LIFE CYCLE ANALYSIS OF BUILDINGS : THE EUROPEAN PROJECT REGENER

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Abstract

Since the reduction of the oil prices, the objective of energy saving has shifted to a more general objective of environmental protection. In parallel, more global environmental approaches are often preferred by professionals and decision makers than solar architecture concepts seen as specialized technical solutions. Environmental quality assessment tools respond to this problematic and should contribute to the promotion of ecotechniques like renewable energies in the building sector.

In the European project REGENER, 8 partners of 5 different E.C. countries joined their efforts in order :
- to define a common methodology to apply life cycle analysis (LCA) in the building sector,
- to develop a design toolbox and
- to perform first applications of the methods, concerning e.g. the integration of renewable energies.

The partnership gathers research institutes involved in LCA and professionals : a building entreprise, consultants and a regional agency for environment and renewable energies. This collaboration supports the orientation of research activities towards the needs of potential users and the integration of innovation in professional practice.

The research activity of REGENER lead to a common framework for the application of LCA in the building sector : the definition of system limits and functional unit as well as the models considered for energy and transport processes have been agreed. A data base on building materials and elements has been collected. Using a STEP approach (standard being developed for computer data exchange) allowed the link of LCA with thermal simulation, a further objective being a future link with CAD or other technical tools (daylighting, acoustics). Evaluation algorithms for environmental indicators were reviewed, and limits of the present knowledge have been identified (e.g. weakness of health related impact evaluation, lack of building specific indicators, uncertainties).

The general scheme of design has been studied, in order to identify the input-output adapted to the various phases of a building project.

First sensitivity studies were performed, concerning for instance the respective effect of design and occupants' behaviour on the performance. The environmental benefit of bioclimatic architectural concepts was estimated. Practical applications in demonstration projects (e.g. highschool, appartment building, exhibition on ecological house) illustrate the approach.

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Synopsis of the contents

In the European project REGENER, 8 partners of 5 different E.C. countries joined their efforts in order :
- to define a common methodology to apply life cycle analysis (LCA) in the building sector,
- to develop a design toolbox and
- to perform first applications of the methods in regional contexts, concerning e.g. the integration of renewable energies in buildings and cities.
The partnership gathers research institutes involved in LCA and professionals : a building entreprise, consultants and a regional agency for environment and renewable energies. This collaboration supports the orientation of research activities towards the needs of potential users and the integration of innovation in professional practice.

1 INTRODUCTION

Since the reduction of the oil prices, the objective of energy saving has shifted to a more general objective of environmental protection. In parallel, more global environmental approaches are often preferred by professionals and decision makers than solar architecture concepts seen as specialized technical solutions.

On the other hand, if "environmental quality" is not defined with enough precision, it may be used as a justification for architectural projects which are indeed very polluting. Existing methods including labels, declarations of content, positive and negative lists, and qualitative appreciations are not transparent and they are often only suited for a limited part of the design and building process.

A more precise assessment is thus needed, with the aim to reduce the contribution of buildings to various environmental problems, from a global scale (e.g. greenhouse effect) to a local one (waste production,etc.). Such tools show the importance of energy processes in the global balance and the environmental benefit of solar energy techniques in the building sector.

The project has been structured in four tasks (cf Fig. 1). Analyzing the present situation (task 1) allowed to identify needs for the development of new tools and to prepare applications. The scientific basis provided by task 2 was used in task 3 for the development of a design toolbox. First applications were experimented in task 4.

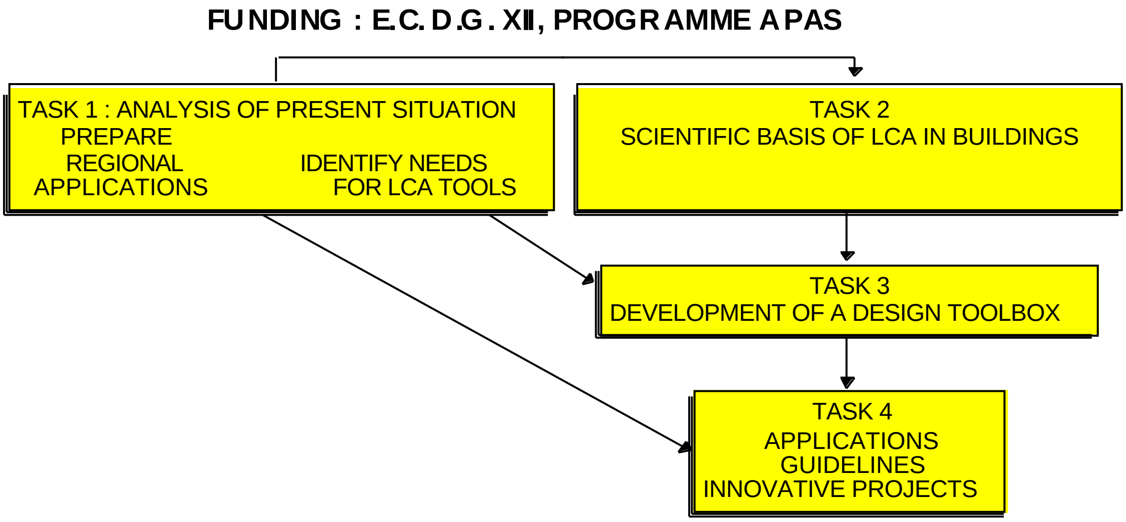

Fig. 1 : General structure of the project

The assessment of previous regional plans supporting environmental quality and renewable energy use in buildings, the review of existing tools and the analysis of planning structures and decision processes were performed to identify of needs for new tools and to prepare applications.

The main idea is to address both the demand side (building clients, regional administrations managing a building stock,...) and the production side (contractors, architects, engineering and industry). The study has thus been very broad, from environmental targets until the detailed design of buildings and construction steps.

2 LIFE CYCLE ANALYSIS OF BUILDINGS - METHODS AND DATABASES

The second task aimed to exchange knowledge between research institutes of different countries and to achieve commonly accepted principles for the application of LCA in the building sector.

The inventory of mass and energy flows during the life cycle of a product is one generally accepted basis for the environmental impact evaluation (Fig.2). The method of Life cycle analysis has been developed by scientific associations like SETAC [1] and has been widely accepted by industry and standardization boards like ISO [2]. We applied this method to buildings in order to study the quantitative aspects of environmental quality.

LCA, which was mainly developed for industrial products with current life times of weeks and months had to be adapted to the building industry [3,4]. Buildings are produced as one-of-a-kind products, their lifetime may be up to hundreds of years, they include a large and still growing number of materials, and their design process is complex, involving many actors with often contradicting targets.

The system limits in time and in space have been defined and models for the simulation of the life cycle (maintenance, refurbishment) have been developed. Specific functional units (adapted to the different steps in planning from design brief through the design and construction process to facility management) have been defined.

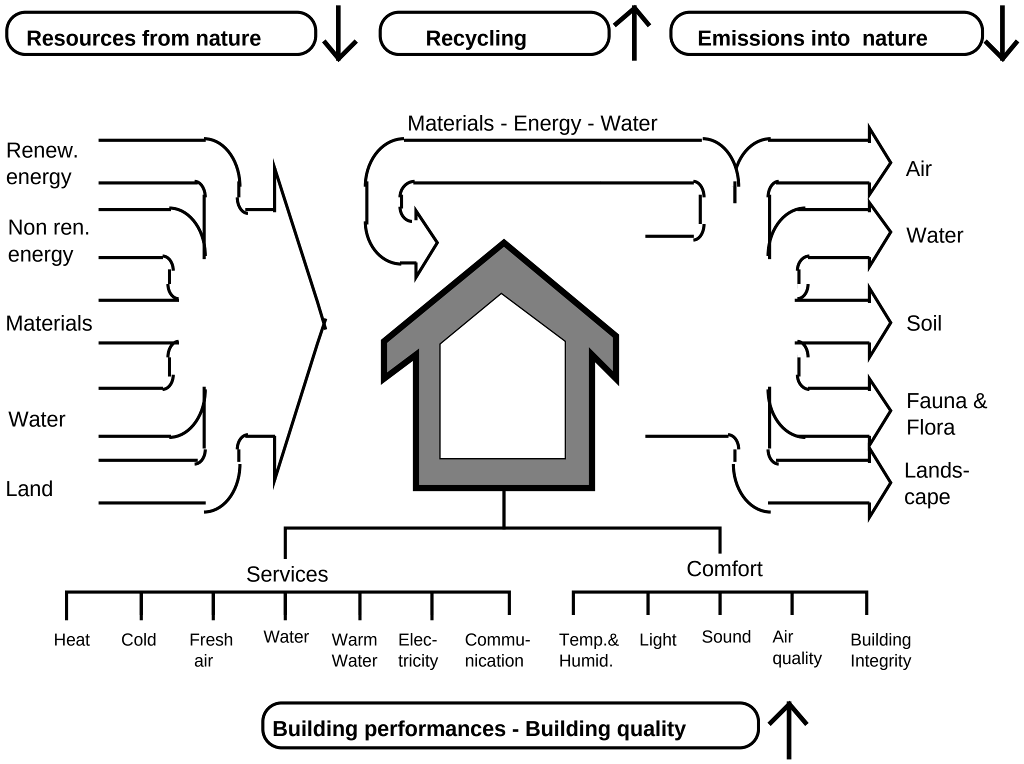

Fig. 2 : input-output quantification using LCA

One of the principal shortcomings of all of the existing methods is the lack of a consistent database with precombustion data, building materials and building processes. A new data base has been established in REGENER and other projects including precombustion, transport and disposal emissions from the process analysis of the Swiss ECOINVENT [5]. Inventories for more than 150 buildings materials have been established together with industry. All data are from the last 3 years and older literature values are no longer used. This database resulting from the collaboration of industry and research, funded by the EC, the German Umweltstiftung and the Swiss Department of Energy, is public.

Attention was paid to building modelling, with the objective of linking LCA to other technical tools. A STEP oriented approach [6] has been proposed and illustrated by linking an LCA tool to a thermal simulation tool. The data collected (inventories of building materials) were transformed through a data processor into a file compatible with the calculations. The evaluation algorithms for environmental indicators were reviewed and the CML [7] indicators were mainly considered.

The main limits of the present study are :
- the lack of building specific indicators, e.g. land use (accounting for semi-external spaces like sunspaces) and local effects (shading, wind deflection, noise),
- the weak evaluation of health related impacts, due to the unlocated emissions considered in LCA,
- the uncertainties concerning both the inventories and the environmental indicators (e.g. global warming potential of gases other than CO2 is known with 35% uncertainty [8]),
- the uncertainty of technological evolution during the long lasting life of buildings (e.g. 80 years).

3 DESIGN TOOLS IN THE PLANNING PROCESS

The design process of buildings is not linear (Fig. 3). Design tools for LCA must be tailored to the main steps in the decision process. One question in the design brief is : do we need a new building or can we transform an existing building. In the building design a question is how does a design alternative relate to functional performance, costs, energy consumption and environmental impact. In the construction stage the optimal choice of building materials and building processes in relation to the environmental requirements are critical.

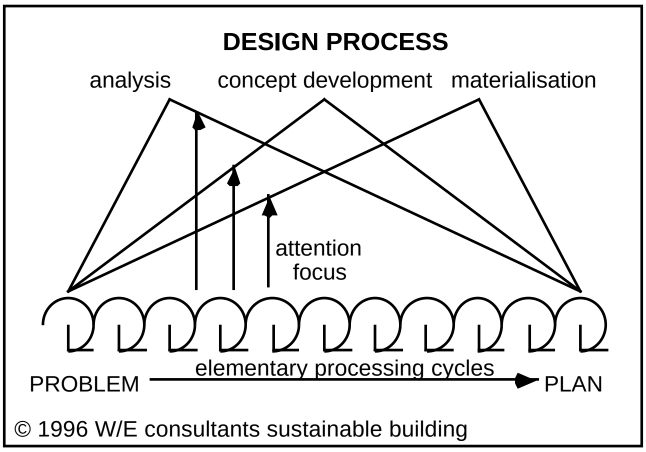

Fig. 3 : Analysis of the design process

Three methods try to take into account this procedure. They differ in the determination of local system limits, national conditions of building practice, and performance specification.

ECOPT - ECOPRO- ECOREAL are three related tools for the different design stages combining cost calculation by elements, annual energy need calculation by the simplified CEN method and environmental impact by the CML criteria. They were developed at IFIB (university of Karlsruhe) [9].

EQUER is an LCA simulation tool linked to a thermal simulation code (COMFIE). The resulting eco-profiles allow comparison of several designs. An English interface, E-QUALITY, has been developed by Ecole des Mines within the REGENER project and it is linked to the database collected by IFIB [10].

ECO-QUANTUM is a LCA calculation method for quantifying the environmental impact of a building, with respect to materials and energy. The outputs are eco-profiles, energy and mass flows, analyzed per phase, component and material. ECOQUANTUM has been developed by IVAM and W/E consultants [11].

4 APPLICATIONS AND DISCUSSION

First sensitivity studies have been performed to illustrate a few possible applications of the LCA method. The benefit of a bioclimatic design has been assessed in two cases : a dwelling unit and a classroom. Such results show that environmental performance is the result of a good design but also of appropriate occupants' behaviour. Comprehensive information must thus be delivered to occupants. The method can also be applied when choosing a construction site, accounting for possibly existing local networks (energy, water, waste management, transportation) and climatic conditions. Various application targets have been identified and advice is given to the concerned actors.

An illustrative experimental application of the method could be performed in Greater Paris Area. Comite 21, created in France after the Rio Conference, has organized an exhibition in Paris on ecological housing. A demonstration house has been built after an international architecture competition. The performance of this house, including a south facing sunspace, has been compared to a standard construction in France (Fig. 4). This reference was defined in a workshop organized by the Ministry of dwelling.

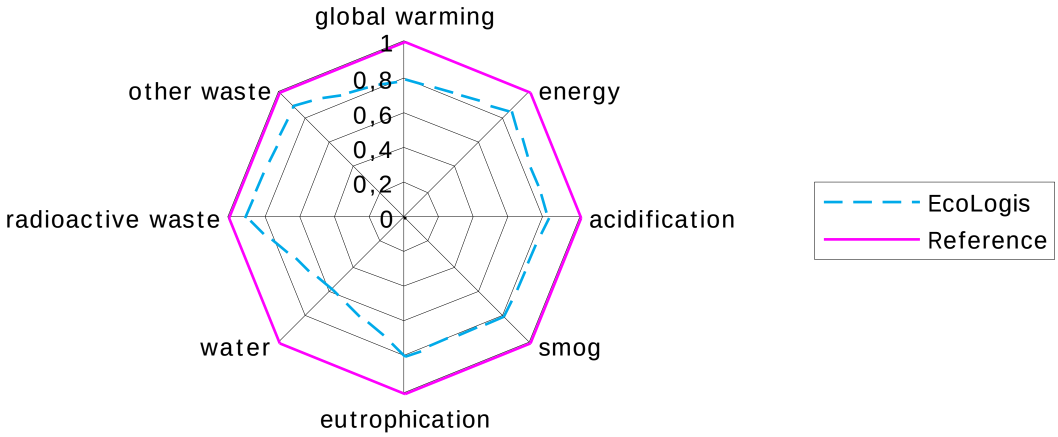

Fig. 4 : comparative ecoprofile of a solar versus a reference house

On the basis of these first applications, the limits of LCA applications in the building sector can be discussed. There remain rather large uncertainties concerning data bases on materials and components, or environmental indicators (e.g. global warming potential, human toxicity). Due to these uncertainties and a rather low sensitivity, it is still difficult to justify the choice of a material using LCA. This method is at the moment more appropriate to study the impacts related to fluxes (energy, water, waste) which have a major influence on environmental performance. Further improvement of data bases and environmental indicators are thus needed in order to provide designers with more precise advice. Simplification of LCA using relevant default values would allow to derive professional tools, more adapted to the design practice.

CONCLUSIONS

The European collaboration presented above allowed the definition of a global framework for applying LCA in the building sector. Three tools are developed according to these principles, and other tool developers will hopefully join this discussion. Supplementary improvement of data quality and of the precision of environmental indicators would be needed in order to address topics like the choice of building materials. Nevertheless, LCA constitutes at the moment one of the most promising tool to assess the quantitative aspects of environmental quality.
First applications were performed, and the tools are operational in practice concerning impacts related to the most important fluxes (energy, water and waste). The benefit of various renewable energy techniques (active or passive solar heating, wood fuel) can be assessed. We hope that the work performed in the REGENER project will be useful to the future developments in this field.

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REFERENCES

REGENER Reports :

General REGENER reports :
- Introduction to Life Cycle Analysis of buildings
- Environmental assessment at the local level
- Application of LCA by target groups

REGENER research reports :
- LCA methodology for buildings
- Integration of environmental assessment in the building design process

1. SETAC, Life cycle assessment, Europe workshop, Bruxelles, Belgique, 1992, 110 p.
2. ISO standard 14040, Environmental management - life cycle assessment - principles and framework, 1997 (final draft)
3. Ray Cole, Ian Cooper, Niklaus Kohler, Thomas Lützkendorf and Peter Smith, "Buildings and the Environment", Proceedings of the International Research Workshop, Cambridge, sept. 1992
4. Kohler, N. Life cycle models of buildings. EuropIA'95, Lyon 1995.
5. R. Frischknecht et al., Ökoinventare für Energie systeme, Eidgenössische Technische Hochschule, Zürich, 1995, 1817p
6. Bo-Christer Björk et Jeff Wix, An introduction to STEP, VTT (Technical research centre of Finland) and Wix McLelland Ltd, 1991, 47p.
7. R. Heijungs, Environmental life cycle assessment of products, Centre of environmental science (CML), Leiden, 1992, 96p
8. Scientific assessment working group of IPCC, Radiative forcing of climate change, World meteorological organization and United nations environment programme, 1994, 28p.
9. Kohler, N; Klingele, M : Simulation von Energie- und Stoffflüssen von Gebäuden während ihrer Lebensdauer . 1996 International Symposium of CIB W67. Vienna 1996
10. Bernd Polster, Bruno Peuportier, Isabelle Blanc Sommereux, Pierre Diaz Pedregal, Christophe Gobin and Eric Durand, Evaluation of the environmental quality of buildings - a step towards a more environmentally conscious design, Solar Energy vol. 57 n°3, 1996
11. John Mak, David Anink / Jaap Kortman et al., ECO-QUANTUM, Design of a LCA based method on building level, W/E consultants sustainable building / IVAM Environmental Research, Gouda / Amsterdam, March 1996 (In Dutch)