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Certification and Assessment of Sustainable Construction in a Circular Economy

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Abstract: *Construction activities are among the main contributors to the greenhouse effect, high consumption of natural resources, production of huge amounts of waste and energy consumption during the life cycle of buildings, suggesting that the study of these activities is of utmost importance. Ensuring a balance between economic development, human well-being and environmental needs is a major challenge of our time in the context of the circular economy. The author of this paper aims to analyze the existing knowledge and methodologies for the certification of sustainable buildings and to consider the possibilities for an integrated assessment of their sustainability throughout their life cycle.*

1. INTRODUCTION

The world faces the challenge of ensuring a balance between economic prosperity, improving people's well-being and environmental needs. Over the next 40 years, global consumption of materials such as biomass, fossil fuels, metals and minerals is expected to double (OECD, 2018), with the amount of waste generated each year increasing by 70% by 2050 (World Bank, 2018). Construction plays a particularly important role in reducing energy use, as well as reducing climate change and adapting to its effects.

Construction activities are among the main causes of the greenhouse effect, high consumption of natural resources, production of a huge amount of waste and energy consumption during the life cycle of buildings. Construction has a significant impact on many sectors of the economy, local employment and quality of life. It uses huge amounts of resources (around 50% of all extracted materials), generates over 35% of the total amount of waste in the EU and around 12% of total national greenhouse gas emissions, which can be reduced by around 80% if materials are used more efficiently (Hertwich, 2020).

The object of research in this paper is the construction sector in the context of a circular economy, and the subject is the possibilities for integrated life cycle assessment (LCSA) of the sustainability of buildings.

The authors in this article aim to analyze the existing knowledge and methodologies for integrated life cycle assessment (LCSA) of buildings, including environmental (LCA), economic (LCC) and social (S-LCA) and to offer opportunities for their application in the construction business in Bulgaria.

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The objective thus formulated implies the execution of the following research tasks:

1. to present the concept of the circular economy;
2. to consider the essence and principles of sustainable construction;
3. to consider some existing certification systems for sustainable buildings;
4. to consider the possibilities of integrating LCA, LCC and S-LCA assessments into the whole life cycle assessment of buildings;
5. to offer opportunities for the application of the LCSA methodology for assessing the sustainability of the entire life cycle of buildings in Bulgaria.

2. CONCEPT OF THE CIRCULAR ECONOMY

According to the Brundtland Report (1987), sustainable development aims to meet the needs and aspirations of the present generation without compromising the ability to meet those of future generations and is based on a three-pillar concept of economic, social and environmental sustainability (Purvis et al., 2019). The economic, social and environmental dimensions of sustainable development reflect the assumption that the development of the economy depends on people, which in turn depends on the possibilities of nature. In order to meet the global challenges of sustainable development in recent decades, thinking is directed toward the concept and model for the development of the circular economy (Geldermans et al., 2019) which imply an extension of the life cycle of products and when they reach the end of their life, the materials of which they are composed can be used again, so as to minimise waste disposal. The circular economy requires not only closed loops and the use of renewable energy but also the improvement of the interrelationships between participants in the process of design, production and use of products, in which the actions of one participant have an impact on other participants. To account for this influence, short-term and long-term consequences must be considered in the selection. Some of the basic elements of the circular economy are presented in Figure 1.

Some benefits of the circular economy can be (European Parliament, 2023):

- Protecting the environment, including biodiversity, reducing greenhouse gas emissions – by designing more efficient and sustainable products, reusing and recycling products, which in turn reduces the need to extract natural resources;
- Reducing dependence on raw materials – with the growth of the population, the demand for raw materials increases, and the possibility of recycling them reduces the risks associated with their procurement;
- Resource efficiency – it is key to strengthening the competitiveness of the economy, creating the conditions for growth and creating new jobs;
- Job creation and cost savings – resource efficiency is a key point in strengthening the competitiveness of the economy, designing products and materials in a way that involves reuse and recycling, will stimulate innovation, and consumers will receive more sustainable and economical products and materials, which will save them costs and improve their quality of life.

The Circular Economy Action Plan (European Commission, 2023) proposes measures on the entire life cycle of products and aims to improve the economy and increase competitiveness while protecting the environment and empowering consumers. The new Action Plan draws attention to sectors that use a lot of resources, including construction, and focuses on design and production where the raw materials used remain as long as possible in the economy.

One of the EU‘s conclusions is to swiftly conclude discussions on the changes to the Renewable Energy Directive, the Energy Efficiency Directive and the Energy Performance of Buildings Directive.

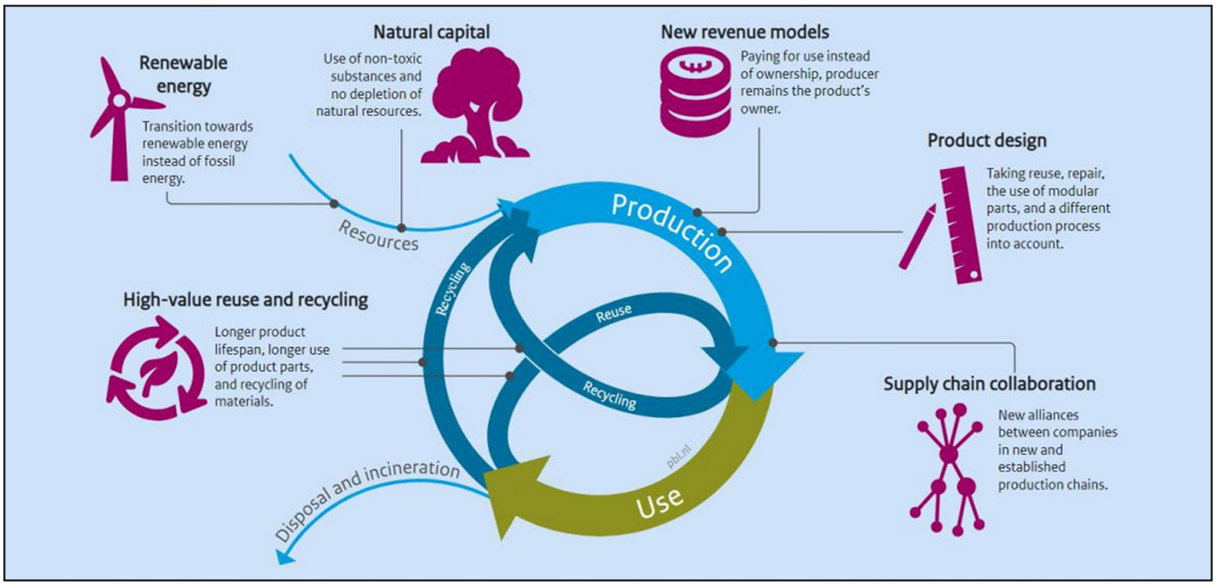

Figure 1. Some of the elements of the circular economy

Source: ASUS, n.d.

The European Green Deal (European Commission, 2019) announced an initiative to fully modernise the construction sector in line with the principles of the circular economy, namely improving the life-cycle efficiency of building assets and recovering construction waste from demolition. One of the initiatives is the introduction of a comprehensive strategy for a sustainable built environment that will promote the application of circular economy principles throughout the life cycle of buildings. This can be achieved by:

- introduction of requirements for the sustainability of construction products, including requirements for the content of recycled materials in certain construction products, taking into account their functionality and safety (Regulation (EU) No 305/2011);
- promoting measures to improve the adaptability and durability of building assets in line with circular economy principles related to building design and the development of digital building logs (European Council, 2022);
- promoting measures to reduce soil sealing, remediation of contaminated or derelict sites, etc.

3. THE ESSENCE OF SUSTAINABLE CONSTRUCTION

One of the areas where the needs of society and economic interests meet with environmental protection is construction. To a certain extent, construction technologies lead to disproportions in nature. The air, water and soil are polluted, the rates of depletion of non-reproducible resources are increasing, climate changes occur, and the so-called global warming is a consequence of environmental pollution. With the current unfavorable trends in the state of the environment, the environmentally friendly development of construction and the economy as a whole is necessary, and the search for an optimal balance between goals and interests.

The term „sustainable construction" was defined at the international conferences held in 1994 and 1997 („Sustainable Construction", Tampa, USA and „Building and the Environment", Paris) as „an approach in which the creation and maintenance of buildings is based on the efficient use of natural resources and the preservation of the principles of environmental development." To be sustainable construction is necessary to increase the requirements for all its stages and to develop preventive activities related to the construction process from the beginning of the development of the project to the end – the demolition of the building. This means that it is necessary to carry out an environmental assessment at all stages – design, construction and operation. It is also necessary to analyze the alternatives to the proposed solutions, which can be in several directions:

- extending the life cycle of buildings;
- energy saving;
- improving the quality of materials;
- Improving the quality of work.

Sustainable construction is a system of practices and technologies that optimize the consumption of materials and raw materials in order to reduce the negative impact of humans on the environment. While short-term economic goals are important for standard construction, long-term economy, quality and efficiency are a sustainable priority. It aims to reduce the environmental impact of buildings while optimizing their value and providing better comfort and a healthy living environment, i.e. with a city designed as sustainable, minimising the use of water, raw materials and energy throughout the life cycle.

In sustainable construction, the aim is to use local and easily accessible materials, with a short production cycle and easy to recycle, to optimize the use of water, energy and energy sources. In other words, sustainable is the construction that is ecological, energy-efficient and durable and there is a balance between three factors: economic, social and ecological.

The economic feasibility is expressed in the possibility of optimizing costs during the entire life cycle of the building, for recycling and reuse of materials.

In social aspect, it is necessary to provide high comfort, internal hygiene, cozy and healthier conditions, free access and efficiency of space.

In environmental terms, the natural environment mustn‘t be negatively affected by the construction of buildings and facilities.

Construction is sustainable if it is subject to the following principles, which are respected during construction and the operation of buildings:

- minimum energy intensity;
- minimum water intensity;
- minimal impact on nature;
- high living comfort;
- aesthetic appearance;
- high quality;
- safety and security;
- durability;
- maximum possibility of reuse of the input materials;
- there is an opportunity for improvement.

Minimum energy and water capacity during construction mean the use of natural materials or those that undergo fewer technological procedures, and the minimum energy and water intensity during operation means energy efficiency and the use of passive architecture techniques, i.e. ensuring that buildings can be heated, cooled and ventilated naturally or using renewable energy sources.

The environmental impact concerns the impact of each building on local ecosystems, such as changing air currents, shading, etc.

High living comfort is determined by taking into account the comfort parameters – temperature, speed, humidity and air purity, as well as the temperature of the surrounding surfaces.

The aesthetic appearance is related to the appropriate entry of the building or facility of the place where it is built and does not disturb or threaten the architectural ensemble and the natural environment.

In terms of quality, safety and security of buildings, the use of quality raw materials and accurate implementation of technology is required.

Durability is a characteristic feature of the objects of construction, it is good for each of them to have a long life, to be repairable and recycled.

In traditional construction, a large part of the materials after repair or demolition turn into unusable construction waste that pollutes the environment. The possibility of their reuse leads to an economy and a cleaner nature.

Each project must have the opportunity for improvement, i.e. green roofs, winter gardens, infrastructure for renewable energy sources, etc. can be built.

Some of the reasons why investments made in sustainable buildings, although larger (10-15% according to practice data) are repeatedly returned during operation are: (1) increased market value; (2) increased efficiency in water and energy consumption; (3) increased durability of the building; (4) provides an improved living environment.

To promote sustainable construction in Bulgaria, measures are needed in the following areas: (1) awareness of the importance of its introduction; (2) adoption of good practices by other countries; (3) development of programmes for its implementation; (4) development of a certification system for sustainable buildings; (5) preparing experts for the assessment and certification of sustainable buildings.

An important requirement for the implementation of sustainable construction in Bulgaria is the adoption of measures and incentives, some of which are: (1) municipalities to reconstruct and build municipal sustainable buildings; (2) to exploit the possibilities of European funding; (3) to apply lower taxes to sustainable buildings and lower garbage charges.

Bulgarian companies are part of the European market and can increase their competitiveness and find adequate solutions to the challenges of modern development by introducing a sustainable construction approach.

4. SOME CERTIFICATION SYSTEMS FOR SUSTAINABLE BUILDINGS

With the current adverse trends in the state of the environment, it is imperative in construction to seek a balance between goals and interests. „True sustainability“ is difficult to achieve through the application of existing building standards, so it is necessary to determine the highest possible measure of sustainability of the construction environment that can be achieved based on the best practices currently in place.

In theory and practice, there are established systems of criteria for assessing the sustainability of buildings. They are developed as systems of loans (ratings) that take into account the impact of various indicators characteristic of sustainability. According to their type, buildings can apply for certification in any of the following categories: eco-homes, residential buildings, offices, commercial buildings, health institutions, schools, industrial buildings, and court buildings. The World Green Building Council recognizes some systems for assessing the sustainability of buildings, but in our opinion, it is necessary to unify the evaluation mechanisms and tools and create a unified assessment system that applies to all types of buildings.

Table 1. Indicators for the assessment of sustainable buildings

System	Indicator	Valuation in loans
BREEAM	1. Management 2. Energy 3. Transportation 4. Water 5. Materials 6. Waste 7. Land use 8. Pollution 9. Well-being and health	Each of these indicators corresponds to a certain number of loans that form an overall score in percentage (100%): **Pass** (average) – over 30%; **Good** (good) – over 45%; **Very good** – over 55%; **Excellent** (excellent) – over 70% **Outstanding** (exclusive) – over 85%.
LEED	1. Environmental friendliness of location; 2. Water efficiency; 3. Energy and atmosphere; 4. Materials and resources; 5. Qualities of the environment; 6. Location and infrastructure connections; 7. Educational impact; 8. Innovativeness of design; 9. Regional importance.	The first seven indicators form a total of 100 points, and the last two bring an additional 4 and 6 points above these 100, respectively, forming a maximum score of 110. The certificates are the four levels: **LEED Certified** – from 40 to 49 points. **LEED Silver** (silver certificate) – from 50 to 59 points. **LEED Gold** (gold certificate) – from 60 to 79 points. **LEED Platinum** (platinum certificate) – over 80 points.
DGNB	1. Environmental friendliness; 2. Economy; 3. Sociocultural qualities and functionality; 4. Technical qualities; 5. Process management; 6. Location.	The indicators cover 49 criteria, with the location score presented separately from the others in the final certificate, so that buildings are assessed regardless of their location. Each of the criteria is evaluated on a scale from 1 to 10 and multiplied by the so-called severity factor, depending on its importance for the given object. The final score is measured on two scales. In one case, the total points collected are related to the maximum possible percentages and three types of certificates are awarded accordingly: **bronzes –** between 50 and 65 per cent; **silver** – between 65 and 89%, **gold –** over 89%.
GREEN STAR	1. Building management; 2. Internal quality; 3. Energy; 4. Transport; 5. Waters; 6. Materials; 7. Land use; 8. Harmful emissions; 9. Innovation.	Once all indicators have been evaluated, the influence of environmental factors, which differ from one territory to another, is also taken into account. Each of these indicators corresponds to a certain number of loans that form an overall score (100 points): **4 Star Green Star Certified –** best practice in environmentally sustainable design – (45-59 points) **5 Star Green Star Certified** – scientific excellence in environmentally sustainable design – (60-74 points) **6 Star Green Star Certified** – world leadership in environmentally sustainable design – (75-100 points)

Source: Own research

This system: (1) must be transparent and flexible; (2) be supported by research; (3) take into account all factors; (4) stimulate the design and construction of sustainable buildings; (5) maintain a standard with quality assurance.

The most widely used environmental assessment systems are the British BREEAM (Building Research Establishment Environmental Assessment Method), the American LEED (Leadership in Energy and Environmental Design), the German DGNB (Deutschen Gesellschaft fur Nachhaltiges Bauen), the Australian Green Star, etc. The German DGNB serves as a basis for the certification applied by the Bulgarian Green Building Council. Significant certification systems for Bulgaria are also the world leaders BREEAM and LEED (see Table 1).

According to their type, buildings can apply for certification in any of the following categories: eco-homes, residential buildings, offices, commercial buildings, health institutions, schools, industrial buildings, and court buildings. The evaluation systems used include aspects related to the use of energy, materials and water, as well as the comfort of the indoor environment (health and well-being), pollution, transport, waste and harmful emissions management, ecology and process management in general, etc.

The need to define the exact criteria and tools for measuring the sustainability of buildings is important from the point of view of property market participants. Buildings that meet certain standards for sustainable construction have many advantages, including many times lower operating costs, while maintaining and gradually increasing their price.

5. BUILDING LIFE CYCLE ASSESSMENT

The need to define the exact criteria and tools for measuring the sustainability of buildings is important from the point of view of property market participants. In terms of what and when to assess sustainability changes over the life cycle of the building – building materials and products are of paramount importance to manufacturers and contractors in terms of costs incurred, return on investment, sales or rental and durability. From the point of view of consumers (owners who have purchased buildings), building materials and products are of considerable interest in terms of their quality, their impact on health, the possibilities of easy maintenance and the provision of comfort.

Buildings that meet certain standards for sustainable construction have many advantages, including many times lower operating costs, while maintaining and gradually increasing their price.

In order to prove the usefulness of constructing new sustainable buildings and retrofitting existing ones, it is also necessary to assess their impact on the environment. With the help of project E nslic_Building: Energy saving by applying life cycle assessment of buildings (ENSLIC-SEC-WP3-100331, 2010). a methodology has been developed to assess environmental aspects and potential environmental impacts throughout the life cycle of buildings. ***Life Cycle Assessment (LCA)*** provides the basis for decision-making in optimizing environmentally friendly design solutions that take into account the lifetime impacts of buildings.

LCA is standardized by the International Organization for Standardization (ISO) (14040 I 14044). The questions that this methodology addresses are related to which supporting structure is most environmentally friendly for the building, which is the best combination of building materials for the facade and what thickness of insulation would be optimal, what energy sources to choose, etc. LCA examines the environmental aspects and potential impacts on the environment throughout the life of the product – from the sourcing of raw materials to its production, use and destruction. The general environmental impact categories considered are resource use, human health, and environmental consequences (ISO 14040:2006).

The LCA assessment provides quantitative information on the contribution of buildings to climate change and the depletion of natural resources. The principle of LCA calculations is that for each stage of the life cycle, the quantities of materials and energy used, as well as the process-related emissions emitted, are examined. The latter are multiplied by characteristic coefficients proportional to the strength of their impact on the environment. A specific emission is selected as a reference and the result is presented in equivalents in terms of the impact of the reference substance. The number of equivalents summed for each environmental impact can be normalised and further weighted to arrive at an integrated result. Different instruments may use different characterization factors and different emission data if production processes differ. These instruments also use different normalization and weighting methods, which can lead to divergent results. The ability to easily obtain building data is constantly improved with the use of modern CAD applications, the use of building information models, and advanced databases. LCA may also include a universal database of emissions for many building materials and energy carriers. For more complex LCA calculations, access to larger international databases such as Ecoinvent (n.d.) is required.

LCA assessment includes several stages: definition of the long-term objective and scope, inventory analysis, impact assessment and analysis of results. In defining the long-term objective and scope, it is necessary to define one functional unit (the unit to which the environmental impact is linked) and the boundaries of the system (the limits of what will be included in the assessment). In order to be able to talk about a life cycle assessment approach, at least two stages of this cycle must be included, e.g. the production of building materials and the operation of the building. The definition of the functional unit is especially important when comparing different products, or in this case, different buildings. In the European standardization process "Sustainability in Construction" (CEN 350) it is recommended that it is called the functional equivalent at the building level in order to distinguish it from the functional unit at the product level (building material).

For a residential building, the functional equivalent can be described as a building with a certain location that meets national norms and requirements regarding comfort, health, safety, energy consumption, etc, for an assumed lifetime. This comparison can only be made when the functional unit or functional equivalent is the same for the two objects or design solutions compared.

Inventory analysis is the stage of collecting the data needed to carry out the assessment, and the calculations themselves are made at the next stage – life cycle impact assessment.

Many ISO and EN standards deal with LCA for built environments. These are EN ISO 14040 (Environmental management – Life cycle assessment – Principles and framework), EN ISO 14044 (Environmental management – Life cycle assessment- Requirements and guidelines), ISO 21930 (Sustainability in buildings and civil works – Basic rules for environmental product declarations for construction products and services), EN 15643 (Sustainability of construction works – Framework for the assessment of buildings and civil engineering structures), EN 15804 (Sustainability of construction works – Declarations for environmental products – Basic rules for the product category of construction products) and EN 15978 (Sustainability of construction works – Assessment of the environmental performance of buildings – Calculation method).

According to ISO 14044:2006, this Life Cycle Impact Assessment (LCIA) has some mandatory elements: selection of impact categories, category indicators, models of characterization, allocation and calculation of results.

Life Cycle Costing (LCC) is a method of assessing the overall cost-effectiveness of an asset over time, including the costs of its acquisition, operation, maintenance and disposal. LCC is often used to determine the total cost of a building over its entire service life, to achieve better value for money invested in buildings and constructed assets. It takes into account all costs, including initial costs (such as capital investment costs, purchases and installation costs), future costs (such as energy costs, operating costs, maintenance costs, capital replacement costs, and financing costs) and any lifetime resale, salvage or disposal costs considered "cradle to grave" (Onat et al., 2013) of a product or project evaluated directly by one or more stakeholders in a product system (Liu & Qian, 2018).

LCC is mainly useful for comparing economic profitability and capital investment and should ideally be analyzed both from the system and end-user perspectives (Janjua et al., 2020) through widely adopted LCC methodologies in the construction sector.

The benefit of LCC is an opportunity to investigate the payback period for the entire life cycle of various construction products and design solutions, and the costs are divided into several groups: investment and construction costs; costs of annual energy consumption, operation, maintenance and repair; renovation and replacement costs; costs for the completion of the service life, demolition and removal of construction waste.

The focus is on both maximizing life-cycle cost reductions and reducing environmental impacts, so the two methods are suitable for combination, thus providing both insights into potential life-cycle costs and environmental impacts from alternative projects.

In recent years, proposals and standardized definitions of LCC and total cost of ownership for building owners have emerged, such as the European standard DS/EN 15643 series (ISO, DS EN 15643-5 2017) for sustainability in construction and civil engineering and the international standard ISO 15686 (Service Life Planning and Lifetime Assessment). In addition, LCC is increasingly an effective method of conducting economic assessments. of the built environment (Toosi et al., 2020) through building sustainability certification systems, such as BREEAM and DGNB.

According to Langdon (2007), when using LCA and LCC in parallel in a larger evaluation process, one forms an input for the other. Combined the two methods can be used to evaluate both investments in a building and to select alternative technical solutions that are achieved with the lowest cost and certain environmental target values. In addition to the Life Cycle Assessment (LCA), which assesses environmental and resource impacts and life cycle assessment (LCC), in the context of the concept of sustainability, it is also necessary to investigate the social life cycle assessment (S-LCA). Typically, social benefits for end-users, such as inclusion, health and well-being, are not yet taken into account in the design, construction and renovation of buildings are not analysed and are not taken into account in certification (Geldermans et al., 2019). Indicators can be very diverse, including health, safety, security, human rights, responsibility, quality, diverse environment, added social value, future value, historical continuity, cultural heritage, governance, socio-economic impacts, etc. (Liu & Qian, 2018) and this leads to a lack of consensus regarding the choice of impact indicators.

In this sense, it is necessary to develop a standardized methodology through the integration of LCA, LCC and S-LCA for a single summary assessment of the sustainability of buildings throughout their life cycle.

There are some developments related to Lifecycle Sustainability Assessment (LCSA) that describe a methodology including the three aspects of sustainability. Kloepffer (2008) develops LCSA for products, and with a broader scope, including for sector and economy, are the model of Valdivia et al. (2012).

LCSA finds application in some sectors, such as transport, agriculture, energy, but is not yet applied in the construction sector.

6. CONCLUSION

Although when we talk about sustainable buildings and sustainable urban development, we mean exactly the three pillars of sustainability – environmental, economic and social, there remains the need for a comprehensive assessment of sustainability throughout the life cycle. Currently, there are few specialists in the construction sector in Bulgaria with in-depth knowledge of LCA, unlike most European countries, where they have extensive experience in developing or using LCA tools for buildings. The most widespread building-related application to date is the use of LCA to compare the environmental impacts of different building materials.

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