**FACTA UNIVERSITATIS**
Series: **Working and Living Environmental Protection** Vol. 11, N° 3, 2014, pp. 191 - 199

# ENERGY EFFICIENCY AND USE OF RENEWABLE ENERGY SOURCES IN BUILDINGS CONSTRUCTION- PERSPECTIVE OF SUSTAINABLE DEVELOPMENT

*UDC 620.9:692] : 502.131.1*

**Jasmina Radosavljević, Miomir Raos, Nenad Živković, Emina Mihajlović, Ljiljana Živković**

Faculty of Occupational Safety of Niš, University of Niš, Serbia

**Abstract**. *The overall energy needs of the buildings and the measures to improve energy efficiency in buildings have been presented in this paper. The importance of sustainable construction, as one of the important segments of environmental protection and sustainable development, has been emphasized. The authors also pointed out the importance of use of renewable energy sources in the construction of energy efficient buildings.*

**Key words**: *energy efficiency, sustainable development, buildings, environment*

## 1. INTRODUCTION

Efficient consumption of energy and resources is one way to reduce energy costs and decrease harmful influence on the environment. That is why governments around the world by introducing a variety of mandatory politics on energy consumption and the environment are trying, more or less successfully to change the business and regulatory environment in which energy consumers are functioning. There is also growing public pressure and expectations that it must operate in a socially responsible manner and that resources must be used efficiently. Special attention is devoted to energy consumption in building constructions, because it is one of the largest consumers of energy.

Energy consumption in buildings construction in Serbia (public and private) in the final energy consumption is 36%, which is higher than the industry and transport sectors individually. Electricity consumption in buildings construction is about 60%.

Sustainable consumption of energy should be prioritized by rational planning of consumption, the implementation of energy efficiency measures in all aspects of the

---

Received September 1, 2014 / Accepted January 15, 2015
**Corresponding author**: Jasmina Radosavljević
Faculty of Occupational Safety in Niš, Čarnojevića 10A, 18000 Niš, Serbia
Pnone: +381 18 529 889 • E-mail: jasmina.radosavljevic@znrfak.ni.ac.rs

energy system of a country. Sustainable building construction is certainly one of the most important segments of sustainable development, which includes:

- Use of building materials that are not harmful for the environment;
- Energy efficient building;
- Reducing heat losses by improving thermal protection of external elements, and a favorable ratio of external surface area and volume of the building;
- Increase of the heat gains during the heating season by choosing the favorable orientation of the building and by passive use of solar energy;
- The use of renewable energy sources (biomass, solar, wind, etc.);
- Increasing the energy efficiency of power plants.

## 2. Policy of Renewable Energy Implementation

Several centuries, since the beginning of the era of application of fossil fuels, have been confronted with the negative consequences of the current energy system: an increase in the concentration of carbon dioxide ($CO_2$) in the atmosphere, and all the visible effects of global warming.

According to the third report of the Intergovernmental Panel on Climate Change (IPCC), it has been established that there is an urgent need for action in order to set a global energy system that will have far less emissions of hazardous gasses. The main reason for the increase of emissions of hazardous gasses is the increased consumption of fossil energy sources. Therefore, it is necessary to limit the use of fossil fuels in order to reduce negative consequences of global warming. Generally it requires significant changes in energy policy around the world. Reducing dependence on non-renewable sources of energy involves a profound change in the current energy model, on one hand, the reduction in global consumption, on the other hand, increasing the share of renewable energy in energy consumption. Introducing and application of renewable energy on a global scale, can significantly contribute on solving these problems. Renewable energy sector represents a significant innovative step compared to existing conventional energy supply options.

The key drivers of development and financing of renewable energy technologies are the appropriate legislative framework and a favorable tax environment. In order to encourage investment in renewable energy sector, the government should implement a number of new mechanisms for funding through the public sector. There is no universal system that can be applied to all markets, but they can establish major financial incentives to investors. [12]

Promoting the renewable energy sources today is a priority for the European Union (EU). Development in renewable energy field is the answer to the two global challenges. It is primarily a very important element of the fight against climate change and reduction of greenhouse gas emissions, and it is in line with the international commitments of the Kyoto Protocol. Development of renewable energy fits into the perspective of a trend of declining available energy from fossil sources on which the growth of world economy has been based, and particularly the European economy in the $20^{th}$ century.

Policies on environmental protection, which have long been regarded as secondary, have become imperative for sustainable development and a tool of combating climate change. Renewable energy gradually gained on the importance after adopting extremely ambitious objectives of the European Union and the member states.

The first step of the European legislation in favor of renewable energy was the announcement of the European Commission in 1997 published in the White Book. This document represents the beginning of European mobilization, where the goals of minimum 12% share of renewable energy in total energy consumption by 2010 were defined for the first time. The Directive 2001/77/EC from 2001 promoted electricity generation from renewable energy sources and also imposed to all States to build a legal framework that would define development of renewable energy sources [2].

The European Union in 2009 adopted the Directive 2009/28/EC which refers to renewable energy, and it is part of the Energy and climate package. The aim of this Directive is to part of renewable energy in total energy consumption in the EU by 2020 be 20%. This also means 20% less greenhouse gas emissions compared to the levels in 1990. The European Union is committed to integrate the environmental issues into all relevant areas, including the energy sector. In late 2011, the European Commission adopted the "Guide to Energy by 2050." In this document, the EU committed to reduce by 2050 greenhouse gas emissions by 80-95% compared to the levels in 1990.

The approach of the EU should be long-term, extending after 2020. Many of the investments that are needed in the energy sector are long-term, so it is therefore necessary that energy policy as clearly as possible be defined now for the period after 2020. In the EU, as well as in Serbia, energy sector in large part contributes to greenhouse gas emissions. For this reason, the reduction of emissions from the energy sector is very important in the EU and Serbia.

The basic idea of the concept of energy efficiency is to use less energy for the same unit of gross national income, with a sustainable quality of a product. Reducing energy use and the elimination of environmental pollution that is a result of energy transformations are among the major goals of energy policy and the majority of other EU policies. Renewable energy sources are becoming increasingly important aspect of the European energy system. Serbian energy sector is facing a number of challenges that must be solved to ensure future reliability, efficiency and sustainable providing of energy services to the population and to the all industry parts of Serbia. The principle of energy efficiency involves the rational use of energy, and the elimination or minimization of energy losses, both in the consumer and in the energy production sector. Energy efficiency must be increased in the sectors of energy consumption by introducing more efficient technologies and appliances, better isolation of the buildings, etc.

Serbia has significant energy potential in renewable energy sources, but it is not sufficiently used or not used at all when it comes to sources of energy like wind or solar radiation. The potential of renewable energy sources in Serbia is significant. According to assessments, over 4,0 million tons of oil equivalent (Mtoe) per year, which is equivalent to almost half of annual energy needs of the country. Biomass is considered to be the greatest potential in Serbia. The potential of biomass is estimated to be about 2,7 (Mtoe), or 63% of a total potential. Also, 0,6 (Mtoe) in unused hydropower (14%), 0,2 (Mtoe) in geothermal (4.5%), 0,2 (Mtoe), in wind power (4.5%) and 0,6 (Mtoe) in solar energy (14%) [3,4,13].

## 3. ENERGY USE IN BUILDINGS

Energy, environmental and economic crises in recent decades of the last century are having a significant impact on urban planning, civil engineering and architecture. In terms of a multiple increase in energy prices and the strengthening of the environmental movement, the architecture has responded with a study of traditionally known methods of building in harmony with nature and tradition, and analyzed the possibilities for using renewable energy sources. Teams of researchers study the existing facilities in order to discover: how an object receives energy, how energy losses in new facilities can be reduced, what can be done to reduce energy losses in the existing buildings. The results showed the possibilities for reducing energy consumption in buildings and at early stage, those results influenced the design energy efficient buildings, energy-efficient buildings that save energy, reduce CO2 emissions, which is very important for the preservation of the environment [9].

Modern architecture should consider all measures that contribute to increase of energy efficiency, use of renewable energy, district heating and cooling, reducing the use of fossil fuels and environmental pollution. Buildings are significant consumers of energy. Statistics show that in developed countries, buildings consume about 40% of the total energy, and thus are responsible for 40% of greenhouse gas emissions into the atmosphere. Total annual energy needs of buildings are equal to the energy needs for heating and domestic hot water, cooling, ventilation and air conditioning, lighting and operation support systems. One can say that the total energy needs of buildings depend on the following energy systems:

- The building envelope (walls, floor, ceiling, roof, windows, doors and associated thermal protection);
- The heating system;
- Systems of ventilation and / or air conditioning;
- Systems for hot water;
- System of electric lighting [1,7].

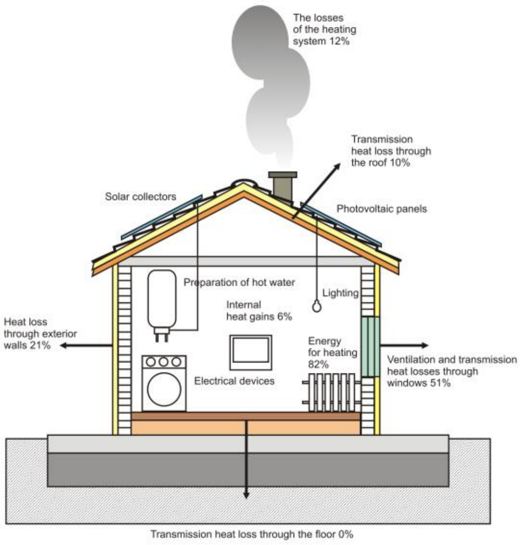


**Fig. 1** Technical systems in a building that determine the consumption of energy in a building

Out of the total annual delivered energy in buildings, about 60% is spent on heating in the building. Therefore, it is important to design a facility that will have less heat losses. With proper design and construction of facilities, heat losses in the house can be significantly reduced, and there will be less need for compensation of lost energy and financial and energy demands for additional warmth.

Comprehensive energy efficient, environmentally positive and economically acceptable measures aimed at creating conditions for a systematic rehabilitation and reconstruction of existing buildings and increase of the required thermal protection for new buildings. The average old house spends 200-300 kWh/m$^2$ of energy for heating, standard insulated homes consume less than 100kWh/m$^2$, modern low energy houses consume about 40kWh/m$^2$, a passive house 15kWh/m$^2$ or less. Energy that is now consumed in the average home in Serbia, can heat up 3-4 low-energy houses or even 8-l0 passive houses.

Insufficient thermal insulation of buildings is the cause of the increased heat losses in winter, cold external structures, damage caused by condensation of moisture and overheating of the space during the summer. The consequences of this are structural damage, non-comfortable and unhealthy living and working conditions. Heating of un-insulated space requires a greater amount of energy, which leads to increase of the price of their use, and maintenance of the space, but also to greater environmental pollution. Heat losses of buildings can be reduced by about 40-80% if the isolation properties of building are better. Large range of reducing heat losses of buildings indicates large differences in the conditions of the existing buildings, which certainly depends on their age, the used materials and the way of maintenance. Energy renovation of old buildings, especially of those built before 1980, would contribute to savings in heating energy consumption with by 60%. Houses and flats built in Serbia before 1970 had almost no thermal isolation, while in the buildings made before 1980, the isolation was very modest. Over 75% of the buildings in Serbia were made before 1980. At these facilities, it is possible to achieve the greatest energy savings for heating, up to 80%. 70% of total energy consumption in buildings is consumed in households and residential buildings, 18% in commercial, while public buildings are consuming about 12% of the energy.

The biggest savings can be achieved by replacing windows and isolation on exterior walls. Additional investments in thermal isolation, in case of reconstruction of already dilapidated facades, are in the total cost of rehabilitation of the facade 20 - 40%, which gives a favorable economic results [10,11].

When constructing a new home it is important for the conceptual design phase to predict all things needed to get optimal energy-efficient buildings. Therefore, it is necessary to:

- Analyze the location, orientation and architectural form of the building;
- Apply a high level of thermal isolation of the building envelope and avoid thermal bridges;
- Take advantage of the heat gains from the sun and apply protection from excessive sunlight;
- Use energy efficient heating, cooling and ventilation systems and combine them with renewable energy sources.

Through the Law of Planning and Constructing, the obligation to improve the energy efficiency of buildings is defined in the design phase, construction, use and maintenance (Article 4), so that the prescribed energy properties are determined by issuing certificates of energy performance of buildings. When the “Regulation of energy efficiency in buildings” and the “Regulations on the conditions, content and manner of issuance of the certificate of energy performance of buildings" come into force, it introduced the certification of buildings, according to which each object should have energy certificates, which describes the total energy quality of existing or future facilities. Determining eligibility of energy efficiency of the building is done by a study of EE, which is an integral part of the technical documentation to be submitted with the application for a building permission or with a request for the issuing the decision for the authorization of the execution of work on adaptation and/or restoration of the building, and repairing of energy systems [5,6,14,15].

Calculating the energy efficiency of buildings should be carried out based on the methodology, which can vary on a regional level, which includes, in addition to thermal isolation and other factors such as the installation of air conditioning and heating, the application of renewable energy and building design. Buildings have an impact on long-term energy consumption and, therefore, new buildings must satisfy minimum requirements in terms of energy efficiency, which are adapted to the local climate.

In addition to reduced energy consumption by improved energy efficiency in all areas, nowadays, a more independent, more vital and resilient energy system in which the renewable energy will play an important role in satisfying energy needs should be developed. In this sense, the use of renewable energy, such as solar energy (active and passive systems), wind energy, biomass energy, geothermal energy, hydropower, and use of "waste" heat should be promoted.

Energy-efficient buildings have low energy consumption for heating, cooling, domestic hot water, ventilation and lighting.

Categories of energy class A represent low-energy buildings. They involve the following:

- Zero-energy facilities ( 0[kWh/m²] consumption per year )
- Passive facilities (up to 15[kWh/m²] consumption per year )
- Energy efficient buildings (up to 40 [kWh/m²] consumption per year).
- Passive houses can be built with almost the same cost - as well as the classic house of the same size. Passive house must satisfy certain criteria:
- Heating - up to 10 [kW/m²];
- Total energy needs (all consumers, electricity and hot water) up to 42 [kW/m²];
- The total primary energy needs (for all), a maximum of 120 [kW/m²].

Average apartments in Serbia are energy efficiency class F and G, which indicates that little attention has been paid to this issue in Serbia. However, this needs to be changed by introducing energy technical inspections and issuing certificates/energy passports for buildings. This certificate will be of great importance, because it will dictate the value of a building and thus contribute to improved energy efficiency in construction.

Low-energy and passive houses with significant isolation have great energy savings for heating, up to 10 times, and also have significantly reduced emission of $CO_2$ into the environment. $CO_2$ emissions generated during the operation of the technical system is determined based on data for specific $CO_2$ emissions for certain sources of power, such as the annual primary energy required for the operation of technical systems, calculated for a particular energy source, is converted by the conversion factor for the specific emissions of $CO_2$.

The concept of low-energy and passive houses is very popular in EU and also financially supported by the governments and in Serbia, there are pilot projects.

Energy consumption in buildings should be minimized so that there is no violation of the conditions of comfort, which means that it is necessary throughout the year to maintain the thermal parameters of the internal environment, air quality, the required level of brightness, a sufficient amount of hot water.

## 4. Technical Requirements for Achieving Energy Efficiency for Buildings

To improve energy efficiency in buildings the following measures are to be applied:

1. *Improving building characteristics*- by reduction the needs for heating in winter and cooling in summer (thermal isolation and sealing, protection against solar radiation in summer);

2. *Improvement of HVAC* - better utilization of primary energy equipment and appliances with high efficiency, use of waste heat and renewable energy sources;

3. *Optimization of operation for technical systems* - maintaining thermal environment parameters to the desired level in the period of buildings' use by introducting an automatic control of installations operation for heating, cooling, ventilation and artificial lighting.

The most important parameters that influence the energy consumption of HVAC systems in the buildings include:

1. *Climatic factors,* which are determined by the location at which the building is situated;

2. *Orientation, architectural concept and the thermal conditions of the building envelope*: proper orientation and architectural concept of the building including a design of a building to maximize the use of natural and created conditions of the location (sun, wind, green); the rooms where people mostly spend time in (living room, etc.) should be oriented to the south to the extent that urban conditions permit; architectural form of the building should be designed so that it provides the most efficient ratio of surface area and volume of the building envelope in relation to climate factors of location, environment (natural and manmade) and use of the building;

3. *Heat zoning of a building*: thermal zoning of a building includes a grouping of rooms in the building in accordance with their temperature requirements; zone with higher temperature requirements should be designed to maximize the natural potential locations (sun, wind, green);

4. *The use of natural light and insolation*: it is necessary, when designing buildings, to maximize natural light while allowing passive heat gains in winter and overheat protection in summer, with adequate shadowing (architectural form of the object or screening systems);

5. *Optimization of the natural ventilation systems*: openings on the building, such as windows, doors, ventilation ducts, which should be designed so that heat loss in winter and heat load in summer is less; whenever possible, openings conceived so that it can maximize passive (natural) night cooling in summer.

6. *Optimization of the building structure in terms to set up a thermal mass*: Depending on the purpose of the building it should be set up thermal mass to allow maximum achievements of a thermal comfort in winter and in summer; thermal mass should increase the thermal inertia of the building, except for short-term use of the facilities; application of a high quality thermal isolation of the entire thermal envelope;

7. *The use of passive and active systems, depending on the type of building*;

8. *The use of atmospheric precipitation*, groundwater and wastewater for irrigation, exterior cleaning, as well as for heating and cooling of buildings [7, 8, 9].

## 5. Conclusion

Permanent increase in the price of conventional energy sources and increase of $CO_2$ emission caused more attention to energy-efficient construction of residential, commercial and manufacturing facilities, reducing reliance on non-renewable sources of energy by increasing the share of renewable energy in energy consumption. When designing energy efficiency facilities, special attention should be paid to the choice of materials (heat transfer coefficient of the wall “k” (U) should be as small as possible, so that there is no condensation in the wall, better fire and sound protection, as lower heat losses, the higher heat capacity), on the selection of the architectural concept forms and determining the optimal total area of external openings. Designing energy-efficient buildings requires: proper orientation of the object based on the grounds that by opening to the south of the south façade; compact volume building a limited depth; implementation canopy for protection from the summer sun; high degree of thermal insulation of the entire building envelope; windows and exterior doors with a minimum of double insulated glass, high thermal properties (k <1.40 W/m²K); design additional rooms to the north; thermal zoning of the building; the shorter piping for heating and hot water to reduce losses; isolating the interior rooms to unheated spaces; application of renewable energy sources; and so on.

The promotion of the use of renewable energy sources is a priority at the global level, because increasing the share of renewable energy in energy consumption significantly reduces the consumption of fossil fuels and also reduces the emissions of greenhouse gases in the atmosphere.

**Acknowledgement.** *Research reported in this paper was supported by the Ministry of Education, Science and Technological Development, The Republic of Serbia, within the project No. III - 43014 and project No. TR-33035.*

## REFERENCES

1. S. Dragicevic, M. Lambic, J. Radosavljevic, and M. Raos: *Estimation of the Effect of Environmental Conditions on the Efficiency of Solar Active Wall Air Heating System*, J. Energy Eng., 10.1061 / (ASCE ) EY, 1943-7897.0000156, 2013th .
2. European Commission (1997), White Paper for a Community Strategy and Action Plan. COM (97) 599 final (26/11/1997).
3. http://www.euractiv.rs/odrzivi-razvoj/2272-renewable-sources-power-energy-future
4. E.Mihajlovic, J. Radosavljevic: *Use of biomass as a renewable energy source in Serbia*, International Symposium: Energetic Technologies 10, V. Banja, p. 72-79, 2010th .
5. Regulations on energy efficiency in buildings ("Off. Gazette of the RS", no. 61/11).
6. Regulations on the conditions, content and manner of issuance of the certificate of energy performance of buildings ("Off. Gazette of the RS", no. 69/2012).
7. J.Radosavljevic, et al.: *The function of windows in buildings that are passively cooled*, Energy Technology, Vol. 2, No. 1-2, pp. 39-41, 2005th .
8. J.Radosavljevic, et al.: *Natural cooling of buildings with passive solar systems*, Energy Technology, Vol.1, pp. 41-44, 2004th .
9. J.Radosavljevic, et al.: *Thermodynamic behavior of solar building with a glass porch and thermo accumulative partition wall made of concrete*, Energy Technology, Vol. 3, pp.1-3, 2005th .
10. J. Radosavljevic, M. Lambic, E. Mihajlovic, and A. Djordjevic: *Estimation of Indoor Temperature for a Direct Gain Passive Solar Building*, J. Energy Eng., 10.1061 / (ASCE) EY.1943- 7897.0000104, 2012.
11. J. Radosavljevic, M. Raos, LJ. Zivkovic, E. Mihajlovic: *Thermal Mass of Passive Buildings With Direct Gain of Solar Radiation*, Facta Universitatis, Series: Working and Living Environmental Protection, Vol.10, (2), pp. 111-117, 2013th.
12. J. Radosavljevic: *Ecological and economic aspects of solar energy*, Engineering, Vol. 62 (5), pp.11-15, 2008th.
13. UNDP / UNEP (2012), Study on Achievements and Perspectives towards a Green Economy and Sustainable Growth in Serbia.
14. Energy Law ("Official Gazette of RS", no. 57/2011 and 80/2011).
15. Law on Planning and Construction ("Official Gazette of RS", no. 72/2009, 81/2009 i24 / 2011).

# ENERGETSKA EFIKASNOST I KORIŠĆENJE OBNOVLJIVIH IZVORA ENERGIJE U ZGRADARSTVU-PERSPEKTIVE ODRŽIVOG RAZVOJA

*U radu su prikazane ukupne energetske potrebe zgrada kao i mere za poboljšanje energetske efikasnosti u zgradama. Prikazan je značaj održive gradnje kao jednog od značajnih segmenata zaštite životne sredine i održivog razvoja. Takođe je ukazano i na značaj primene obnovljivih izvora energije pri izgradnji energetski efikasnih zgrada.*

Ključne reči*: energetska efikasnost, održivi razvoj, zgradarstvo, životna sredina*