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THE CONCEPT OF AUTONOMOUS BUILDING IN THE CONTEXT OF SUSTAINABLE DEVELOPMENT

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Abstract: *The concept of sustainable development emerged as an effect of the awareness regarding the great challenges of today's society: energy and environment. Autonomous and ecological buildings respond to these requirements and must be conceived from the design phase in order to be energy efficient - from an architectural and constructive point of view and also to valorize at a maximum level the potential of renewable energy sources.*

Key words: *autonomous building, sustainable development, renewable energy, hybrid system.*

1. Introduction

As a result of the energy crises in the ‘70s and ‘80s of the 20th century, and after some ecological catastrophes culminating with the Chernobyl incident in 1986, the General Assembly of the United Nations decided to establish the World Commission on Environment and Development (WCED) led by Gro Bruntland. Following the activity and research of this commission, several directions of economic development have been formulated, which obviously can’t be stopped, and some new concepts have been defined, including the sustainable development.

In the Commission's Report, sustainable development has been defined as "the development that aimed at meeting the needs of the present, without compromising the possibility of future generations to meet their own needs." The concept targets a few macro areas, namely:

• Economics, in terms of efficiency, growth rate and stability;
• Society that seeks to ensure a minimum standard of living, reducing social inequities, the respect among nations and the protection of cultural heritage;
• Ecology, which involves preserving and protecting natural resources and obviously avoiding or at least reducing pollution.

The development/emergence of this concept had also implications regarding the conceiving and design of buildings. These must be energy efficient and have to use

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renewable energies so that to conserve classical resources and for ecological reasons, respectively to provide a certain degree of autonomy.

Autonomy should not be perceived as being equivalent to building isolation. This would be impossible because people live in an interconnected world where humans are interacting and depending on a series of facilities.

Total autonomy is relatively difficult to achieve, so most often the objective is a partial autonomy, which targets the fields of electricity, heating/cooling of habitat spaces and the preparation of hot water. More broadly, autonomy also addresses water management issues, but ii doesn't represent the subject of this paper.

The desire to gain energy autonomy is most often caused by accidental disruptions due to either outdated networks or extreme natural phenomena (thunderstorms, earthquakes), which unfortunately, are increasingly common in the last time. In addition, cannot be excluded the risks of energy or fossil fuel interruptions due to political reasons or international conflicts (sabotage) [2].

One knows that energy plays an essential role in everything that civilization and the evolution of contemporary society means, therefore its management must be treated with all responsibility.

2. Methods and Principles for Achieving Autonomous Buildings

Autonomous buildings must be designed to be energy-efficient. In this respect it is necessary to know some principles or requirements to be considered, starting with the design stage and ending with the execution. Further, a summary of these are presented.

2.1. Energy efficiency through architecture and constructive elements

- **The shape of the building**

When choosing the shape of the building, it is good that, besides the aesthetic option of the beneficiary, to consider first the experts opinions related to the energy of buildings. If we denote with A the surface at the ground of the building and its volume with V, it must be known that the most efficient buildings are the ones which have the smallest A/V ratio. Thus, the sphere has the best report and the cube is closest to it.

In terms of the heat demand, if one relates to the cube or parallelepiped forms, which are the most common, we may have aggravations or improvements as it is shown in Figure 1 [6].

A representative project of autonomous and ecological construction is Domespace Rotating House, designed by Patrick Marsilli [8]. These houses can rotate so that to cool down during the summer, respectively to worm up during the winter – Figure 2.

Since the shape of the spherical cap is difficult to achieve as a structure, the closest forms are used, such as the geodesic dome.

Any surface can be approximated by a polygonal spatial network, taking on that surface indirect points and resulting vertices, edges and triangular or polygonal faces. The approximation of a surface with a polyhedron is more accurate as the polyhedron has smaller edges [7].

The most stable geodesic surfaces are the omni-triangular structures that provides a solid structure with outstanding resistance to the natural factors due to the aerodynamic shape. But according to the load to which the building is subjected one can also find domes having pentagons or hexagons regular faces. Figure 3 shows an ecological house in the form of geodesic dome.

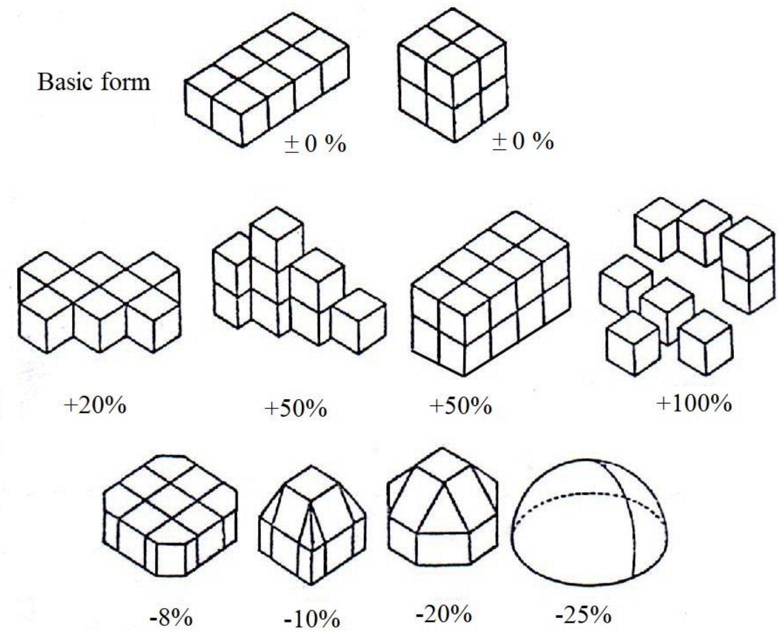

Fig. 1. *Variation of heat demand depending on the shape of the building for the same useful volume [6]*

Fig. 2. *Domespace house [8]*

Fig. 3. *Geodesic dome constructions [7]*

- **Building orientation**

The building should be oriented with the main facade towards south, so the solar energy inputs to be optimal and to capture the maximum heat in the cold period and at the same time to be the base for solar thermal and photovoltaic panels. To some extent, this is a disadvantage in the summer but can be eliminated by taking measures to block the sunlight. Also, the proper inclination of the window openings has a positive effect on the solar energy input.

- **Opaque elements of the building envelope**

Generally, in order to reduce thermal losses through transmission, there must be a high thermal insulation of the opaque area (walls, floors, terraces). For this purpose, the thickness of the insulation will be about 25-40 cm, depending on the thermal insulation material. There was a special concern of specialists for finding new materials with superior properties than traditional ones. Among these new materials, are mentioned [3]:

a. Biological thermal insulation, such as sheep's wool; it must be treated for protection against pests with ureic derivatives, and for fireproof and protection against mold with boron salts;
b. Composite structure thermal insulation systems also called thermal skin;
c. Vacuum thermal insulations consisting of sheets wrapped in foil with vacuumed inside, a process in which the conductivity will be 5-10 times lower than in the case of usual materials.

To achieve thermo-energy performance, the opaque elements must have the transfer coefficient $U \leq 0.15$ W / m^{2}K.

A superior concept is represented by walls with high thermal inertia, which passively harness solar energy. This category includes the collector wall and the Trombe-Michel wall. But the most advanced type of wall is the one with dynamic-adaptive structures, where the envelope is thermo-activated by creating inside a space for air circulation or, more generally, by integrating an active thermal system inside the wall [3]. It has the ability to change its behavior according to external climatic parameters, respectively it can receive, release or store heat, depending on the heating and cooling needs of the rooms.

- **Glazed elements of the building**

High-sealing windows and doors will be used to prevent infiltration of air from and to the outside; for this purpose, windows with thermal transfer coefficient $U < 0.85$ W/m^{2}K and doors with $U < 0.8$ W / m^{2}K must be used.

The dimensions of the windows will be designed to ensure the need for natural lighting. Glazed surfaces must be designed in such a way as to provide natural lighting for as long as possible. In this regard, one turns to different solutions for accessing natural light, such as skylights, reflective lamellas or glass bricks. These can be a part of the building's architecture.

A solution that perfectly meets the requirements of energy efficient buildings is achieved by using double or triple glazed facades that allow, due to the absorbent / reflective blinds, ventilation flaps, fans and adjusting mechanisms located between the two glass walls (spaced about 60 cm) an immediate and effective response to weather changes.

A newer concept is the parietodynamic window [2], which consists of three layers of glass between which the air circulates. In winter, the air heats up as it circulates between the sun-heated glass. This system allows natural ventilation and passive intake of pre-heated air.

2.2. Energy efficiency through building installations

2.2.1. Electrical lighting installations

In terms of artificial lighting, incandescent lamps have been gradually replaced with low-consumption compact fluorescent lamps and LED lamps that have low energy consumption and a long lifetime. Also, the development and implementation of Organic Light Emitting Diodes (OLED) panels represents a future solution.

2.2.2. Heat recovery ventilation system

A mechanical ventilation system for the fresh air inlet will be used, which means that the windows can remain closed in the cold season. In this case it can be provided an advanced heat recovery system.

To save energy, fresh air from outside can be directed before entering the ventilation block through a heat exchanger placed in the ground placed below the frost level to increase the air temperature, called Canadian well. Otherwise, the central ventilation block must be equipped with a frost protection system, which is energy-consuming.

2.2.3. The use of renewable energy sources in autonomous houses

The concept of autonomous house, in the context of sustainable development, involves the production of thermal and electrical energy from alternative sources, other than fossil fuels.

Figure 4 represents the schematic diagram of energy balance for a partially autonomous building that is supplied both from its own renewable sources and also from classical sources. Depending on the energy production from renewable sources, one may have a deficit or excess of energy that compensates from or within the national electricity network. In this case, the energy was obtained from renewable sources located on site and in the proximity.

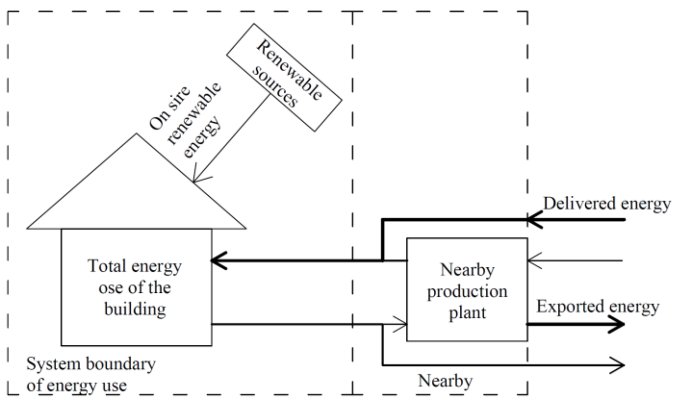

Fig. 4. *Diagram of energy balance for a partially autonomous building*

According to Figure 4, the energy balance for the primary energy is calculated with the relation [1]:

$$E_{P,sc} = \sum_i (E_{liv,i} f_{liv,sc,i}) - \sum_i (E_{\exp,i} f_{\exp,sc,i}) \quad (1)$$

where:
$E_{P,sc}$ is the energy used in the system from classical sources [kWh/year];
$E_{liv,i\_}$ is the delivered energy on site or nearby for energy carrier i [kWh/ year];
$E_{exp,i\_}$ is the exported energy on site or nearby for energy carrier i [kWh/ year];
$f_{liv,sc,i}$ is the non-renewable primary energy factor for the delivered energy carrier i;
$f_{exp,sc,i}$ is the non-renewable primary energy factor of the delivered energy compensated by the exported energy carrier for energy carrier i.

The primary energy indicator is obtained with the relationship [1]:

$$EP_P = \frac{E_{P,sc}}{A_{net}} \text{ [kWh/m}^2\text{year]} \quad (2)$$

where, A_{net} is the useful floor area of the construction [m^2].

In energy-efficient buildings, energy input from renewable sources should increase so that exported energy can compensate the energy obtained from classical sources.

When construct this type of buildings, a first step should be the properly sizing and optimization of the installation systems. One of the commonly encountered mistakes in installation design is oversizing, which leads to a high investment cost. It is also important to establish and calculate the renewable sources energy production systems, considering the estimated energy needs of the building and the potential of the area.

The renewable sources used in the case of autonomous houses can be:

- **Solar energy**

It is an inexhaustible energy source on the entire surface of the Earth because of the thermonuclear transformations of hydrogen into helium that take place in the Sun, resulting a continuously radiant energy flow in the cosmic space characterized by the solar constant E_o having an approximate value of 1350 W / m^2. The radiant energy flow that reaches the Earth is diminished by crossing (7-17 km) through the troposphere to about 900 W / m^2 [5].

As applications in the field of constructions, one of the main target represents the use of solar energy to obtain electricity through photovoltaic panels and thermal energy for heating and domestic hot water using solar thermal panels.

- **Wind energy**

It uses the wind power and the most common applications involve producing electricity through wind turbines of various construction types, covering a wide range of powers, from hundreds of kilowatts up to a maximum of 7 MW.

- **Geothermal energy**

Geothermal energy can have high potential (taken from volcanoes, thermal waters, geysers) and low potential (from the thermal energy of Earth's crust) [5]. The most common applications encountered are heating residential buildings using either large collectors near the surface or deep boreholes through heat pumps. Another application uses Canadian wells for preheating or cooling air in ventilation systems.

- **Biomass**

It comprises a wide range of products. In autonomous buildings it is suitable to use wood under different forms for heating and hot water preparation. High efficiency of combustion is ensured by using pellets or briquettes. Another product that can be valorized from biomass energy is biogas obtained in the proximity of buildings having different compositions and calorific capacities, depending on the raw material used and the conversion processes.

- **Hydraulic energy**

The use of hydraulic energy is conditioned by the presence of a nearby watercourse with a relative constant flow and can be used to supply electricity to the autonomous buildings by means of micro and pico hydro plants.

- **Hydrogen**

Hydrogen represents a vector of alternative energy and its use is supported by the fact that in combination with other elements is the main constituent of the universe. Afterwards, by discovering the electrolysis process of the fuel cell and later, successfully transforming some internal combustion engines into hydrogen engines, it has become obviously that hydrogen can be used as a energy source [5]. In the case of autonomous houses, hydrogen can be used as an alternative to provide electricity through fuel cells or may have household uses, but it needs special burners.

These alternative sources are clean and non-polluting energy sources, and their use involves a drastic reduction of pollutants and greenhouse gases emissions.

Figure 5 shows a possible system using renewable energy for a partially autonomous construction [3].

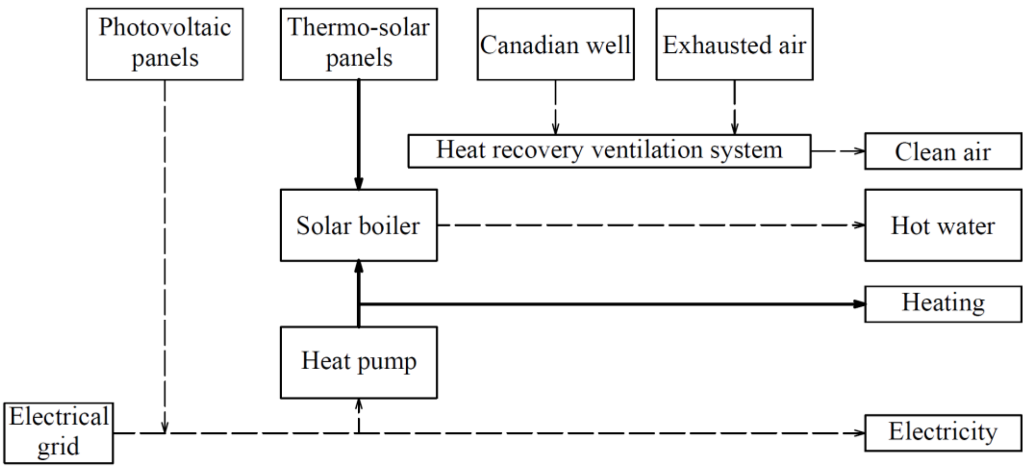

Fig. 5. *The power supply scheme for a partially autonomous building*

In the case of using renewable energy sources for the supply of isolated or totally autonomous houses, an important component is the energy storage system, which varies according to the energy source. The disadvantage of storage is the high investment cost.

The most used form of electricity storage is in secondary batteries, whose operating principle consists of a reversible reaction, which allows for a large number of charging / discharging cycles over the lifetime.

Among these, lead-acid batteries, despite their small capacities and energy densities, are the most common method for storing electricity, mainly because of the relatively low cost and of the various thermal regime coverage [4].

3. Conclusions

An autonomous building should be personalized from the project stage depending on the climate, its location and the available energy sources in the proximity.

Considering that most renewable sources do not generate constant energy and the costs for the initial investment are relatively high, hybrid systems typically use two sources to generate energy. These so-called bivalent systems can work in the following ways:

- alternatively, depending on the external conditions (such as the season), only one of the sources is used for a longer period, after which it switches over to the other;
- partially parallel, to which periodically, depending on the request, one or the other sources are used, respectively these complement each other;
- parallel, in which case both sources work all the time.

Obviously, these hybrid systems, especially those operating in the last two ways, must be equipped with installations requiring a high degree of automation in order to be efficient.

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