the barriers encountered by predecessors, the progress can be fulfilled. Without understanding the evolution of the energy efficient buildings, new concepts and new solutions to reduce energy consumption in building sector will be hard to imagine.

A study of the historical evolution of the energy efficient buildings is necessary for a better understanding of changes made through time with the aim of improving comfort and optimizing the energy consumption. Generally speaking, people are aware of the need to apply new concepts, standards and laws when they are presented in contrast with old ones. Scientists accept new concepts rapidly if they are based on the results of specific equations or experiments. On the contrary, regular people accept them because “the present standard/law imposes the solution” or just because they are “topical” and promoted by mass-media. An intellectual, regardless its specialization will always desire to understand the stream of thinking and will not accept a concept as an axiom. He will explore the evolution of technology in time, to get to the roots.

On the other hand, this kind of studies induce a demystification of some arbitrary practices, called “rules of good practices”, that

* Corresponding author. Tel.: +40 721 934 418.

E-mail addresses: cristi.ionescu@energy.pub.ro (C. Ionescu), tbaracu@yahoo.co.uk (T. Baracu), gabi_ev@yahoo.com (G.-E. Vlad), horia.necula@energ.pub.ro (H. Necula), badea46@yahoo.fr (A. Badea).

sometimes are controversial. Sciences like philosophy, arts, mathematics, physics, engineering have dedicated studies of their historical evolution and this fact encourage related studies for the domain of energy and energy efficient buildings.

This paper presents, beyond the chronological aspects, an exposure that facilitates the awareness of the historical evolution of the energy concept applied to the buildings. Indoor comfort is not achieved unilaterally to fulfill certain ergonomic demands but it is inherently followed by economical optimization and increasing of energy efficiency.

Undoubtedly, the evolution of the concern in the energy efficiency of buildings over time has many dimensions and ramifications, but the purpose of this study is only to emphasize the key moments in the evolution of energy efficient buildings. It covers issues that have had an important impact, durability of use and mass adoption. There are many techniques to improve the energy efficiency of the buildings and this study does not aim to present them all, because the evolution of the concepts is intended to be observed globally. This paper tries to identify the degree of impact and of innovation at their time, related to the energy consumption reduction. It also presents the degree of preservation and classicization and how much are found in the exigencies of the present, aiming to find some invariants of design.

The requirements defined for buildings are not recent findings. They are the outcome of science and mentality evolution throughout human history in the broadest sense, with an acceleration of change and innovation on buildings beginning with the 19th century.

The concern for energy efficiency always exists in a latent form but awareness of this issue has occurred in the 19th century, when the main sciences underwent a sensitive differentiation and took the form known today. The 20th century helped to insert into the collective mentality through media, standardization and regulation, the importance of energy efficiency. The 21st century is found in the conjuncture of widespread energy concerns in most areas of science and technology.

After passing through the oldest time of building technologies, from thermal point of view, up to the contemporaneity, this paper will insist especially on the period that began in 1990s with the design of passive houses, exposing the technics, requirements and exigencies of the new designs and concepts.

This paper is elaborated by authors mainly in the context of the experiences accumulated during the designing and building of the passive house constructed in the campus of University Politehnica of Bucharest.

The energy efficiency of a building is mainly related to two components: passive properties – given by thermal insulation, captured solar radiation, natural ventilation, shading; and active properties given by equipment of capture, conversion and use of energy (renewable energy). In this regard, the trends of used design and its usefulness as comfort and cost for the people that benefit from it must be explained.

2. Historical evolution of the technics and concepts of the energy efficient buildings

The purpose of this section is to make a historic journey in order to highlight various ingenious solutions in building houses used over time with benefits in terms of comfort and energy. The main text will reveal the most important aspects of the evolution and the information will be presented in a smooth way to keep the continuity between distinct events. More events about the history of energy efficiency of the buildings are shown in [Table 1](#) where the information is chronologically summarized.

Since ancient times, man has found ways of using and converting natural mechanisms to improve the living conditions and among them are the houses and their construction techniques.

Even if the “energy efficiency” was not a common term as it is nowadays, before the 20th century, people have created and transferred from one generation to another the good practice codes. Therefore the method used to build a house was based on previous experiments. At that moment, this was a satisfactory method to improve and to preserve certain construction techniques.

Each age brought something new or improved the existing techniques, but a remarkable fact is that systems based on renewable sources of energy used nowadays have ancient forerunners.

It is found that in 5500 BC in the region of Carpathians [2] people used the solution of the houses built partially buried, obtaining in this way a more stable indoor temperature. Benefits of the ground thermal properties were also used later in the houses of the Cappadocians, Essenen communities from Middle East and Native Americans. An evolution of those designs has to be remarked in the Persians’ “badghir” (wind tower) [3], where in dedicated routings the wind and ground energy were employed to assure indoor comfort. A similar technique, but only using wind energy can be found in the Egyptian’s “malqaf” (wind catchers) [4]. An improvement in the thermal comfort by the wall’s structure design was materialized by Egyptians using thick brick walls or tiles [5] (that have also special acoustic properties) and later by Greeks and Romans who used cavity walls [6]. Romans also used the heating with burning gases that flows through cavities in the floor or the walls [7]. These elements with high thermal mass actively keep the indoor temperature at a comfortable level for a longer period of time. Windows covered with mica were also an active way to preserve a pleasant temperature of the inside air by trapping the solar radiation. This solution conducted to special design of rooms in Roman Empire, namely “Heliocaminus” [8].

The Ancient times had brought real gains to the buildings sector. They were considered traditional, a form to express aspects of the national identity and they were preserved through centuries, including Middle Ages. Renaissance brought to the fore and accentuated the values of the Ancient times and marked various fields from culture to science, architecture and technologies.

The 19th century marked the maturity of classicism in science and progress also occurred in the domain of buildings. This was one of the most important ages of the scientific discoveries by classic meaning. Scientists not only materialized the technical innovation but also formed a fundamental scientific base by various treatises, books, dissertations, etc.

In the last decade of the 19th century, the scientific works in the building field implied studies of the thermal insulation effect in the heat transfer domain, formation and transport of the moisture in the walls, multilayer configurations of windows, etc. At this time, the preheating of the air at the service room located in the basement became a common method. In this way the ventilation process was being initialized by convective circulation of the air towards the top floors.

At the beginning of the 20th century, the researchers already had the theoretical and technological foundations to achieve naturally the desire of a future energy efficient house. Carrier invented the electric equipment of air conditioning and later issued a psychometric diagram.

“House of Tomorrow” of George F. Keck and “MIT Solar House 1” of Hoyt C. Hottel built in 1930s demonstrated the important heat gains from the Sun [9,10]. The two buildings started the stream concept of energy efficiency in buildings based on scientific methodologies of calculation, strategies of design and construction. Thermal design of the components and the equipment such as solar collectors were the keys of these buildings. Later on, the number of technical solutions had been increased. The enhancement of the

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