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Examination and Study of Zero Energy Buildings in the Case Study of BCA Academy, Masder Institute

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Abstract

The energy crisis and the pollution caused by the fossil fuels combustion and the increasing acceleration towards the use of these resources have led human beings to use clean and renewable energies. The fossil energy resources' limitation and the its price increasing and the lack of security and stability of the energy market along with the pollution and the earth warming have caused that designers search ways to realize zero energy architecture. Zero energy buildings with the intelligent use of renewable technologies creates balance between energy consumption and production. In these buildings, we are witness that as a part of the surrounding environment and nature, they not only does not cause the energy loss, does not cause environmental pollution, and does not have a negative impact on human health, but also with reserve and optimize energy consumption, having materials that are compatible with the climate and being in the ecosystem cycle, moves towards the sustainable development goals realization. The present research wants to find solutions for achieving zero energy architecture by the successful case examples study in the world in five categories; passive solar system, lighting performance improvement, the building envelope performance improvement, energy load management of devices and equipment, and using renewable resources. And the conducted studies indicate that passive solar solutions have more efficiency and variety than other solutions.

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1. Introduction

Sustainable architecture has been paid attention in response to environmental pollution, energy shortage crisis and limited environmental resources. Buildings consume about 40% of energy consumption of the country and play a role up to the same extent in the production of polluting gases, especially CO2. The necessity of preserving life on the earth planet and its essential resources for the present and future generations, was proved sustainable development approach in the last decade of the 20th century. This global approach tries to give response into five basic needs: protection and development integration, providing basic biological needs of human, achieving to social justice, autonomy and cultural unity protection (Torcellini et al., 2006).

In the years 2000 to 2015, the use of renewable energy has special importance and paid attention to it in various parts of the industry. So, in order to the widespread use of new energy, study and research about renewable energy, its development and use in various parts of the industry, especially the building industry, is an undeniable necessity (Marszal et al., 2011).

The augmentation of the world's population, the view of comfort for life, and the constant dependence on the consuming energy of its ready - burned sources, on the other hand, adds up the irreparable discoloration of the environment. While the cost of supplying the energy of the building over time and the use of which it is applied to the exploiters, architecture can in particular be reduced to the designs of the necessary tools and to the use of new energy and the quality of human existence (Iranmanesh ,2020).

A zero energy building, which is known as a net zero energy building, is a building with zero energy consumption, it means that the required energy in a year is exactly equal to the amount of renewable energy produced in the site. These buildings do not cause increasing in the rate of greenhouse gases. These buildings goal is reducing the released carbon and reducing dependence on fossil fuels. (Wang et al., 2013).

2. Renewable Energy

An important principle to access a zero energy building is to provide the building's needed energy from accessible renewable energies. There is no specific guide to choose the type of renewable energy, but wind energy and water waves are usually used for coastal areas and islands, geothermal energy is used in temperate zones, and solar energy is used in arid and semi-arid zones. However, the feasibility study of using renewable energy and determining its type and rate should be done separately for each project (Goldemberg, 2012).

Zero energy buildings use renewable technologies to reduce energy consumption. The number and type of these technologies use depends on the building’s type and is not predefined. It should be noted that these buildings benefit from technologies combination and do not rely on a specific type of them. The most important technologies in zero energy buildings are as follows: 1- photovoltaic, which can be used in two types, crystalline and amorphous, 2- wind energy, 3- biofuel, 4- solar heating, which is done in both flat and tubular forms, 5- The use of static solar systems, the most common of which is the solar greenhouse. In early 1111, Peabody Trust, which is one of the largest housing institutions in London, chose ARUP great company as the designer of the Beading Zero Energy Development program (http://www.energysavingsecrets.co.uk).

2.1. Wind Energy

By converting the wind's kinetic energy, wind energy may either be transformed directly into mechanical power or indirectly into electrical energy. The wind turbine is an essential part of any wind energy system since it is the component responsible for converting the potential energy of the wind into a form of mechanical power that can then be used in various contexts. At the beginning of the 20th century, construction began on the first wind turbine designed to generate electrical power. (Sayed et al., 2023).

3. Zero Energy Buildings

The US Energy Department defines zero energy buildings as follows: buildings in which a balance is created between energy consumption and production through renewable technologies applying. These buildings combine artistic expression, useful energy design principles and equipment with production of renewable energies on site and meet the energy needs of the residents. Zero energy is a building that is very efficient and produces its own energy and produces as much energy as it consumes in a year. It can be said zero energy buildings have two distinct orientations: 1- reduce the need (demand) of energy 2-produce energy from renewable sources. In the definitions related to zero energy buildings, should pay attention to the following points: a. A zero energy building does not mean zero energy consumption. b. These buildings are not independent from amenities. c: The use of these buildings does not mean energy rationing. d: Energy in these buildings is not infinite (https://energy.appstate.edu/do). Therefore, energy house, in order to design zero energy buildings, tries to apply the latest methods and standards such as ASHRAE 90.1, ASHRAE AEDG, IECC and minimize building's needed energy rate and using various time-based building performance simulation software such as IES VE and Design Builder to control the thermal behavior of the building at different times and determine the building exact energy consumption. In the following, using specialized software in the renewable energies field such as PVSOL and T*SOL, the annual energy production magnitude in the building is determined, and with the improvement of consumption and production conditions, the building annual energy balance becomes zero (http://homeenergy.ir). It should be noted that according to the DOE definition, zero energy does not have any difference from a normal building in appearance.

In addition, zero energy building was categorized into 3 groups, namely the low-rise, high rise and town for zero energy structures. The "Energy-Saving Strategy 2011" was officially adopted by Japan, which aims to continue to limit both structure energy and emissions to zero technology under the guidance of German Passive House Institute, zero energy structures were established as greenhouse (Belussi, and Barozzi, 2025: 15).

3.1. Zero Energy Buildings Advantages

Most zero energy buildings apply the electrical grid to power storage, but some of them are independent from the grid. Energy is typically restrained on-site by energy-construction technologies such as solar and wind energy, while total energy consumption is reduced by lighting and high-efficiency HVAC technologies. The zero energy goal is becoming more feasible because the cost of alternative fuels decreases and fossil fuels increases. The modern zero energy buildings progress not only has been gained in energy consumption and building construction, but also there are significant developments in academic research and detailed information is provided. Zero energy buildings can be a part of the smart grid. Some advantages of these buildings are:

1. Compatibility with nature
2. Energy consumption and energy demand balance
3. Passive energy's maximum use
4. Energy demand reduction
5. Electricity consumption reduction
6. Remove unnecessary energy consuming systems
7. Just sufficient design
8. Zero fossil fuel
9. 100% use from renewable energies
10. Heating through inactive systems
11. Buildings' zero heating
12. 50% reduction in drinking water consumption
13. Using ventilation system without mechanical vehicles
14. Optimal use of wood waste and biofuel production
15. Easy maintenance (http://homeenergy.ir)

3.2. Zero Energy Buildings Disadvantages

1- Initial costs can be higher. 2- Very few designers or home builders have the required skills or experience to build zero energy buildings. 3- The new photovoltaic solar cell equipment technology price decreases approximately 17% annually, as the result the amount of exist capital in the solar electricity system production decreases. 4- As the mass photovoltaic production reduces its price, the financial supports allocated to these projects will gradually stop.5- Each home may use zero grid energy average over a year, but it may require energy when peak demand for the grid occurs. In such case, the grid capacity should provide electricity for all loads. (http://homeenergy.ir)

3.3. Design Principles

The general principle in the zero energy buildings design is to reduce energy consumption as much as possible. The Zero Energy Houses Association of Canada offers two general solutions for these houses design:

1- Appropriate design of the building structure and physics. That by observing its principles

- which will be discussed later - we find a 70 to 80 % reduction in energy consumption. 2. Renewable energy sources use such as solar energy, wind, biofuel. This is possible by applying reversible technologies in these houses. In general, there are five solutions for realizing zero energy buildings. (http://homeenergy.ir)

a. Design of Passive Solar

It refers to systems, that after converting radiant energy into thermal energy, the control of energy flow resulting from natural ways without using any secondary energy or at most with very little energy consumption is done. Design of passive solar actually refers to the ability of building to absorb, store and natural energy distributing as it is needed and according to the specific climate of the project site. The basic types of passive solar systems are: (1) water heater. (2) Solar chimney. (3) Solar window (4) Trumpet wall (5) pond roof (6) atrium (7) double skin facade (8) greenhouse (9) green wall and roof. Studies conducted by braker, 1996, show that the usual teaching factors increased energy to 10 times more. The architect part of the building can increase the average cost from two to five times the normal use. if we add electric and mechanical plants, the amount will increase to twice the normal use. the remainder of the ten times as large as 2. At first glance it worried you that the architect was involved with the engineers and the people. There are two acceptable reasons why one of the architect's strategic decisions is important to the building. In the first place, they are closely connected with a building that is very rare. It can only happen if the building is completely replaced. The management should be able to encourage people to improve energy. Secondly, that the grand trio were not operating apart, and that the great - scale strategy of building energy was used to design the structure and depend on the behavior of the building. Apart from decisions that are used in architecture as a means to create energy, it is also a renewable energy, and, indeed, much of it is devoted to the never renewed energy that comes from fossil fuels, to use the deactivated systems by means of architecture, and to create environmental conditions.

b. Improving Building Spatial Envelope Efficiency

The building spatial envelope plays a very important role in reducing the building thermal demand. The general solutions that are in this category mainly are:

Optimal form choosing: the mass form of a zero energy building should be simple and as small as possible. From theoretical point of view, the ideal form for a low-energy building is sphere. The best form has the lowest surface-to-volume ratio, and try to make this ratio less than or equal to 1. The overall shape of building, should be square and rectangular, as much as possible, so that it contains at least corners and surrounding walls (Olgyay, 2015; Berköz, 1977).

Optimization of the widening to wall ratio (WWR): as this ratio is high, it leads to excessive entering of light in to the space, creating glare on the screen, fading in equipment floor construction, and printed plates, heat loss in winter and excessive heat input in summer. The conducted research in the lighting strategies field in the building indicates that the WWR=0.20-0.30 ratio is a suitable and reasonable ratio for the overall building (Cortese et al., 2013; http://buildingscience.com)

Improving the windows' thermal performance: In order to improve the windows thermal performance, the following 5 criteria should be considered:

u Factor: (U Value) This factor determines that how much heat passes through a building component such as a window. A triple layer insulated window can have U-value = 0.09. For many common double-layer windows, this magnitude is equal to 0.35. If the building walls are insulated well and the WWR ratio is low, in this case can use a window with U value=0.40. (Green Garage, 2009)

Solar Heat gain Coefficient (SHGC): This coefficient determines transmitted sun's thermal energy rate through a window. This coefficient has a value between 0 and 1. Therefore, to improve the windows thermal efficiency, the appropriate SHGC should be chosen. In this choice, the provision of sufficient daylight, the absorption of solar heat in winter and minimizing the absorption of heat in summer should be considered. For this purpose, it is considered SHGC=0.30 for the east, west and north views and SHGC=0.55 for the south view. (Gratia, and De Herde, 2003).

Low Emissivity Glass: Choosing this glass type has a significant effect on the light entrance and reducing the absorption of solar heat.

Visible light transmission (VLT): The value of this factor determines the visible light magnitude passing through a window, which has a value between 0 and 1. For normal windows this value is between 0.3 and 0.8. The optimal VLT value is about 0.5, which maximizes the daylight entrance and also reduces glare. (Gratia, and De Herde, 2003).

Light to thermal absorption ratio: This ratio compares the light transmission efficiency with its thermal absorption. The higher is its value, means that the window has reduced the absorption of the sun's heat and has brought more light into the building. The weakest state has a value less than 1 and the best state has a value greater than 1.55. For a building with high energy efficiency, this coefficient should be 1.67 (VT 0.50/SHGC). 0.30=1.67) (Gratia, and De Herde, 2003).

Improving the building insulated condition: The best situation is when the building is completely air-light. This is done by adding high-performance multi-layer insulator to the common air structure or by using prefabricated systems in the place for the walls. These prefabricated systems in the form of structural insulating panels (SIPs)-insulated panels and insulated concrete (ICFs)-forms. (Hausladen, 2005. Spiru, P. 2014)

c. Building Lighting Performance Improvement

There are three strategies to improve building lighting efficiency: 1) maximum use of daylight. 2) Replacement of low-energy consumption lighting systems (3) sensors' use to detect users (Watch, and Tolat, 2012). Daylight should be the primary source of light supplying and artificial light should be used as an auxiliary source. Normally, the depth of light entrance is 4.5 meters from the space light-reflecting edges during the day, and the use of light shelves increases this depth up to 14 m. (Frej, and Browning, 2005). Combination of ambient and thematic light should be used, as much as possible, and LED and CFL systems should be used instead of incandescent lamps (Marszal et al., 2011).

d. Electrical Devices and Equipment Energy Load Management

One of the ways to reduce energy consumption in offices is to manage the electrical devices energy load. This is done by monitoring electronic devices through the users' smart dashboard (ID-O) wirelessly or cloud-based. This system automatically exits electrical appliances from circuit when they are not in use (Lobato et al., 2011; New Buildings Institute, 2014).

4. Insulator

Increasing the building insulation rate will reduce the building energy consumption, but on the other hand, the initial costs of the project will increase. On the other hand, if the energy consumption in the building increases, it is necessary to use larger solar systems for compensating this increase in energy consumption, which will result in an increase in the project initial costs. Therefore, by finding an optimal point for the building insulation rate, in which the maximum saving in energy consumption is achieved with the lowest initial cost, can determine the required insulation rate. Also, it is necessary to consider the insulation rate up to some extent in which the building construction process can have implemented capability. In the Materials Research Institute zero energy building, the insulating of the building has been selected in a way that the thermal power factor has been improved by 40% compared to the requirements of topic 19. (http://zero-energy.ir/index.php).

Table 1 Review of case sample

Performance	Solution	Form	Case sample
Supply the required power for a specific use Shading and absorption of sun heat Reducing the temperature due to the radiant heat absorption and preventing of heat transfer Using natural daylight and reducing the use of artificial light on the roof for energy conversion Reducing light reflection and sun heat absorption	Solar Panels Canopy and covered corridors green roof green wall Light shelves Photovoltaic technology Electro chromic glasses Air conditioning sensors Roof lights Roof chimneys	Elongated rectangular cube Curved roof Locating the building in shadow	BCA Academy Singapore  
Trapping heat and transferring it to the outside Evaporative cooling in the site by water and wind conduction Life cycle review Natural ventilation Solar energy absorption and energy conversion Cold and heat recovery from outlet air Reducing the air exchange rate Supplying heating energy	Atrium Outdoor wind chimes Materials Windbreaker Solar panels chiller Fan coil + sensor Photovoltaic and solar water heater	Angled orientation for shading Skin façade design	Masdar Institute, UAE  

5. Conclusion

One of the techniques for reaching the ultimate purpose of building designing and that, besides building beautiful designs and modern architecture, culture, and the need for adequate energy to reduce the cost of maintaining the air by slow degrees of fuzz and sympathy, that has been told to maintain the main purpose. As it was pointed out, building is one of the largest parts of energy - consuming in most communities. attention to the slight improvements in the building, to the accompaniment of energy and mechanisms, can have a very effective quantity in this sense.

This is noted that high energy use does not at all mean convenience in the building. The discomforts of life returning to the building with the mechanical equipment of its money supply and heat. The building that the aerobic system exists and contains higher energy, far more dissatisfied with the buildings without air. So, in many cases we use the building that can't raise a few times over, despite how much energy we have.

Studies conducted by braker, 1996, show that the usual teaching factors increased energy to 10 times more. The architect part of the building can increase the average cost from two to five times the normal use. if we add electric and mechanical plants, the amount will increase to twice the normal use. the remainder of the ten times as large as 2. At first glance it worried you that the architect was involved with the engineers and the people. There are two acceptable reasons why one of the architect's strategic decisions is important to the building. In the first place, they are closely connected with a building that is very rare. It can only happen if the building is completely replaced. The management should be able to encourage people to improve energy. Secondly, that the grand trio were not operating apart, and that the great - scale strategy of building energy was used to design the structure and depend on the behavior of the building. Apart from decisions that are used in architecture as a means to create energy, it is also a renewable energy, and, indeed, much of it is devoted to the never renewed energy that comes from fossil fuels, to use the deactivated systems by means of architecture, and to create environmental conditions

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