ROLE OF BUILDINGS LIFE CYCLE ASSESSMENT FOR SHAPING SUSTAINABLE CITIES

Maricel PALAMARIU, Prof. dr. eng., University of Agricultural Sciences and Veterinary Medicine, Cluj-Napoca, Romania, e-mail: mpalamariu@gmail.com
Alexandra DREGHICI, Lect. dr. eng., „1 Decembrie 1918" University of Alba Iulia, Romania, e-mail: apopa@uab.ro
Ildiko TULBURE, Prof.(D) dr. eng. habil., „1 Decembrie 1918" University of Alba Iulia, Romania, PhD supervisor at Technical University of Cluj-Napoca, and PD at Clausthal University of Technology, Germany, e-mail: ildiko.tulbure@gmail.com

***Abstract**: Beside positive desired direct effects of industrial activities having the goal to increase humanity quality of life by developing, applying and using diverse technologies, these can also have negative, undesired impacts on environment and society. In this regard the concept of sustainable development has been recognized and accepted as being the possible solution for the arisen complex global environmental, economic and social problems, which humanity is actually confronted with. To assure the transition of our society toward sustainability technical, economic, environmental as well as socio-political aspects have to be simultaneously considered as much as possible in decision making processes. For engineers this means to lead technology assessment studies and to comprehensively assess industrial applications as well as correlated necessary infrastructure, especially existing and planned buildings. From this reason it is very important to develop analytical tools to analyze and assess buildings from the point of view of their potential impacts with regard to shaping sustainable cities. One of these tools already applied in technological field is the Life Cycle Assessment. In this paper the applying possibility of Life Cycle Assessment in the context of diverse buildings will be presented and debated in order to assure shaping sustainable cities.*

***Keywords:** Buildings, Life Cycle Assessment, Sustainable City, Interdisciplinary Approach*

1. Introduction

In the worldwide debates regarding currently existing possibilities for assuring the sustainability of our human society several times has been emphasized the important role played by shaping on a local level cost and energy friendly housing alternatives as well as high living standards for inhabitants, including not only technical and economic aspects, but also environmental, sportive and cultural ones. All these requirements are directed to the vision of shaping in the future all over the world the necessary technical infrastructure and also the appropriate mentality for living in the so-called "sustainable city". Worldwide began in the last time discussions on scientific, political and social levels in order to find the best solutions for shaping the Sustainable City, which could be applicable to several countries all over the world, but with respect to specific regional especially cultural differences [1], [2], [3]. After the release of the Brundtland Report defining for the first time the concept of sustainable development [3], followed by debates 1992 during the Conference for Environment and Development in Rio de Janeiro and by publishing the much discussed document „Agenda 21" it was more than clear that there is a need to simultaneously consider several fields in order to succeed the successful operationalisation of sustainable development on different levels, on global, national, regional as well as on a local level [2], [4]. The vision is to find the best strategies for assuring especially the local sustainability, by taking into account the multitude of aspects related to the technological, economic and social activities [5].

In this regard in the activity of evaluation and monitoring of buildings, the term "building" is generally used for objectives such as civil, socio-cultural buildings, industrial constructions, chimneys, TV towers, dams, hydro power plants, bridges, roads, waste deposits, tailing ponds and dumps etc.

Typically, in a building life cycle assessment (LCA), three phases are identified (pre-use, use and post-use), starting with the supply (extraction) of raw materials and the manufacture of construction materials, construction, usage, exploitation and maintenance, and finally, end of life, by in-situ abandonment, total or partial demolition and recycling and reuse, if applicable (Fig. 1) [6].

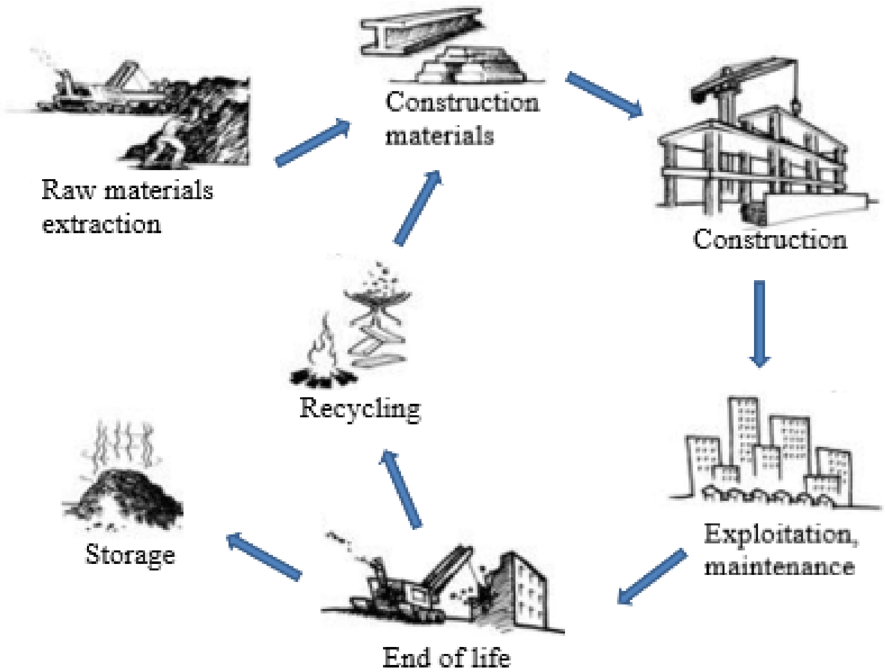

Fig. 1. Building Life Cycle Assessment [7]

Moreover, the legislation at national level stipulates that all the categories of geodetic and cadastral works that must be executed for the good functioning of a building must be executed in a particular way for the corresponding building life cycle phase: pre-use, use, post-use of the building. These geodetic and cadastral works refer to the behavior monitoring in execution, exploitation, investments and post-use of buildings. The objectives of these works are [8]:

- the correct and exact application in the field of the building itself and building networks projects, in order to ensure the safety in exploitation, the stability and durability of the building: stake out and execution monitoring;
- detection of degradations: monitoring the building behavior in exploitation;
- maintaining or even improving the building ability to function: interventions over time, restoration, modernisation and even change of destination;
- the safe demolition of buildings and the efficient recovery of materials or reuse of building elements.

2. Materials and Methods

At this point should be stated that developing strategies for urban sustainability in cities actually means elaborating strategies on local level by considering life cycle assessment of most important buildings and products applied in this regard. The vision of having in the future sustainable cities, by taking into account regional differences, is worldwide a pretty discussed topic, also in Eastern European countries [9], [3]. It was recognised that urban sustainability is among most critically important global issues of the 21st century [1]. It is estimated that over 50% of the world's population now lives in urban areas. Some developed scenarios for the future urban development estimate that by 2050 the proportion of the global population living in cities will rise to 70% [9]. The big challenge is that cities now consume about 75% of all of world's energy and emit around 80% of all greenhouse gases [9]. Therefore the fight against climate change will be won or lost in cities, so it is crucial that urban habitats, i.e. buildings, will become more efficient - not only for themselves, but for future generations and the Earth's diverse ecosystems [9]. Several newly discussed strategies for sustainable urban development have at their base the concept of "Decoupling", that is a pretty recent term in the sustainability literature. It was mentioned first time by the Club of Rome, during its Conference "Governance of the Commons", that took place in September 2013 in Ottawa, Canada. This notion typically refers to the ability of breaking the long held causal relationship between economic growth and growth in the consumption of natural resources [10]. The essence of decoupling means to assure a high quality of life for all citizens in the world, but without having a rasant growth in the energy consumption, with all its impacts on the environment, and not only.

Regarding the concrete situation in Romania currently the question is how to succeed in transforming a city in Romania in a regional model of sustainable development, in a so-called "sustainable city" [9]. After joining the European Union in 2007, the word "sustainability" started to be heard more frequently in Romania. New opportunities for people to know and learn from Western countries were suddenly opened. Several steps have been made since then, sometimes because of bureaucracy, sometimes because of other priorities, and sometimes because of lack of knowledge and lack of financial resources. Nevertheless it has to be mentioned that in last time advance has been registered in the field of shaping sustainable cities. Anyway in this regard has been pointed out the need to consider buildings life cycle assessment for trying to mitigate potential environmental impacts. Also the idea of constructing green buildings come very much into discussions. Starting with 2013 the construction of green buildings has been encouraged by local authorities of several cities, where the life cycle assessment of singular buildings in cities should be of foremost importance.

In this regard the phases can be assessed separately in order to obtain information on the environmental impact of each phase (information that would be relevant to the production companies), or an overall assessment can be made, in which one phase may depend on another phase (Fig. 2). For example, energy consumption varies from phase to phase, and therefore decreasing the energy input in one of the phases can lead to an increase in the energy incorporated in another phase. Building an energy-efficient house with energy-efficient walls, floors, windows and doors will reduce the building's operational energy needs; however, due to the energy required to produce the materials and the added volume of materials required, the energy requirements will increase during the construction phase as well as the built-in energy of the entire building. Other elements with a big impact on the environment, apart from energy, may have the same trends. For example, research on two types of foam insulation indicated that greenhouse gases emitted during the manufacturing process and emissions from foaming produced a higher global warming impact category than the emissions saved from additional combustion of fossil fuels during the exploitation phase for heating and cooling. However, this study was not conducted as a complete building LCA, but rather as an evaluation of products, based on specific characteristics [6].

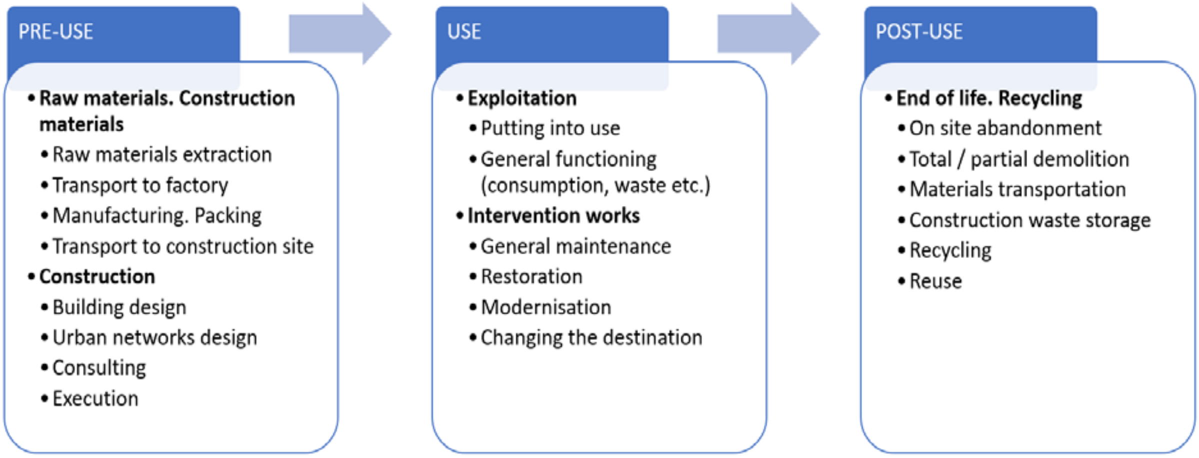

Fig. 2. Building Life Cyclce Assessment Phases

2.1. Pre-use Phase

The activities in the pre-use phase of a building include the extraction and processing of raw materials, the transport from the quarry site to the factory, the manufacture of construction materials, the transport of materials from the factory to the construction site and the construction of the building (Fig. 3) [7].

At this stage, the main processes are developed [7]:

- Raw material extraction includes processes such as mining, cultivation / harvesting, drilling processes leading to iron ores, bauxite and oil. The primary materials are then transported to the processing centers to be transformed into manufactured materials such as steel, aluminum, timber, polystyrene and nylon, through specific steelmaking processes, refining / melting processes, grinding and refining / polymerization;
- These materials are then introduced into the manufacturing and assembly process of building components (eg. roofs, windows and exterior walls), furniture (eg. nylon carpet) and appliances;
- Construction of the building, on site, which also includes ground leveling and stake out works;
- The transport of materials is also inventoried, from the extraction of raw materials to the factory for manufacture of construction materials, packing and then transport to construction sites.

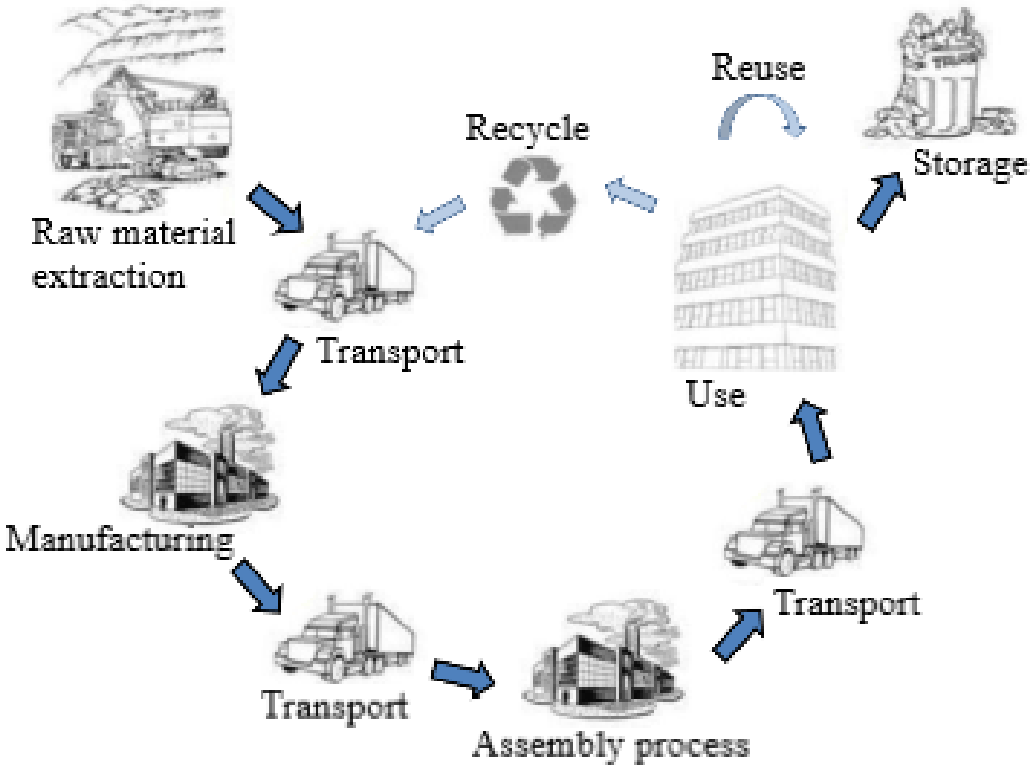

Fig. 3. Analysis of the pre-use phase of a construction [7]

2.2. Use Phase

The activities in the use phase of a building include: putting the building into use, general functioning of the building (energy and water consumption; waste generation), and intervention works, such as general maintenance works, as well as carrying out repairs (repairs, replacements, transport of materials, execution of works) or modernisation works (renovations, transport of materials , execution of works).

An important activity during the entire use phase is building monitoring, which consists of repeated geodetic measurements, recording, processing and systematic interpretation of the values of the parameters that define the buildings capacity to maintain their requirements of security, stability and durability [11].

In this phase, three aspects are identified [12], [7]:

- the supply of resources (eg. natural gas) for heating the building;
- the supply of electricity for the general functioning of the building (air conditioning and all appliances), as well as all activities related to the improvement and maintenance of the building;
- the latter activity includes the production and installation of maintenance and improvement components (eg. shingles, carpeting);
- change of destination and the energy needed for the intervention works.

Although the use phase currently dominates the life cycle energy consumption, the importance of material production and manufacturing / construction is expected to increase as models become more energy efficient (Fig. 4) [7].

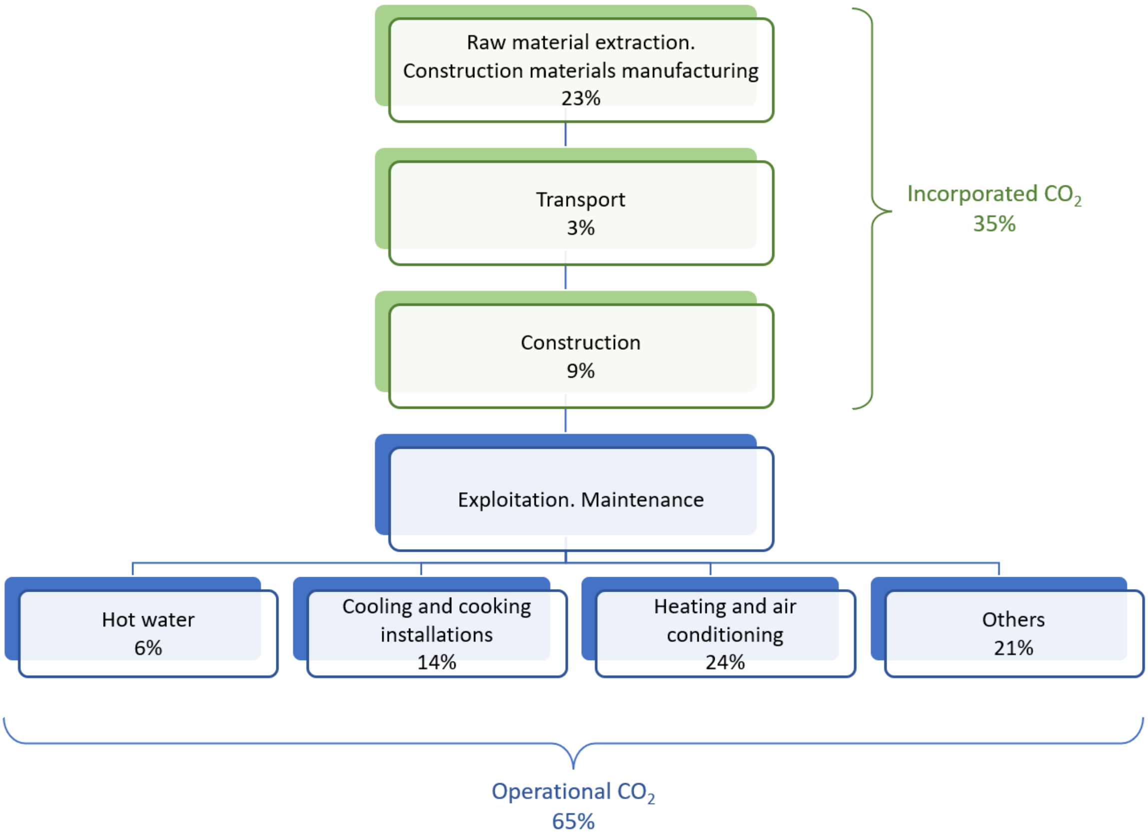

Fig. 4. CO_2 emissions for a building [13]

2.3. Post-use Phase

This phase includes all activities related to the end of the building life, which may include [12], [7]:

- abandon of the building on site;
- total demolition of the building and the energy needed to demolish it;
- partial demolition of the building, the energy needed to demolish unwanted elements and reuse of the elements that can be saved (concrete foundation, which is supposed to remain unaffected, certain facades etc.).
- transport and deliver materials to waste storage sites;
- activities of recycling process and reuse of waste resulting from demolition.

3. Results and Discussion

From made presentations became clear that the life cycle assessment, LCA is presently worldwide used to assess environmental effects of products, recently starting to be used also for assessing buildings from different points of view. Results regarding singular consideration of different phases in Buildings Life Cyclce, this means the Pre-use Phase, Use Phase as well as Post-use Phase are demonstrating the potential of considering life cycle assessment for buildings. The idea of such an analysis is to finally reduce as much as possible the impacts on environment of each of these phases in buildings life-cycle.

By assessing the building life cycle, it is possible to obtain [14], [15]:

- increased emphasis on building safety, stability and durability;

- based on the evaluation of the total energy consumption, energy efficiency policies for buildings can be elaborated;
- development of tools for evaluating the performance of buildings throughout the life cycle;
- inclusion of data on efficiency in specific databases, in order to obtain results at regional and national level.

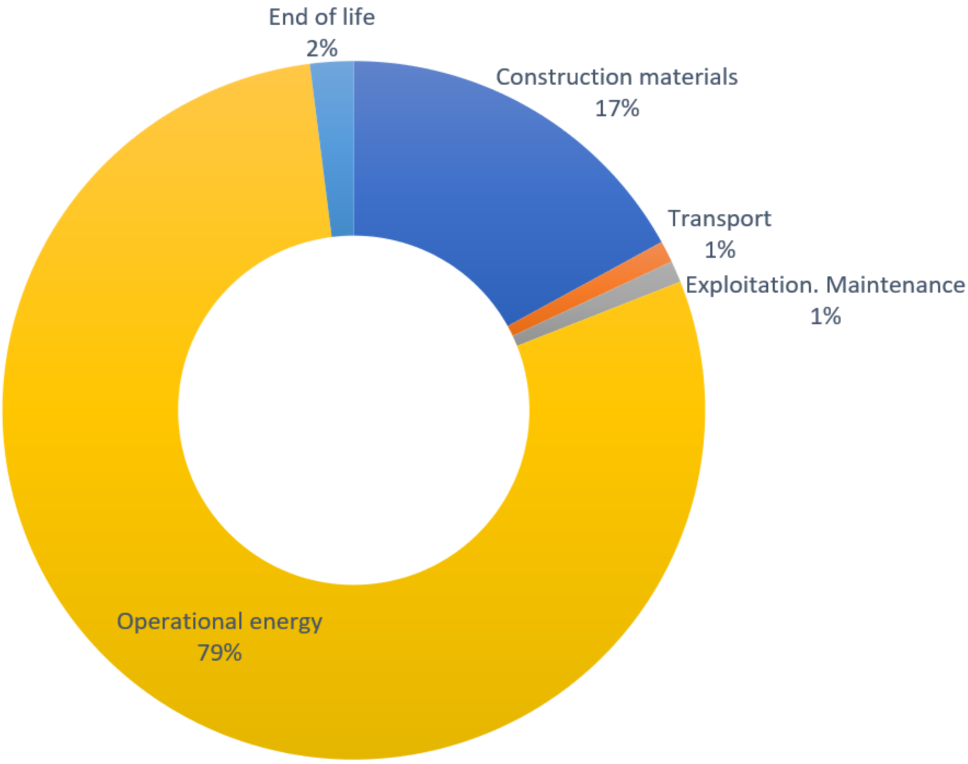

Fig. 5. The environmental impact of a building [13]

4. Conclusions

The concept of sustainable development has begun to find its important place from global to local levels. The heightened awareness for potential environmental impacts associated with different buildings, and manufactured products have increased the interest in the development of diverse methods for carrying out buildings life cycle assessment with the goal of shaping sustainable cities. It is a known fact that industrial activities have the direct goal to support increasing population quality of life, anyway beside positive direct desired impacts of such activities, also negative, undesired impacts on environment and society can be registered. In this regard the life cycle assessment, LCA is presently worldwide used to assess environmental effects of products, and of buildings. Results emphasize the working way of the presented method and allow an evaluation of different phases in the buildings life cycle. The idea is to mitigate impacts on environment of each of these phases in the general life-cycle of a building. The ones related to obtaining construction materials needed for buildings are relevant, but the phase of buildings use can have significant environmental impacts. In this regard the field of changing human mentalities is much more complicated than getting a less pollutant buildings life cycle and overrun the technical competencies of engineers, what means that interdisciplinary cooperation is needed.

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