Presentation of Eco-Quantum, the LCA-based computer tool for the quantitative determination of the environmental impact of buildings

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Abstract
The Dutch government and building industry have agreed that life cycle assessment (LCA) should be the basis for the determination of environmental effects of (building) products. In order to provide architects and project developers with an instrument to measure the environmental performance of buildings, the Dutch government and other organisations financed the development of Eco-Quantum (EQ).

EQ is a computer tool on the basis of LCA which calculates the environmental effects during the entire life cycle of the building: from the moment the raw materials are extracted, via production, building and use, to the final demolition or reuse. This includes the impact of energy and water use, the maintenance during the use phase, the differences in the durability of parts or construction needs, like adhesives and nails. EQ also takes into account the possibility for selective demolition or renovation. The method can be used for both dwellings and non-domestic buildings.

Two types of computer tools are developed and will be presented at the conference: EQ-domestic and EQ-research. EQ-domestic is a tool for architects. With this instrument architects are able to quickly include environmental consequences of material, water and energy use in their designs of domestic buildings. So Eco-Quantum can be used to communicate on issues related to sustainable building between various partners, like project developers and designers. EQ-research is the tool for developing innovative designs for sustainable buildings and offices.

Keywords: Eco-Quantum, computer tool, building design, life cycle assessment, quantitative, environmental impact
1. Introduction

The life cycle of a building is responsible for a considerable part of the environmental effects caused by human activities. It is therefore important to dispose of instruments which show the environmental consequences of decisions of a building design. Two types of computer tools are developed in the Netherlands which enable architects and project developers to measure the environmental performance of complete buildings on the basis of LCA. They are named Eco-Quantum Domestic and Eco-Quantum Research. With Eco-Quantum Domestic architects are able to quickly identify environmental consequences of material choices and water and energy consumption in their designs of domestic buildings. Eco-Quantum-Research is the tool for in depth analysing of the environmental performance of buildings and developing innovative designs for sustainable houses and offices.

The Dutch government and building industry have agreed that life cycle assessment (LCA) should be the basis for the determination of environmental effects of buildings and building products. In order to provide architects and project developers with an instrument to measure the environmental performance of buildings, the Steering Committee for Experiments in Public Housing, the Dutch Building Research Foundation, the Association of Dutch Architects and the Dutch government financed the development of Eco-Quantum.

Until recently, only LCA’s of building components and materials were carried out. But, a building is more than adding the various components, for example the life cycle of a building is important. Therefore IVAM Environmental Research and W/E consultants sustainable building developed Eco-Quantum, a computer tool on the basis of LCA which calculates the environmental effects during the entire life cycle of a complete building: from the moment the raw materials are extracted, via production, building and use, to the final demolition or reuse [1, 2, 3]. This includes the impact of energy and water use, the maintenance during the use phase, the differences in the durability of parts or construction needs, like adhesives and nails. EQ also takes into account the possibility for selective demolition or renovation.
2. General lay out of Eco-Quantum

Eco-Quantum consists of 3 related programmes, Eco-Quantum Research, Eco-Quantum Domestic and SimaPro. Databases are another part of Eco-Quantum. The two most important databases are: the database Components and the database Environmental Profiles.

In figure 1 the general lay out of Eco-Quantum is presented. Eco-Quantum Domestic and Eco-Quantum Research are provided with information from a stand-alone version of the Dutch LCA programme SimaPro 4 [4] and the Dutch Environmental Performance Standard (EP). SimaPro calculates split environmental profiles per kilogram building materials and for processes related to the production of energy and water, transportation and waste processing. These environmental profiles are the input to the database Environmental profiles in Eco-Quantum Research. The Dutch Energy Performance standard is applied to determine the energy consumption during the use of the building.

Architects provide the input of the design: materials and quantities of the building components of the design, together with figures about energy and water consumption. Eco-Quantum translates this in kilogram materials and water flows and MJ energy. For this Eco-Quantum comprises of an extensive database components which consists of materialised components of the building, with information about life span, materials needs, maintenance and waste scenarios.

In order to calculate the environmental performance of a building the environmental information from the database Environmental profiles is connected to the material, water and energy flows of the building. By doing this the environmental interventions related to the total life cycle of the building are accumulated. Furthermore the environmental interventions are converted on the basis of characterisation factors of the LCA methodology of Heijungs et al. [5] into 11 environmental effectscores such as raw material depletion, ecotoxicity and greenhouse effect. In a following step these 11 effectscores are converted into four environmental indicators: raw material depletion, emissions, energy consumption and waste according to the Dutch project “Environmental Ratings in the construction industry set up by the Council for the Construction Industry (see figure 3).

Various outputs can be presented in de from of environmental indicators, environmental profiles and material flows.
Performing LCA of complete buildings is normally a complex and time consuming task. Environmental requirements are added to an enormous amount of design requirements which architects have to consider for designing a building. If an instrument does not consider this complex task and the time constraints of architects, it won’t be used in a design process.

Against this background EQ domestic is developed as a practical computer programme which enables architects to quickly reveal the environmental performance of a housing project. In order to do so environmental information about standardised building components is prepared in Eco-Quantum Research for Eco-Quantum Domestic in the form of environmental profiles of components (see figure 1).

If the specifications of a building design are available it is possible to determine the environmental impacts in about a half an hour. The environmental profiles of standardised components in Eco-Quantum Domestic serve as an aid to the architect. The user can identify the most important causes of the environmental impacts, make changes in the design of the building and evaluate the alternative solutions.

The user performs the following steps in EQ domestic:
• enter information about the building project
In order to calculate the environmental performance of a housing project the user opens a new project and describes it by filling in the name and other general information. It is expected that various design variants will be developed. Therefore the user also gives each variant of the project a unique name. Eco-Quantum connects to each variant a tree structure which consists of 4 levels: the complete building, 8 building parts, 24 building elements and about 60 building components. The structure of the tree follows the structure of the Dutch NL/SfB Building element method.

• enter the design data of the project
In Eco-Quantum Domestic the input of a design is as limited as possible. In figure 2 an input screen is presented. In the upper part of the figure a small part of the tree is shown following the four levels:
  - building
  - 8 building parts, e.g. external wall
  - buildings elements: only one building element is folded out: e.g. external wall construction
  - buildings components: only one component is folded out: e.g. internal wall skin

The architect folds out one element (in this case external wall construction) and selects one component (in this case the inner side of the cavity wall, the internal wall skin). In the lower part of the screen the architects enters the necessary design information in the form of the amount of walls (37,7 m2). Furthermore the architect can change the life span (here 75 years) and choose between demolition scenario A (current situation) and B (optimised situation). After finishing the input for this component Eco-Quantum Domestic automatically goes to the following component. Besides this information both the information about energy consumption and water consumption of the specific design is entered in the programme.
- **calculate the environmental profile of the building**

On the basis of these inputs the programme calculates the environmental performance of the building. First, Eco-Quantum relates the environmental profiles to the corresponding material, energy and water flows. By doing so the environmental interventions related to the total life cycle of the building are accumulated in the form of raw materials, energy input, waste and emissions. Second, the environmental interventions are converted on the basis of characterisation factors of the LCA methodology [5] into 11 environmental effect scores such as raw material depletion, ecotoxicity and greenhouse effect. In the following step these 11 effect scores are automatically converted into four environmental indicators: raw material depletion (exhaustions of resources), emissions, energy consumption and waste according to the Dutch Environmental Rating methodology (see figure 3).

- **presentation of results**

The user can choose between various kinds of output depending on the question to answer. The three possibilities are:

1. an overview of materials streams
2. 11 effect scores, according to the life cycle analysis of Heijungs.
3. 4 environmental indicators, according to the “Environmental ratings in the constructions industry” (exhaustion of resources, emissions, energy and waste)
If an architect wants to detect the causes of the environmental burden of the design it is possible to give a division of the environmental impacts over the stages of the life cycle of the parts, elements and components of the building.

- **optimise the environmental profile of a design**

The user can environmentally optimise the design in various ways. The components and constuctions at which the largest environmental benefit can be obtained are indicated. So the user can optimise these with the material alternatives offered. So the environmental burden can be reduced mostly. The user can also select alternative building components and constructions and see what the impact is on the environment. Of course, installation concepts for reducing energy and water consumption can also be changed, just like the life span, and the use of secondary materials and recyclable products.

Eco-Quantum Domestic enables the architect to easily change the input and quickly calculate the new environmental profile and compare the original design with the optimised one (see figure 3).

Figure 3  Output: comparing the original and the optimised design
• compare the environmental performance of various designs
In figure 3 the environmental profile of a standard sand lime brick house is compared to an optimised sand lime brick house. In the latter the improvement options from the Dutch manual for sustainable building: Nationaal pakket Woningbouw (National Package Sustainable Housing) [6] are implemented. Examples are energy saving installations, better insulation, less use of scarce materials and wood from not-sustainable managed woods.

4. EQ research
Eco-Quantum Research is the instrument for in depth research of the environmental impacts for all types of buildings by researchers, consultants and large design offices. An important difference is that in Eco-Quantum Research users can enter new building components whereas Eco-Quantum Domestic works with fixed standardised building components. This makes Eco-Quantum Research a tool which is suited for all building types. The environmental impact of any building type can be calculated with it, like schools, hospitals and other health buildings, offices and other industry buildings. This can on the other hand make EQ Research a more time consuming instrument. A user can, but is not obliged to, add self made building components. If the user wants to add components, he or she has to enter the design data himself, for example material consumption per square meter, building waste, time span and waste scenario.

5. Concluding remarks
Both the prototypes of Eco-Quantum Domestic and Eco-Quantum Research will be presented by W/E consultants sustainable building and IVAM Environmental Research at the conference in order to enable participants to see the details of the programme. Eco-Quantum makes it possible to communicate on the environmental impact of buildings during the design of a building. By presenting quantitative results in a relatively simple way, architects can improve the environmental quality of a building themselves. Other qualities of a building are of course at the same time considered. And Eco-Quantum enables them to communicate with their initiators and future owners.
References


