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Life cycle assessment applied to the comparative evaluation of single family houses in the French context

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Abstract

A life cycle simulation tool has been developed and linked with thermal simulation. Inventories given in the Oekoinventare database or collected in the European REGENER project are considered to evaluate the environmental impacts of material fabrication and other processes (energy, transport, etc.). An application of this tool is presented here concerning the comparison of three houses: the present construction standard in France (reference), a solar and a wooden frame house. The results of this exercise are presented and its limits are discussed. It seems still difficult to apply life cycle assessment (LCA) to the selection of materials and components. Rather, LCA can be used for the improvement of technical solutions (e.g. increasing the roof insulation in the solar house). © 2001 Elsevier Science B.V. All rights reserved.

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1. Introduction

The motivation for solar or bioclimatic architecture was first to save natural resources by reducing energy consumption in buildings, while providing a high level of thermal comfort. At the end of the 1980s, energy prices decreased and energy saving was not perceived anymore as a major issue in France. Concern for broader environmental problems like global warming or ozone depletion, stricter regulations concerning waste and water management, higher concern for toxicity appeared at the beginning of the 1990s. This context leads to question again the design and construction approach and to study the application of the sustainability concept in the building sector.

Sustainability includes both the satisfaction of present needs and the ability of future generations to satisfy theirs, which imposes to make a synthesis between potentially contradicting aspects. Bioclimatic architecture is an example of such a synthesis where both comfort issues (present needs) and energy efficiency (future) are addressed. This synthesis is often misunderstood, e.g. an air-conditioned sunspace was proposed in a project during a competition for ‘‘high environmental quality’’ in France, with the argument that a sunspace is ecological and that more comfort is achieved by air-conditioning. The building is existing, and we can check that the comfort is poor and that the energy bill is high. In most ‘‘high environmental quality’’ buildings, the approach has been based upon symbols rather than on the assessment of environmental impacts. Many examples show that substantial education effort is still necessary.

Compensation is often underlying environmental evaluation methods, e.g. one project may have good points on comfort and bad points on pollution, so that the global evaluation is correct. In fact according to its definition, sustainability does not mean finding such a compromise between our needs and environmental safeguards, but a synthesis allowing a long-term functioning of ecosystems.

The environmental impact of a building depends on decisions taken by a large quantity of actors: owners, designers, enterprises, inhabitants, etc. An evaluation tool can help these actors to foresee the consequences of their decisions and to integrate environmental aspects into their choices, preferably by adopting prevention strategies. We propose here a contribution concerning the evaluation of quantifiable environmental impacts of buildings. The methodology is presented and illustrated by a comparative study of single family houses. The results and the limits of the present knowledge are then discussed.

2. Presentation of the method: life cycle assessment applied to buildings

Evaluating the environmental quality of buildings has been discussed in various seminars (e.g. [1]). We used the life cycle assessment (LCA) method [2,3] because environmental quality is the result of a global process integrating the

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whole life of a complex system. Occupants behaviour and interactions with the surrounding site should be taken into account, so that a specific approach must be developed for buildings [4]. LCA methods represent a rational approach, which can evolve with the progress of knowledge, and this may help various actors to agree on common strategies. The interest and potential of new technologies like renewable energy systems can be assessed by this precise approach. Another advantage is the standardisation of LCA [3], allowing a link between evaluations concerning materials and buildings.

This work has been done within the French EQUER project (evaluation of environmental quality of buildings), gathering researchers and professional partners [5].

A general framework for applying LCA in buildings has been elaborated in the European project REGENER [4]. The different phases considered in a building life cycle are the fabrication of components, the construction, the use of the building, the renovation and the renewal of components, the final dismantling and the treatment after use of components. The possible reuse and recycling of components is also taken into account.

We consider in the environmental assessment of a building only its influence on the outside environment. The aspects related to the inside comfort are supposed to be addressed by other existing tools. Therefore, the calculation of the inside air quality, illumination and noise level as well as the thermal comfort analysis are not dealt with in this article. They are, however, implicitly taken into account in the definition of the "functional unit", cf. Section 2.1.

The environmental impact of building components or processes (e.g. energy use, transport) can be evaluated on the basis of inventories. An inventory is a table of impact factors, indicating the quantity of each emitted or used substance with regard to the unit of the component or process. The used inventories contain impact factors on the following categories:

- the used resources (e.g. rare materials, energy);
- the emissions into air, water, ground (e.g. CO_2 into air, ammonia into water, oil into ground);
- the created waste (e.g. inert, toxic, radioactive).

Data collected in the REGENER project [4], or from the Oekoinventare database [6] has been used concerning the inventories corresponding to the different processes considered (energy, transportation, manufacturing of building materials).

The overall input and output of a whole building during its life cycle is calculated by the tool and constitutes the inventory of the building.

Beyond the product definition, LCA requires the definition of the "functional unit" considered and the system boundaries. According to ISO 14040 standard [3], the models considered for energy, transport and recycling processes should also be presented. The used method for aggregating the data of the building inventory, in order to get an environmental profile, has also to be indicated.

2.1. Definition of the functional unit

Comparing different products by LCA is meaningful only if these products fulfil the same function. A building has many functions: allowing activities, providing comfort, etc. Thus, the functional unit has to be defined so that different buildings compared provide the same services, over a similar duration.

We consider as the functional unit a whole building, built in a given site and planned for a specified use (dwelling, office, etc.). This building is of course generally occupied and is assumed comfortable and healthy. Its comfort is defined by a given set point temperature (possibly varying in the time), for heating and if needed for air conditioning, and by sufficient illumination, ventilation and noise protection. A satisfactory indoor air quality is necessary for sanitary reasons. Also a unit of living area (1 m^2) can be used as functional unit under the same conditions as above which allows the comparison of different projects on a homogeneous basis.

2.2. System boundaries

The system boundaries define which fluxes (e.g. materials and energy used, emissions) are taken into consideration and if the impacts due to infrastructure (construction, maintenance, etc.) are assigned to the studied system in a certain proportion.

Processes could take place inside or outside a building. We take into account direct fluxes caused by external processes (e.g. energy use for transportation of materials), but the effects created by making available their infrastructure are in general negligible (e.g. the impacts corresponding to the production of a truck are negligible compared to the impact of fuel combustion over the whole service life of the truck). External processes are for example the fabrication of building components, their transport and recycling processes and waste treatment. Daily transport of occupants and urban waste processing may be included according to the purpose of the study, e.g. if different building sites are compared and the possibility of sorting domestic waste is studied.

For processes which could also be located in a building (e.g. water treatment) making their infrastructure available is taken into account. This allows a comparison between an external system and a system integrated in the building, for which the construction impact is accounted for. This approach is applied to energy production and water processing. Thus, we can study local electricity production by a photovoltaic system, solar space heating, passive cooling, reuse of grey water, rain water collection, etc. An example of this approach is the production of domestic hot water which can be done either by using a solar collector or fossil fuel. All the fabrication processes of the collector are attributed to