BUILDING LIFE CYCLE.
Tools for Building Components and Industrial Products

Cristina Allione
PhD Student in Technology Innovation for Architecture and Industrial Design
Politecnico di Torino – I Faculty of Architecture
Viale Mattioli, 39 - 10125 Torino – E-mail: cristina.allione@polito.it

Keywords: Building Life Cycle Approach, LCA, Ecotools, Ecosoftware

ABSTRACT
In the research activity carried out in this PhD’s Project, the Ecodesign approaches and tools are transferred into the Building Sector in order to check the common concepts between these two cultures. This main goal is justified by the awareness that in the building sector several changes have been done. First of all to conform itself to Sustainable principles, and then, in wide use of building components which can be taken into account as industrial products.
In relation to this main purpose, it has been developed a sort of “toolbox” for architects which includes several software tools, linked to evaluation methodologies or to Ecodesign strategies helpful during the design process. Specifically, the study has been focused on a review of the main software, which nowadays are available from the Ecodesign and Green Architecture fields.
The outcomes of this review are explained in this paper using a matrix scheme, which underlines some key aspects of these ecosoftware.
In this way, it is possible to show the state of the art of ecosoftware and understand how they can be combined together in a synergetic way in order to support the architects during the choice of suitable tools throughout the building planning activities.

Main goal of the research
In the research carried out in this PhD, the Ecodesign approaches and principles are transferred into the Building Sector in order to check the common concepts and the mutual knowledge between these two cultures and identify the Ecodesign Ecotools, which can be useful to improve the environmental performances of building components.
Underling that eco-compatibility of whole building is achieved by a good interactions between its parts, subparts and components, the fulfillment of building occupants and the synergetic relation between the building and its site, this research has been focalized only on eco-efficient interrelations between its components, because they are a real link between industry and construction, and so they could represent the way to translate the eco-compatibility principles from Industry and Ecodesign to Building Sector.

Building Components and Industrial Products
This aim is supported by the awareness that in the building and construction sector several innovations have been done, firstly to satisfy the sustainability principles, and then in the wide using of building elements which can be taken into account as an industrial products.
In relation to sustainability, the building sector can be considered as one of the most responsible for material and energy consumption and emissions in the environment.
As a result, consistently with ecodesign where the product has been viewed as a system-product with its own life cycle [1], also in architecture we can assume the same concept of system-building, made the following phases: pre-production, component production and building construction, building and component life span and end of life of building and its elements, which involve several inputs/outputs flows between all the activities included in each phase [2].
Nowadays the methodology of Life Cycle Assessment is suitable for assessing the environmental performances of building components, i.e. it is very effective in cradle to gate phases to achieve Ecolabel or EPD certification,
but unfortunately during the design stage it can not be used as a practical tool. This is due to the large number of information which have to manage simultaneously and secondary for the lack of databases which include data on environmental performances of these components along their life cycle and also on its behavior as a part of the building as well [2].

At the same time, the widespread using of new building components produced by manufacturing industries is another important chance in this sector. These elements are the results of new system of production in the manufacturing industries more flexible, which gives architects the possibility to chose dry assembled techniques for the construction and so to pursue a bigger technological flexibility of whole building [3]. Consequently, with these building components, produced out of building site, the architects have the chance to pursue three kinds of flexibility:

- Constructive: the opportunity to have a small number of components, which are delivered into building site ready for assembling and integration with other components through dry assembled techniques;
- Performance: the option to make use of custom-made components, whose performances can be modified easily in relation to technical, physical and environmental requirements fixed for the building;
- Usage: the possibility to project buildings, that can be changed in relation to developing trends in user needs, because they are made of metal frames, column-beam system and cladding box structure, which are assembled together with dry procedures.

On these assumptions, it is possible argue that a building can be assumed as a “sophisticated” industrial product made by assembling of building industrial components, whose performances will influence the life cycle of the entire building.

**Ecotools and Ecosoftware**

For all these reasons the object of research has been the Ecotools useful to analyze eco-compatibility aspects of building components.

In relation to this purpose, the methodological approach of Concurrent Ecodesign (CED) has been adopted as a theoretical background of this research. Such approach has been conceived by Ecodesign Laboratory of Politecnico di Torino in order to pursue eco-compatibility requirements of new industrial products and combine in a sustainable way the advanced industrial knowledge with the inevitable ecosystem’s complexity [4]. In short terms, the CED could be defined a sort of “toolbox” because it includes several kinds of tools aimed at pursuing eco-efficiency of industrial product along its life cycle, which can be used in a strategic way in relation to the different fields.

According to CED principles, the specific goal of this research was to develop a similar toolbox able to be used in a flexible way during the building process design, which involves several kind of Ecotools. Consequently Ecotools such as methodological approaches, Life Cycle Design (LCD) strategies and guidelines, evaluation methodologies (LCA method in its full or simplified versions) and Eco-labelling certification have been analyzed in order to identify which of them are actually used into ecodesign and industry procedures and could be used also for pursuing the eco-compatibility of building components [5].

After this first step, the next stage of this study has been specifically focused on ecosoftware, which are connected with LCA or LCD methodologies and strategies. These ecosoftware can be definitely considered as practical tools useful during the design process because they outline a rough or detailed evaluation which can facilitate the architects in the choice of suitable design solutions [6]. Therefore, several ecosoftware developed within Ecodesign and Green Architecture fields has been picked out

---

1 The software picked out are the following: Athena Model (Athena Sustainable Materials Institute, USA), BEAT 2002 (SBI – Danish Building Research Institute, DK), BEEES (Building Fire Research Laboratory, NIST – National Institute of Standard and Technology, USA), Boustead Model (Boustead Consulting Ltd., UK), Cambridge Engineering Selector (Granta Design Limited, UK), Design For Assembly software, Design for Environment software, Design for Manufacturing software (BDI - Boothroyd Deswhurst Inc., USA), Ecolnvent (Swiss Centre for LCI, Dubendorf, CH & Pré Consultants, NL), Eco-iT (Pré Consultants, NL), EcoScan Dare, EcoScan Life (TNO Industrial Technology, NL), EDGE (Pacific Northwest National Laboratory, USA), EVA (DINSE Dipartimento di Scienze e Tecniche per i Processi di Insediamento, Politecnico di Torino, (IT), eVerdee (ENEA, Centro Ricerche Bologna, Divisione Sistemi Energetici Ecosostenibili, IT), Galler (IKP of the University of Stuttgart & PE Europe GmbH, Life Cycle Engineering, DE), Green Building Advisor
and they have been carefully investigated on a common format, which highlights the following aspects: object of the study (industrial product or building component), classification, methodology and backgrounds, Life Cycle Phases studied, data required to start the analysis, results gathered by the software (and the different ways on showing them), evaluation system used for the environmental cost analysis, target user, its utility in the different process design phases and kind of database included.

Matrix results
Following this, the results of this ecosoftware review have been summed up into a matrix scheme, as shown in the next figure (Fig. 1)

(CREST - Centre for Renewable Energy and Sustainable Technology, USA), Idemat (Design for Sustainability Program, Delft University of Technology, Faculty of Design, Engineering and Production), LCAit (CIT Ekologik, A division of Chalmers Industrieteknik, SE), LISA (BHP Billiton Limited Sustainable Development & University of Newcastle, Centre for Sustainable Technology, AU), SimaPrò (PRé Consultants, NL), TCAce (PRé Consultants, NL & Earthshift, US), TEAM (Ecobilan Group, FR/US/GB), Twin Model (NIBE - Netherlands Institute voor
Using this matrix format, it is possible not only drawing the state of the art of eco-software, but also comparing them during the different phases of building life cycle phases on the following common aspects: classification, their utility, what environmental cost accounting and environmental effects assessment they give and what life cycle phases they include in their analysis (Fig. 2).

### Classification

These operative tools can be classified in two main groups: Analysis Software and Focused Analysis Software (Fig. 1) [9].

The Analysis Software study the building product performances along its whole life cycle and, in general, have their theoretical backgrounds in the methodology of Life Cycle Assessment (LCA).

These software can be divided in different sub-groups in relation to LCA procedural steps they follow and the kind of assessment they do, such as:

- **Life Cycle Inventory (LCI) software**: which give an inventory of energy and all environmental impacts;
- **Life Cycle Assessment (LCA) software**: which provide a scientific and detailed assessment of environmental effects;
- **Abridged or simplified LCA software**: which adopt a simplified LCA methodology or an endpoint weighting system;
- **Life Cycle Cost (LCC) software**: which offer an evaluation of environmental cost in accordance to LCC or Total Cost Assessment (TCA) methodology.

The Focused Analysis Software, instead, have their theoretical backgrounds in the Ecodesign Life Cycle Strategies. These strategies are aimed at obtaining better environmental performances of components in some specific phases of their life cycle or has been developed for particular purposes, such as facilitating their disassembling or improving the production efficiency. Consequently, in this group there are:

- **Design For Assembly (DFA) software**: which are aimed at improving the manufacturing phase;
- **Design for Life (DFL) Software**: which optimize the performances of the building life span;
- **Design for Disassembly (DFD) Software**: which are useful to evaluate disassembling and recycling attitude;
- **Selection Materials (SM) Software**: which are helpful to select materials or processes in relation to both their environmental performances and applications.

### Utility

These eco-software can be sorted out in relation to their practical utility during the design process, which can be divided in four main steps:

- needs analysis and requirement definition,
- concept design (preliminary design),
- product design (definitive design),
- engineering (executive design).

In this way some of them can be useful during the concept design phase and others are more efficient during the product design or engineering phases, in accordance to the types of data included and the evaluation which they can offer (Fig. 3).
Moreover on this utility exam (Fig. 3) it is easy to identify the target user of ecosoftware for instance, architects or designers, building or product engineers, LCA technical advisors, product or process managers, building constructors and enterprises or other figures and point out the ecosoftware developed specifically for architects (Fig. 2).

**Environmental cost accounting**

The economical aspects related the environmental performances of building components have been taken into account in analysis of the some ecosoftware (Fig. 1). These economical consequences are crucial to implement an environmental innovation in the enterprise activities.

Consequently in relation to the software classification into two main groups, analysis or focused analysis software, we can identify what kind of accounting they give, as following (Fig. 2):

- a detailed accounting based on Life Cycle Cost or Total Cost Assessment methodology, which takes into account the usual cost, hidden, liabilities and less tangible (internal and external) costs involved along life cycle;
- a simple appraisal or review of direct and indirect costs focused on a specific phase and time period.

From this point of view, another result is the lack of software able to consider both environmental and economical performances and so it can be concluded that there is a need of a field range of actual ecosoftware in order to encompass the economical consequences.

**Environmental effects assessment**

The investigated ecosoftware offer different kinds of assessment of the environmental consequences of building components.

In the case of:

- analysis software: they give a quantitative assessment of environmental impacts, based on endpoint or midpoint weighting systems adoptable during the LCIA stage, because they generally are related to LCA assessment method, simplified or not [10];
- focused analysis software: they adopt a qualitative methods aimed at obtaining a rating score of building components, because they are built on drawing up checklists founded on Green Architecture strategies and guidelines.

With an examination of different evaluation systems adopted by the software (Fig. 4), it makes easier linking the analysis made by ecosoftware with the environmental effects on different scale, from the level of all global ecosystem, through the national or macro-regional level to the local scale for the individual comfort.

![Fig. 3 - Utility during the process design](image-url)

![Fig. 4 - Evaluation systems adopted by the ecosoftware and their link to environmental effects.](image-url)
In other words the matrix (Fig. 2) underlines how it is important using the, quantitative or qualitative, ecosoftware evaluation to improve the environmental performances of building components in the different phases of life cycle.

Moreover the final matrix illustrates a lack of ecosoftware able to take into account the effects on local scale. These effects, such as indoor air quality or the land use, are very important for a real eco-compatibility of building and so an enlargement of ecosoftware analysis to comprise these effects is required, in particular for the software founded on LCA method.

Life Cycle Phases
An overview of matrix (Fig. 2) shows that, in relation to the life cycle phases included in the ecosoftware analysis, there is a scarcity of ecosoftware helpful to analyze the environmental performances of building components during the life span phase, related to both single component and whole building. In particular this is true for the Focused Analysis Software, which are generally focalized on pre-production and production phases or, at least, on the end of life activities.

As a results, we can underlie the need of new software able to consider the life span performances of building components and, eventually, its resources consumption and emissions.

Conclusions
In conclusion, as illustrated in this paper, the matrix filled in every parts (Fig. 2) can be considered as a toolbox for architects useful to understand how they can be used in a synergic way along the different phases of building life cycle. In other words it is possible comparing simultaneously the software and understanding how they can be combined together to pursue the best environmental performances related to the different phases of building life cycle.

In this way the research results give a guide aimed at choosing the suitable tools in relation to different situations that the architects and engineers have to faced.

References