MODERNIZATION OF THE BUILDING STOCK BY USING ELEMENTS OF GREEN CONSTRUCTION

Katya Antonova

University of Economics – Varna,
77, Knyaz Boris I Blvd, 9002 Varna, Bulgaria,
e-mail: katia_antonova@ue-varna.bg

Abstract. The challenge facing the world in the 21^{st} century is to ensure a balance between economic development and improving the well-being of people and the needs of the environment. The concept of sustainable construction has been developed for more than 30 years and is applied in many countries around the world. The aim of the author of this paper is to present the state of green activities in the field of construction in some countries and to give recommendations for the implementation of green projects in Bulgaria.

Keywords: green construction, green design, green activities.

1. INTRODUCTION

At the beginning of the 21^{st} century, the concept of sustainable construction has been increasingly adopted by the construction industry and has had a tangible impact on the design, construction, management of and trade with immovable property. It has created preconditions for higher productivity, better quality of work and has increased the market value of projects [1]. The detailed knowledge of the advantages of green buildings would bring benefits to the organizations offering construction, maintenance and management of immovable properties.

The purpose of the author in this article is to present the state of green construction activities in some countries worldwide and to give recommendations for the implementation of green projects in Bulgaria.

2. STATE OF GREEN BUILDING IN SOME COUNTRIES WORLDWIDE

Construction activities have the largest share in the consumption of global resources and the emission of harmful emissions, and they are a major factor

DOI: 10.7546/EngSci.LIX.22.01.04

influencing the environment, which is why there is a need for a new approach to construction. The essence of a sustainable approach is a balance between the economic, social and environmental aspects of construction activities.

The Strategy for the sustainable competitiveness of the construction sector and its enterprises published by the European Commission (EC) [2] focuses on promoting favourable market conditions for sustainable growth in the construction sector. Some of the main goals set out in the Strategy are: to promote favourable conditions for investment, in particular in the renovation of existing buildings and the maintenance of infrastructure; to improve resource efficiency and environmental performance; mutual recognition of sustainable construction systems in the EU and strengthening the global positions of European construction companies to promote quality work under sustainable standards in third countries.

The aim of the author is to present the state of green construction activities in some countries worldwide and to give recommendations for the implementation of green projects in Bulgaria.

The criteria according to which a building is considered sustainable are: minimizing the negative impacts on the environment and the health of users; energy efficiency and low operating costs; high quality of technical performance; security and comfort of living [3].

Sustainable buildings are characterized by [4]:

– Resource efficiency: use of terrains, construction materials, energy, water;
– Healthy environment: comfort, fresh air, daylight and as a result achieving high productivity, human satisfaction and reduction in healthcare costs;
– Achieving economies during the whole life cycle by reducing the maintenance costs of buildings and the impact on the environment.

Sustainable construction includes all measures from the location of new buildings, through the functional distribution of the homes themselves to the use of sustainable materials and installations in the construction and operation of buildings.

These measures are expressed in [5]:

– Proper location of the new buildings and simplification of their contour, i.e. the buildings should have such location so that the dwellings and the premises in them have the most favourable exposure and protection against the winds;
– Design of more dwellings facing two different directions, so as to achieve natural transverse ventilation and all-day use of sunlight;
– Orientation of the premises in the dwelling so as to achieve the best natural lighting and ventilation;

– Use of materials that do not pollute the environment;
– Installation of local heating systems and power plants that use local waste resources and combined production of electricity and heat through cogeneration;
– Introduction of alternative energy sources: passive and active use of sunlight by installing collectors for water heating and photovoltaic systems for electricity generation;
– Introduction of modern systems for waste recycling, use of rainwater and treatment of the water used for domestic purposes, etc.

Green building activities have a different presentation on the market. The companies in the construction industry are gradually beginning to perceive it as necessary. World Green Building Trends is a survey that has been conducted three times already, and the number of countries participating in this study on the development of green activities has increased many times from 2008 to 2018. Countries from Europe, America, Asia and Africa have also taken part. The study in [6] shows that emerging economies such as Brazil, India, Saudi Arabia and South Africa are drivers of green growth, and the growth of green construction is projected to increase two to sixfold compared to the current levels. The results show that the expansion of green activities will continue in developed countries such as the United States, Germany and the United Kingdom.

The study held in [7] expands the scope of the studies in [6, 8]. The new participating countries are the UAE, Spain, Norway, Ireland, and Canada.

According to the data in Table 1 profit growth is largely due to countries still developing activities related to green building. The developed markets in the United States and Europe have registered moderate rates of growth. In contrast, respondents from Mexico, South Africa, Australia, the UAE, Spain, Norway and Ireland reported much higher growth in the percentage of their green projects.

An interesting trend that can be noted is that many respondents implement green projects but do not certify them due to the still complicated procedure.

The activities for which investments are planned can be conditionally divided into four groups:
– for the construction of new residential building;
– for reconstruction and repair of existing buildings;
– for construction of new commercial buildings (offices, shops, hotels, mixed-use buildings, etc.);

Table 1. Surveyed construction companies that anticipate to make more than 60% of their projects green

Construction companies/country	2015 (%)	2018 (%)	2021(%)
USA	24	32	45
Mexico	21	44	54
Brazil	6	21	42
Colombia	18	38	46
Germany	13	31	33
The United Kingdom	17	27	40
Poland	13	21	29
Saudi Arabia	8	13	32
South Africa	27	48	61
Australia	27	46	64
Singapore	23	38	45
China	5	28	47
India	20	28	55
UAE	*	34	66
Spain	*	29	61
Norway	*	30	64
Ireland	*	40	54
Canada	*	*	48

* no data

Source: World Green Building Trends, 2012, 2016, 2018

– for the construction of new public buildings (hospitals, schools, kindergartens, stadiums, sports facilities, etc.), Table 2.

Investments in new green residential buildings are planned as follows – in Vietnam (61%), China (52%), UAE (50%) and Canada (49%). The lowest share of planned investments is in the USA (23%), Germany, the United Kingdom, Saudi Arabia and South Africa (24%) and Colombia (26%), Fig. 1.

The relative share of planned investments in the reconstruction and repair of existing buildings is highest in Singapore and Ireland (55%) and in Spain and Canada (52%). The lowest share of planned investments is observed in China (19%), Poland (21%), Saudi Arabia (22%) and India (24%), Fig. 2.

The share of planned investments for the construction of new green commercial buildings is significant. For all countries surveyed, it is over 40%, with the exception of Australia, the United Kingdom and Germany. The highest amount of investments is planned in Norway (73%), UAE (69%), Mexico and China (65%), Spain, India and Vietnam (61%), Colombia (59%), Singapore (53%) and Poland (50%), Fig. 3.

Table 2. Planned green activities for the period 2015–2021

Country	New residential buildings (%)	Reconstruction of existing buildings (%)	Construction of new commercial buildings (%)	Construction of new public buildings (%)
USA	23	50	41	45
Mexico	33	46	65	25
Brazil	35	47	47	33
Colombia	26	31	59	29
Germany	24	36	39	39
The United Kingdom	40	44	33	37
Poland	24	21	50	15
Saudi Arabia	24	22	44	50
South Africa	31	46	40	29
Australia	39	33	27	30
Singapore	35	55	53	48
China	52	19	65	54
India	48	24	61	26
UAE	50	50	69	50
Ireland	*	55	*	*
Spain	*	52	61	*
Canada	49	52	*	60
Vietnam	61	*	61	*
Norway	*	*	73	*

* no data

Source: World Green Building Trends, 2012, 2016, 2018

The investments planned in new green public buildings vary between 15% and 60% for all respondents, with the largest share in Canada (60%), China (54%), the UAE and Saudi Arabia (50%), and the lowest – in Poland (15%), Fig. 4.

The surveyed companies pointed out the following problems facing green building:

✓ Higher initial costs – USA (73%), Ireland (68%), Colombia (58%), Australia (57%), Norway (55%);

✓ Accessibility – Australia (42%), Norway and UAE (41%), UK (39%), China (38%);

✓ Lack of support from the state, included government regulations and financial incentives – Colombia (49%), Spain (45%), Brazil (44%), Vietnam (41%), China (39%);

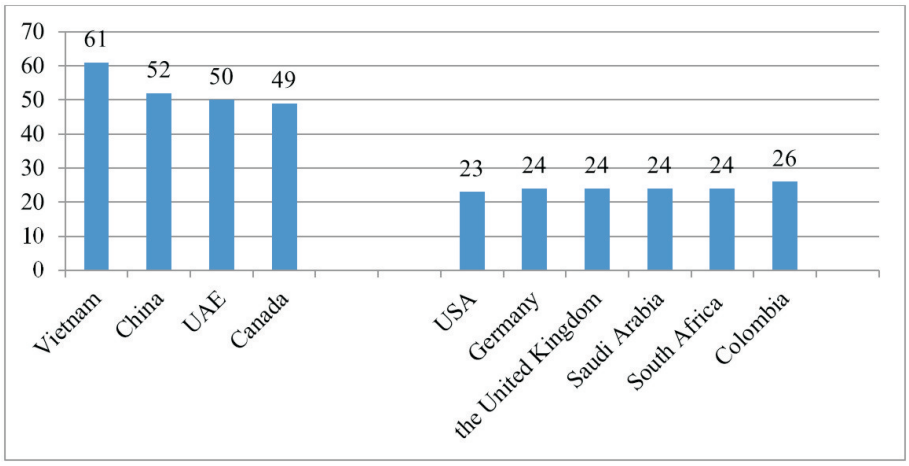

Fig. 1. Construction of new residential buildings to 2021
Source: World Green Building Trends, 2018

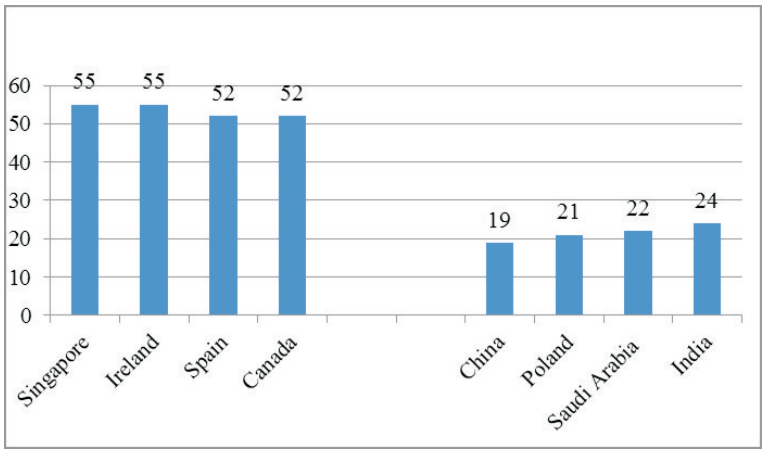

Fig. 2. Reconstruction of existing buildings to 2021
Source: World Green Building Trends, 2018

✓ Lack of public awareness – India (50%), Poland (46%), UAE (45%), Spain (42%), Vietnam (37%).

The companies that took part in the study (World Green Building Trends, 2018) were asked to rank sixteen factors that influence the decision to implement a green project. Figure 5 shows the results for the first ten that are the most important for them. In the first place, the respondents point out the requirements of the client (34%), second come the provisions for environmen-

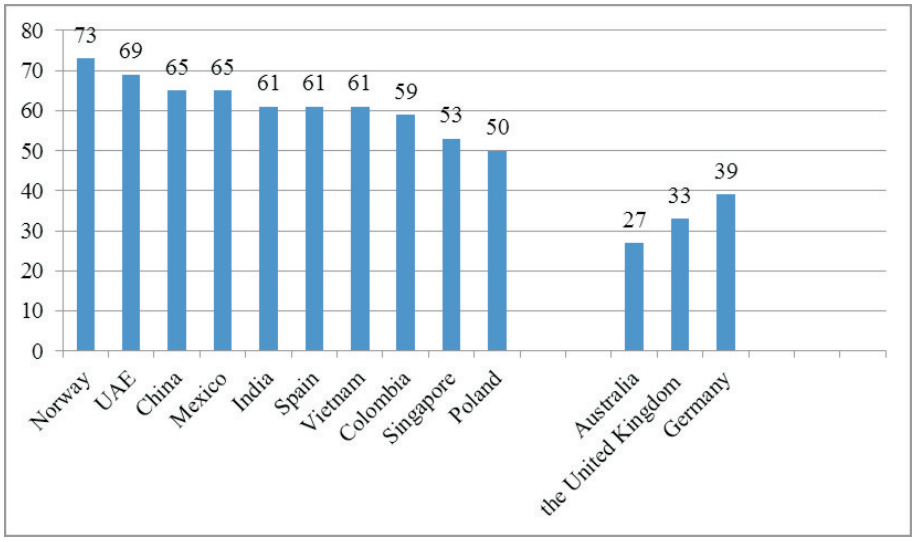

Fig. 3. Planned investments for new commercial buildings to 2021
Source: World Green Building Trends, 2018

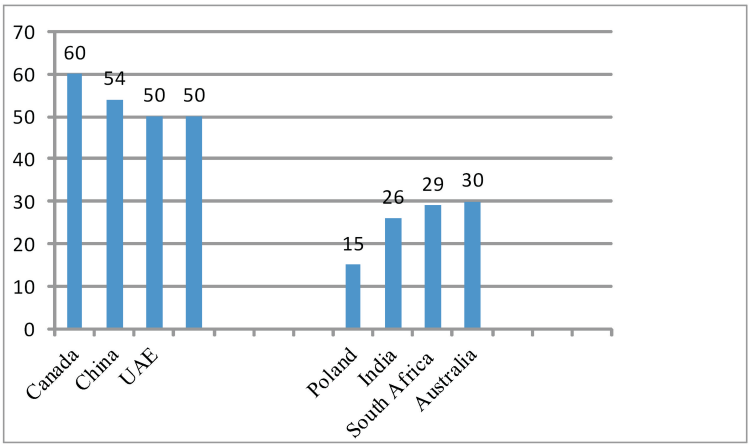

Fig. 4. Planned investments for new public buildings to 2021
Source: World Green Building Trends, 2018

tal protection (33%), and third – a healthy living and working environment (27%).

As it is crucial to demonstrate positive financial and business impacts from the implementation of green projects, the study shows that they have significantly lower operating costs compared to the costs of traditional buildings.

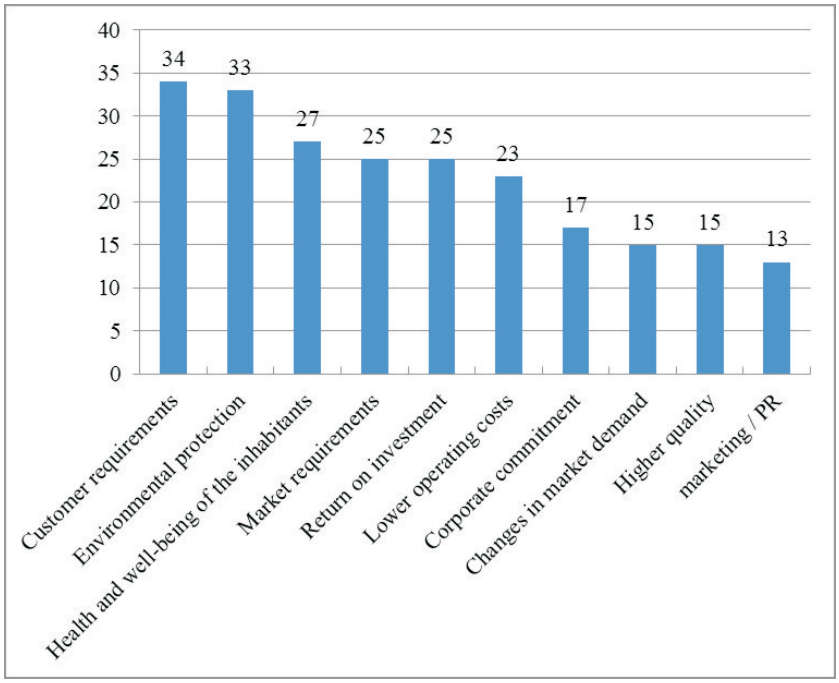

Fig. 5. Factors influencing decision making to implement a green project
Source: World Green Building Trends, 2018

The expectations of the respondents who participated in the survey for a five-year period are about 15–20% savings in operating costs for new green buildings and about 14–18% savings in the reconstruction and modernization of existing buildings.

More than 40 million people in Europe (excluding the countries of the former Soviet Union) live in nearly 12 million homes in large post-war housing estates. These housing estates have come into being as a result of the global process of rapid urbanization, industrialization and mass production of residential complexes built on the basis of industrialized technologies in a very short period of time (the 1960s and 1970s). The quality of the buildings constructed at that time has deteriorated and measures are needed to renovate them.

Problems with the ageing building stock are also encountered in our country. The measures to deal with the obsolescence and physical ageing of buildings, the depreciation and inefficiency of installations, the ageing of materials used, the deterioration of the overall appearance, the lack of adequacy in terms of requirements for accessible environment and energy efficiency are different.

The practice of technology development in the position of "smarter" building installations offers an opportunity to support and create favorable conditions for providing information to consumers and investors on energy consumption, to adapt to consumer demands and for efficient and convenient operation of buildings. In our opinion, the measures for modernization of the building stock can be divided in four main groups:

1. Measures for physical modernization of the buildings;
2. Measures to reduce energy consumption;
3. Measures to ensure adequate attitude towards the environment;
4. Measures for social rehabilitation of the environment and to ensure comfort for the inhabitants.

Architectural and structural audits as well as energy audits need to be performed before proceeding to the modernization of existing buildings in order to establish the current level of energy consumption and the measures to be undertaken for their modernization.

The physical modernization of buildings can be achieved by rehabilitating building structures, eliminating construction problems, replacing roof insulation and windows, installing effective insulation on facades to minimize thermal bridges, ensuring airtightness of the buildings, improving the outer appearance, etc. One of the methods of inspecting existing buildings is infrared thermography. This is a method of visualizing heat waves emitted or reflected by our environment. Thermography allows quick analyses of single-family houses, residential and non-residential buildings for the presence of temperature anomalies, the purpose of the assessment being to determine the condition of buildings before renovation, to analyze the quality of existing insulation systems, tightness, quality of installation of windows and suspended facades, the presence of leaks in roofs, facades, roof terraces and balconies. Detection and localization of problems is possible through the thermal images and photos, on the basis of which reports are prepared for the actual state of affairs.

One of the basic principles of the Energy Union is "Energy efficiency first" according to the Energy Performance of Buildings Directive [9]. Most buildings in Europe have not yet been renovated and offer significant potential for energy savings. One way to improve energy efficiency is to exploit the huge potential for efficiency gains in the building sector. The Directive states that the building stock is the largest consumer of energy in Europe, consuming nearly 40% of the final energy. About 75% of buildings are not energy efficient and the annual percentage of rehabilitated buildings in the different Member States varies between only 0.4 and 1.2% of the building stock [9].

Optimizing a building in terms of energy means finding ways to use solar energy for lighting and heating in winter and cooling in summer. In order to achieve this, it is necessary that a building functional zoning as a planning scheme and its location on the ground provide the necessary comfort with minimal energy consumption without the use of active solar equipment according to [4].

Heating, air conditioning and ventilation systems are considered to have the largest share in the overall energy balance of buildings, therefore taking measures to reduce energy consumption by upgrading inefficient heating and ventilation systems, replacing heating appliances and installations, renovation of electrical and sanitary installations, installation of high-efficiency windows, use of glass walls, use of renewable energy sources, installation of energy storage facilities, are important steps. Depending on the type of building, there are options for high-efficiency heating and cooling, such as inverter air conditioners, heat pump systems, high-efficiency windows and glass bricks, central air conditioning systems, Renewable Energy Sources (RES), etc. Among the measures for adequate treatment of the environment are the reduction in the non-renewable natural resources consumption, the increase in the use of local resources and construction waste management. Increased water consumption and the limited flow of water sources are one of the main problems of our time. Some of the possibilities of reducing the use of clean water are the use of purified rainwater for domestic needs, reuse of dirty water from dishwashers and washing machines, installation of water-saving sanitary equipment, etc.

Waste from construction, repair and demolition of old buildings is highly recyclable and reusable [10]. The main approach in sustainable waste management, imposed by the active EU policy in this direction, is for construction waste to be transformed from an environmental problem into a resource. The investment measures are mainly related to the implementation of projects for systems, facilities and installations for selective demolition, preparation, recycling and recovery of construction waste and for the production of recycled construction materials. The need for the construction of such facilities, their location and capacity are defined in the National Strategic Plan for Waste Management of Construction and Demolition in the Republic of Bulgaria for the period 2011–2020.

Measures for social rehabilitation of the environment and ensuring comfort for the inhabitants are expressed in maintaining the quality of water and air quality indoors, providing balanced ventilation, recycling of waste heat, providing natural light, etc.

The quality of water in buildings largely depends on the plumbing. It is necessary to replace the old metal pipes with polypropylene ones, which do not corrode and provide a guarantee of over 50 years durability in extreme conditions (water temperature of 70 °C and pressure of 10 bar). Polypropylene is a significantly weak conductor of heat, which is why heat losses are lower.

The indoor air quality is especially important for providing a healthy living environment within a building. The choice of building materials and interior solutions with zero or low emissions contributes to the air quality improvement. The choice of treatment options for natural organized ventilation, night ventilation or a combination of naturally organized and forced ventilation is the first stage for fresh air systems. In case of forced ventilation, highly efficient air-to-air heat exchangers are used. Small fresh air recuperating chambers are suitable for homes and small offices. In large public and administrative buildings active thermodynamic recovery provides comfort with minimal energy consumption. Balanced ventilation systems with waste heat recycling have been known since the time of the first passive building, designed in 1991 under a demonstration project in Darmstadt Kranichstein.

The provision of natural light as an architectural device historically dates back to Egypt's temple architecture, ranging from bright sunlight to semi-darkness or gloom. In the architecture of ancient Greece, light was used as a powerful tool to form a strong light-and-shadow effect, emphasizing the rich sculptural decoration and tectonics of the temple. In Rome's basilica architecture there is a strong upper side lighting, coming from a greater height, while in Latin architecture the richly decorated and painted stained glass windows in the temples are a source of natural light and colored light. In the middle of the 19^{th} and the beginning of the 20^{th} century, remarkable buildings were built with abundant upper and side natural light, using glass and steel.

The traditional architectural methods of providing natural light are windows. Their shape, size and positioning have a functional purpose, in addition to the artistic one. Providing an original architectural composition is only part of their purpose. Natural light is an important element and through the windows it varies depending on their shape, size, location and orientation to geographical directions according to [11]. It also depends on the season, the climate, the time of day. Properly designed natural lighting provides comfort when living and working indoors. Due to its special importance, the natural lighting of the buildings is subject to normative regulation [12].

Successful design of energy efficient buildings is not limited to the design of energy saving building shells. When designing, the shape of the building can be chosen so as to make the most of the available solar radiation and

light, which are usually limited in an urban environment. For this purpose, a preliminary analysis of various building forms is needed to determine which of them would make the best use of solar resources. One of the methods for such preliminary analysis is a method known as the "rose of the solar radiation" [13]. This term refers to a polar diagram that illustrates the amount of average daily or total solar radiation falling per square meter of vertical building surfaces with different orientations for given periods of time (months, seasons, years). Robinson's "Rose" is based on the annual radiation calculated for points on vertical surfaces using the Rtrace module of the RADIANCE program [13]. The obtained results are averaged or summarized. The purpose of the "orientation rose" is to be used in the early stages of urban planning, before calculations are made for solar radiation and light falling on future building surfaces. This analysis can be used as an indicator of the available solar resources for a plot of land situated in an urban environment, as well as to check where to situate the building in this plot and how best to orientate its main facades. At a later stage, this information can be useful to determine where openings (windows, large glazing) through which sunlight penetrates the building should be situated on the facades.

Modern technologies and new building materials allow a wide variety of possibilities and make feasible non-standard architectural ideas and practical standard projects emphasizing on the sufficient sun exposure of living spaces.

The implementation of these measures requires targeted support from the state, and according to [14], the provision of funds can be done with the help of European funds and programs, through the eligible basic activities leading to sustainable development of a given territory and improving the quality of life of the population, by categories of local resources, including human and natural resources, infrastructure, etc.

The measures taken by the surveyed Bulgarian enterprises include mainly outreach (35%) and discussion of the possibilities for implementation of green projects (33%). The role of the state in improving the overall energy efficiency of buildings is highly rated (36%) [1].

In this sense, in accordance with the Integrated Energy and Climate Plan [15], the definition of measures for modernization of the building stock with elements of green building in Bulgaria is done mainly in terms of determining cost-effective approaches to improve the energy performance of buildings through:

– energy saving measures in the buildings, including measures for the structure of buildings and the buildings installation;

– measures for utilization of energy from renewable sources and utilization of waste heat;
– passive measures.

After taking into account the objective characteristics of the types of building structures of the existing housing stock in terms of reliability and suitability for normal operation, the target group for renovation is single-family and multi-family residential buildings with an area of 184 million square meters.

According to the presented scenario, by 2050, 60% of the housing stock and nearly 17% of the non-housing stock will be renovated. The area of renovated buildings will be over 45% of the entire building stock (state and municipal non-residential buildings represent only 29% of the non-residential building stock).

Indicators and milestones for renewal of the residential and non-residential building stock in Bulgaria are presented in Table 3.

Table 3. Indicators and milestones for renovation of the residential and non-residential building stock in Bulgaria

Index		2021–2030	2031–2040	2041–2050
Total saved energy	GWh	2 917	6 502	7 329
Residential buildings	GWh	2477	5694	6294
Non-residential buildings	GWh	440	808	1035
Renovated areas	m^2	22 203 509	49 570 668	55 823 015
Residential buildings	m^2	19 026 656	43 735 175	48 343 297
Non-residential buildings	m^2	3 176 852	5 835 493	7 479 718
Renovated area as part of the existing building stock	%	8%	18%	20%
Saved CO_2 emissions	ton	1 306 435	2 891 610	3 274 453
Residential buildings	ton	1 065 184	2 448 461	2 706 441
Non-residential buildings	ton	241 251	443 149	568 012

Source: The National Integrated Energy and Climate Plan 2021–2030, 2020

According to the Low Carbon Economy Component of Pillar 2 "Green Bulgaria" of the Recovery and Resilience Plan of the Republic of Bulgaria [16], with regard to the building stock, investments will be directed to:

1) energy efficiency, including measures to increase energy efficiency in residential buildings, and measures for financing energy renovation of non-residential buildings, including public buildings and buildings intended for production, trade and services, as well as buildings in the tourism sector;

2) financing of single measures for energy efficiency of single-family buildings and multi-family buildings that are not connected to heat and gas transmission networks, including construction of solar systems for domestic hot water supply and construction of photovoltaic systems up to 4 kW;
3) energy efficient municipal systems for outdoor artificial lighting – reduction of energy costs for outdoor artificial lighting and improving the standard of living of the population of the country through technological renovation and updating the outdoor artificial lighting systems;
4) support for the construction of a minimum of 1.7 GW RES and batteries;
5) research activities for the development of a pilot project for combined heat and power production from geothermal sources.

In percentage terms, the priorities of Bulgarian enterprises in the construction sector intending to invest in green construction are the following:
– Providing energy efficient sources in buildings (50%);
– Using ecological raw materials (44%);
– Using recycled raw materials (39%);
– Using renewable energy sources in buildings (33%).

The ranking of these priorities depends on their accessibility and impact on consumer orientations. It is necessary in each project to have a possibility for improvement, i.e. to be able to build infrastructure for renewable energy sources, green roofs, conservatories, etc.

Issues related to the modernization of the existing building stock with elements of a sustainable building are extremely important. Bulgaria still lacks a legislative framework to regulate and ensure activities related to the modernization of existing buildings, there is not neither a functioning and consistent national housing policy, nor legal and financial mechanisms for general maintenance of buildings, or measures for physical, economic and environmental restoration of the living environment and gradual spatial restructuring to replace the housing stock with new forms of housing.

In order to provide favorable conditions for investments in the construction of new and the modernization of existing buildings and maintenance of infrastructure, it is necessary to:
– adopt the good practices of the countries in which the methods of green building are applied;
– develop financial instruments and procedures for the renovation of buildings;
– improve the possibilities for inspection and assessment of the energy performance of existing buildings and simplification of the administrative procedures for obtaining a permit for their renovation.

3. CONCLUSION

In order to promote green construction and to implement more green projects by Bulgarian construction companies, it is necessary to realize the importance and benefits of this construction, to adopt good practices from other countries and to train experts to develop programs and measures for implementation of green activities in the construction sector.

NOTES

For the purposes of this study, the concepts "green environment" and "sustainable environment" are considered to be equivalent.

REFERENCES

[1] S. Vasileva, Green Buildings as an Element of Sustainable Development, in: Proceedings of the 30th Anniversary International Scientific-Practical Conference "Construction Entrepreneurship and Real Estate", Science and Economics, Varna, 2015 (in Bulgarian).

[2] Communication from the Commission to the European Parliament and the Council Strategy for the Sustainable Competitiveness of the Construction Sector and its Enterprises, COM/2012/0433 final/.

[3] K. Antonova, Influence of the Strategy for Sustainable Development of the European Union on the Bulgarian Construction Sector, *Science and Economics*, Varna (2016) **43** 272 (in Bulgarian).

[4] A. Kovachev, *Urban Planning – Part 1*, Avangard Prima, Sofia (2013) (in Bulgarian).

[5] M. Nanova-Mihailova, Modern European Approaches to the Renovation of Neighborhoods Built on Industrialized Technologies between the 60s and 70s of the 20th Century, Abstract of a Dissertation for the Award of ONS "Doctor" UNWE, Sofia (2014) (in Bulgarian).

[6] World Green Building Trends – Developing Markets Accelerate Global Green Growth Smart Market Report (2016), www.construction.com/market_research.

[7] World Green Building Trends – Developing Markets Accelerate Global Green Growth Smart Market Report (2018), www.construction.com/market_research.

[8] World Green Building Trends – Business Benefits Driving New and Retrofit Market Opportunities in Over 60 Countries, Smart Market Report (2012) www.construction.com/market_research.

[9] COM 765 final, Directive of the European Parliament and of the Council Amending Directive 2010/31/EU on the Energy Performance of Buildings, Brussels (2016) (in Bulgarian).

[10] *National Waste Management Plan 2014–2020*, Ministry of Environment and Water, Sofia (2014), http://www.moew.government.bg/static/media/ups/tiny/file (in Bulgarian).

[11] G. Stefanova, Abstract of the Dissertation for the Scientific and Educational Degree "Doctor", Design through the Light of Architectural Space, Sofia (2014) (in Bulgarian).

[12] Ordinance No. 7 of 22 December 2003 on Rules and Regulations for the Development of Certain Types of Territories and Development Zones, State Newspaper, Issue 3 of January 13, 2004. . . Last Ed. NP, Issue 21 of March 1, 2013 (in Bulgarian).

[13] COMPAGNON, RADIANCE: A Simulation Tool for Daylighting Systems, http://raphael.compagno.home.hefr.ch/ref/RADIANCE_tutorial_E.pdf

[14] S. Hristova, E. Tonkova, and D. Petrov, *Development of Local Potential for Socio-Economic Development of the Regions*, Steno, Varna (2015) (in Bulgarian).

[15] *Integrated Plan in the Field of Energy and Climate 2021–2030*, Council of Ministers (2020), https://www.me.government.bg/files/useruploads/files (in Bulgarian).

[16] *Recovery and Sustainability Plan of the Republic of Bulgaria*, Council of Ministers, Version 1.4 from 15.10.2021, https: // www. nextgeneration.bg/14 (in Bulgarian).

Received December 14, 2021