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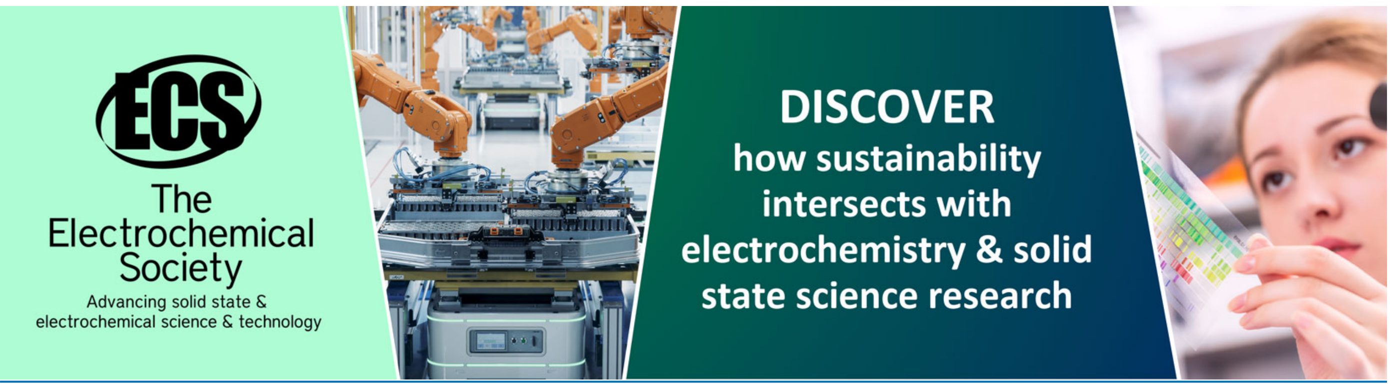

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The impact of green building principles in the sustainable development of the built environment

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Abstract. Climate change and the exhaustion of natural resources is a topical issue and represents a "to be solved immediately" goal in the development of built environment. The increasing development of buildings affects the natural environment more than any other industrial process. In Europe, the construction sector is responsible for consuming approximately 50% of the natural resources extracted per year, 40% of the energy produced, 16% of the treated water, and also for producing around 36% of the CO_2 emissions and 40-50% of the solid waste. Nowadays, specialists involved in building design have to think, more and more, about the strategies toward high performance buildings, and apply the principles of sustainability to find ways to coexist with the natural conditions, conserving natural resources, preventing land pollution, protecting the environment, and reducing energy consumption. This paper attempts to investigate the results of SWOT analyses on two aspects of the implementation of the principles of eco-innovative design of buildings in Romania: technical regulations for design and execution technologies. Then, analysing cases of green buildings design in the world, and their impact on the environment, it is concluded with the measures to be taken into account for the creation of healthy built areas, by applying the eco-friendly principles in all forms of their manifestation, and also with the protection of the environment surrounding.

1. Introduction

It is scientifically proven that 250 million years ago the earth underwent a dramatic global warming event, and the global temperature increased in that period by 9 degrees Celsius over a period of about 20,000 years. Nature managed to restore balance in a period of 200,000 years, and due to the fairly long period of global warming, almost all species have managed to adapt to the new tropical environment [1].

Nowadays, the global temperature increase rate is over 20 times faster. The average global temperature has already increased by more than one degree Celsius between 1880 and 2000, and by the end of 2100 there is a risk of an increase of even more than 4°C [1]. So the question arises whether ecosystems can adapt to this climate change.

One cause of global warming is the greenhouse effect produced by the pollutant emissions of industries that increase the amount of gases in the atmosphere. The issue of global warming can be prevented by minimizing greenhouse gas (GHG) emissions in the natural environment.

Supported by the United Nations, the COP21 Summit, Paris in 2015 brought together over 195 nations around the world, aiming at concluding an international treaty of anti-pollution rules, measures and laws to limit global warming by 2 degrees Celsius at the end of the year 2100. Above this limit of

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2 degrees Celsius, the world of scientists warned that we could face an extremely severe climate change as a result of too much pollution. According to the report „Climate Change 2014 - Mitigation of Climate Change" of WG3 issued by the Intergovernmental Panel on Climate Change (IPCC), the total anthropogenic GHG emissions reached 49 (±4.5) $GtCO_2eq$/year in 2010, where the CO_2 accounts for 76% (38±3.8 $GtCO_2eq$/year) [2].

In Europe, the commercial and residential building sector accounts for almost 36% of the carbon dioxide (CO_2) emissions per year. The construction sector is responsible for consuming approximately 50% of the natural resources extracted per year, 40% of the energy produced, 16% of the treated water, and also for producing around 36% of the CO_2 emissions and 40-50% of solid waste. Most of the CO_2 emissions come from the combustion of fossil fuels to provide heating, cooling and lighting, and to power appliances and electrical equipment. This includes also the CO_2 generated through the entire building process: extraction, manufacturing (including the energy to manufacture capital equipment, heating and lighting of factories and so on), transportation, construction, maintenance, and disposal.

Nowadays, specialists involved in building design have to think, more and more, about the strategies toward high performance buildings, and apply the principles of sustainability to find ways to coexist with the natural conditions, conserving natural resources, preventing land pollution, protecting the environment, and reducing energy consumption.

One of the current basic strategies is the implementation of green buildings which aims to reduce the environmental impact of building. In line with the definition given by the U.S. Environmental Protection Agency, a green building is the result of a complex work in which a design team creates structures where using processes and products that are environmentally responsible and resource-efficient throughout a building's life-cycle. A green building is conceived, from the early stage of its creation, paying special attention to all required factors for design, construction, operation, maintenance, renovation and deconstruction. The classical building design is expanded and complemented by these new principles related to economy, utility, durability, and comfort, and, therefore, a green building or an eco-friendly building is also known as a sustainable or high performance building [3]. The green building has developed in response to the knowledge that buildings often have a negative impact on the environment and natural resources.

The green building brings together a vast array of practices, techniques and skills to reduce and, ultimately, eliminate the impacts of buildings on the environment and human health [4, 5]. The multi-criteria system developed by Ding and Langston [6] is now considered a useful tool for setting sustainability performance to new constructions and renovation, and is a key factor in the implementation of green buildings. The multi-criteria system is based on four fundamental criteria:

- maximizing economic efficiency with the goal of maximizing profits, which includes aspects of maintenance and sustainability;
- maximizing utility, which can be linked to external benefits such as social inclusion;
- resources minimization analysed over the lifetime of the construction, in terms of energy used in execution and consumed for operation;
- impact minimization on environment.

Today, the green buildings, recycling and eco-labelling of building materials have captured the attention of professional builders around the world. In the construction industry, a sustainable building can make a difference in terms of global environmental sustainability by reducing the consumption of natural resources and energy-intensive materials. According to Plessis [7], ignorance and lack of information about sustainable construction are a major obstacle which the construction industry has to overcome.

Eco-design and energy efficiency are concepts that need to find new building materials and technologies that are environmentally friendly and lead to a decrease in material and energy consumption. In other words, reducing the impact of buildings on the environment is possible by rethinking and redesigning materials and technologies used in the construction sector.

This paper attempts to investigate the results of the SWOT analyses on two aspects related to the green building implementation in Romania: the technical regulations for design and execution technologies. The results were obtained during the activities of the implementation of the project "Eco-Innovative Products and Technologies for Energy Efficiency in Construction" in "Gheorghe Asachi" Technical University of Iasi. The project has been developed in the program co-financed by the European Regional Development Fund: Operational Program Competitiveness 2014-2020, POC / 71/1/4 / Knowledge Transfer Partnerships, Priority Axis 1 - Research, Technological Development and Innovation in Support of Economic Competitiveness and Business Development, Action 1.2.3: Knowledge Transfer Partnerships [8].

2. The implementation of green building principles in Romania. EU and national legislation

Governments around the world rely on building codes to protect their citizens from harm due to structural collapse and other building related risks. The codes should meet these needs by specifying at least the minimum requirements for both construction materials and construction practices. Events such as earthquakes highlight the importance of implementing building codes which should continually evolve from the point of view of their consistent enforcement.

Generally, the strategies offered for green building design are voluntary and presented as design options or ideas to be taken into consideration. The strategies do not necessarily support one another, and the use of one strategy may preclude the use of others. Designers, owners, developers and other people involved in the processes of green building maintenance will need to weight the benefits of using any particular set of strategies. There may be phases and particular analyses needed to achieve the diverse design goals of any particular project.

The EU's legislative framework for energy efficient buildings was strengthened in 2002 with the adoption of the Energy Performance of Buildings Directive (EPBD – Directive 2002/91/EC), which introduced Energy Performance Certificates (EPCs) and minimum energy performance requirements. The original EPBD 2002/91/EC included the following main aspects: establishment of a calculation methodology, minimum energy performance requirements, and the requirement of energy performance certificates.

Directive 2010/31/EU on the energy performance of buildings (EPBD recast) widened the scope of the EPBD and raised the standards. It introduced the concept of Nearly Zero Energy Buildings (NZEB) and a target of 2018/2020 for their introduction. It also introduced the idea of "cost-optimal levels" of energy performance in buildings, meaning the "energy performance which leads to the lowest cost during the estimated economic life cycle". Furthermore, the EU Directive encourages the creation of national plans to lay in practice the definition of nearly zero energy buildings, the definition of intermediate targets for improving the energy performance of new buildings by 2015. In November 2016, the European Commission submitted a package of legislative proposals under the title "Clean Energy for All Europeans", with the goal of providing a stable regulatory framework, needed to facilitate the clean energy transition, and, thus, a significant step was taken towards the creation of the Energy Union. The "Clean Energy for All Europeans" proposals are intended to help the EU energy sector to become more stable, more competitive, and more sustainable, suited to the 21st century as well as enabling the EU to deliver on its Paris Agreement commitments.

Related to the products used in the construction industry, mention must be made of the Directive 2009/125/EC of the European Parliament and of the Council issued on 21 October 2009 which establishes a framework for setting the eco-design requirements of energy-related products [Eco-design Directive 2009].

In Romania, the annual specific energy consumption registered in buildings is extremely high, mainly due to the heat losses through the construction elements, as well as to the poor exploitation of the heating systems. In this case, the thermal rehabilitation of the buildings and the use of renewable energy have became key objectives at national level, in order to ensure energy savings and environmental protection. In order to facilitate the environmental protection, a series of policies started to be developed in Romania.

In order to reach the targets set by the EU in Directive 2009/28/EC of the European Parliament and of the Council issued on 23 April 2009 on the promotion of the use of energy from renewable sources, which amended and repealed Directives 2001/77/EC and 2003/30/EC, the Member States have to increase the share of renewable energy sources in the energy mix, [Renewable Energy Directive 2009].

After transposing Directive 2010/31/EU into the Romanian legislative regulation, the Law no. 372/2005 was amended and completed in 2016, and the Law no.121/2014 was implemented. The energy performance of the building, as defined in the Romanian Law 372/2005 updated and republished in 2013, represents the actual energy, consumed or estimated, to meet the needs of the normal use of the building which mainly includes: heating, hot water, cooling, ventilation and lighting.

The Romanian Government Decision no. 55/2011 on establishing the eco-design requirements for energy-related products specifies the requirements that these products must meet for the increase of the energy efficiency and the environmental protection level, in order to contribute to a sustainable development of built environment. This decision is represented by Directive 2009/125/EC.

Directive 2009/28/EC is implemented by the Romanian Law no. 220/2008, with subsequent amendments, establishing the system to promote energy production from renewable energy sources.

The green building design strategy challenges the specialists involved in design and execution, to consider both the inside and the outside of the house with the aim to achieve: proper location selection, efficiency in water consumption, increased day lighting, use of eco-power, and use of environmentally friendly materials. The first segment in the green building design strategies is, therefore, subjected to "eco-innovation". Eco-Innovation refers to all forms of innovation – technological and non-technological – that create opportunities for the development of economic activities and that have a positive effect on the environment, by preventing or reducing the impact of these activities, or by optimizing the use of resources.

The measurement of innovativeness of EU countries, through various parameters, aims to promote a global view on economic, environmental and social performance. Two surveys, which complement other parameters, are relevant: the Eco-Innovation Scoreboard (Eco-IS) and the Eco-Innovation Index. They illustrate eco-innovation performance across the EU Member States and aim at capturing the different aspects of eco-innovation by applying 16 indicators grouped under five categories: eco-innovation inputs, eco-innovation activities, eco-innovation outputs, resource efficiency, and socio-economic outcomes. The Eco-Innovation Index shows how well individual Member States perform under different classes of eco-innovation compared to the EU average, and indicates their strengths and weaknesses [9, 10].

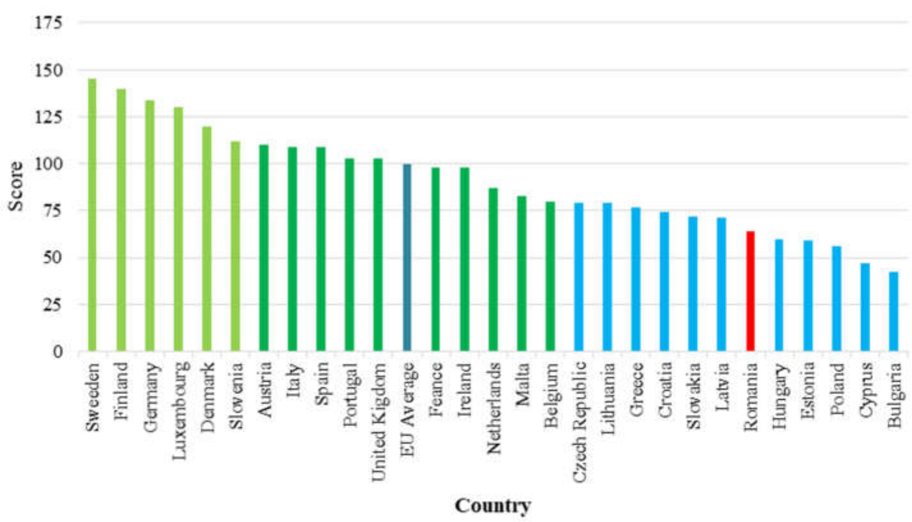

Figure 1. The chart of European Eco-Innovation Index by countries, 2017, [10].

In figure 1, the chart for Eco-Innovation Index in EU [10], highlights Romania's low position, which is mainly due to the lack of efficient management of the available resources. The Eco-Innovation Scoreboard (Eco-IS) tool also shows that, in Romania, the indicator for "the value of green early stage investments (per capita) is almost nearly zero [10].

3. SWOT analyses

3.1. SWOT analysis of the eco-innovation design of buildings

Figure 2 presents the strategic planning technique with the inputs for the Strengths, Weaknesses, Opportunities, and Threats in a SWOT analysis related to the eco-innovation design of buildings. It aims to identify the internal and external factors that are favourable and unfavourable to achieving the specified objective in the goals.

Strengths: S1 - positive environmental balance S2 - rehabilitation of structures by functional reconversion of industrial spaces S3 - the existence of technologies in the market in this field S4 - use of local materials S5 - site rehabilitation	Weaknesses: W1 - insufficient popularization of strategies W2 - lack / insufficiency of existing norms W3 - lack of collaboration in the fields involved (architecture, construction, sociology, installations) W4 - insufficient training of specialists W5 - lack of national strategy
Opportunities: O1 - updating the legislation O2 - orientation towards eco-sustainable materials O3 - tax deduction for designers adopting eco-innovation O4 - modern technologies development for useful traditional materials O5 - high demand of investors / beneficiaries O6 - stimulating designers to these solutions	Threats: T1 - high costs T2 - depreciation of long-term investments T3 - reluctance of designers to leave the comfort zone professionally T4 - lack of information for beneficiaries (public)

Figure 2. Chart with internal and external factors for the SWOT analysis of the eco-innovation design of buildings, [11].

The results, after a statistical processing of responses received from stakeholders are presented in figure 3.

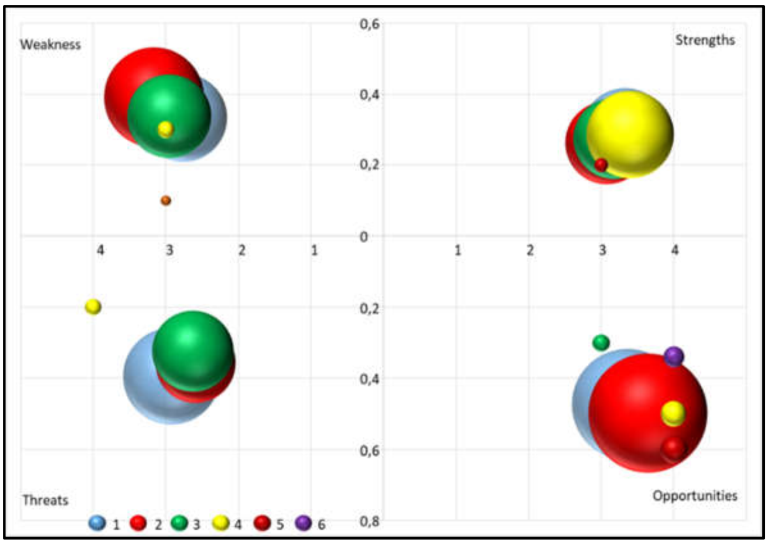

Figure 3. Results of the SWOT analysis of the eco-innovation design of buildings, [11].

For the eco-innovation design of buildings, following the SWOT analysis, the results highlighted that it is necessary to prioritize the setting of objectives for strategic planning, as follows:

- emphasis should be placed on positive environmental balance (S1) and use of local materials (S4);
- the problems identified in relation to the insufficient training of specialists (W4) and lack of a national strategy in domain (W5) should be minimized;
- the legislation should be updated (O1) and the owners and developers should be stimulated to accept these solutions (O6);
- measures should be taken to create financial compensations for the high costs (T1) at the construction stage;
- data bases shoudl be created to overcome the lack of information for beneficiaries (T4) and to improve the knowledge in domain.

3.2. SWOT analysis of the eco-sustainable technologies for the manufacturing of construction materials

Strengths: S1 - re-incorporation of materials / waste into the production cycle S2 - reducing the amount of energy embedded S3 - high insulation capacity (thermal, hydro and acoustic to fire action) S4 - reduction / elimination of waste emissions in the manufacturing process S5 - implementation of circular economy principles	Weaknesses: W1 - lack / insufficiency of necessary arrangements; W2 - lack / insufficiency of collection points for construction waste W3 - lack of information W4 - lack of recycling, W5 - high costs, W6 - lack of government strategy, W7 - lack of capital of private investors
Opportunities: O1 - increased recycling and bio-degradation of used materials O2 - reducing CO2 emissions and pollutants during the manufacturing process O3 - improving production yield O4 - rational / responsible management of natural resources O5 - involving local people in production using local materials	Threats: T1 - lack of specialists in the field T2 - lack of marketing actions T3 - depreciation of long-term investments

Figure 4. Chart with internal and external factors for the SWOT analysis of the eco-sustainable technologies for the manufacturing of construction materials, [11].

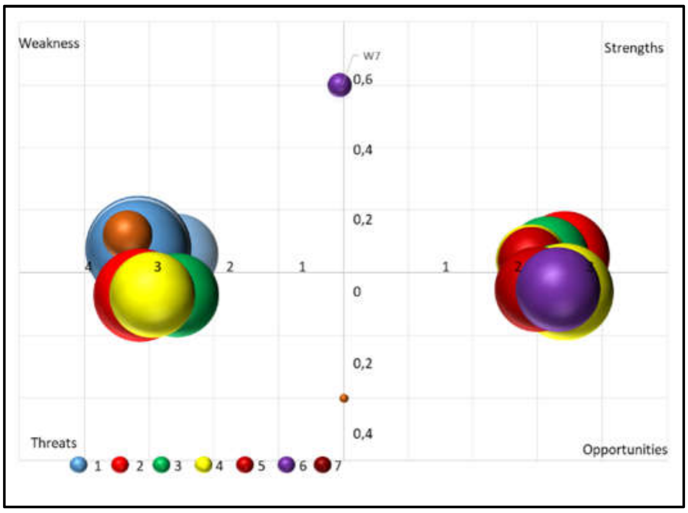

Figure 5. Results of the SWOT analysis of the eco-sustainable technologies for the manufacturing of construction materials, [11].

The strategic planning technique with the inputs for the Strengths, Weaknesses, Opportunities, and Threats related to the eco-sustainable technologies for the manufacturing of construction materials is presented in figure 4. Figure 5 presents the statistically processed answers received from stakeholders According to the SWOT analysis, the results highlighted that in the cases of eco-sustainable technologies for the manufacturing of construction materials, it is necessary to prioritize the setting of strategic planning objectives. Therefore, the following prioritizations have to be implemented:

- emphasis should be placed on the re-incorporation of materials / waste into the production cycle (S1), on the decrease of the amount of energy embedded (S2) and on the implementation of circular economy principles (S5);
- the problems identified related to the lack of government strategy (W6) and the lack of capital of private investors (W7) should be minimized;
- the use of recycled and bio-degradation materials (O1) should be increased;
- policies for the rational / responsible management of natural resources (O4) should be implemented;
- the lack of specialists in the field (T1) and the lack of marketing actions (T2) in the domain should be solved .

3.3. Discussions

The SWOT analyses were developed in the project "Eco-Innovative Products and Technologies for Energy Efficiency in Construction" implemented in "Gheorghe Asachi" Technical University of Iasi [11]. The period of project implementation is between 2016 and 2021, and the estimated project results are:

- creating eco-innovative products and improving the energy performance of existing products used in civil, industrial and agricultural buildings;
- developing and implementing an integrated system of design and execution of passive buildings (energy efficient);
- optimizing the energy performance of buildings through the use of software modelling energy consumption;
- making an interactive energy management tool in construction products;
- implementing renewable energy sources of high efficiency in manufacturing products used in buildings, and also, throughout the phases of construction and use of buildings;
- setting up the European technical assessment body for construction products;
- setting up the platform of information and transfer of knowledge about eco-innovative products and technologies for energy efficient constructions.

Some project actions were dedicated to identifying the actual situation of the factors which influence the Romanian's targets in green buildings implementation. The SWOT analyses developed in the project have involved identifying and mapping the internal and external factors that support or hinder the achievement of Romanian's goals in this domain. The SWOT analyses provided a good framework for reviewing the current strategies and directions of implementing the green building goals in Romania. These analyses lead to a better understanding of what the existing strategies can offer at present, and the key weaknesses that need to be solved in the future in order to succeed.

The charts presented in figures 3 and 5, through the distribution of the analysed parameters, highlight the fact that in Romania the problems related to the design and the execution technologies of the green building are poorly perceived by the actors involved in the implementation of the principles that are defining for this type of buildings. From the analyses of the charts, a set of questions arises: is it a problem related to poor information in the field or is it cumbersome to overcome certain stereotypes formed over time by the traditional design of the buildings? An affirmative answer to these questions leads to the urgent need for national support policies which, by providing tax benefits to the owners, which will lead to increasing the use of the environmentally friendly buildings.

4. Eco-innovative principles applied in the design of green buildings

The design principles of green buildings are applied in many countries. In the technical literature one can identify multiple examples of green buildings in which one or more eco-innovative solutions for products and/or execution technologies have been implemented successfully. In the author's opinion, the most important strategies which must be observed in the design of green buildings are:

- Passive solar design, which is a cumulative method of organizing the parts of a building in such a manner as to exploit and control the solar radiation; this is the key to take the best advantage of the local climate. The goal is to maximize the positive inputs of solar radiation in the cold season while reducing the effects of overheating during the warm season. Solar design is part of a wider approach, integrated design, which involves several aspects that need to be considered from the conception phase and the collaboration of the specialists involved.
- During the design stage, care must be taken to balance the architectural aesthetics with the shape factor. The shape factor is defined as the ratio between the wall and roof surface and the inner volume (SA: V), determining the compactness of a building, and influencing the energy efficiency. This ratio is inversely proportional to the size of the building - the larger the construction, the smaller the ratio. Small buildings have a SA: V ratio higher than large-scale constructions of identical shape. Compactness is closely related to energy efficiency, and therefore this parameter is important and must be considered when designing green buildings.
- "Life cycle" estimates of a building are increasingly included in the design phase as fundamental sustainability assessment methods and include two major components: Life Cycle Costing (LCC), and Life Cycle Assessment (LCA). The "LCC" procedure allows cost-optimization design, taking the form of an investment estimate in an overall approach. The "LCA" methodology evaluates inputs and outputs from a system, in particular a construction, over a life cycle, in terms of the system interaction with the natural environment. Systemic modelling takes into account all inputs, including extraction of raw materials and fuel use, water consumption, and so on. Also, this modelling takes into account all outputs, including mainly air emissions, water pollution and soil pollution, as an environmental impact assessment over the building lifetime, from construction to demolition.
- The study of green buildings through the evolution of digital technologies is an important concern at global level. In parallel with the advancement of engineering sciences, most of the concepts underpinning traditional architecture are reconsidered by computer, which becomes a central factor. Advanced technologies for green buildings include: innovative materials in order to ensure low carbon dioxide emissions and better thermal insulation qualities, complex structural systems to reduce the use of materials through engineering conceptual solutions, and social evaluations to predict the requirements of the building owners.

The implementation of these design strategies has led to certain benefits during life of the buildings. Therefore, the case studies analysed confirm the need to implement specific solutions to each region but with certain results in achieving the main purpose of green buildings, namely energy efficiency and low impact on environmental pollution.

5. Conclusion

This synthetic analysis of the implementation of the principles of design and execution of green buildings, as well as their influence on the sustainable development of the built environment, highlights the key directions for the implementation of the existing strategies in the creation of healthy built areas, by applying the eco-friendly development principles in all forms of their manifestation.

The construction sector has a significant environmental impact, being one of the most important consumers of natural resources and, at the same time, having a significant carbon footprint. Therefore, civil engineering specialists should develop and implement specific solutions with a reduced environmental negative influence such as the following: to stop the unsustainable urbanization of the cities, to reduce the natural resources consumption rates applying the principles of the sustainable management of raw materials, to use the renewable energy sources, and to develop new eco-friendly materials, technologies, and design principles.

Two factors are decisive: the national governments that will have to create adequate legislation and provide financial support for the research on this topic, and the local authorities that should promote a sustainable urbanization through local tax policies.

In Romania the need to develop technical, sustainable and legislative supported strategies for the green buildings implementation is obvious. A comparison with the stages undergone by other states in Europe or other continents, shows that in Romania there is a delay in the implementation of the green buildings principles in the built environment, with a gap of approximately 20 years.

The steps taken so far indicate that there is interest at government level, but the education of the population on this matter is delayed, thus generating negative effects in understanding the consequences of global warming phenomenon and in taking actions. The Romanian specialists, through all means of mass information, are permanently involved in overcoming these negative aspects and are constantly trying to comply with the requirements implemented at international level.

The efficient use of resources and the development of circular economy will be challenges for Romania's construction sector on its way to becoming more sustainable and more "green". The implementation will stimulate investment and bring benefits both in the short and long term for the built environment, environment and citizens alike.

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