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# Building Energy Studies

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**Abstract**

In recent years researchers, experts, building companies, and ordinary people have been interested in such matters as the use of various energy sources and the increase of the energy efficiency of buildings. The main goal of the given study is to present an overview of modern ideas and approaches to the use of various energy sources at different sites (including the co-utilization) and the increase of the energy efficiency of buildings and structures. The main method of the given study is the analysis of related information from different open sources. The conclusion of the study includes recommendations concerning the prospects of the utilization of the analyzed engineering ideas and project solutions in different areas of building for the purpose of increasing the energy efficiency of buildings and structures.

**Keywords**: energy efficiency, alternative energy sources, building and structure energy supply, building, innovation, project.

## 1. Introduction

Nowadays new types of buildings are being developed and used in the building industry: multi-purpose complexes, supermarkets, high-rise buildings, villas, energy-efficient buildings, etc. New building materials, insurants, protective guard structures, glass structures, and translucent structures, allowing building residential buildings with large window areas and even “glass buildings”, are being developed.

A wide range of individual heat and energy sources is available. The use of alternative energy sources (heat pumps, solar collectors, fuel cells, etc.) is becoming more and more popular. At the same time, microclimate requirements are changing, and environment protection and energy saving requirements are getting higher. The need to protect the environment, reduce negative anthropogenic impact, and limiting the maintenance costs of residential and production facilities inevitably leads to the development of new solutions in the sphere of building energy efficiency and supply.

That is why there is no doubt concerning the importance to consider the use of different energy sources (including alternative) and the reduction of electrical and thermal energy consumption during the construction of structures and buildings. In the present study, we analyze modern approaches and innovations connected with the co-use of different (including alternative and autonomous) sources of building and structure energy supply and the possibilities of reducing costs connected with the use of thermal and electrical energy by increasing the energy efficiency of buildings and structures.

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## 2. Co-use of different energy sources in buildings and structures

Modern equipment and the development level of the building industry allow architects and designers to create new, peculiar types of buildings and structures. Nowadays the creativity of architects should be supported by unconventional engineering solutions. Let's take Dusseldorfer Stadttor building made of glass – it has a system of "climate buffers" between two external protective guard structures allowing the building to function without mechanical ventilation and reduce heating energy consumption by 30%. That is achieved through the use of solar radiation heat during the transition period and low-temperature ground water and cooled ceilings when cooling is needed (see Figure 1)

**Figure 1: Dusseldorfer Stadttor building [1]**

On especially cold winter days, Stadttor can receive extra external heat from energy sites nearby in addition to energy generated by solar panels. Moreover, air in the building is heated thanks heat recuperation in the ventilation system. In summer the building's external sun-protective coating protects prevents overheating. Intaken air is conditioned to a comfortable temperature by the adiabatic cooling system. Dusseldorfer Stadttor is equipped with over 14 thousand sensors and measurement points monitoring the functioning of the life support and energy supply systems. Nowadays high-rise buildings, both residential and commercial – are being built all over the world. The design of climate control systems in such buildings is noticeably more complicated than the one of standard multi-story buildings (up to 75-meter-high), as the impact of external conditions on high-rise buildings and the internal flows of energy and heat in them are extremely serious. Moreover, high-rise buildings often lack room for vertical communications, which means that central systems can sometimes be unsuitable for such buildings.

On the other hand, the height of such buildings creates high pressure in pipe works, which results in the necessity to divide them into zones. Due to the length of pipe works in high-rise buildings, the importance of water balancing is very high. Designing a multi-story building, one should carefully calculate the rate of thermal expansion and contraction of cold/hot water standpipes.

Compared to “old” high-rise buildings, modern high-rise residential buildings and complexes have the following peculiarities in the design and maintenance of their engineering equipment:

- Modern multi-purpose high-rise residential complexes have well-developed infrastructures: besides apartments, such buildings have underground parking lots, fitness halls with tennis courts, water parks, bowling halls, etc. There are recreation areas, children playgrounds, football fields with running tracks, and even yacht clubs in adjacent territories. Nowadays there are sky bridges between separate multi-story buildings. Such multi-functionality of modern building complexes results in their saturation with engineering equipment and high energy supply requirements;
- high requirements concerning the climate control of premises demand the installation of a central supply-extract mechanical ventilation, air conditioning systems, and individual air supply units (within apartments) as well as split systems;
- the use of automated accounting and billing systems allowing flat owners to pay only for actually consumed electricity and hot and cold water have resulted in the implementation of fundamentally different systems of heating and water supply: nowadays high-rise buildings are equipped with horizontal apartment-by-apartment systems allowing tenants to regulate air temperature within their apartments using thermostats; apartments are also equipped with individual heat, cold, and hot water meters;
- the big number of household appliances and electric devices used in apartments has significantly changed power supply: the peak of energy consumption has switched towards the warmer periods, which, however, does not mean that in winter energy consumption is low. The use of computer, automatic, Internet, and cable TV equipment has filled apartments with low-current systems that previously were almost unused;
- the requirement of electricity, heat, and hot water continuity, as well as high fire protection and consumer requirements towards buildings have demanded the automation and dispatching of hot and cold water supply, ventilation, air conditioning, and fume ventilation systems;

Nowadays specialists develop futuristic concepts of skyscrapers equipped with different energy supply and climate control systems. Below are several examples of such peculiar concepts using different life support and energy supply systems?

The Tree Skyscraper concept has been developed by French architects Eric Gangaye, Frédéric Velaye Andy, Alvin Pakeeroo, Yann Terrer, and Thomas Liaigre. According to the concept, the skyscraper will be located in the town of Montpellier. It looks like a giant tree. The building’s vertical design will be used to connect different districts of the town. The building will be provided with energy through solar panels and wind turbines. In order to maintain an appropriate microclimate within the building greenery and a water collection system will be used (see Figure 2)

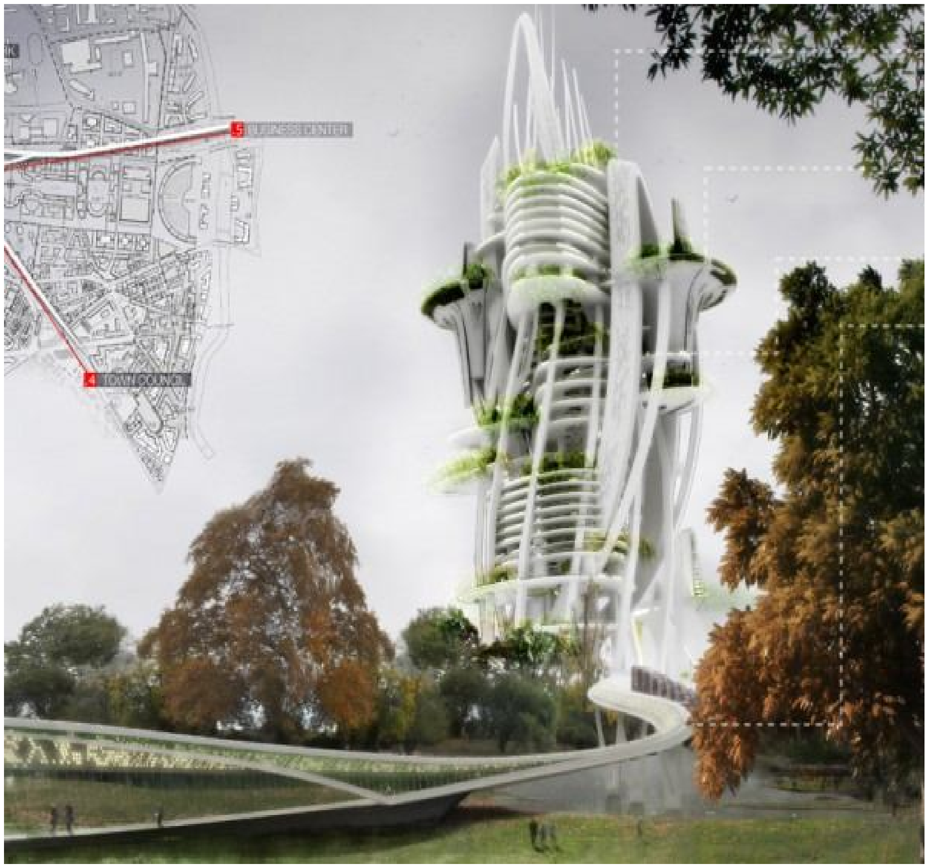


**Figure 2: The Montpellier Tree Skyscraper project [2]**

The Himalaya Water Tower project by a group of Chinese architects (Zhi Zheng, Hongchuan Zhao, Dongbai Song) is intended to be implemented within the glacier areas of the Himalayas where a significant share of the world's fresh water deposits is located. The building complex is planned to collect water during the rain season, purify it, and store in the form of ice for further use. Water will also be supplied to the adjacent regions of China. Wind turbines will be used as the main source of electricity for the building complex (see Figure 3).

The lower part of Himalaya Water Tower consists of six curved stack pipes, wind turbines, and water tanks. Each of the six pipes has additional layers over the main pipe, which helps the system retain water. The top of the building visible over the snow line is used for the storage of frozen water (ice). It consists of four massive ice-filled tubes supported by a steel frame. Between the two sections of the building there is equipment which freezes collected water when it's too warm for it, purifies it, and controls the distribution of water and ice all though the building. In the lower part of the tower, between the six tubes, there is a water transportation system distributing water to cities and towns located below the complex.

**Figure 3: The Himalaya Water Tower project [3]**

The development of another group of Chinese architects and designers (Ting Xu, Yiming Chen) looks as peculiar. It is called Light Park Floating Skyscraper. The project is a skyscraper park floating in the air. It is planned to be built in Beijing (Figure 4).

**Figure 4: The Light Park Floating Skyscraper project [4]**

The building is supposed to be kept in the air by a kind of a huge balloon powered by solar panels and equipped with a motor (screw propeller) system. Besides the solar panels, the balloon will be equipped with a rainwater collection system that will collect and filter rainwater for further use in households. The structure will have parks, sports areas, and other facilities for active recreation. Those facilities will be located on platforms on different levels (for the maximum illumination) hung by reinforced steel cables. Those platforms will rotate about the same axis.

## 3. Alternative and autonomous sources of energy for buildings and structures

Alternative sources of energy for public buildings and structures are not only a means of saving money, but also help prevent energy supply irregularities. They also reduce the risk of fire accidents caused by the damage of wear of external energy equipment (pillars, wires, etc.). Moreover, it should be noted that large public buildings and structures can sometimes consume as much energy as industrial complexes do. It is especially important in summer when the client flow of such buildings and structures grow significantly.

In summer, such alternative sources of energy as solar panels and wind generators become especially efficient. Nowadays such power sources are widely used in different countries. In autumn, when the amount of solar energy decreases, thermal pumps become highly energy-efficient. To assess the energy economy of such approach we should note that an average efficiency of one pump amounts to 5 kW for 1 kW of energy consumed. As a result, such approach allows saving 70% of energy resources. The wide range of thermal pumps (5 – 1,000 kW) available in the market allows choosing equipment that suits the specific needs of particular buildings, based on their client flow. That is why many modern buildings are equipped with harmonized power supply system's consisting of uniformly loaded solar panels and thermal pumps.

Nowadays the provision of single-family houses with thermal and electrical energy by alternative supply systems is becoming a vital task. It should be noted that nowadays the range of available alternative heating systems is quite wide:

- Solar collectors utilizing solar thermal energy;
- Boiler units using solid, liquid, or biofuel;
- Thermal pumps utilizing geothermal energy;
- Various types of IR heaters, "warm floor moldings", "warm floors", and other built-in electrical heating systems.

Nowadays such systems are a common thing supplementing and sometimes replacing conventional central heating systems.

## 4. Increasing energy efficiency of buildings and structures

In building, energy efficiency means a set of measures intended to reduce buildings' and structures' consumption of thermal energy required for the maintenance of a desired microclimate in such buildings and structures. Such measures should meet certain economic and safety requirements. Presently there is a big number of buildings, micro-districts, and architectural zones designed and built on the basis of energy-efficient and environment-friendly technologies.

Energy-efficient buildings are nowadays much spoken of. They are buildings efficiently utilizing energy resources thanks to the use of innovative solutions that are technically feasible and substantiated economically, as well as acceptable from the ecological and social points of view. Moreover, they should not change people's usual lifestyle. The energy consumption of energy-efficient buildings can be either low or zero.

Nowadays many laboratories and other R&D facilities study the energy efficiency of buildings under construction and develop innovative approaches in this field. It should be noted that energy-efficiency ideas and developments of different scopes and areas of implementation are presently widely used in different countries. Below is the brief description of several energy-efficient building projects. The Heliotrope project implemented in Freiburg, Germany, is one of the first "zero-energy" buildings consuming no energy from city networks and emitting no $CO_2$ to the atmosphere (see Figure 5).

**Figure 5: A heliotrope [5]**

Beside the standard water-purification and rain water collection systems the roof of the building is equipped with a solar panel which does 180° turns during the daytime following the Sun. It allows the building to accumulate 5 times as much energy as it needs. The design of the building is based on a project by Ralph Disch Solar Architecture. In 2010, the HQ of SAP located in Newtown Square, Pennsylvania, USA, was awarded platinum Leadership in Energy and Environmental Design certificate by the U.S. Green Building Council for its environment friendliness. The building consumes 49% less energy than an average office building of a similar size. Among the key features of the building is the sensor lighting control system – the building has automatically opening/closing glass walls and light-sensitive shutters. The building is also equipped with ice storage and production facilities: melting ice cools the building during the daytime and freezes during the nighttime. The glass walls of the building ensure maximal thermal insulation and are capable of filtering UV radiation (see Figure 6).

**Figure 6: A heliotrope [6]**

33.5-thousand-square-metre G. Park Blue Planet logistics center (Staffordshire, UK) designed by Chet woods and built in 2009 is full of latest developments in the fields of eco development and building energy studies. This project is the world's first building awarded with a BREEAM (Building Research Establishment Environmental Assessment Method) certificate in the Design category (See Figure 7).

The building is provided with thermal and electrical energy on a continuous basis due to the use of a bio station. It is also equipped with a rainwater collection, purification, and distribution system, as well as special roof lamps allowing controlling lighting during the nighttime. The wall material of the building is capable of accumulating heat. The building has a low flat roof that collects water and directs it, via special channels, to ponds within the technical area. The building can be powered by different renewable sources of energy including solar and kinetic. Moreover, the building generates so much energy, that it can satisfy the needs of nearby buildings as well.

**Figure 7: G.Park Blue Planet [7]**

G.Park Blue Planet The building provides 100% energy and heat from renewable sources, saving 49% on heat and power, 68% on heating, and 68% on water, to provide an overall energy cost in use saving of £300,000 per annum. This sustainable logistics scheme is an example of Chetwoods' holistic approach to environmental design in addressing the social (green corridor and ecology park), environmental (carbon positive creation of energy for general consumption), and economic (savings in cost in use) facets of sustainable design [7].

## 5. Conclusion and Recommendations

The given review proves that nowadays different building projects are based on technologies connected with the use of different energy sources, natural ventilation (even in high-rise buildings), and alternative sources of thermal and electrical energy. The use of such systems has advantages in terms of environment protection and the reduction of electrical energy consumption as well. Some modern buildings are designed as "zero-energy" buildings, i.e. they only use energy generated by themselves. Other buildings are capable of both providing themselves with enough energy via the use of alternative energy sources and distributing extra energy to nearby facilities.

Obviously, the further development of building technologies will be accompanied by the wide use of alternative sources of energy that will partly or completely replace conventional ones. In the nearest future advanced energy, supply and energy-efficiency technologies should transform from bold fantasies and creative projects into standard solutions for both large sites or small single-family houses.

In this connection, it is especially important to understand how compatible buildings' and structures' sources of energy are with their internal microclimate control systems, as their incompatibility can affect the efficiency of their use. In our opinion, that is the main direction in which building energy studies should develop.

## 6. References

Das Dusseldorfer Stadttor. http://www.stadttor.com/.

Montpellier Tree Skyscraper. http://www.evolo.us/architecture/montpellier-tree-skyscraper/.

Himalaya Water Tower. http://www.evolo.us/competition/himalaya-water-tower/.

Light Park Floating Skyscraper. http://www.evolo.us/competition/light-park-floating-skyscraper/.

Michler, A. Heliotrope: The World's First Energy Positive Solar Home. http://inhabitat.com/heliotrope-the-worlds-first-energy-positive-solar-home/.

[Wink, C. Why is SAP North America headquartered in Newtown Square? http://technical.ly/philly/2015/03/16/sap-headquarters-newtown-square-philadelphia-delaware-county/.

G.Park Blue Planet, Chatterley Valley, Stoke-on-Trent. http://chetwoods.com/portfolio/g-park-blue-planet/..