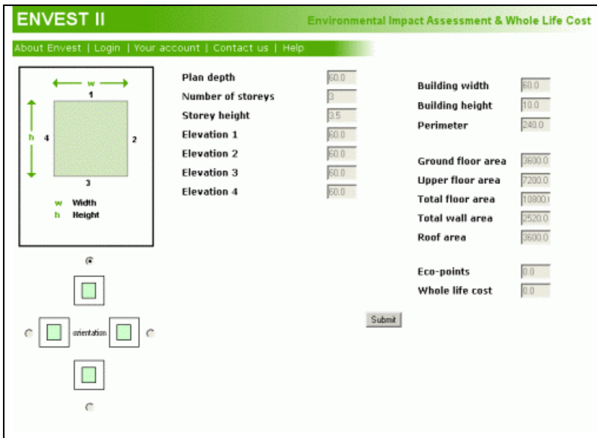
Inter-comparison and benchmarking of LCA-based environmental assessment and design tools

Bruno Peuportier, ARMINES
Daniel Kellenberger, EMPA
David Anink, W/E Sustainable Building
Hildegund Mötzl, IBO
Jane Anderson, BRE
Sirje Vares, VTT
Jacques Chevalier, CSTB
Holger König, ASCONA

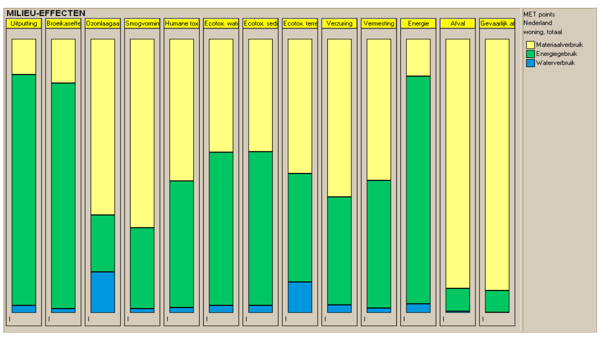
Various methods are proposed to evaluate the environmental quality of buildings. In general, these methods integrate issues of concern like the protection of the human health and eco-system (e.g. protection of the climate, fauna and flora), and the efficient use of resources (energy, water, materials). Life cycle assessment (LCA) allows a quantification of indicators related to these issues and is widely used among industrials as well as academics. This method has been applied in the building sector and several tools have been developed. The precision of these tools and their relevance as a design aid is often questioned. The aim of the work presented here is to have a clearer view upon these questions, and to propose some harmonisation regarding LCA based assessment of buildings. This work has been performed in the frame of the European thematic network PRESCO (Practical Recommendations for Sustainable Construction).

Previous inter-comparison exercises had been performed in the European project REGENER and in a working group of the International Energy Agency. But the hypotheses and results of the different tools had not been analysed in detail. The experience gained in these first activities allowed to plan a more precise protocol for the present inter-comparison. In a first step, the tools were compared in the case of a very simple "cube" building, and the main hypotheses were listed and analysed. A real case study has then been considered in a second phase : a single family house with a rather simple geometry. This exchange should help the participating tool developers to identify some good practice and to improve their tools.

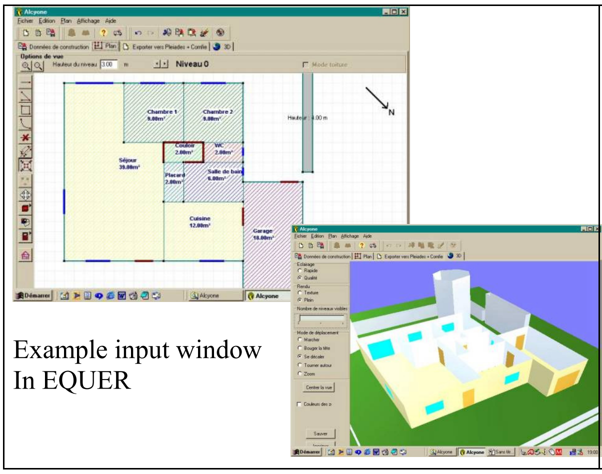
The tools considered are : ECO-QUANTUM (W/E Sustainable Building, The Netherlands), LEGEP (ASCONA, Germany), OGIP (EMPA, Switzerland), EQUER (ARMINES, France), ENVEST (BRE, United Kingdom), Eco-Soft (IBO, Austria), BeCost (VTT, Finland), SIMA-PRO (BDA Milieu, The Netherlands), ESCALE (CSTB, France). In general, the input data include a description of the studied building (geometry, techniques…) and its context (e.g. electricity production mix). The output is a multi-indicator comparison of design alternatives, supporting decision making.



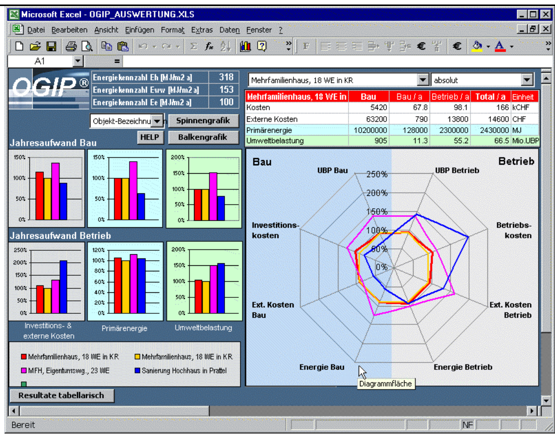
Example input window in ENVEST



Example output window in ECO-QUANTUM



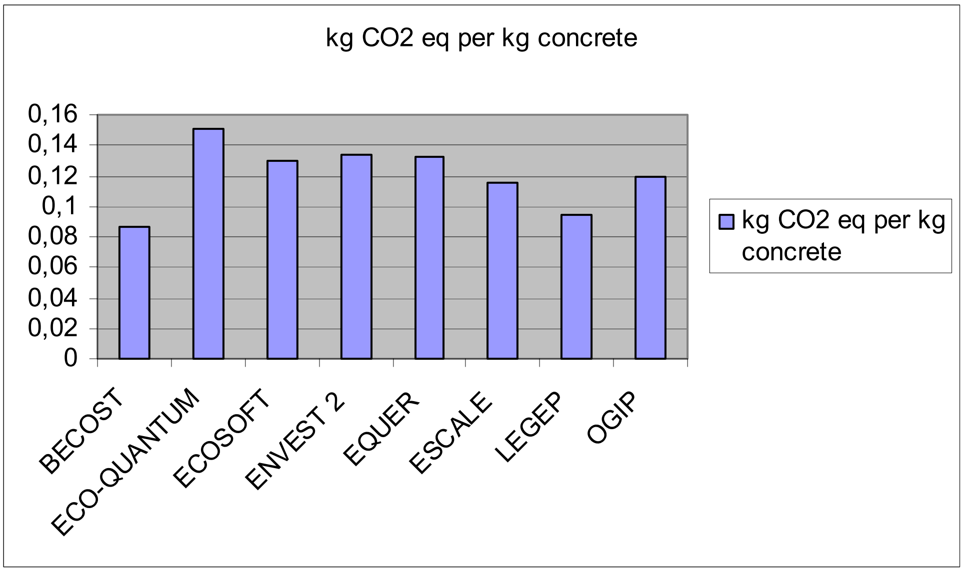
Example input window
In EQUER



Example output window in OGIP

The first activity consisted in defining the 5 case studies considered in the inter-comparison. The first case study corresponds to a very simple concrete parallelepiped with an electric heating (considering a European electricity production mix), assuming a 50 years duration. The objective is to exchange on the main assumptions of the tools (fabrication of the steel reinforced concrete, transport of the material to the building site, building process and waste, demolition process and possible recycling,…), on the data (LCI of the concrete and electricity production, waste treatment, transport) and on the results (impact indicators).

We present hereunder a few examples of the results obtained by the group.

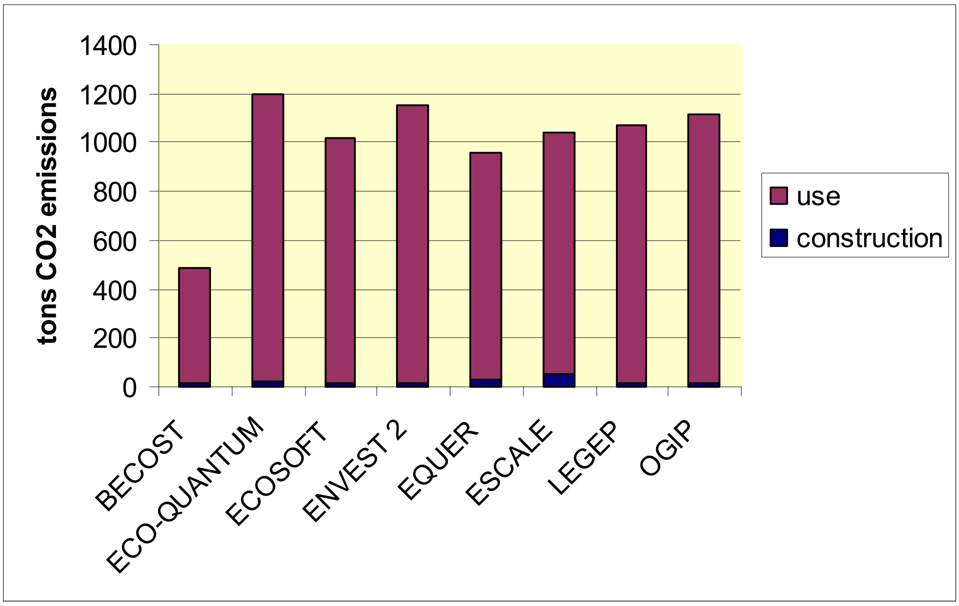


Example 1 : Material data, contribution in global warming by the production of 1 kg concrete

The difference between tools may be related to :

- different cement content in the concrete,
- different production processes (national or European data bases),
- different global warming potential indicators (IPCC, CML…).

The following graph shows the greenhouse gases emissions corresponding to the construction and operation phases of the “cube”. In two of the tools (BeCost and Envest), only a national electricity mix can be considered which partly explains the differing results. If we except BeCost (the Finnish electricity mix being very far from the European mix which was to consider), the overall discrepancy is +/- 10%.



Example 2 : building life cycle, contribution in global warming by the cube over 50 years

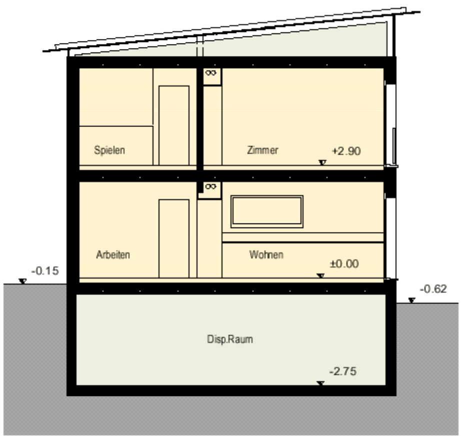
Among the other causes for discrepancy are assumptions concerning :

- the material quantities (exact calculation or value derived from simplified geometric input),
- the material surplus or waste during construction,
- different steel content in the reinforced concrete,
- different assumption concerning the use of recycled steel,
- the transport of materials (construction and end of life),
- the life span of building components,
- end of life processes.

The 3 next case studies correspond to a green building in Switzerland, the FUTURA prefabricated house, considering 3 alternatives : wooden, brick and concrete structure. The last case study is defined by applying PRESCO recommendations to the FUTURA house. These case studies will allow to compare the sensitivity of the tools to some building characteristics.

The FUTURA house is a single family house with two levels (210 m^2 heated area), well insulated, with a high solar aperture. The energy for space heating and domestic hot water is gas, and the heating demand corresponds to a Swiss climate. The European electricity mix is considered. A detailed description of the building has been provided to all tools developers, who performed a life cycle assessment considering an 80 years operation period.

The Swiss "FUTURA" house considered in the exercise



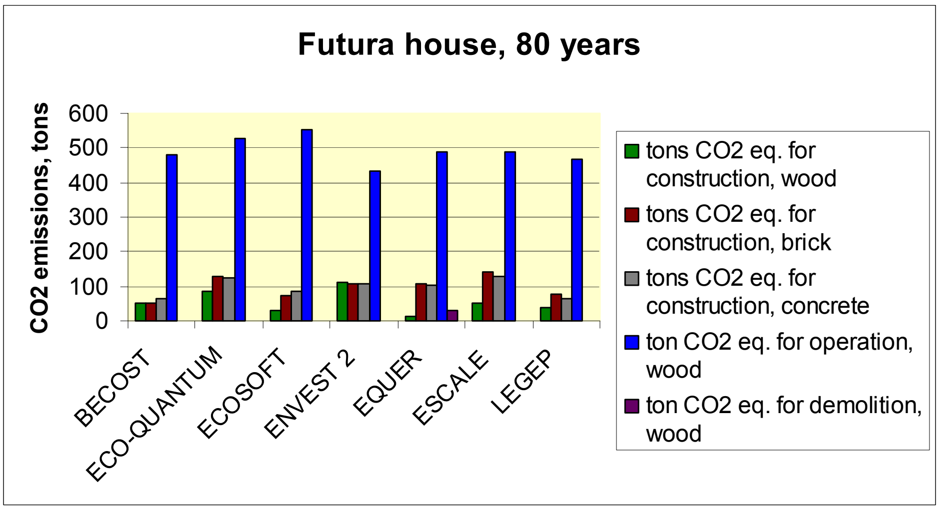
In a first step, inventory data has been compared for materials and gas heating. This comparison has been performed on the basis of the greenhouse gases emissions, which is the only common indicator between all tools (except OGIP), expressed as a weight of equivalent CO_2 emission. The results are summarised in the table below.

In the case of wood, some tools consider a CO_2 storage in the forest related to photosynthesis (and a CO_2 release at the end of the life cycle), while other tools consider a global zero emission process. The total CO_2 balance for the whole life cycle should be the same, but the carbon stored in the wooden structure during 80 years is not in the atmosphere, and this contributes to protect the climate.

For the whole life cycle of the house, the results are similar to the first case of the cube : there is a +/-10% discrepancy between the tools, cf. the table below.

Functional unit	Mean eq. CO_2 emissions	Relative difference for the lowest value (%)	Relative difference for the highest value (%)
1 kg brick	0.255 kg	-15%	+25%
1 TJ gas (end energy)	64 400 kg	-15%	+15%
Whole house, wood structure, 80 years	550 tons	-10%	+10%

Concerning the comparison between wood, brick and concrete structures, the global warming indicator is lower for wood in all tool except Envest. But the results may be different when comparing brick and concrete, cf. the figure below. The emissions during the operation phase are very similar for the three alternatives, so only the case of wood is included in the figure. Some tools account for CO_2 emissions at the end of life of wood, therefore demolition is also represented on the graph for the wooden alternative. In all tools, the highest CO_2 emissions correspond to the operation phase.



The other indicators considered in the tools are differing. The tools may consider acidification, smog, waste (possibly indicating also radioactive waste), primary energy consumption, water consumption, exhaust of resources, eutrophication, ozone depletion, toxicity, eco-toxicity, cost, and global indicators like eco-points or eco-scarcity. Therefore it is difficult to compare the ranking of the three alternatives considered (wood, brick and concrete).

The last case study corresponds to the same house, but considering alternative designs which were derived by applying recommendations elaborated within the PRESCO network. Environmental quality is only a part of sustainability, therefore the LCA tools can deal with only a part of the PRESCO recommendations. Each tool developer has selected a set of 3 to 5 recommendations. The indicators have been compared considering the concrete structure with and without applying each recommendation. All concerned tools have obtained reduced impacts applying recommendations n°305 (selecting appropriate glazing, i.e. triple glazing in the considered case), n°325 (water saving), n°77 (reduce material transport) and n°107 (using renewable energy, solar domestic hot water). The results are more contrasted for n°324 (use rain water) where some impacts increase due to the installation, for n°107 (using renewable energy, wood fuel) because pollutants are emitted during the combustion, and n°134 (use renewable materials) according to the materials considered. The effect of recommendation 12 (use materials with an environmental declaration) is difficult to assess. In general, all tools are in good agreement to show that each recommendation individually has a limited influence on the global life cycle indicators : eco-design should include many aspects in order to improve the quality of a project in a significant way.

This exercise allowed to improve the software and aims at increasing the confidence in the tools. Its added value is also to clarify the main assumptions in each tool and to identify good practice from the discussion regarding :
- life cycle inventories (allocation, transport, recycling, infrastructure, representativeness, data age, cut-off rules, validation…),
- building and process model (construction site, renovation, maintenance, life span…),
- indicators (e.g. is renewable and feedstock energy included in the energy consumption indicator, is photosynthesis included in the global warming indicator etc.).

Some good practice is proposed by the group, for instance :

- account both for the use of recycled materials in construction and for recycling at the end of life, at each phase with 50% of the total possible avoided impacts compared to no recycling,
- include water consumption in the analysis,
- use product specific data when available with a consistent methodology, recent data being preferable,
- propose default values for transport distances to site and for each type of waste treatment process (incineration, landfill, recycling, ...).

As a conclusion of this exercise, some work is still needed to harmonise the methods and to facilitate the interpretation of the results by the building practitioners. Some tools are already used in practice, and educational material exist to train professionals. Therefore, impact reduction objectives could be integrated in the design briefs for green buildings. If we are to achieve a 75% reduction of greenhouse gases emissions by 2050, it is needed to integrate this objective in new buildings because they are likely to remain part of the building stock for a long time.