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2. THE ROLE OF SUSTAINABLE DESIGN IN ECO-FRIENDLY BUILDINGS

2.1. Sustainability in Construction Sector

Earth's global average surface temperature in 2020 tied with 2016 as the warmest year on record, according to an analysis by NASA (NASA, 2022). The sources show that buildings are responsible for 40% of energy consumption and more than 36% of CO_2 emissions in the EU (EEW, 2015). 80% of energy use over a building's life-cycle is from the building's operation. Construction of infrastructure and buildings is an extremely carbon-intensive process that encompasses the entire supply chain, from the extraction of natural resources to its transportation and manufacturing. Add in other infrastructure and activities, such transportation and industry, that are associated with construction or buildings, and that number will increase. There's a consensus (NASA, 2022) among the scientific community around the world that human activity is a driver of global warming. That's why we need to do something for our home as soon as possible. The mainstream trend nowadays is sustainable development of countries as well as other development theories such as: blue economy, silver economy, "donut's economy" etc.

Sustainable development is a dynamic process through the countries, which means that there is no precise definition of it and every society and city evolves over time to become better or worse. The term was popularised in the end of XX century and means "*development which meets the needs of the present without compromising the ability of future generations to meet their own needs*". The sustainability can be described as incontestable development of society and economy on a long-term basis within the framework of the carrying inclusion of the earth's ecosystems (Kamari et al, 2017).

Climate change and need for sustainable solutions are now playing a critical role in the decision-making of governments and companies all over the world. The growing importance of sustainability across the key stakeholders of government, industry and the public, compounded by the impending climate emergency, creates a need to act now (Royan, 2021). Almost half of the companies surveyed in EU in 2021 report sustainability is an important part of the strategy, or even a cornerstone of their business.

The main idea of sustainable development is making world better place for all – and some goals should be changed as soon as possible. The world is challenged not

only by climate change, pollution and dwindling supplies of fossil fuels affecting all spheres of human activity. Sustainability is no longer an option we can choose or not – but a way of living which we need to rapidly adopt for our survival and sustainability of humanity. If we are building a sustainable future, the construction sector must lead the way forward.

In the centre of Sustainable development there are 17 goals – Sustainable Development Goals (SDGs) (UN, 2022):

1. No poverty;
2. Zero hunger;
3. Good health and well-being;
4. Quality education;
5. Gender equality;
6. Clean water and sanitation;
7. Affordable and clean energy;
8. Decent work and economic growth;
9. Industry, innovation and infrastructure;
10. Reduced inequalities;
11. Sustainable cities and communities;
12. Responsible consumption and production;
13. Climate action;
14. Life below water;
15. Life on land;
16. Peace, justice and strong institutions;
17. Partnerships for the goals.

Together with the SDGs, the European Green Deal is another key driver of sustainability across the architecture, engineering, and construction (AEC) and manufacturing industries in Europe (Royan, 2021). The European Green Deal is a differentiator that will catalyse the low-carbon transition and drive sustainability on the global stage. These initiatives will help transform industry sectors that are particularly challenged by environmental impact and transition to more sustainable methods.

Investment in infrastructure and innovation are crucial drivers of economic growth and development. Some of SDG are more about construction sector opportunities to change the world, some are less. Green buildings, zero-emission construction, zero-waste management in construction – can be part of the solution in combating climate change. The construction industry must make calculations and don't exceed carbon credits. Their resources should be entered accurately and with minimal waste. Some studies show, that construction has a huge impact on general economic growth and that there are definite effects of economic recessions on construction quality (Pheng, 2019). The built environment has a significant impact on many sectors of the economy, on local jobs and quality of life not only in EU, but all over the world. It requires vast amounts of resources and accounts for about 50% of all extracted

materials. That's why it is so important to go forward in sustainability of the construction sector and take the leading role in this process. Figure 2.1 highlights some of the key digital enabled trends in the building sector:

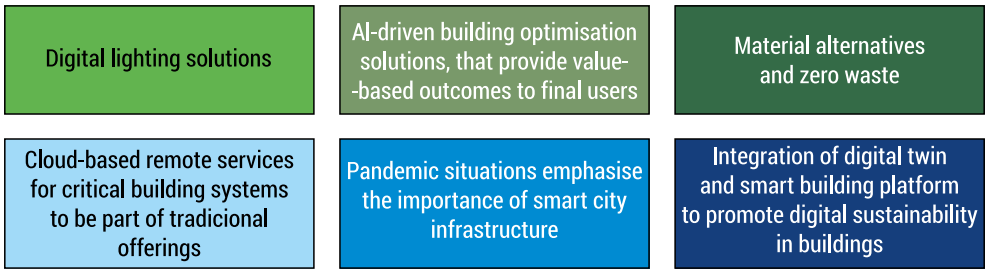

FIG. 2.1. Key trends in the building sector in EU (Source: own elaboration based on Frost & Sullivan)

The European Commission's energy efficiency and energy performance directives for buildings were updated in 2018. The directives mention installing automation and control systems and energy management systems in certain buildings, with an objective to improve energy efficiency. The directives reference long-term renovation strategies for decarbonising national building stocks by 2050 and have mandated that all new buildings must be Net Zero Energy Buildings (nZEB) from 31 December 2020 (Royan, 2021). Today the EU construction policy aims green deal's Renovation Wave Initiative – it can lead to significant improvements in energy efficiency in the region. European Union will implement the Initiative along with circular economy principles, notably optimised lifecycle performance, and longer life expectancy of built assets (EC, 2022b). As part of revising the recovery targets for construction and demolition waste, the EU has plans to pay special attention to insulation materials which generate a growing waste stream.

2.1.1. Ecological and Sustainable Cuilding Design

Sustainable architecture is the application of the principles of sustainable development in the design, construction and operation of buildings. Its main objectives are the search for energy efficiency and low environmental impact – not only by projecting and constructing, but also for the whole building life cycle. Studies show (Lavagna, 2018), that life cycle assessment (LCA) is still too little to implement. Five factors are considered for sustainability**:**

1. Ecosystem,
2. Energy,
3. Type of materials,
4. Waste,
5. Mobility.

On the other hand, it aims to save resources and understand the design according to the user's needs. The social side of design is the most important part that makes buildings more sustainable. With these factors and principles in mind, greater energy efficiency is achieved throughout the life cycle of a building; it is accomplished at the architecture, construction, employment and operation levels (Fig. 2.2).

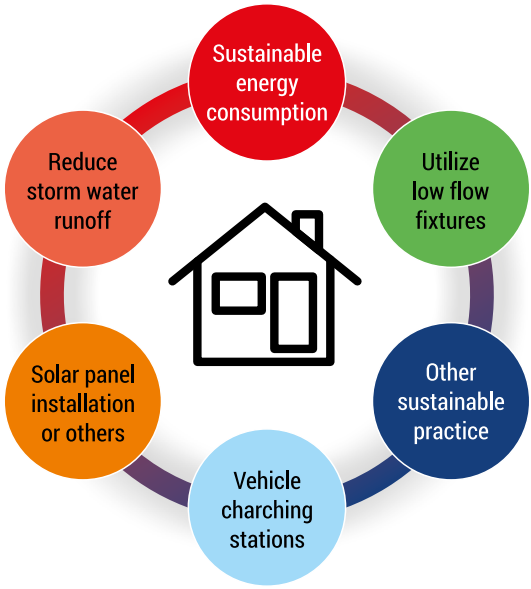

FIG. 2.2. Sustainable construction practice (Source: own elaboration)

The building as an object must contain several different common elements in order to become sustainable:

- healthy inside microclimate;
- indoor environmental quality (visual, acoustic comfort etc.);
- monitoring of energy consumption;
- A++ energy efficiency;
- carbon neutral materials;
- reuse of parts of the building;
- renewable energy;
- assembly of modules in the factory;
- rainwater harvesting for irrigation;
- vegetation of local origin;
- natural lighting;
- universal architecture;
- infrastructure outside the building.

Sustainable design aims to reduce the use of non-renewable energy and maximize the use of renewable energy (EC, 2020b). In this sense, the use of clean energy systems such as solar, wind, geothermal and hydropower is encouraged, but still used fragmentarily (Fig. 2.3):

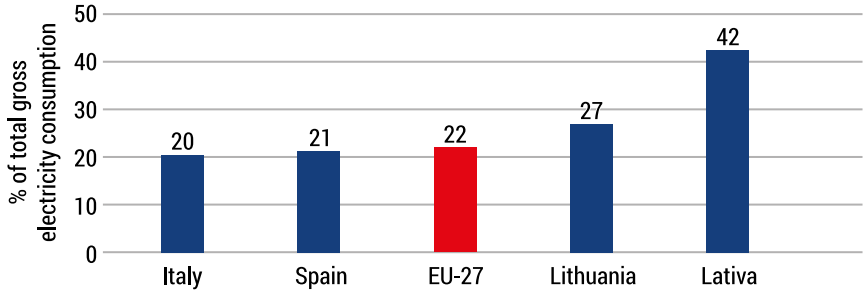

FIG. 2.3. Electricity from renewable sources in construction in the EU, 2020 (Source: EC, 2020b)

An increase in the use of renewable energy has multiple benefits for society such as mitigating climate change, reducing the emission of air pollutants and improving energy security. The EU had set the goal of ensuring that 20% of its gross final energy consumption would come from renewable sources by 2020 (EC, 2022a), increasing to 32% by 2030. Some studies show (Vita, 2019), that passive housing and decentralized renewable energy reduces carbon emissions up to 5 and 14%, respectively. The share of renewable energy in buildings (heating and cooling) also increased in the last few years, albeit at a lower rate (Fig. 2.4):

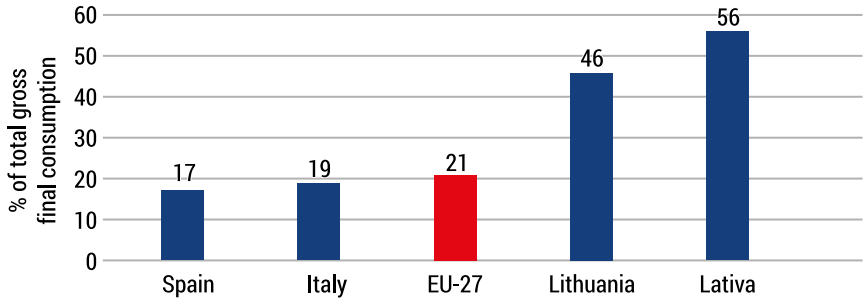

FIG. 2.4. Renewable energy used for heating and cooling in the EU (Source: EC, 2020b)

The next aim is to use water efficiently, using rainwater and recycling grey water. On the other hand, a relationship with the natural environment is essential, so it is also common to use green roofs. In Europe (Germany, France, Austria) these technologies have become very well established (however in the USA not yet, but they are starting to emerge). The most important green roofs benefits are:

- aesthetic improvements;
- energy efficiency;
- fire retardation;

- improved air quality;
- improved health and well-being;
- increased biodiversity;
- new meeting places for people;
- noise reduction;
- stormwater management;
- waste diversion;
- urban agriculture and architecture.

Sustainability in not only a trend we should fallow – its everyday life for construction sector as well. Denmark (WEB–5) is a leading country in sustainability of new building and construction projects. Port of Copenhagen is a good example of how smart decisions can change a part of a city into sustainable area (WEB–8). Nordic countries are more sustainable than other European countries for several reasons: this region has the lowest level of perceived challenges with regards to sustainability and companies in the region are most likely to leverage software and technology – design as well – to drive sustainability. There are so many decisions in construction and design that are not only about ecology but about social aspect of sustainability as well. Here ecological, social design plays an important role from education to real projects and everyday life. Another interesting example is the municipal school in Guastalla (Bailey, 2017), a little town in Italy's Emilia-Romagna region in the centre of the Po Valley – it is a highly symbolic achievement. Built to replace two similar facilities damaged by the 2012 earthquake, it stands for the area's determination to rebuild its communities but at the same time rethink the way educational spaces are organized, based on the idea that learning should be fun and that school buildings should help make that possible.

And here we can find the most popular solution for making buildings more sustainable or greener: creating green roofs. The great benefit or green roofs is not only less air pollution, but also new social meeting places and possibilities of spend time in open areas, not only inside the buildings. The most popular examples of green roofs and walls are:

- The 8 House, Copenhagen, Denmark;
- The Biesbosch Museum Island, the Netherlands;
- The California Academy of Sciences, USA;
- The City Hall, Chicago, USA;
- The Moesgaard Museum, Højbjerg, Denmark;
- The Namba Parks, Japan;
- The ACROS Fukuoka Prefectural International Hall, Fukuoka City, Japan;
- The Daniel F. and Ada L. Rice Plant Conservation Science Center, Chicago, USA;
- The Javits Centre, NYC, USA;
- The Kö-Bogen retail and office complex in Düsseldorf, Germany;
- The landscaped green roof at Beijing airport, China;
- The Nanyang Technological University, Singapore;

- The Solaire, NYC, USA;
- The Vancouver Convention Centre, Canada;
- The Vendée History Museum Les Lucs-sur-Boulogne, France.

Another interesting example of a green roof can be seen in Italy: Salpi Plant. Enzo Eusebi's (Bailey, 2017) project for the Salpi cured meat processing plant in the open countryside – it some contradictions with the realism and pragmatism of the engineer and the vision and sense of experimentation of the architect (not only the green roof but also outer facades, ventilation at night, thermal accumulation, sun shading, elevations, plan).

Another interesting example of sustainable design – how wind turbines can be used in buildings – is The Bahrain World Trade Centre. It is the first commercial building to use wind turbines on a horizontal axis, attached to the actual building for electricity (WEB–6). In Brisbane Australia, the Kurilpa Bridge holds the title of the largest foot bridge powered by solar panels. A prime example of wastewater management is the Robert Redford Building located just outside of Los Angeles. By using low-water fixtures, waterless urinals, efficient subsurface irrigation, a grey water system for toilets and irrigation, and an effective rain harvesting system, this building sets the bar for sustainable design and function. The building was awarded a LEED (certificate of *Leadership in Energy and Environmental Design*) Platinum rating and is among the greenest buildings in the world. For more information look here (WEB–9). Torre Reforma building in Mexico City or Transoceanic Building in Santiago, Chile (WEB – 11) are other examples of structures with LEED certificate (WEB–10).

Another important aspect of sustainable decisions is construction waste management based on the rule of three ecological principles: reduction, reuse and recycling. In addition, sustainable constructions emphasize the use of materials derived from renewable or recycled natural resources. Waste can be used in the construction industry in two ways (Dachowski, 2016): by reusing (using components again) and recycling (processing waste into raw materials used in the production of building materials). Construction sector and housing must be low-carbon in both construction and use, with on-site materials reused or recycled wherever possible. Some housing items should be locally manufactured if possible. Initiatives such as rain water harvesting, grey water capturing for landscape and food production (local), communal composting and on-site wastewater treatment should be considered where appropriate. New buildings must be created for the users to feel comfortable inside and around their homes.

Today, structures that are designed, built and managed according to sustainability criteria are becoming more common (criteria include the product's recyclability level, recycled content, eco-friendliness, regional aspects, indoor air quality, life cycle impact, as well as the company's social responsibility and responsible environmental management across the product's supply chain). In this sense, there are organizations that provide certificates for sustainable buildings, such as the LEED Green Building

Councils in Lithuania, Spain, Poland and Italy or Latvian Sustainable Building Council in Latvia, and others, such as WELL, FITWEL, GREEN GLOBES, BREEAM, DGNB, GREEN STAR or BCA GREEN MARK SCHEME. The number of buildings with such certification is expected to increase significantly in the future.

2.2. The Role of Ecological Design and its Benefits

More than ever before, we need to apply the principles of circular economy and resource efficiency to buildings to reduce future resource consumption (EC, 2020c). End-users look for sustainable building concepts (Bauer et al, 2010), with low energy and smaller operating costs, which offer open, socially acceptable and communication-friendly structures made from materials that are ecologically acceptable for the building and have been left in as natural a state as possible – in the cites. Sustainable design is not only about construction – it's about architectural input: it also requires structural, mechanical and perhaps electrical design so that investors can use the buildings for as long as possible and repurpose them if needed. New technologies in construction provide the opportunity to "live" some moments in the buildings, even if they are only in the design phase – it is now easier to understand what is needed at each stage design and construction. A good design includes how the space will function.

2.2.1. The Future of Ecological Design in Sustainable Construction

Green, sustainable buildings were first promoted for environmental reasons. The projects involved high start-up costs, specialized teams and unusual equipment and construction practices. Government agencies, universities, and non-profit organisations began to adopt sustainable designs early, using subsidies and grants to offset more expensive construction costs and recoup returns from long-term use. Green buildings are buildings of any usage category that follow the principle of a conscientious handling of natural resources.

Today, sustainable design is becoming commonplace as more building developers are discovering the value that is created when low upfront capital costs and short payback times increase rental rates as well as attract and retain tenants (Pientka, 2015).

Sustainable design makes sense. For a development to become "sustainable", engineers must incorporate „sustainability" into all their planning and engineering of products and projects.

And today, the most common principles of sustainability in construction are:

- Circular economy (by using energy, water and materials – some com-panies are using CO_2 footprint calculation today as a part of general strategy);
- Lifecycle of design (the need to analyse construction processes and their impact on the environment – not only at the design stage, but also during construction

and operation. Reducing material and energy use throughout manufacturing life cycle as most important sustainable task indicates more than 41% of construction companies in EU (Royan, 2021));

- Consumer oriented design and decisions (sustainable projects must promote the interaction of people and nature. This means that preserving natural conditions must be an integral part of any urban design.
- In addition, the quality of life of the user needs to be maintained).

Sustainability must occur at all stages of the building's life cycle (design, construction, operation, maintenance and demolition). Sustainability aims such important sites of infrastructure as living quality and mobility inside the living area. And it is not only about closed areas, but about the whole cities as well. People must have access to safe, inclusive, green public spaces, especially women and children, the elderly, and people with disabilities. Systems thinking of connecting the different dots and looking at it from a different perspective in totality, which will help in reaching new levels of sustainability – that's the key to better results.

According to the United Nations, today more than half of us live in cities. By 2050, two-thirds of all humanity—6.5 billion people—will be urban dwellers. Sustainable development cannot be achieved without significantly transforming the way we build and manage our urban spaces (UN, 2022).

One of future solutions for sustainable cities is the concept of „15-minutes city" (WEB–1), whose main idea is that everyone living in a city should have quick access to essential urban services. The „15-minutes city" project is designed to help access-focused urban transformations be what they need to be: ambitious, inclusive, measurable and effectively implemented.

Sustainable cities, buildings and design depend on several key factors:

- New projects –but also older but renovated places – must stay in harmony with the ecosystem and biosphere. Both the construction process and the operation of the building are expected to have the least possible negative impact on the environment. To this end, the building and its support system (provision of services, transport routes) must be integrated as much as possible into the natural environment. One of the most incredible examples of such design is the circular eco-friendly Brondby garden city of Copenhagen in Denmark (WEB – 3). Incorporating nature into the design is a very wise and sustainable solution. Circularity—reduced use of scarce resources and an increased focus on design for reuse instead of single use (digitalisation has a key role) and design thinking from the start, with a shift in focus on material use from what needs to be built to the most efficient use of resources in a circular economy – that's the future trend (Royan, 2021).
- To force a building to produce energy for itself. The focus is on renewable energy for the air conditioning systems, which consume a lot of energy and thus reduce the building's impact on the environment. This considers the design of the building, the use of suitable materials and the orientation of the building. Ventilation

is required to lower building temperatures and adequate insulation is required for efficient heating. However, glass is a bad heat insulator, so it is necessary to reduce heat loss through the glass. Water reuse serves the same purpose.

- The materials used in the design and construction in accordance with the principle of sustainable architecture/design should have a low environmental impact. Therefore, substances whose acquisition may be harmful to the environment must be disposed of. Cement production and calcination account for 8% of global anthropogenic CO_2 emissions, which is about four times that of the aviation industry. Due to the massive consumption of carbon-intensive materials (such as concrete and steel) and its associated high emission factor, robotics and 3D printing can significantly reduce the construction sector's environmental impact (Royan, 2021). That's why today becomes popular use natural materials in construction. Interesting sustainable trend can be seen in Scandinavian (WEB – 12) countries and Lithuania as well: wooden construction or buildings from clay or raw earth (WEB – 4). All the time earth as a building material (Minke, 2015) was very important. Wooden materials (in some areas – bamboo) must have the certification too. There are a lot of new materials in construction engineering that can be reused (WEB – 7): from different waste such as plastic, gum to useful materials. More and more innovations are coming into construction sectors such 3D printing (WEB – 2), augmented reality, BIM, virtual reality, Internet of Things, artificial intelligence and others. Digital technology will drive tangible efficiency improvements in manufacturing and AEC with greater integration of design, process and operational workflows.
- There are many software tools looking to cover embodied carbon; however, the databases that support this software are not fully reliable and require many manual overrides (Royan, 2021). There is a definite role for BIM to help in supporting the reliable calculations of embodied carbon. Buildings performance management is an increasing focus of sustainability initiatives linked to energy intensive lighting and heating, ventilation and air conditioning systems (HVAC) operations, both in AEC and manufacturing. There is a growing role for building energy management systems that are expanding on the sensors and data that monitor, measure, and manage energy efficiency.
- Waste management – as a solution and guarantor for reducing environmental pollution in the construction sector. Waste management is considered in the construction process when waste is generated that has a significant impact on the environment. It therefore aims to use materials efficiently, generate less waste and reuse or recycle manufactured products. An appropriate waste management system for population must then be established. Other aspects may include waste sorting for recycling and reuse and composting of organic waste for orchards.

Never before design and construction sectors have been so interesting as they are today. New challenges give more opportunities to communicate between owners and builders and to achieve more sustainable goals than ever before – for saving our

planet. Building and creating an environment is a huge responsibility (Dos Santos Gervasio, 2018), and the pursuit of sustainable design should not be the prerogative of several companies, but the commitment of all stakeholders in the construction sector.

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