BUILDING PROCESS AND REALIZATION OF ZERO ENERGY OBJECTS

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Abstract: Buildings are the biggest energy consumers, as well as the biggest producers of CO2. In order to change this, in recent years, many approaches are developed, and one of them is zero energy objects. In the core of zero energy concept is producing energy for building energy needs from renewable energy sources, or other technologies which have very low impact on environment. In this paper, analysis of building process of zero energy objects, as well as experience in realization of residential and public zero energy object is presented. Also, recommendations for designing zero energy objects are given.

Key words: building process, zero energy, renewable sources.

1. Introduction

Buildings are one of the largest consumers of final energy, in most cases electric. The total for all buildings is more than one-third of the primary energy consumption and approximately 70% of the electricity consumption [1]. Production of energy at the place of consumption would significantly reduce distribution losses, as well as the emission of harmful gases.

Better design of new buildings can lead to 50-75% reduction of energy consumption, while appropriate interventions on existing buildings would result in a 30% reduction in energy consumption. In addition to the positive effect on the object itself, the implementation of these measures would have a significant impact on energy consumption in the country, contributing to environmental protection and mitigation of climate change at the national, regional and global levels [2].

In this paper, phases of building process and realization of zero energy objects, as well as examples of built public and residential zero energy objects, are presented. Planning of use renewable energy sources is one of the most important steps in design process of energy efficient buildings. Although this activity is sometimes difficult to implement from the urban and architectural aspect, it enables the use of new technical and technological solutions through active and passive measures, all with the aim of achieving an energy efficient object that is in accordance with the Zero Energy Building approach.

2. Definition of zero energy objects

Definition of zero energy objects is based on the annual energy use of object – zero energy object generates a sufficient amount of renewable energy, which is equal to, or bigger than the annual energy consumption of object. When system generates more energy than a building can use, this surplus must be stored in some energy storage system. These systems are usually batteries, that represents source of energy when production from renewable sources is not enough, so building is autonomous and energy independent [3]. Based on this is also developed the Net Zero Energy Building approach, which refers to building that has similar energy performance as zero energy building, but is connected to the energy infrastructure – electricity grid (Fig. 1). When object have surplus of energy in some period of the year, that surplus is delivered to the grid, and when object do not have enough energy, required energy is taken from the grid.
So, there is a balance between energy taken from and supplied back to the electricity grid over a period of time, nominally a year [4, 5].

3. Phases of the building process of zero energy objects

The process of building zero energy objects includes a multidisciplinary approach, from beginning concept to completion of construction, and use of the building. The most important phase when designing an energy efficient object is design phase. In this case, design strategies represent a union of architecture and technology, in order to achieve better energy performance [6].

3.1. Exploratory phase

The first research about the project takes place in this phase. It is necessary to investigate whether the selected location corresponds to the purpose of the object, how to maximize the potential of the site, or overcome the possible disadvantages.

When it comes to zero energy objects, it is very important to choose renewable sources of energy and systems for energy production in accordance to location, climate and type of object. Because of that, it is important to analyze not only narrow but also the wider location, as well as the geographic and climate characteristics of area where the construction of the facility is planned. Also, analysis of already built similar objects can use as a good example, or to avoid possible mistakes. Although every building is unique, lessons from zero energy object case studies can be implied – understanding the success of a zero energy project can influence on the improvement of such buildings in the future. The final result of this phase is defining basic principles, including information about organization, the main requirements and a feasibility study [6].

3.2. Programme of requirements

Setting goals is very important for achieving high performance object, so the way zero energy goal is defined is crucial for understanding and applying a combination of energy-efficient measures and renewable energy supply options. It is necessary to define specific and measurable targets of energy performance, which can include the share of energy savings, the share of energy costs and the reduction of emissions of harmful gases [6].

Fig. 1. Scheme of connection between net zero energy buildings and energy grid [4]
3.3. Design
Although there is no exact approach for designing and realization of zero energy objects, there is consensus that design of such buildings should start from a passive solar design. According to this, net zero goal can be achieved as a result of application of two steps: (a) reducing building energy requirements, and (b) the production of electricity or other type of energy, in order to obtain sufficient credit to achieve an “energy balance” – the amount of electricity delivered to the electricity distribution network should be equal to or greater than the amount of electricity taken from grid [1].

3.4. Materialization
Choosing materials usually takes place in the design phase and then is finished in materialization phase. Appropriate choice of materials and their quality is extremely important. Materials used for construction of zero energy objects should be from recycled materials (or recyclable materials), renewable products, and, if possible, regional, which means that they are delivered from maximum 800 km from the site. Since building envelope can have a huge impact on heat gains/losses, material selection is important item in the design of zero energy objects.

3.5. Use and management
After construction is complete, it is important to check whether the object meets the expected results. A careful analysis of the object’s functions can help identify possible problems. This does not apply only to the period immediately after the construction of the building, but also for a longer period of time. Evaluation in this phase can be used for improving object itself, or to assist design processes of another object. Based on this, guidelines for programs of requirements and designs for similar objects can be made, especially if evaluations of several different objects are taken into account [6, 7].

Only building which is managed properly can meet predicted energy-efficient goals. People who are in charged for object maintaining must understand how to properly manage the building in order to achieve maximum performance [1].

4. Realization of residential zero energy object – house in Denver
Design of this house in Denver combines the application of well insulated envelope, energy-efficient equipment, appliances and lighting, as well as the passive and active use of solar energy in order to achieve a zero energy goal (Fig. 2). This family house, dimensions 7.3x14 m, has three bedrooms. Project is realized in cooperation with Habitat for Humanity of Metro Denver and National Renewable Energy Laboratory (NREL). In first two years of use, house exceeded the net zero energy target and was a net energy producer, i.e., in the first year of using it produced 24% more energy than it consumed, and in the second year 12% more than it consumed. This house uses electrical grid to store surplus electricity when system produce more energy than the house uses, and takes electricity from electrical grid when the system produces less energy than house needs. This approach eliminates the need for an energy storage battery, thereby reducing the cost and maintenance of the complete photovoltaic system [8].

The design of the house began with an analysis of the location that, due to adequate characteristics, was selected in Wheat Ridge. Considering position of trees lined along the south side of the plot, the building is placed along the northern edge of the plot. Building envelope is from a double stud wall with fiberglass batt construction, which significantly affects the reduction of heat losses. In order to reduce house heating needs the glazing area on the south façade is increased, while on the other orientations is reduced (Fig. 3). Double-glazed, low-emissivity (U-value = 1.70 W/m2K) with high solar heat gain coefficient (SHGC = 0.58) glass was chosen for the southern windows, while double glazed low emissivity (U-value = 1.24 W/m2K) with low SHGC (0.27) were used for the east, west, and north windows [8].
5. Realization of public zero energy object – Research Support Facility in National Renewable Energy Laboratory (NREL) campus

The Research Support Facility (RSF), located on the main campus of the National Renewable Energy Laboratory (NREL) in Golden, Colorado, is a good example for sustainable, high-performance design that incorporates the best in energy efficiency, environmental performance, and advanced controls using a "whole building" integrated design process. The preliminary design goal was to make the Research Support Facility as energy efficient as possible. Achieving net zero energy goal required optimization and integration of all the energy flows and systems of the building [9, 10].

Building is organized in two 18 m long wings for optimal solar orientation. On the west and east facades the number of windows is reduced, while on the north and south side windows of optimal size and with blinds provide daylight, and reduce unwanted heat gains when necessary (Fig. 4). Thermal comfort of building is achieved by using an integrated system of thermal mass, radiant slabs and natural ventilation.

The building includes a large thermal labyrinth under the two main office wings, which can store heat from the transpired solar collectors on the south facades of the building (Fig. 5). This heat is used to passively temper the ventilation air during the heating season. The labyrinth also serves as a thermal sink for rejected heat from the building's data center; lowering the cooling loads of the data center during year [9].

Before reaching the labyrinth, the outside air is passively heated over solar collectors located on the south facade of the building. This type of transpired solar collector has a metal sheet perforated with small holes. Fans pull air through the holes on sunny winter days to preheat building ventilation air and "charge" the labyrinth (Fig. 6). National Renewable Energy Laboratory and Conserval Engineering, Inc. developed this collector, and won both the Popular Science Best of What's New Award and an R&D Magazine R&D 100 Award in 1994 [10].

Exterior walls of the RSF are made from modular and thermal insulated panels, designed by project team. Prefabricated panels consist of 5 cm thick insulation between 7 cm thick prefabricated concrete on the outside, and prefabricated concrete 15 cm thick from the inside. Prefabricated concrete, which is manufactured in Denver, of concrete and aggregates from Colorado, represents finishing from both the outside and the inside of the building, but on the inside it is painted. Although they are manufactured in various shapes and with different dimensions, the average dimensions of these panels are 4x9 m [9].
Daylight was one of the main influencing factors during the design process of the RSF – the building’s “H” configuration evolved in response to the need for daylight deep into the building. A combination of extensive computer modeling and careful selection and placement of windows and light-reflecting devices produced a building in which parts that are up to 9 m away from the windows are illuminated. On the south facade, overhangs shade the lower glass, so light enters through the upper glass and highly reflective louvers, which direct it toward the ceiling and deeper into the space (Fig. 7). The north glazing is not shaded because the softer and more diffused north light does not usually create glare problems.

The roof of the building is covered with photovoltaic panels with a total installed power of 450 kW. Photovoltaic panels on the rooftop alone will not offset the RSF’s energy needs, so several parking structures are covered with additional photovoltaic panels. The combination of panels on rooftop and parking structure provides 1.6 MW of electricity to offset all the building’s annual energy needs [10].

Selection of materials confirms object’s sustainability. A series of gabion walls that run through the site and courtyards are made of stones found during excavation. Instead of being transferred to another location, they are reintegrated and used to build supporting walls. Also, the interior walls of the lobby are made from pine, from Colorado forest, that was destroyed by insect invasion and cannot be used for other purposes [9].

6. Final remarks

Location choice is important step in designing zero energy objects, considering that it has a big impact on organization of object, passive solar characteristics, possibility of natural ventilation, material selection and construction costs, and users health and satisfaction. Envelope of the zero energy buildings should satisfy all requirements related to increasing energy efficiency.

Daylight is also an important characteristic of zero energy objects – except natural light is much more comfortable for people it also contributes to significant energy savings. Control of electric lightning, can be applied in all climatic conditions and in all types of buildings.

It is well known that natural ventilation positively affects human health. Design of natural ventilation should rely on the natural air flow, and, unless the direction and speed of the wind are not constant, the need for using mechanical ventilation systems is eliminated.
Integral part of zero energy objects are photovoltaic systems, as part of the roofs and facades. On low-rise objects photovoltaic panels are usually located on the roof, while in high-rise buildings they are installed as non-transparent and semi-transparent façade elements [11].

7. Conclusion
In this paper, phases of building process as well as experience in realization of residential and public zero energy objects, is analyzed. The biggest challenge in designing zero energy objects is finding the best method for energy savings in combination with use of renewable sources for producing energy on site. These challenges are especially big in cases of a renovation projects for existing objects, with the aim of becoming a zero energy objects. Typical examples of systems using renewable energy sources today include photovoltaic systems, solar water heating systems and wind generators.

Main idea of zero energy concept is that buildings can meet all their energy needs using low-cost, locally accessible and nonpolluting renewable energy sources. At the strictest level, zero energy building produces enough amount of renewable energy to equal to or exceeds annual energy requirements. Integration of generation and consumption of electricity in one place, in a multi-functional object, represents direct connection between technology and architecture. This kind of projects enables combination of renewable energy technologies and modern architectural principles, making architectural objects more attractive and efficient.

Although is this concept still in development, and the construction of buildings according to it is a serious architectural and technical venture with high initial investment, built objects justify setting the challenge of achieving zero energy consumption. Reduction of energy consumption and emission of harmful gases requires improvements in the performance of existing buildings, as well as the design and construction of new buildings in line with energy efficiency goals.

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ПРОЦЕСС СТРОИТЕЛЬСТВА И РЕАЛИЗАЦИЯ ОБЪЕКТОВ С НУЛЕВЫМ ПОТРЕБЛЕНИЕМ ЭНЕРГИИ

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Аннотация: Здания являются крупнейшими потребителями энергии, а также крупнейшими производителями CO2. Чтобы изменить это, в последние годы развиваются многие подходы, и один из них – объекты с нулевым потреблением энергии. В основе концепции «нулевой энергии» – производство энергии для энергетических потребностей здания из возобновляемых источников энергии или других технологий, которые оказывают очень низкое воздействие на окружающую среду. В данной статье представлен анализ процесса строительства объектов с нулевым потреблением энергии, а также опыта в реализации жилых и общественных объектов с нулевым потреблением энергии. Также приводятся рекомендации для проектирования объектов с нулевым потреблением энергии.

Ключевые слова: строительный процесс, нулевая энергия, возобновляемые источники.