Review paper

Received: January 28, 2013
Accepted: February 2, 2013

Life cycle assessment of an intermodal steel building unit

Ocena trajnostnega cikla intermodulne jeklene gradbene enote

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Abstract

To minimize and in the near future eventually eliminate the negative environmental impacts, such as emissions, waste, energy and excessive raw material consumption, the life cycle assessment of buildings is essential. This paper provides an insight in environmental life cycle assessment (LCA) of a typical intermodal steel building unit (ISBU).

Key words: Life Cycle Assessment (LCA), intermodal steel building unit, environmental impact

Izvleček

Za zmanjšanje in v bližnji prihodnosti tudi odpravo negativnih vplivov na okolje, kot so onesnaženje, odpad, prekomerno izkoriščanje energije in surovin, je ocena trajnostnega cikla zgradb neobhodna. V prispevku je prikazan primer ocene trajnostnega cikla (LCA) tipske intermodulne jeklene gradbene enote (ISBU).

Ključne besede: ocena trajnostnega cikla (LCA), intermodulne jeklene gradbene enote, vpliv na okolje

Introduction

The built environment is a major contributor to both social and economic development and represents a large portion of real capital in many countries; but it's also a primary source of environmental impacts. Furthermore, existing building stock requires continuous investments for repair and renovations. The notion that building structures that would last for centuries is the best environmental solution to our problems does not match with our existing building use trends and knowledge of the built environment.

Buildings will be replaced with newer designs that are more suited towards the needs of future occupants. Energy is an essential input to every production, transport, and communication process and is thus a driver for the economy as well as social development of any nation. The building construction industry consumes 40 % of the materials, entering the global economy and generates approximately 45 % of the global output of greenhouse gases and the agents of acid rain. [1–3] The growing concern of environmental problems, such as global warming, which have been linked to the extended use of energy, has increased both the importance of all kinds of so-called ''energy saving measures'', and the necessity for an increased efficiency in all forms of energy utilization. [4] As a consequence of the latest reports on climate change and the need for a reduction in CO_2 emissions, huge efforts must be made in the future to conserve high quality, or primary energy, resources. [5] While consuming large amounts of energy, building industry has also caused a large burden on the environment due to the environmental emissions by the production of building materials and the running of building system. [6] Extraction or purification of materials from their natural ores is an activity that consumes energy, generates waste, and also contributes to environmental damage with negative impacts such as resource depletion, biological diversity losses, and other. On the other hand they provide the necessary infrastructure for many productive activities such as industries, services, commerce, and utilities, and thus satisfy a very basic human need. However, due to this very basic nature of buildings, stakeholders in development sometimes do not consider the environmental impacts of building, especially in developing economies. [7]

Methodology

As a significant tool of environmental management, life-cycle assessment has become an internationally recognized criterion. It is the basis for establishing an environmental policy and is generally used to guide the clean production, development of green production, and the environmental harmonization design. A life cycle assessment (LCA) is a technique to assess environmental impacts associated with all the stages of a product's life from cradle to grave (i.e., from raw material extraction through materials processing, manufacture, distribution, use, repair and maintenance, and disposal or recycling). LCA can help avoid a narrow outlook on environmental concerns by [8]:

— compiling an inventory of relevant energy and material inputs and environmental releases,
— evaluating the potential impacts associated with identified inputs and releases, and
— interpreting the results to help make a more informed decision.

The LCA process is a systematic, phased approach and consists of four components [9,10]:

— goal definition and scoping,
— inventory analysis,
— impact assessment, and
— interpretation.

The goal of this study is to estimate the environmental impacts of a typical intermodal steel building unit (Figure 1 and Table 1).

The system studied includes the part of a life cycle of the building, including manufacturing of building materials, construction, operation, and maintenance. For the demolition and disposal stage, due to lack of relevance data, landfilling is assumed. Transport for each life cycle stage was also included. Only the structure and envelope of the selected building are assessed. Special emphasis is put on energy consumption. The functional unit for this estimation was defined as one intermodal steel building unit

Figure 1: *Intermodal steel building unit (ISBU).*

Table 1: *Input data gathered for assessment of ISBU*

Building parameters	Specifications
Dimensions	12.2 m × 2.4 m × 2.6 m
Service life	approx. 25 years
Floor area	approx. 30 m^2
Office volume	67.7 m^3
Structure	Construction steel
Envelope	Construction steel
Foundation	Reinforced concrete
Coverings	Gypsum, Plaster, Insulation
Floor finish	Linoleum
Windows	PVC

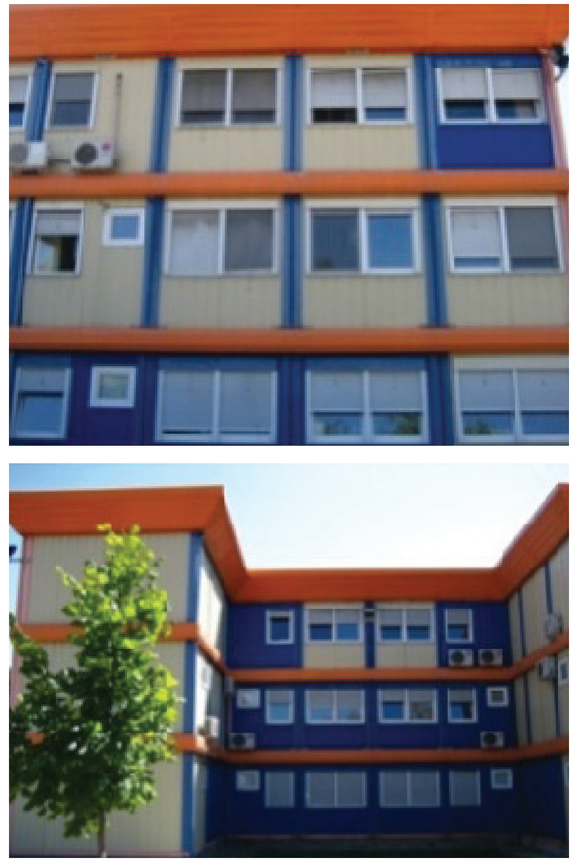

Figure 2: *Case study: Intermodal steel building units used for office purposes.*

for a period of 25 years which is used for office purpose (Figure 2).

The second step of the LCA is inventory analysis. It contains the data collection and calculation procedures, and is of key importance since this data will be the basis for the study. Inventory is also tied to the scoping exercise since data collection and other issues may lead to refinement or redefinition of the system boundaries. Data needed were gathered from EcoInvent Database v2.2 and other scientific and technical publications and sources. [11, 12]

The LCA process has three major phases:
— building materials production phase,
— use phase, and
— the end of life phase.

Each of them includes production, transportation, and distribution.

Life cycle assessment

The assessment follows the LCI analysis first categorizes the impacts (resources consumption and emissions) into a range of impact categories. The characterization step is then performed, which converts the quantities of various types of impacts under each category into equivalent quantities of a reference impact (e.g. methane into an equivalent amount of CO_2 under the global warming category), yielding one single impact indicator for each impact category. Each impact indicator retains the unit of measurement of the quantity.

In this case, the BEES method is employed. BEES is the acronym for Building for Environmental and Economic Sustainability, a software tool developed by the National Institute of Standards and Technology (NIST). BEES combines a partial life cycle assessment and life cycle cost for building and construction materials into one tool. Results are presented in terms of life cycle assessment impacts, costs, or a combination of both. BEES strives to assist the architect, engineer, or purchaser to choose a product that balances environmental and economical performance, thus finding cost effective solutions for protecting the environment. BEES uses the SETAC method of classification and characterization.

Characterization results are presented in Figure 3. The impact of ISBU is represented via 12 impact categories according to BEES methodology. Figure 4 presents the results of energy consumption compared during the production and installation stage and operation and use stage.

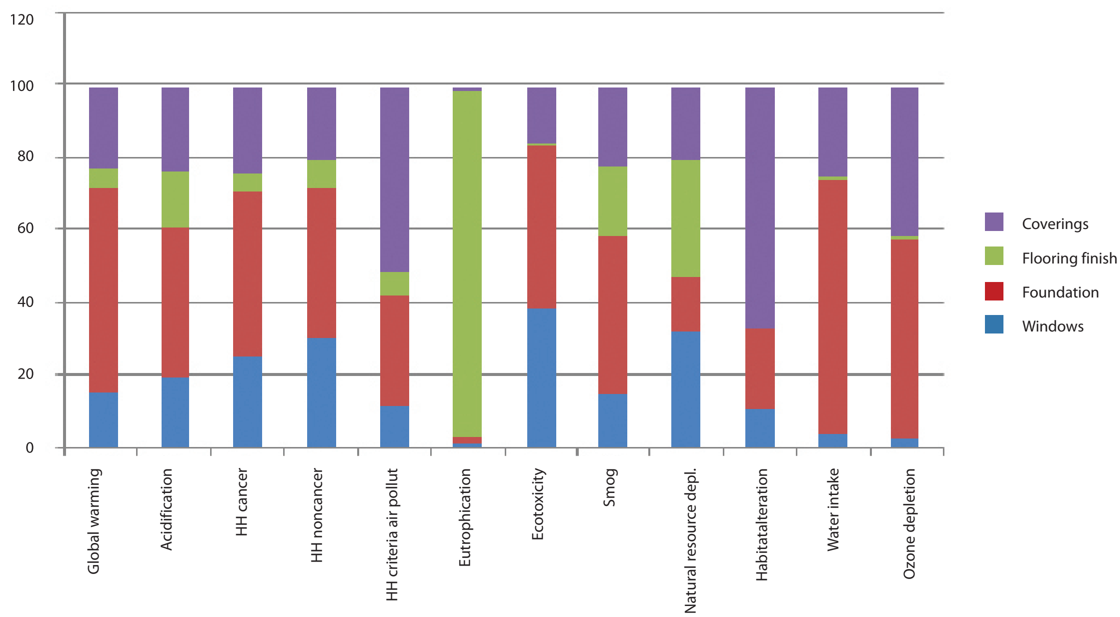

Figure 3: *Characterization results of an ISBU production stage.*

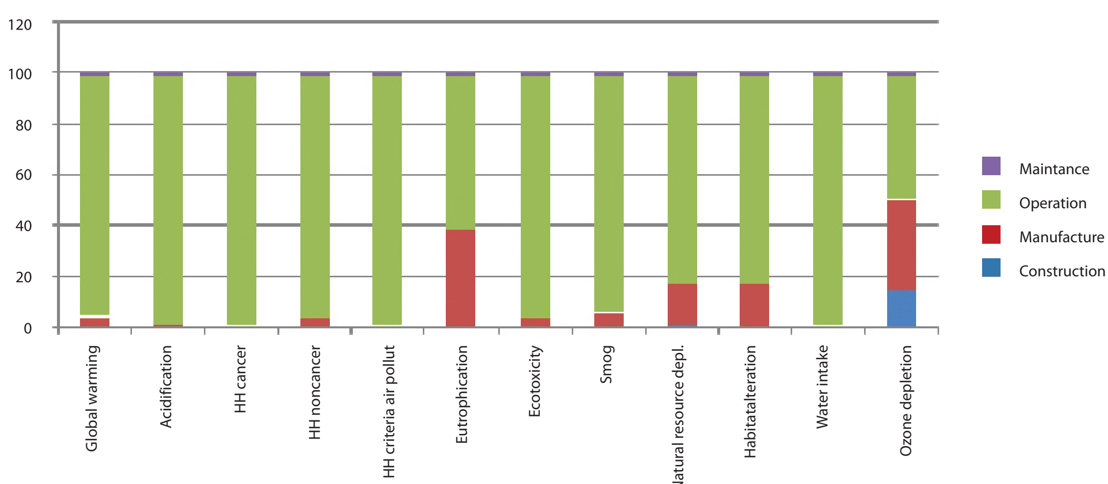

Figure 4: *Characterization results of an ISBU regarding energy consumption.*

Discussion

Based on the results obtained, ISBU that is analyzed indicates certain problem areas observed in the product life cycle and that within three main impact categories:

— water intake,
— ozone depletion and
— global warming.

The largest impact within the above mentioned categories results from processes of cement production that is used for the foundation on which the object is installed and also steel from which structure and envelope is built. Processes observed in the use phase of the ISBU life cycle with its influence on the environment stands out from the rest, mainly because of the total electricity consumption in the assumed lifetime of 25 years. These problems can be successfully overcome if the existing structure is adapted to the rigorous requirements of a Leadership in Energy and Environmental Design (LEED) certification. A LEED certified office is designed and constructed in accordance with the rigorous guidelines of the LEED for offices green building certification program. LEED for offices is a consensus developed, third party verified, voluntary rating system which promotes the design and construction of high performance green offices. Main advantages of ISBU modules are:

— strong building construction,
— earthquake proof,
— fire proof,
— strong, corrosion resistant construction steel,
— extreme security,
— recyclable - green construction and modifications,
— saves trees,
— unibody construction,
— ideal for multiple floors and levels,
— fast construction,
— insulation: bonds easily with space-age,
— ceramic insulations,
— easily adapted to prefab automation, and
— easily adapted to custom homes/offices.

Intermodal steel building units (ISBU) have become very popular and trendy for use as homes, storages, prefabs, and business construction purposes. Only recently has the world begun to realize their value in housing, office construction, storage and emergency shelters. The possibilities are virtually endless.

Conclusions

The goal of the presented study is the determination of the impact of intermodal steel building units (ISBU) life time on the environment. For materials and methods in discussed in this work, a combination of input–output and process analysis was used in assessing the potential environmental impact associated with the system under study according to the standard ISO 14040 methodology.

The study covered the whole life cycle of the ISBU including design, materials production, construction, occupation, maintenance, demolition, and disposal.

Globally, the main reason for so high interest in intermodal steel building units is off-course the relatively low cost of construction.

Acknowledgement

A part of result presented in this paper is obtained in the framework of the project “Continuous quality improvement of products and processes throughout the entire life cycle”, TR 114-451-1924/2011-02, supported by the Provincial Secretariat for Science and Technological Development of AP Vojvodina, Republic of Serbia.

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