# WORK PACKAGE 2

# INTER-COMPARISON AND BENCHMARKING OF LCA-BASED ENVIRONMENTAL ASSESSMENT AND DESIGN TOOLS

# FINAL REPORT

Authors:
Peuportier Bruno, ENSMP (FR)
Putzeys Katrien, BBRI (BE)

Contributors in the PRESCO WP2 activities:
Anderson Jane, BRE (UK)
Anink David, W/E (NL)
Hendriks Nico, BDA Group (NL)
Kellenberger Daniel, EMPA (CH)
Mötzl Hildegund, IBO (AT)
Nibel Sylviane, CSTB (FR)
Peuportier Bruno, ENSMP (FR)
Vares Sirje, VTT (FI)

External contributor:
König Holger, ASCONA (DE)

- February 2005 -

# Content list

# Introduction

Assessing and demonstrating compliance of buildings, building designs and building projects with environmental objectives is becoming more and more important. The PRESCO network therefore wanted to assist especially the LCA-based environmental assessment tools - useful for design purposes - in their further developments.

It was clear from the start that the aim of Work Package 2 was not to create a new tool, but to provide the different European assessment tool developers with a forum for exchange of ideas and data, discussion, reflection, benchmarking and definition of common points of view on methodology concepts.

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.

Previous inter-comparison exercises had been performed in the European project REGENER[1] and in a working group of the International Energy Agency[2]. 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.

Because of the different construction practices (e.g. wood construction compared to masonry) and priority issues across Europe (e.g. heating in Northern Europe compared to cooling in Southern Europe), it was not easy to carry out comparisons between the tools. It was therefore decided to select approximately 5 pilot study buildings, whether existing or virtual, which could be assessed by all tool developers. The obtained results were thus used as the basis for the discussions.

The first chapter of this report describes the tools which have participated in the PRESCO WP2 actions. At the start of the project 6 tool developers were already selected for WP2. Early in the second year of the project, a seventh tool was identified. One additional PRESCO member volunteered to take part in the activities and there was even a tool developer outside the network who wanted to take part in the WP2 activities on a voluntary basis. So finally, there were 9 participating tools instead of the 7 which were originally foreseen.

In chapter 2, the process of identifying the case study buildings are presented. After the initial discussions, the WP2 members agreed to undertake the exercise in three levels, starting with a simple geometric volume, then assessing a complete building and finally evaluating an 'improved' building design, where a number of the PRESCO recommendations are applied.

Chapter 3 forms the main part of this WP2 report. It describes the results of the 3 comparison exercises. The results obtained by each of the tools will be explained and the

[1] European project REGENER, final report n°2, Application of the Life Cycle Analysis to buildings, C.E.C. DG XII contract n° RENA CT94-0033, January 1997, 563 p

[2] International Energy Agency, Energy Conservation In Buildings And Community Systems programme, Annex 31: Energy Related Environmental Impact of Buildings, Comparative Applications - A Comparison of Different Tool Results on Similar Residential and Commercial Building, October 2001, 151p

most remarkable differences are highlighted. Also the difficulties experienced during the exercise are noted. This chapter also takes up the preliminary conclusions on each of the individual comparisons.

The last two chapters reflect on the overall activities of PRESCO Work Package 2. The results of all comparison exercises are brought together, to draw some overall conclusions on best practices for environmental assessment. Based upon this, a number of recommendations are formulated for the future improvement of existing tools. The application of these recommendations should also lead to more harmonisation in the European environmental assessment tools.

# 1. Presentation of the participating tools

## 1.1. EQUER

EQUER performs simulations of a building's life cycle, in order to provide mechanical, energy and architectural engineers or architects with environmental indicators, allowing a project to be assessed from an environmental perspective (e.g. global warming, acidification and eutrophication potentials, exhaust of natural resources,…). The Swiss Oekoinventare 1996 database and other data collected in the frame of the European REGENER project are used for material fabrication and other processes (energy, water, waste, transport). EQUER is linked to the energy simulation tool COMFIE.

The tool is aimed at a wide range of professionals, such as mechanical, energy, and architectural engineers working for architect/engineer firms, architects, consulting firms, utilities, federal agencies, urban designers, universities, and research laboratories

The tool requires input from the user about the building geometry, material characteristics, internal loads and schedules, climate, heating and cooling equipment characteristics. Water consumption, waste generation and transport issues may be taken into account, depending on the goal of the study. Readable, structured input file is generated by the PLEIADES (thermal simulation) and ALCYONE (2-3D modeller) user interface (see figure 6).

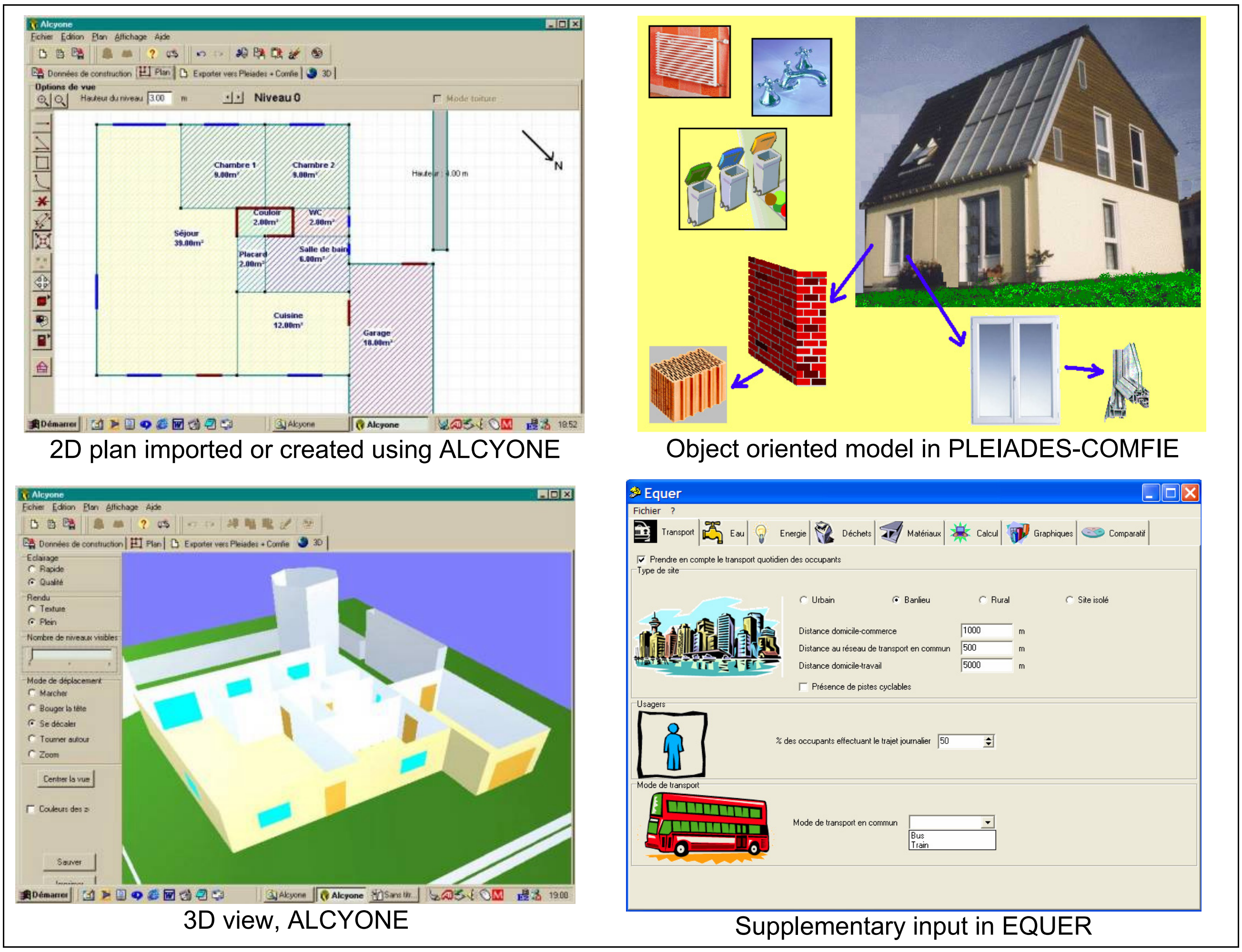
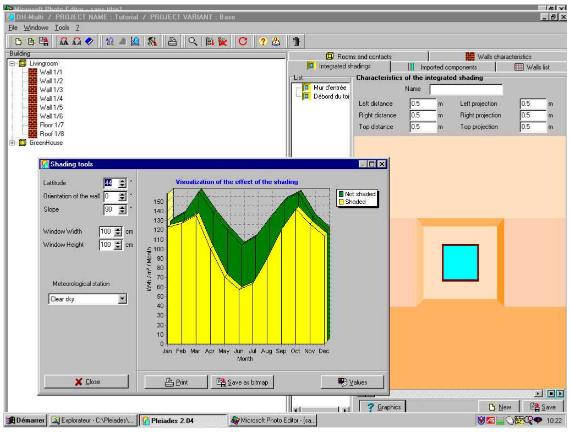
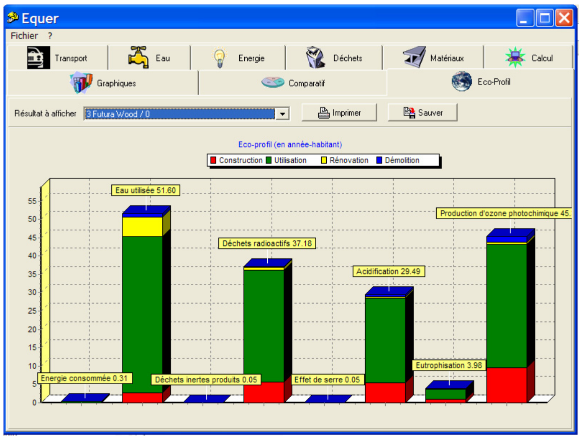



*Figure 1: Input in EQUER*

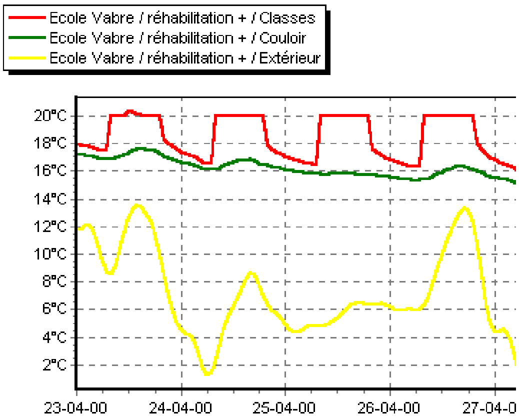
The assessment results are represented by means of environmental indicators such as contribution to global warming, acidification, eutrophication, exhaust of abiotic resources, human toxicity, ecotoxicity, smog and odours, primary energy and water consumption, radioactive and other waste production.



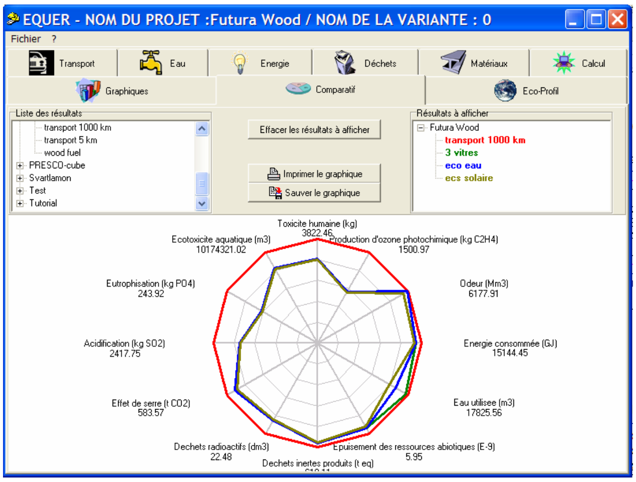
Calculation of solar gains, shading, energy load




EQUER output : environmental indicators for 4 phases (construction, operation, renovation, and demolition)




Evaluation of temperature profiles using PLEIADES-COMFIE




Comparison of alternatives using EQUER

*Figure 2: Output in EQUER*

The main strengths of EQUER are the link with an energy simulation tool and a user friendly interface (PLEIADES, ALCYONE) that allows a more global assessment. Life cycle simulation reduces the risk of errors when taking renovation into account because the materials quantities are automatically calculated; focussing on the envelope allows for use by architects. Future improvements can be implemented with regard to building equipment. Currently, equipment is very simply modelled (maximum power, set point, position of the thermostat in the building), impacts from heating equipment fabrication is included in the inventory of 1 kWh heating.

## *1.2. ENVEST*

Envest was the first UK software programme to explore ways of reducing a building's environmental impact at the design stage. Four years on, the programme has been upgraded to include a whole life costing tool that will help designers minimise not just the environmental impact, but the long term cost of maintaining and operating a building as well. Now a web-based tool, Envest 2 also enables the user to share information with colleagues and so promote improved understanding of environmental design and in-house benchmarking.

Entering simple data about building form, materials, components and operating systems, designers can identify those elements that most influence environmental impact and cost. Alternative options can then be weighed up until the optimum balance is reached.

Graphs and reports help the user to compare different specifications and decide which is the most appropriate. The graphs can also be used to benchmark one building against others. The data is easy to understand. Environmental impacts are calculated under twelve headings ranging from climate change to toxicity, but are also given as a single Ecopoint score. Costs are measured using net present value and discounted with a rate set by the user.

The tool is available in two versions:

- *Envest 2 estimator* in which cost and replacement intervals are set and cannot be seen or changed by the user
- *Envest 2 calculator* for those who want the choice of either entering their own costs/replacement intervals or using the defaults.

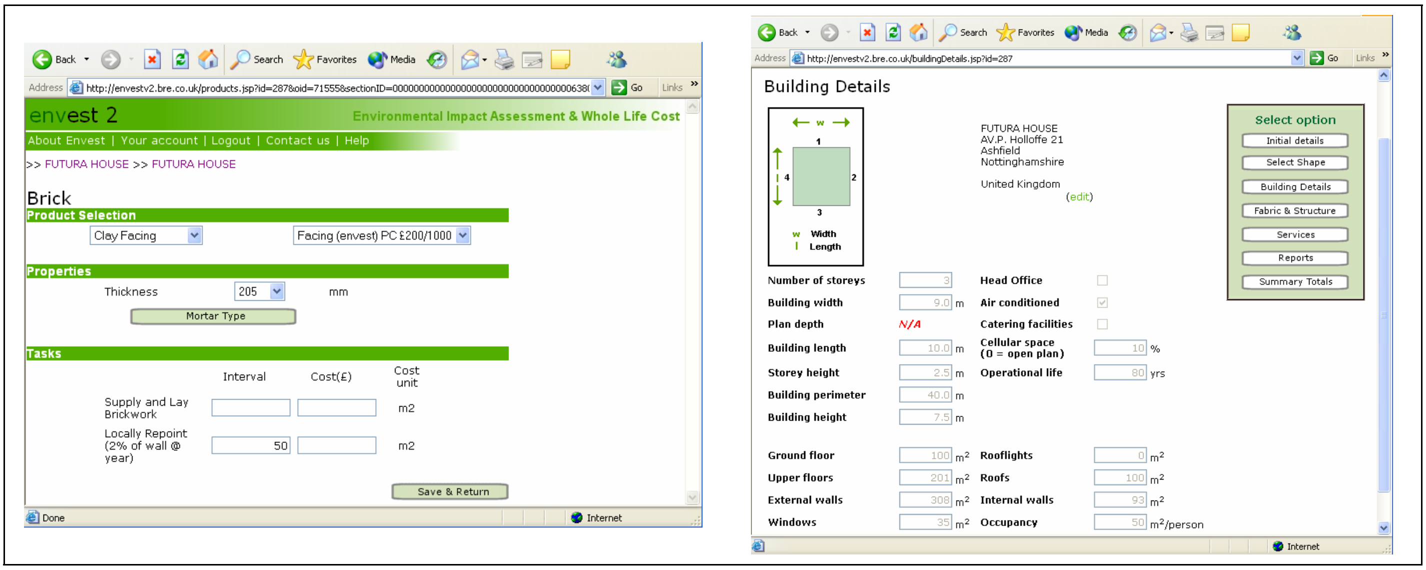



*Figure 3: Input of building data in ENVEST 2*

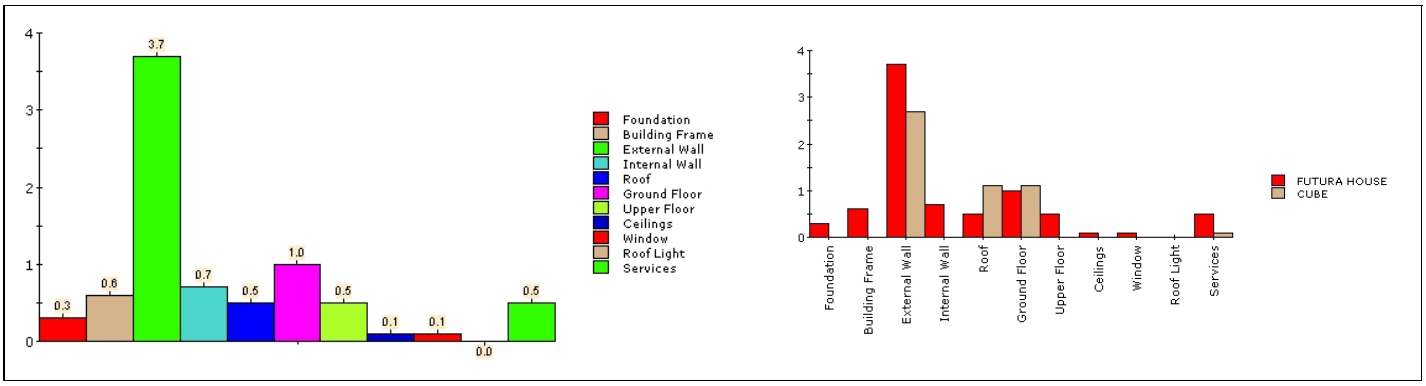



*Figure 4: Presentation of results in ENVEST 2*

## 1.3. OGIP

OGIP is short for **O**ptimisation of **G**lobal Demands in terms of costs, energy and environment within an **I**ntegrated **P**lanning Process.
OGIP is a design tool for the integral planning of buildings. It permits the assessment of construction and operating costs, the grey energy of the structure and the operating energy

and it provides a standardised method for calculating the environmental impact of the building's construction and operation. It can be linked to standard tools developed by the CRB, building associations and the SIA.

OGIP gives architects and designers a practical tool that portrays the complex relationships between costs, energy and environmental impact over the building's life cycle and assists those in charge of the project with decision-making. Consumption of resources is optimised interdependently and represented graphically.

The program is based on the construction element method developed by the CRB. Construction elements are structures which are assembled from various materials and components into functional units – e.g. a window, rendered external thermal insulation or a thermally insulated flat roof. In contrast to simple building materials, a function can be assigned to each element which, for example, enables the definition of the expected life cycle or the calculation of the annual heat losses. If the materials from which these elements are made are linked to material data, periods of use, life cycle inventory data and appropriate analytical models, judgements can be made with regard to consumption of the resources costs, energy and environment. These analyses can be carried out for individual construction elements, systems or whole buildings.

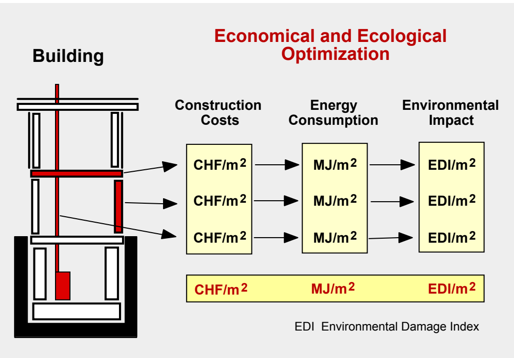



*Figure 5: In addition to the indicators for costs and energy, OGIP also supplies an indicator for the environmental impact of the building. It is expressed in environmental impact points as described in SAEFL publication 297*

OGIP's database currently contains some 2,500 construction elements. The life cycle inventory data is based on the EcoInvent '96 database developed by the Swiss Federal Institute of Technology in Zurich. It includes information on building materials, fuels and processes.

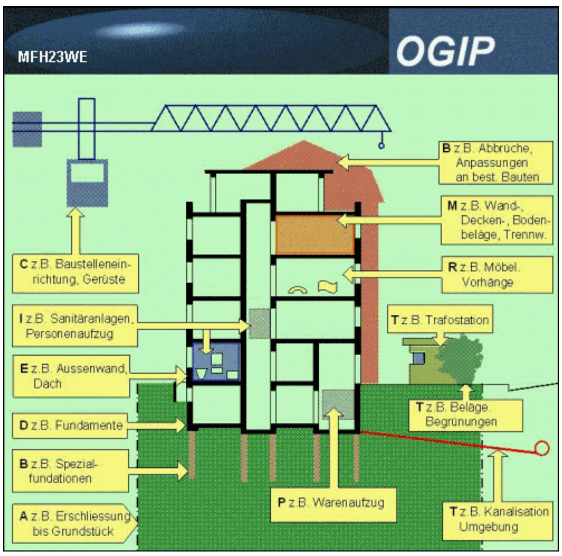
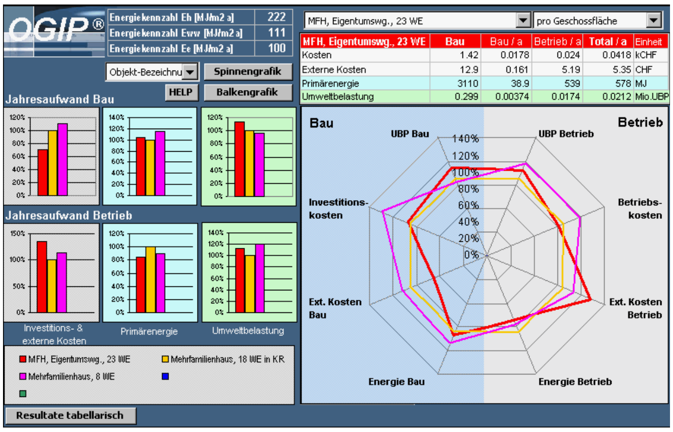


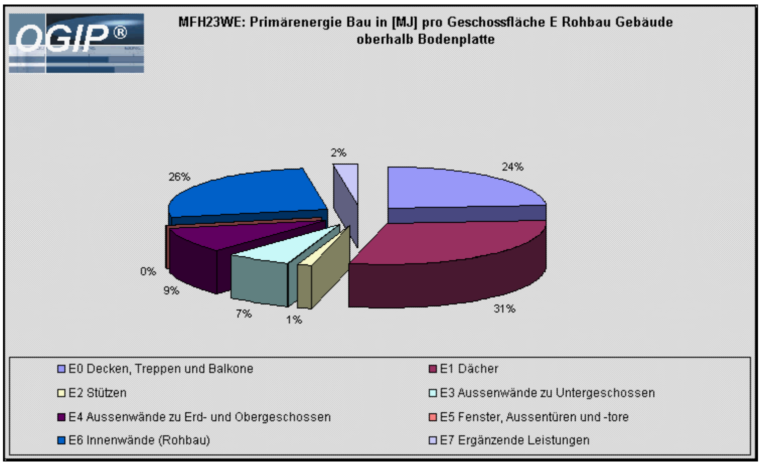
*Figure 6: OGIP is based on approx. 2,500 data sets for structural elements and components ranging from peripheral works and the foundations right up to the service equipment.*

In the area of costs and energy, indicators have long functioned as important project parameters. These parameters impose precisely defined limits for architects and engineers and enable clients to check their criteria and compare them with others.
In the environmental sphere, there have until now been no comparable indicators based on life cycle assessments. With OGIP it is now possible to calculate such indicators. Previous comparisons in other projects have been limited to studies of the "grey energy" or other specific aspects. To satisfy the requirement for high overall quality, it is necessary for the environmental impact during the construction and operation of buildings to be fully taken into account.
OGIP presents the calculated indicators either absolutely (tabular) or in comparison with similar structures (graphically). Up to 5 different buildings or variants can be compared.




Presentation of primary analysis results with a spider diagram


detailed results analysis through a bar chart




analysis of primary structural components

*Figure 7: Presentation of results in OGIP*

## 1.4. BeCost

BeCost is a web-based tool for life cycle assessment of building structures and for the whole building.
The program includes:

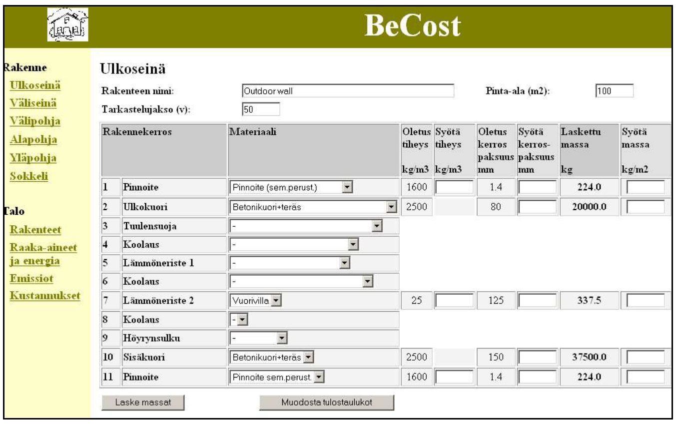
- Environmental profiles, costs and maintenance costs of building materials produced in Finland,
- The structures for designing outdoor walls, indoor walls, roofs, floors, etc.

- Material quantity calculations
- Environmental profile calculation for designed structure
- Result as plot of environmental profile (emissions), energy- and raw-material use, and cost impact for the structure and whole building.

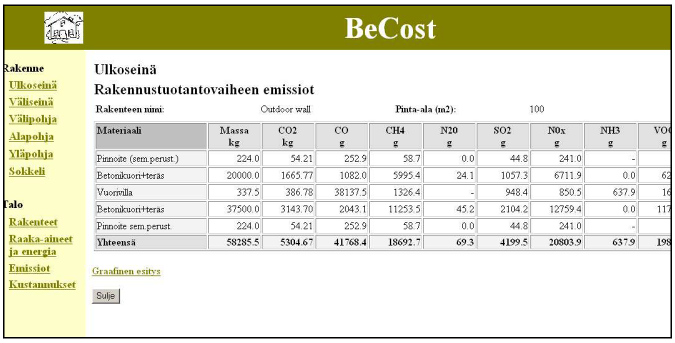
BeCost is an easy to use program. The user should first define the building by making relevant choices, by choosing the structure and materials, by giving the volumes in m2 and by choosing the service life of the building.
This can be used for different purposes:
- to examine the ecological effect of building choices related to materials used and service life of the whole building (designer and constructors use);
- verifying environmental characteristics' fulfillment, if such has been demanded (designer use);
- for owners to examine their building's environmental profiles (owner use);
- checking the affect of care, maintenance and repairing actions on the environment;
- comparing environmental profiles of structures having the same functional units; and
- comparing environmental impacts of produced- and competing materials in certain structure or building (use of building material producer).


*Cover page of the BeCost tool*


Page for structure design




Calculation page




Environmental profile for the designed structure (emissions)

*Figure 8: Input and outputs in BeCost*

## 1.5. Eco-Quantum

One of the main motives for the development of Eco-Quantum was the need of the Dutch building market for environmental information. As the multitude of different qualitative methods and checklists for building materials were felt to be confusing, there was a need for a generic, quantitative assessment method.

The main aim of Eco-Quantum was to develop a tool for the determination of the environmental performance of a building over its total life span, with a calculation method based on LCA, which would offer architects quick analysis of their building design, a communication tool between actors and which could be used to optimise building components and the entire building design.  Furthermore, local governments can use Ecp-Quantum to set environmental requirements and for communication between the different actors of the building sector.

An Eco-Quantum assessment consists of 5 steps:

1. from design to material & energy flows and input in Eco-Quantum
2. calculation of environmental in- and outputs
3. calculation of environmental effects (12)
4. calculation of environmental scores (4)
5. calculation of Eco-Quantum indicator (1)

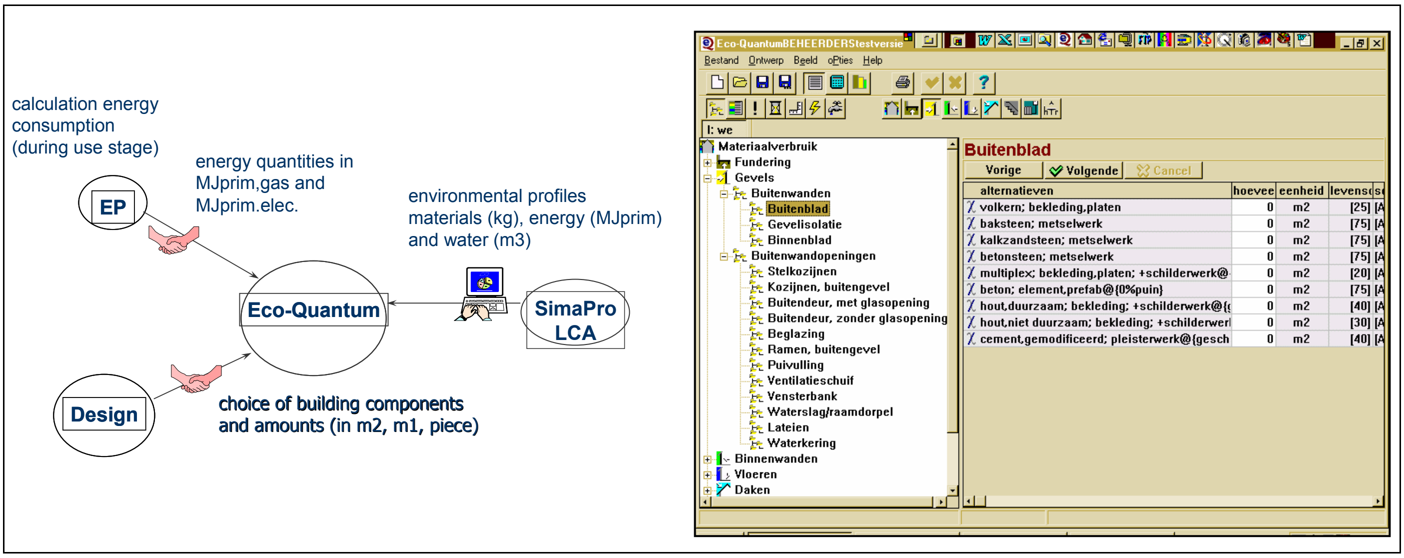



*Figure 9: Input data in Eco-Quantum*

After the calculation of the environmental in- and outputs, Eco-Quantum gives the environmental performance of the building, using a set of environmental effects:

1. depletion of resources
2. greenhouse effect
3. depletion of the ozone layer
4. photochemical oxidant formation
5. human toxicity
6. ecotoxicity (water, sedimental, terristic)
7. acidification
8. nutrification
9. energy consumption
10. waste
11. dangerous waste

These environmental effects are then aggregated into 4 environmental scores: resources, emissions, energy and waste.  Each of the effects and scores are subdivided in the material related (yellow), energy related (green) and water related (blue) impact – see figure 15.

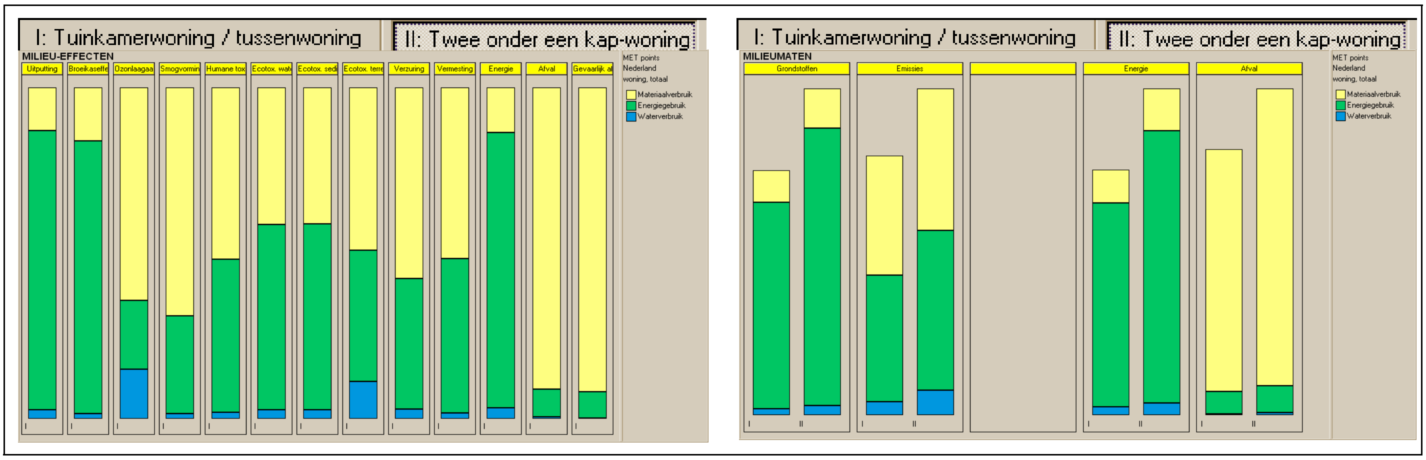



*Figure 10: Environmental effects and environmental scores in Eco-Quantum*

For the four environmental scores, it is also possible to split the environmental performance over the different stages of the building's life cycle (see Figure 11).

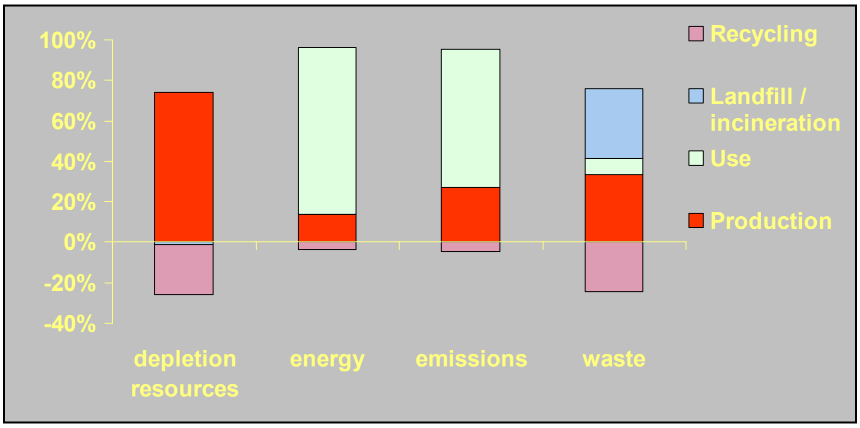



*Figure 11: Environmental performance scores over the total life span of the building*

The final step in the Eco-Quantum assessment is the calculation of the single environmental indicator. The results of the 4 environmental score are again aggregated and weighted to calculate an overall environmental performance for the building. This last step however is still experimental.

The main advantages of Eco-Quantum are that it is easy to use ("language" of the designer), it offers a wide variety of assessment methods, it is useful for target setting (policy makers) and is a useful decision support tool for designers and clients. Drawbacks however are that the tool is only applicable in the later design stages as a lot of data needs to be available and that the user can't extend the materials database. The tool can only be used for residential buildings and the advanced aggregation leads to a subjective weighting in the assessment.

## *1.6. Eco-Soft*

ECOSOFT is an LCA tool developed by IBO. It provides environmental indicators for the construction and the energy use of a building.

ECOSOFT is mainly used as a research and education tool.
Its database and method is also:

- part of building certification systems such as "Total Quality" and "Ökopass"
- part of calculation tools for building physics (e.g. A0, Zehetmayer, ECOTECH)
- part of government aid for housing (f.e in Salzburg and Vorarlberg)

The constructions of the building are calculated by choosing the building materials from the database and put in the thickness of the layer and the percent in volume of material within this layer. The database contains a suggestion for the density and the life-span of the material.  These parameters can easily be changed by the user.
For functional units (e.g. upgraded insulation) two possibilities are available in ECOSOFT: you can either choose the whole functional unit (e.g. upgraded insulation from polystyrene 5-10 cm) or you give in all layers separately (e.g. glue, insulation, fibreglass cloth etc.).

Inputs in ECOSOFT are:

- construction: amount (m, $m^2$ or $m^3$) + materials resp layers resp whole construction
- energy: amount (MJ) + type of energy
- transport: amount (tkm) + means of transport

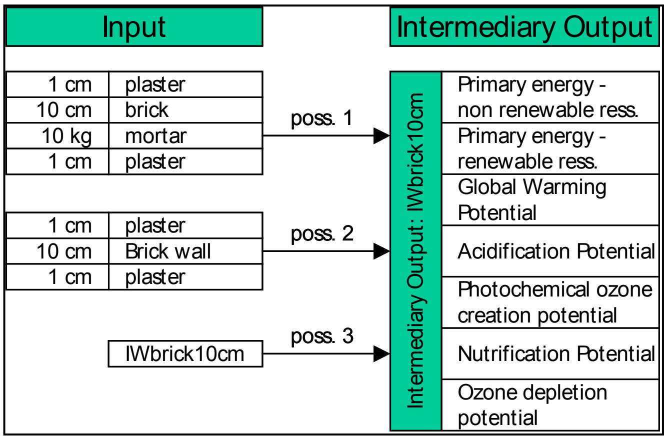
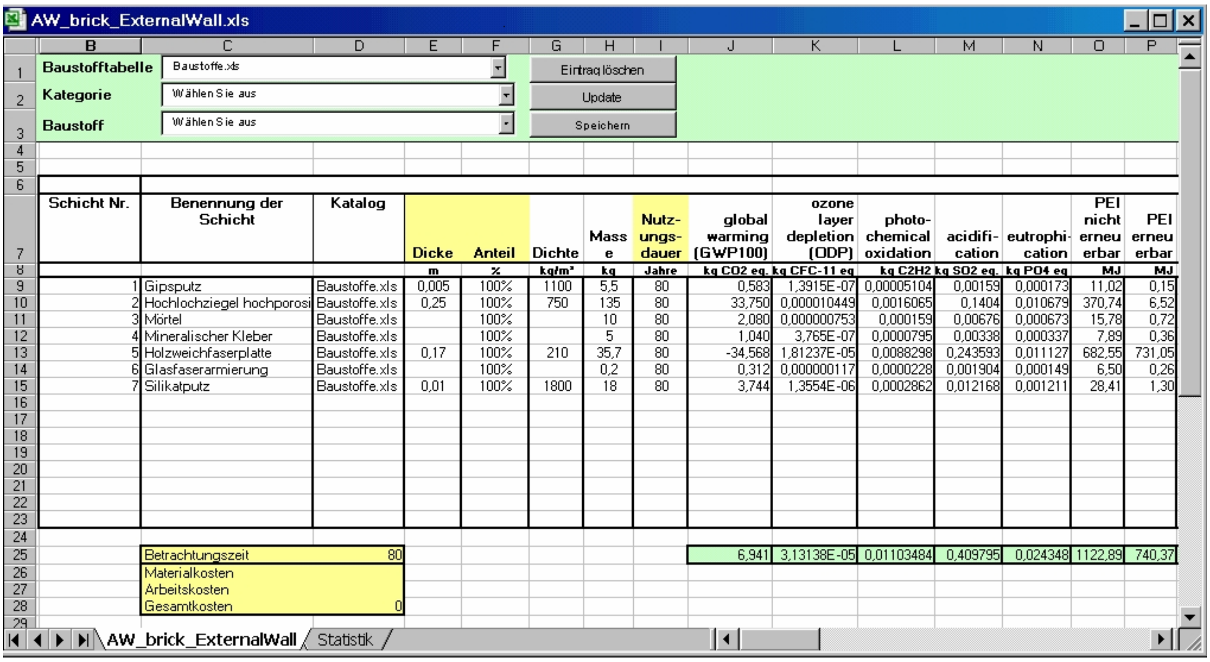



*Figure 12: 3 possibilities to give in an internal brick wall*



AW_brick_ExternalWall.xls

Baustofftabelle: Baustoffe.xls
Kategorie: Wählen Sie aus
Baustoff: Wählen Sie aus
Eintrag löschen | Update | Speichern

| Schicht Nr. | Benennung der Schicht | Katalog | Dicke | Anteil | Dichte | Masse | Nutzungsdauer | global warming (GWP100) | ozone layer depletion (ODP) | photo-chemical oxidation | acidification | eutrophication | PEI nicht erneuerbar | PEI erneuerbar |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | m | % | kg/m³ | kg | Jahre | kg CO2 eq. | kg CFC-11 eq | kg C2H2 | kg SO2 eq. | kg PO4 eq | MJ | MJ |
| 1 | Gipsputz | Baustoffe.xls | 0,005 | 100% | 1100 | 5,5 | 80 | 0,583 | 1,3915E-07 | 0,00005104 | 0,00159 | 0,000173 | 11,02 | 0,15 |
| 2 | Hochlochziegel hochporosi | Baustoffe.xls | 0,25 | 100% | 750 | 135 | 80 | 33,750 | 0,000010449 | 0,0016065 | 0,1404 | 0,010679 | 370,74 | 6,52 |
| 3 | Mörtel | Baustoffe.xls | | 100% | | 10 | 80 | 2,080 | 0,000000753 | 0,000159 | 0,00676 | 0,000673 | 15,78 | 0,72 |
| 4 | Mineralischer Kleber | Baustoffe.xls | | 100% | | 5 | 80 | 1,040 | 3,765E-07 | 0,0000795 | 0,00338 | 0,000337 | 7,89 | 0,36 |
| 5 | Holzweichfaserplatte | Baustoffe.xls | 0,17 | 100% | 210 | 35,7 | 80 | -34,568 | 1,81237E-05 | 0,0088298 | 0,243593 | 0,011127 | 682,55 | 731,05 |
| 6 | Glasfaserarmierung | Baustoffe.xls | | 100% | | 0,2 | 80 | 0,312 | 0,000000117 | 0,0000228 | 0,001904 | 0,000149 | 6,50 | 0,26 |
| 7 | Silikatputz | Baustoffe.xls | 0,01 | 100% | 1800 | 18 | 80 | 3,744 | 1,3554E-06 | 0,0002862 | 0,012168 | 0,001211 | 28,41 | 1,30 |
| | Betrachtungszeit | 80 | | | | | | 6,941 | 3,13138E-05 | 0,01103484 | 0,409795 | 0,024348 | 1122,89 | 740,37 |
| | Materialkosten | | | | | | | | | | | | | |
| | Arbeitskosten | | | | | | | | | | | | | |
| | Gesamtkosten | 0 | | | | | | | | | | | | |

AW_brick_ExternalWall / Statistik

*Figure 13: Input of the brick wall of FUTURA-house*

Outputs of ECOSOFT are a set of environmental indicators: GWP100 (Green house potential 100 years), Acidification potential, Photochemical ozone creation potential, Ozone depletion potential, Eutrophication potential, primary energy consumption - renewable and primary energy consumption - non-renewable.

RenggliHouse.xls

**Kategorie** Innenwände | **Wählen sie die Konstruktion aus:** Wählen Sie aus | Statistik | Update

**PRESCORenggliHouse**

| Pos. | Bauteil / Konstruktion | Länge / Fläche / Aushub | unit | global warming (GWP100) | ozone layer depletion (ODP) | photo-chemical oxidation | acidification | eutro-phication | PEI nicht erneuerbar | PEI erneuerbar |
|---|---|---|---|---|---|---|---|---|---|---|
| | | m/m2/m3 | | kg CO2 eq. | kg CFC-11 | kg C2H2 | kg SO2 eq. | kg PO4--- e | MJ | MJ |
| | | | | 73.263,26 | 6,0529 | 9,92 | 327,77 | 23,63 | 873.919,25 | 195.802,21 |
| 1 | FU_Basementfloor | 100,5 | m2 | 17.900,17 | 2,4421 | 2,29 | 44,96 | 3,74 | 139.695,60 | 3.067,83 |
| 2 | FU_FloorAboveBasement | 100,5 | m2 | 15.843,29 | 1,5540 | 1,60 | 46,51 | 3,77 | 132.856,36 | 3.864,37 |
| 3 | DE_concre_FloorAboveGroundFlo | 100,5 | m2 | 9.154,26 | 0,0023 | 0,71 | 34,25 | 3,06 | 81.926,79 | 2.464,48 |
| 4 | Ke_ExternalWallsBelowGround | 92,5 | m2 | 15.786,44 | 2,0427 | 1,64 | 39,48 | 3,39 | 114.278,95 | 2.598,91 |
| 5 | AW_brick_ExternalWall | 213 | m2 | 1.478,52 | 0,0067 | 2,35 | 87,29 | 5,19 | 239.176,30 | 157.697,97 |
| 6 | DA_concrete_Flatroof | 100,5 | m2 | 8.055,46 | 0,0028 | 0,71 | 32,51 | 2,69 | 84.125,95 | 2.378,63 |
| 7 | IW_brick_InterierWall | 99,5 | m2 | 3.185,69 | 0,0010 | 0,17 | 12,78 | 1,00 | 36.303,17 | 655,49 |
| 8 | Oe_WindowWoodAlu | 32,4 | m2 | 1.877,14 | 0,0012 | 0,28 | 28,08 | 0,68 | 39.874,91 | 17.558,65 |
| 9 | Oe_Exterior_door | 2 | m2 | -31,80 | 0,0000 | 0,02 | 0,17 | 0,01 | 397,44 | 802,60 |
| 10 | Oe_InteriorDoorWood | 16 | m2 | -241,37 | 0,0001 | 0,05 | 0,45 | 0,03 | 928,84 | 4.625,16 |
| 11 | Oe_GarageMetallicDoor | 5,25 | m2 | 255,47 | 0,0001 | 0,11 | 1,29 | 0,07 | 4.354,94 | 88,14 |
| | | | | 556.931,76 | 0,1144 | 51,42 | 1.837,62 | 124,61 | 10.789.096,33 | 408.372,94 |
| 12 | EuropeanMix | 16.800,00 | MJ/a | 192.192,00 | 0,0796 | 6,26 | 1.491,84 | 46,77 | 4.129.098,09 | 267.829,63 |
| 13 | NaturalGas | 62.370,00 | MJ/a | 364.739,76 | 0,0348 | 45,16 | 345,78 | 77,84 | 6.659.998,24 | 140.543,31 |

RenggliBrick / RenggliConcrete / RenggliHouse_brick / PRESCORenggliHouse_concrete / PRESCORenggliHous

*Figure 14: Screen Shot: ECOSOFT-Results for the FUTURA-house*

ECOSOFT includes data for building materials, energy sources and transportation means. It uses data from the following sources:
- Oekoinventare 96 LCI database
- Baustoffe – Oekoiventare (Kohler,N. et al., Karlsruhe/Weimar/Zürich 1995)
- IBO-database (status april 2002)

The building materials are calculated by SimaPro using the CML 2 Baseline 2000.
Data for electric installation, sanitary installation or furniture are not included.

ECOSOFT is used both for calculating the ecological performance of the construction of a building and for calculating the ecological performance of the construction and operation of the building during life-time. It does not include the calculation of end of life (deposition and recycling) because of the incertitude of the deposition/recycling-scenarios.

## 1.7. ESCALE

ESCALE has been designed to be adapted to the iterative design process, to speak the decision-makers language and to provide understandable and interpretable results. It is structured by 11 main criteria, declined in sub-criteria. An assessment module corresponds to each sub-criterion.

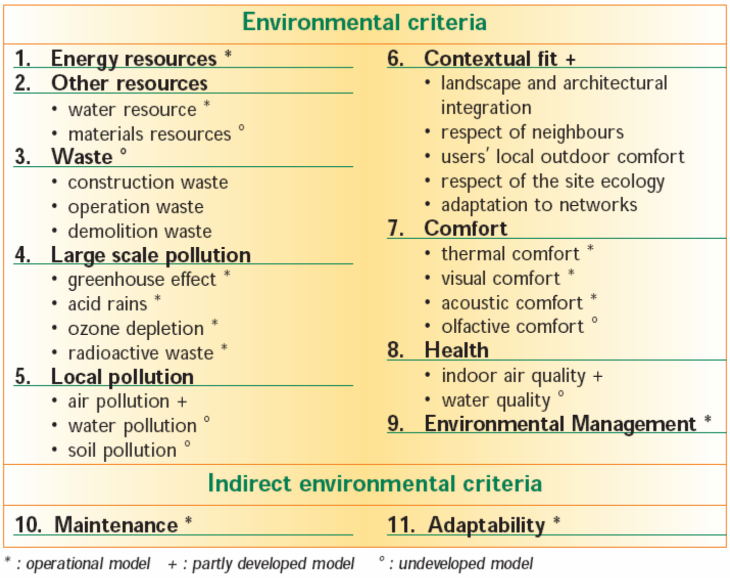



*Figure 15: Hierarchical criteria structure*

Escale has two levels of assessment modules: simplified and detailed. The elementary assessment is made in 2 steps, an indicator value and a score on a performance scale. The results are partially aggregated and finally result in an environmental multi-criteria profile with 24 components

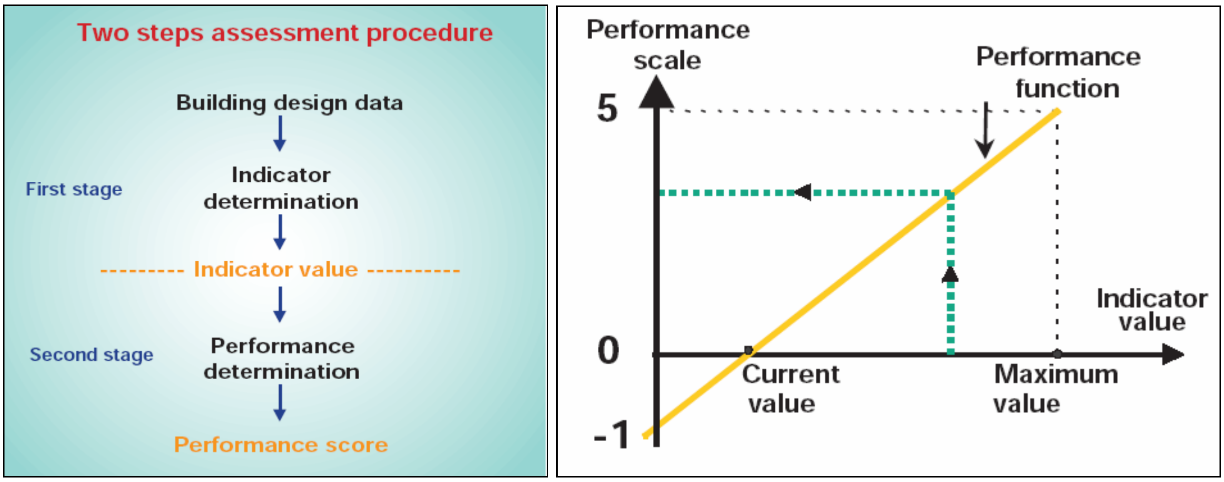



*Figure 16: Two step approach – indicator value and score on a performance scale*

The performance scale is defined by a reference value (0, equal to a statutory value or one frequently met in practice); a upper limit also called target value (5, equal to a best possible value); a lower value (-1, equal to a non-statutory value or below normal practice); and by a performance function that makes the link between the value of the indicator and a numerical value from -1 to +5 (not necessary linear).

In the ESCALE method, the assessment based on each criterion (or sub-criterion) is the aggregated result, generally by weighted sum, of the assessments of the previous levels of the tree structure. However, complex and incomparable criteria are not aggregated.

The final environmental profile is a 24-component multi-criteria profile, expressed in terms of performance.

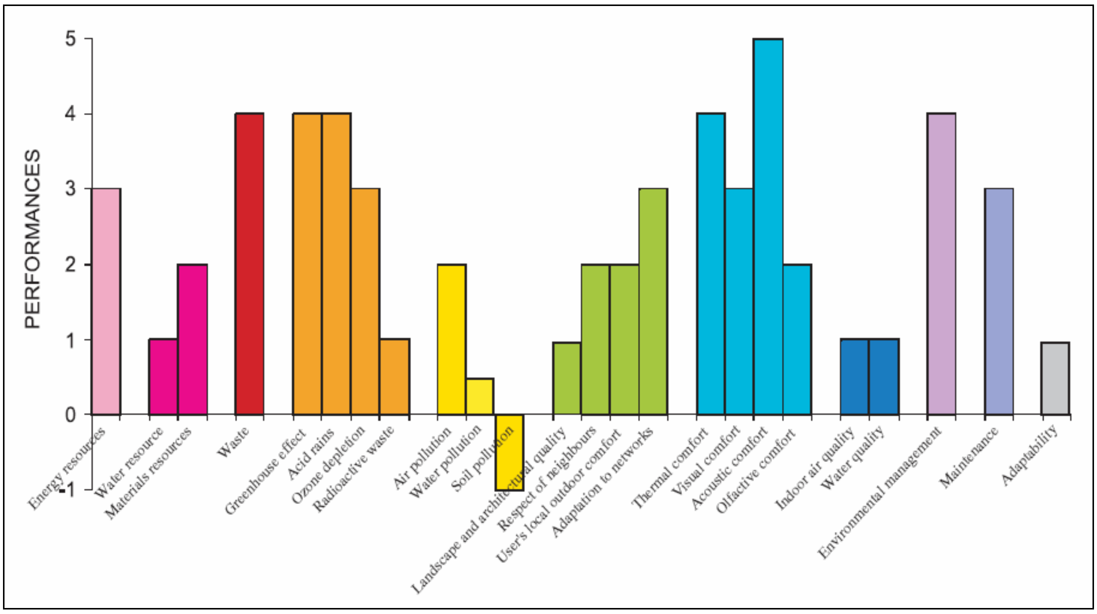



*Figure 17: Final environmental profile*

ESCALE, based on a wide range of criteria which are directly or indirectly environmental, is a first stage in a decision-making tool. The environmental information produced may form a common basis for discussion and negotiation with involved parties (building owner, architect, engineers, etc.).

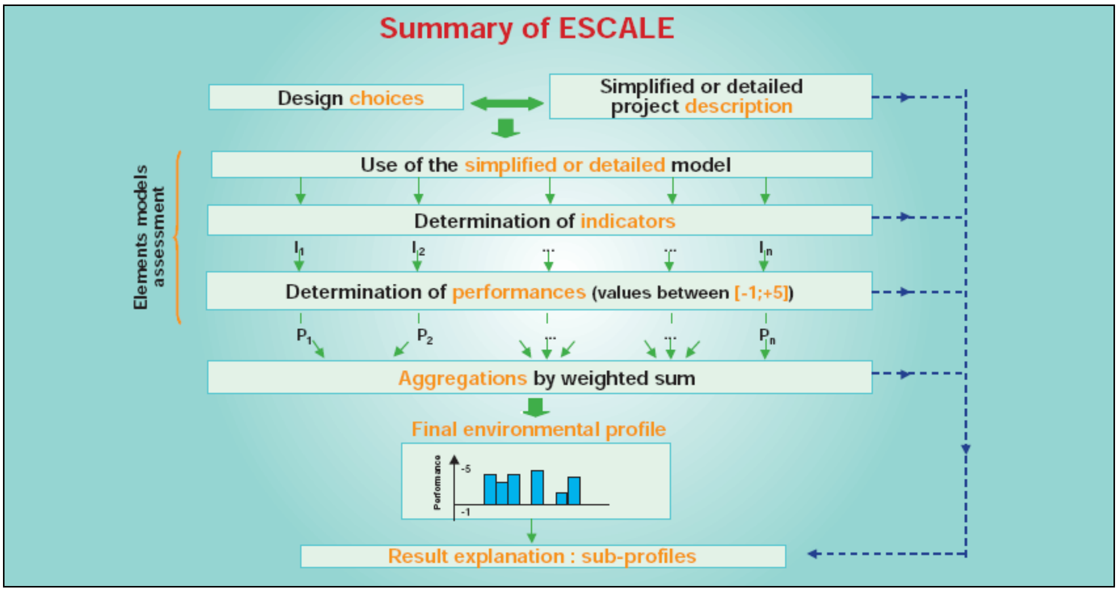



*Figure 18: Summary of ESCALE*

## 1.8. SimaPro

SimaPro stands for "System for Integrated Environmental Assessment of Products". Nowadays it is not only used for product assessment; its generic setup means use has expanded to analysis of processes and services. SimaPro was first released in 1990 as a professional tool to collect, analyze and monitor the environmental performance of products and services. The tool enables easy modelling and analysing of complex life cycles in a systematic and transparent way, following the ISO 14040 series recommendations.

SimaPro includes the following features:

- Intuitive user interface following ISO 14040.

- Easy modelling, with powerful wizards available to assist you.
- Direct impact assessment calculations from each stage of your model.
- Monte Carlo analysis
- Full transparency: trace results back to their origins, in real time.
- Weak point analysis: use the process tree to identify any "hot spots".
- Extensive filtering options for all results.
- Analyze complex waste treatment and recycling scenarios.
- Allocation of multiple output processes.

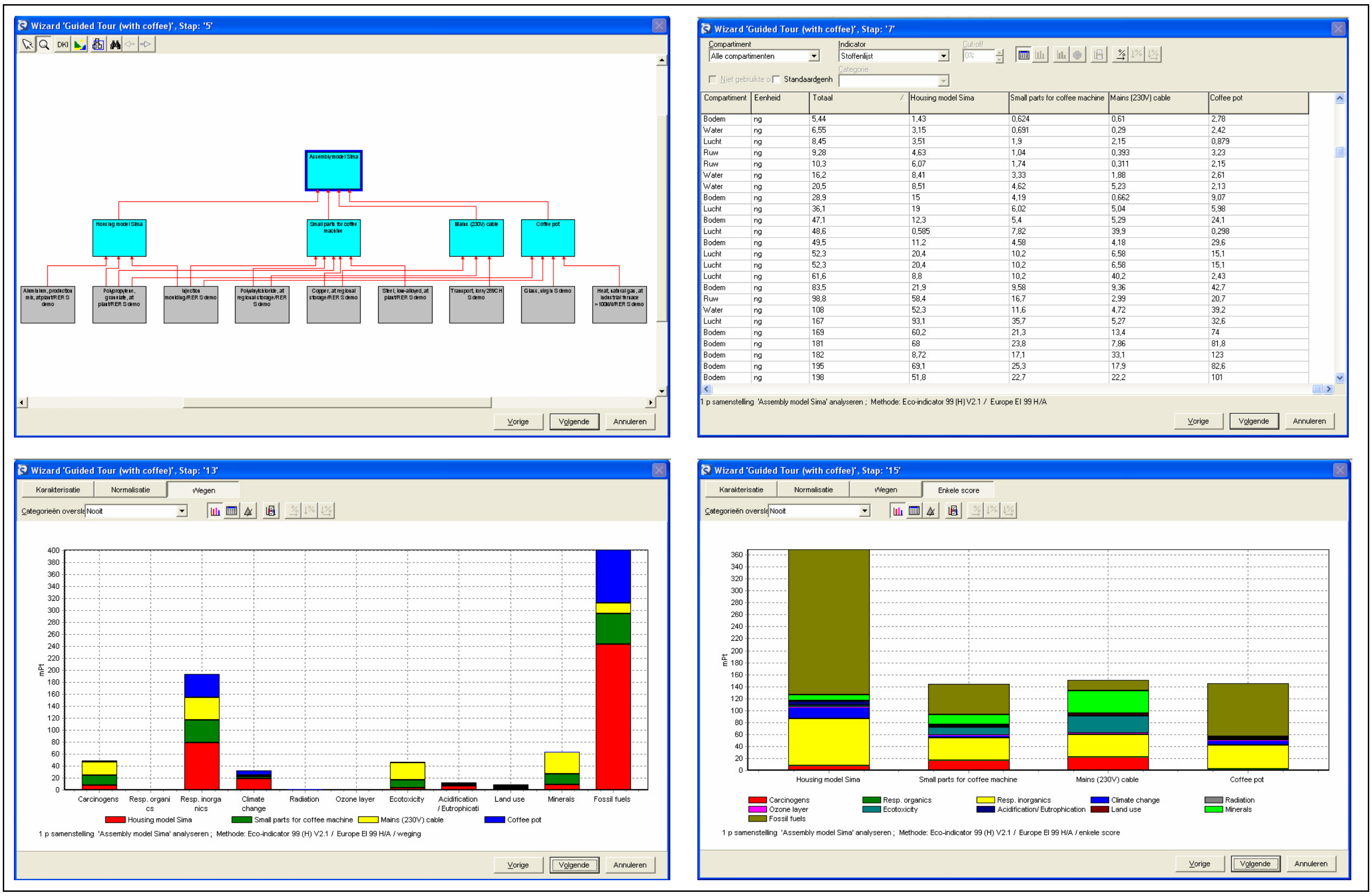



*Figure 19: Environmental impact calculation in SimaPro, based on LCA*

## 1.9. LEGEP

LEGEP is a tool for integrated life-cycle analysis. It supports the planning teams in the design, construction, quantity surveying and evaluation of new or existing buildings or building products. The LEGEP database contains the description of all elements of a building (based on DIN 276); their life cycle costs (LCC/WLC) based on DIN 18960 and the final report EU-TG4 LCC in Construction. All information is structured along life cycle phases (construction, maintenance, operation (cleaning), refurbishment and demolition. LEGEP establishes the energy needs for heating, warm-water, electricity and their cost (following EnEV 2002 and EN 832). The environmental assessment comprises the material flows (input and waste) as well as an effect oriented evaluation based on ISO 14040 – 43.

LEGEP is organised along four software tools, each with it's own database. The method is based on cost planning by "elements". The database is hierarchically organised, starting with the LCI-data at the bottom, building material data, work-process description, simple elements for material layers, composed elements like windows, and ends with macro-elements like the complete roof. The data are fully scaleable and can be used either "bottom-up" or "top-down".

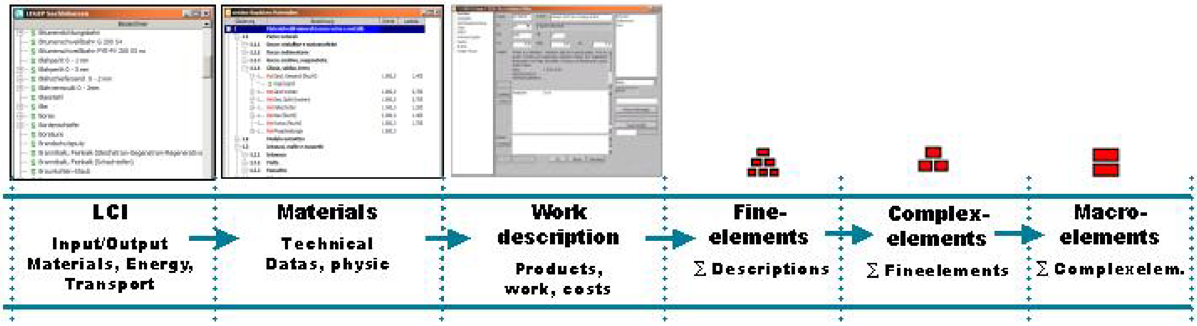



*Figure 20: Hierarchical organization of data " Staircase" in LEGEP*

Elements at each level contain all necessary data for cost, energy, and mass-flow and impact evaluation. A building can be described using either preassembled elements or defining elements from scratch. The user can also define a specific composition by exchanging layers or descriptions of the element. The advantage of the top down approach is its completeness: if an element is not explicitly changed or eliminated it will remain in the calculation. The costs of the elements are established by the SIRADOS database, which is published each year. There are about 6.000 elements "ready for use" for the building fabric, technical equipment and landscape work. The LC Inventories are based on the ECOINVENT data and specific values from the Baustoff Ökoinventare (Kohler, N., Lützlendorf, Th. et al., Karlsruhe/Weimar/Zürich 1995).

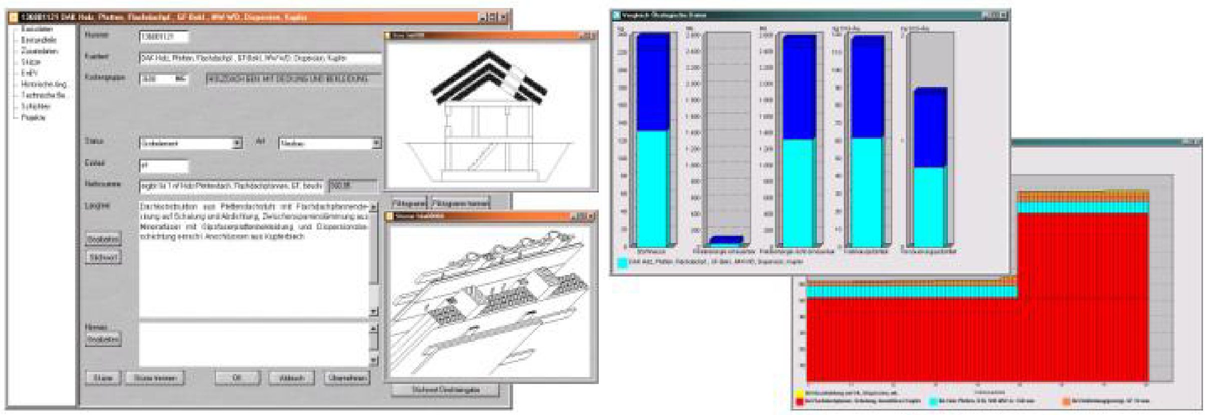


*Figure 21: Element with environmental profile. Roof construction with five indicators and the impact of CO2 equiv. over eighty years.*

**Input in LEGEP:** A building can be described alternatively with 15 macro-elements, 40 complex elements, or approx. 150 simple elements. This corresponds to the increase in knowledge during the design and planning process allowing describing the building more and more in detail without loosing the overall framework. At each level a complete evaluation can be made and documented automatically.

**Output of LEGEP:** at each phase a complete, interrelated set of cost, energy, mass-flow and environmental indicators. The number of indicators, which are displayed, can be chosen from the CML indicators (Green house potential 100 years, Acidification potential, Photochemical Ozone creation potential, Ozone depletion potential, Eutrophication potential, primary energy consumption renewable and non-renewable, Ecoindicator etc.). Additional indicators are under implementation (DALY etc.). It is possible to show separately specific indicators or all indicators, for each life cycle phase (new construction, operation, cleaning, maintenance, refurbishment, demolition) of the building. The different evaluations are represented in the form of tables and appropriated graphs.

Through the use of LEGEP the main effort of the designers and other specialists is shifted from the extremely cumbersome description of a building and extensive input of data into a specific software to the interpretation of large number of synthetic results at each moment. The combined effects of changes can be immediately visualized; new methods of design can be founded on experience gained from LCA knowledge.

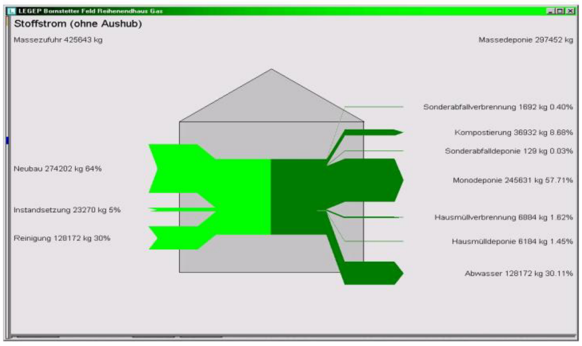



*Figure 22: Material flows as realistic input and output in different EWC*

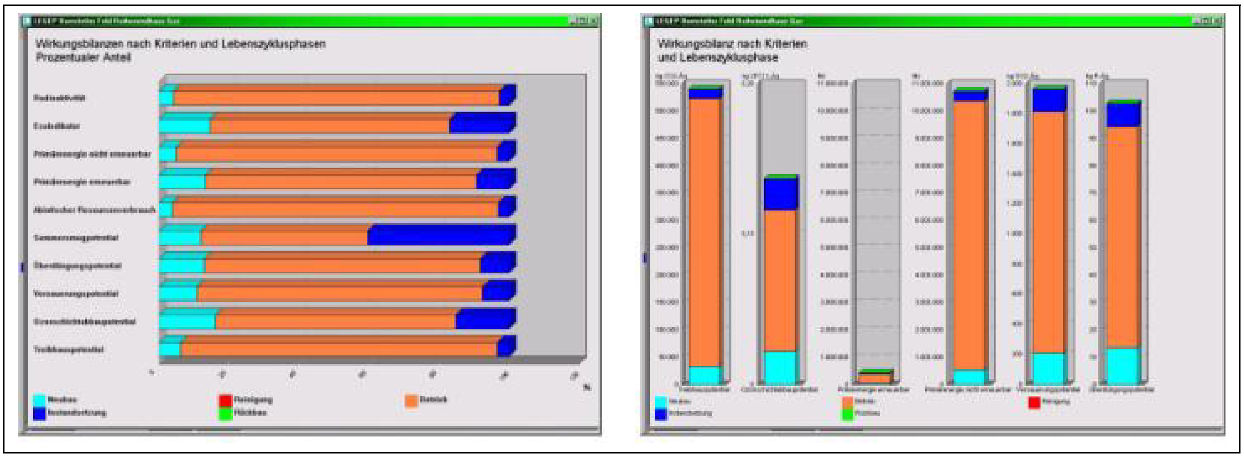



*Figure 23: Environmental impact of different indicators in percentage and absolute figures. The phases of the lifecycle are shown with different colours.*

LEGEP is used at present mainly for the design of new built buildings, taking into account the future life cycle. The information is highly appreciated by clients and facility managers. For existing buildings LEGEP assists in the decisions on refurbishment operations and long term, sustainable management of buildings and building stocks.

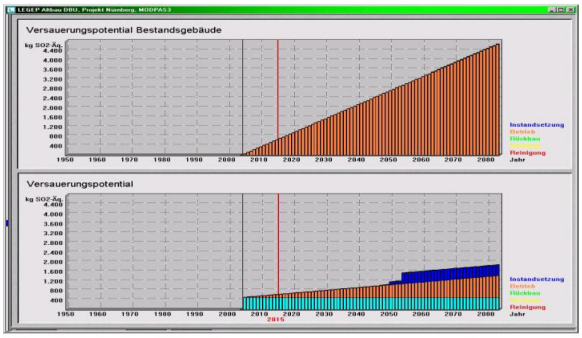



*Figure 24: Impact of CO2 equiv. for an existing building before (above) and after (under) the renovation with insulation, new windows and heating system over 80 years.*

The software is available in German and Italian language; French and English versions are in preparation.

# 2. Background on the 3 steps of the exercise

The activities PRESCO Work Package 2 were divided into 3 main parts. Before the actual environmental assessments, the WP2 members agreed on the definition of the buildings to be used for the assessment exercises. The availability of the necessary input data for describing the buildings was considered to be extremely important for the selection process, as this can have a large influence on the final outcomes of the assessment.

Because of the complexity of an environmental assessment of a building, the WP2 members agreed to start with the 'easy' exercise of assessing a simple geometric volume. After this, the tool developers would compare the assessment of a complete building. The last step in the exercise was to assess the impact of applying the PRESCO recommendations to a building. The background of these three steps is hereafter explained in more detail.

## *2.1. CUBE*

In order to get a first identification of the major differences between the assessment tools, it was decided to start with the evaluation of a simple parallelepiped, built up of 1 material. It was called the "CUBE" for practical reasons. All basic parameters of the CUBE were agreed on, so that every partner could use exactly the same data as input in their tool. The group of tool developers agreed on the following details:

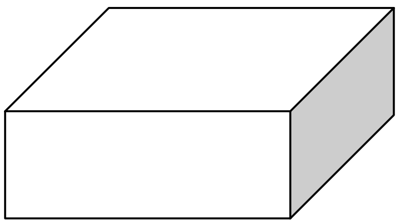


*Figure 25: Sketch of the "CUBE"*

**Geometry**

- The dimensions of the parallelepiped: 7m x 8m x 2,5m (interior dimensions)
- Thickness of all walls (including floor and ceiling): 20cm
- No windows or doors

**Other data**

- Material of the parallelepiped: reinforced concrete, in situ fabrication
- Percentage of steel in the concrete: 3% in volume
- Life span: 50 years
- Neglect maintenance and replacements of components
- Electricity for space heating - 'European mix':
    - 36.9% nuclear
    - 17.5% coal
    - 10.5% lignite (brown coal)
    - 15.2% hydro
    - 9.7% oil
    - 7.9% natural gas
    - 1.9% other gas
    - 0.4% other
- No other energy consumption

- End of life and possible recycling: according to the assumptions in the tools / in the national practice

**Specific data for the evaluation of the heating load**

- Location: Switzerland (considering climatic data for Mâcon for the heating load calculation, altitude = 217 m)
- Thermostat set point : 20°C (constant)
- Ventilation : 0.6 ach (air change per hour)
- No internal gains
- Properties of the materials:

| material | Density (kg/m3) | Conductivity (W/m/K) | Specific heat (J/kg/K) |
|---|---|---|---|
| concrete | 2,100 | 1.28 | 820 |
| steel | 7,850 | 46 | 490 |

- Optical properties of the surfaces : absorption factor = 0.6, emission factor = 0.9
- The larger facades (8 m length) face north and south
- There is a ventilated crawl space under the floor (considered at the ambient external temperature)
- Resulting heating load : 38 900 kWh, i.e. 700 kWh/m2/a (the building is not insulated and all the walls are external, thus the heating load is very large).

The objective of the assessment of this simple "building" is to extract information on the methods and assumptions used in the tools on the basis of some building materials (reinforcing steel, concrete and electricity production and distribution), the used masses (e.g. amount of steel included) and the used LCI data (included building process, transports, infrastructure, demolition process, etc.)

Other reasons for starting with this rather simple assessment were to identify the differences in input possibilities (e.g. being able to enter own data or modifying available data), to have a view on the different indicators used by each of the tools and to verify if the obtained results were comparable. The results of the assessment of the CUBE are presented in section 3.1.

## *2.2. FUTURA*

The second phase of the comparisons consisted in the environmental assessment of a complete building. At the start of the project, an evaluation of several buildings was envisaged. However, as the availability of all the necessary input data would have been time consuming without added value, the group decided to spend more time on the analysis than on collecting data. As data for one pre-fabricated building in different construction types were available, it was decided to assess that building – the FUTURA house.

The materialization was proposed by EMPA, one of the participating WP2 members. The FUTURA house started as a Swiss demonstration project for low-energy, pre-fabricated wooden construction. EMPA had already performed an assessment of this building with OGIP, the Swiss environmental assessment tool, which ensured that sufficient data was available for the exercise. It was however agreed to modify the building slightly, so that it would better fit the purpose of the PRESCO activities. The starting point was an extensive excel sheet prepared by EMPA, describing the material use of the building. Where necessary, this information was adapted to be useful for all WP2 tools or to simplify the calculations (e.g. the veranda was not considered). The figures below show plans of the FUTURA project and the house as built in Switzerland.

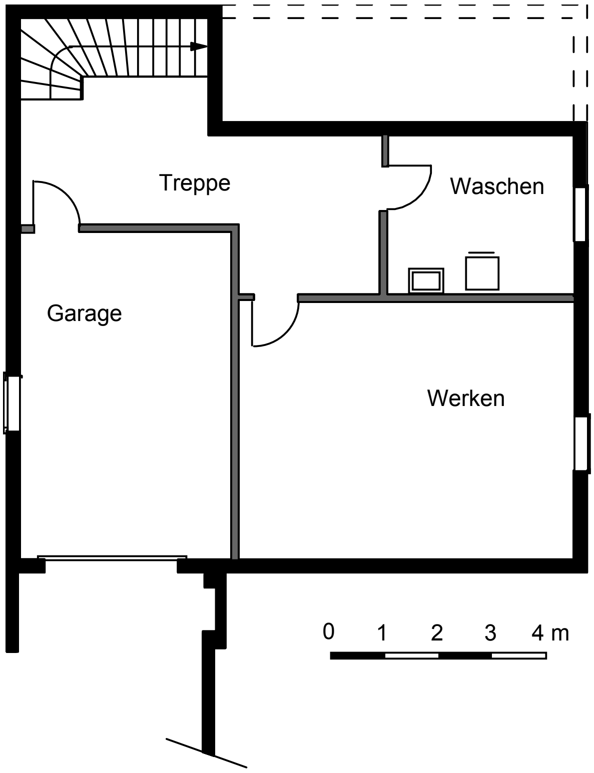



*Figure 26:FUTURA Basement*

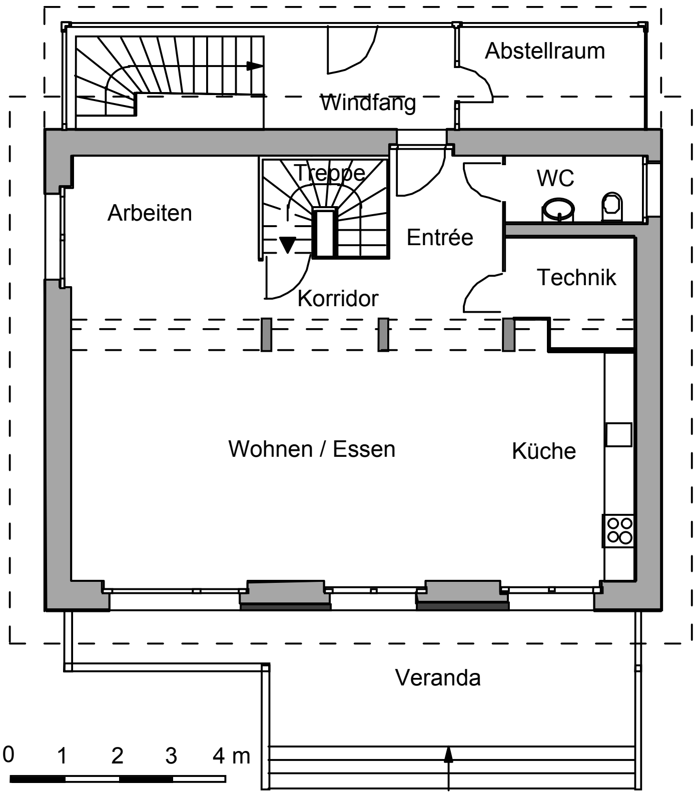



*Figure 27: Ground floor*

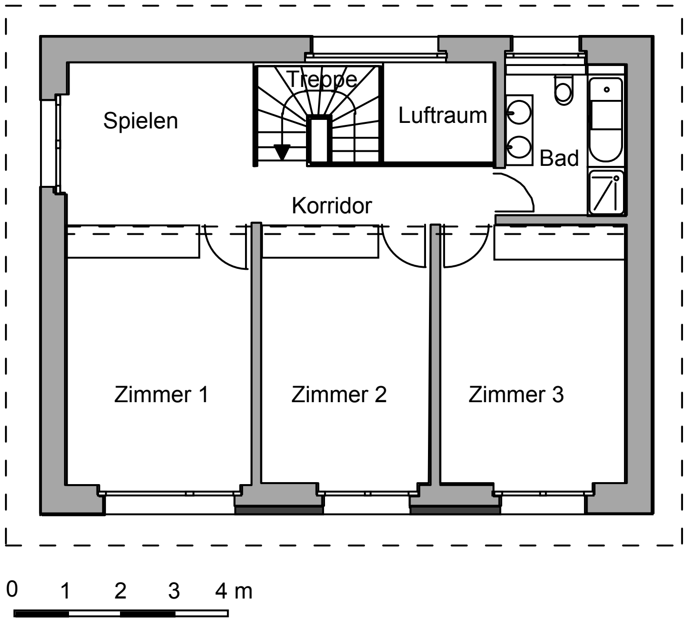



*Figure 28: Upper floor*

*Figure 29: FUTURA House as built*

The FUTURA is originally designed as a low-energy building. For the WP2 assessment, however, values for the energy consumption for space heating, domestic hot water and electricity have been provided to the tool developers.

Three different structural versions of the FUTURA house were studied, i.e. a wooden structure (comparable to ‘as built’ house), a concrete structure and a brick masonry structure. The design of the building was adapted where necessary: the insulation thickness in the brick and concrete alternatives were fixed so that the thermal losses were the same as in the wooden structure.

The tables below summarize the basic input data (materialisation) with regard to the structure for each of the structural alternatives.

| **Element** | **Layer** | $\lambda$ **(W/m*K)** | $\rho$ **(kg/m$^3$)** | **c (Wh/kg*K)** | **Thickness (cm)** |
|---|---|---|---|---|---|
| 1. Basement floor (wood/brick/concrete) | Concrete | 1.280 | 2100 | 0.230 | 20 |
| | Polystyrene high resistance foam board, extruded | 0.029 | 35 | 0.330 | 11 |

| | | | | | |
|---|---|---|---|---|---|
| | Anhydride cast plaster floor | 1.1 | 2200 | 0.28 | 5 |
| 2. Floor above basement (wood/brick/concrete) 0.33 W/m²K (Our overall calculated U: 0.34 W/m²K)) | Reinforced concrete | 1.32 | 2272 | 0.22 | 20 |
| | Polystyrene high resistance foam board, 2 layers | 0.031 | 25 | 0.383 | 7 |
| | Glass wool | 0.041 | 30 | 0.233 | 2 |
| | Anhydride cast plaster floor | 1.1 | 2200 | 0.28 | 5 |
| 3a. Floor above ground floor (wood) | Wooden beam | 0.150 | 500 | 0.333 | 4.4 |
| | Wood particle board | 0.150 | 800 | 0.580 | 2.2 |
| | Polystyrene high resistance foam board, 2 layers | 0.039 | 25 | 0.383 | 7 |
| | Glass wool | 0.041 | 30 | 0.233 | 2 |
| | Anhydride cast plaster floor | 1.1 | 2200 | 0.28 | 5 |
| 3b. Floor above ground floor (brick/concrete) | Reinforced concrete | 1.32 | 2272 | 0.22 | 20 |
| | Rock wool | 0.041 | 30 | 0.256 | 10 |
| | Glass wool | 0.041 | 30 | 0.233 | 2 |
| | Cement | 1.280 | 2100 | 0.230 | 6 |
| 4. External walls below ground (wood/brick/concrete) | Concrete | 1.28 | 2100 | 0.230 | 7 |
| | Bituminous | 0.5 | 1700 | 0.28 | 0.24 |
| | Polystyrene high resistance foam board, extruded | 0.029 | 35 | 0.330 | 10 |
| | Reinforced concrete waterproof | 1.32 | 2272 | 0.22 | 20 |
| 5a. External walls above ground (wood) **0.26 W/m²K** (Our overall calculated U: 0.22 W/m²K) | Larch boards | 0.150 | 800 | 0.580 | 2.1 |
| | Lattice grid | 0.15 | 500 | 0.333 | 0.2 |
| | OSB panels | 0.150 | 800 | 0.28 | 1.5 |
| | Wood studs | 0.230 | 650 | 0.667 | 1.9 |
| | Mineral wool | 0.041 | 30 | 0.233 | 16 |
| | OSB panels | 0.150 | 800 | 0.28 | 1.5 |
| | Gypsum plaster board | 0.420 | 850 | 0.233 | 1.5 |
| 5b. External walls above ground (brick)* **0.27 W/m²K** (Our overall calculated U: 0.22 W/m²K) | Silicate cover coat | 1.13 | 1570 | 0.28 | 1 |
| | Fibrous insulating material | 0.041 | 30 | 0.233 | 17** |
| | Brick | 1.07 | 1700 | 0.220 | 18 |
| | Plaster | 0.350 | 1000 | 0.222 | 0.5 |
| 5c. External walls above ground (concrete)* **0.27 W/m²K** (Our overall calculated U: 0.22 W/m²K) | Silicate cover coat | 1.13 | 1570 | 0.28 | 1 |
| | Fibrous insulating material | 0.041 | 30 | 0.233 | 17** |
| | Concrete | 1.280 | 2100 | 0.230 | 18 |
| | Plaster | 0.350 | 1000 | 0.222 | 0.5 |
| 6a. Flat roof (wood) **0.25 W/m²K** (Our overall calculated U: 0.20 W/m²K)) | Gravel | 0.97 | 1800 | 0.28 | 10 |
| | Bituminous | 0.5 | 1700 | 0.28 | 1 |
| | Particle board | 0.150 | 800 | 0.580 | 2.2 |
| | Wood lattice | 0.150 | 500 | 0.333 | 1.125 |
| | Wood fiber board | 0.150 | 800 | 0.580 | 2.2 |
| | Wood beams | 0.150 | 500 | 0.333 | 3 |
| | Rock wool | 0.041 | 30 | 0.256 | 16 |
| | Wooden boards | 0.150 | 800 | 0.580 | 2.7 |
| 6b. Flat roof (brick/concrete) **0.25 W/m²K** (Our overall calculated U: 21 W/m²K) | Gravel | 0.97 | 1800 | 0.28 | 10 |
| | Bituminous | 0.5 | 1700 | 0.28 | 1 |
| | Rock wool | 0.041 | 30 | 0.256 | 18 |
| | Reinforced concrete | 1.32 | 2272 | 0.22 | 20 |
| 7a. Interior walls (wood) | Gypsum plaster board | 0.420 | 850 | 0.233 | 1.5 |
| | OSB panels | 0.150 | 500 | 0.333 | 1.5 |
| | Rock wool | 0.041 | 30 | 0.256 | 6 |
| | Wood studs | 0.230 | 650 | 0.667 | 10 |
| | OSB panels | 0.150 | 500 | 0.333 | 1.5 |
| | Gypsum plaster board | 0.420 | 850 | 0.233 | 1.5 |
| 7b. Interior walls (brick) | Plaster | 0.350 | 1000 | 0.222 | 1 |
| | Brick | 1.17 | 1700 | 0.220 | 15 |

| | | | | | |
|---|---|---|---|---|---|
| | Plaster | 0.350 | 1000 | 0.222 | 1 |
| 7c. Interior walls (concrete) | Plaster | 0.350 | 1000 | 0.222 | 1 |
| | Concrete | 1.28 | 2100 | 0.220 | 15 |
| | Plaster | 0.350 | 1000 | 0.222 | 1 |

* the external walls composition was inversed in order to have the thermal insulation on outside thus eliminating the thermal bridges problem.
** the insulation thickness in the brick and concrete alternatives is reinforced so that the thermal losses are the same as in the wood structure case.

*Table 1: Summary of input data for FUTURA house - Structure*

| **Element** | **Layer** | **Coef. frame** (W/m²*K) | **Coef. glass** (W/m²*K) | **Glazing solar factor** | **Area** (m²) |
|---|---|---|---|---|---|
| Windows 1.5 W/m²K (85% glass) | Wood double heat protection glass (2 glasses 4 mm, air filled, coated) (15% frame) | 1.7 | 1.46 | 0.75 | (N) 2.4 + (E) 1.7 + (S) 26 + (W) 4 |
| External door 2.6 W/m²K | Insulated door | 2.6 | 0 | 0 | (N) 2 |
| Garage door | Metallic door | 5.8 | 0 | 0 | (S) 5.25 |
| Internal doors | Non-insulated door | 5 | 0 | 0 | 10*1.6 |

*Table 2: Summary of input data for FUTURA house – doors & windows*

A detailed presentation of the results of the assessment of the three alternatives of the FUTURA project can be found in section 3.2.

## 2.3. FUTURA + Recommendations

The last part of the comparison exercise within PRESCO WP2 was aimed at investigating the influence of applying a number of recommendations from the database which has been developed in PRESCO WP1.

The starting point for applying the recommendations was the concrete structure alternative of the FUTURA house, because this offered most possibilities for applying recommendations. In total, seven recommendations were selected for this phase in the comparison exercise. They were applied one by one on the FUTURA project, and each time an assessment was made to verify the change in the resulting environmental impact. The complete results of these assessments can be found in Section 3.3.

The selected recommendations were:

1. Use environmental declarations on building products as an information source
2. Use locally sourced materials, including materials salvaged on site
3. Use renewable energy
4. Use renewable resource based materials
5. Choose an appropriate glazing type
6. Install a system for the use of rainwater and/or grey water in the building
7. Apply (drinking) water saving measures and use water saving appliances.

# 3. Results

In a first step, the results of the tools were compared in the case of a very simple "cube" and the main hypotheses were listed and analysed. In a second phase a single family house with a rather simple geometry was assessed, considering three structures. The results concerning the application of recommendations on sustainable constructions, which were elaborated in WP1of the PRESCO network, are presented in the third section.

The contribution to global warming, expressed as $CO_2$ equivalent emissions, is the most widely spread indicator among the group, and corresponds to an important issue of concern. This indicator has therefore been used to compare the tools, even if each tool evaluates also other indicators.

## *3.1. CUBE*

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 analysis addressed 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,…), the data (LCI of the concrete and electricity production, waste treatment, transport) and the results (impact indicators).

We present first a few examples of the greenhouse gases emissions obtained by the tools using life cycle inventory data concerning materials or processes.

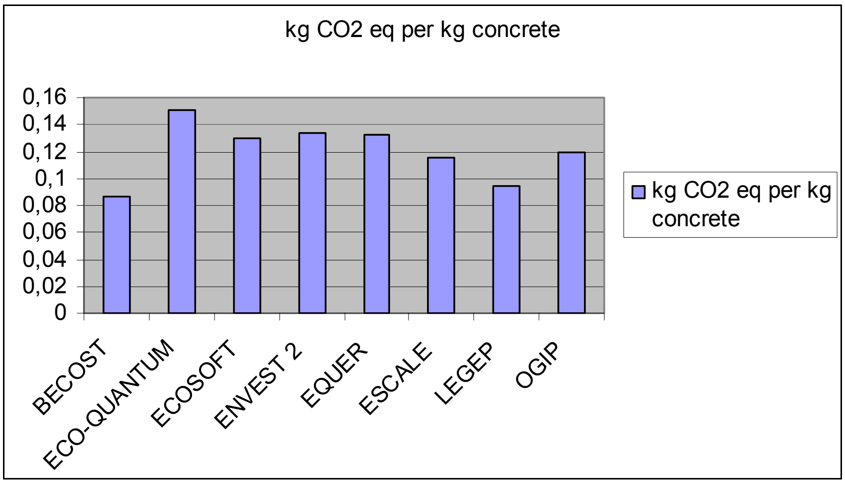



*Figure 30: Material data, contribution to global warming by the production of 1 kg concrete*

The different results concerning 'concrete' between the tools may be caused by:
- different cement content in the concrete
- different density of the concrete
- different production processes (national or European data bases)
- different global warming potential indicators (IPCC[3], CML[4]…)

[3] Scientific assessment working group of IPCC, Radiative forcing of climate change, World meteorological organization and United nations environment programme, 1994, 28p
[4] R. Heijungs, Environmental life cycle assessment of products, Centre of environmental science (CML), Leiden, 1992.

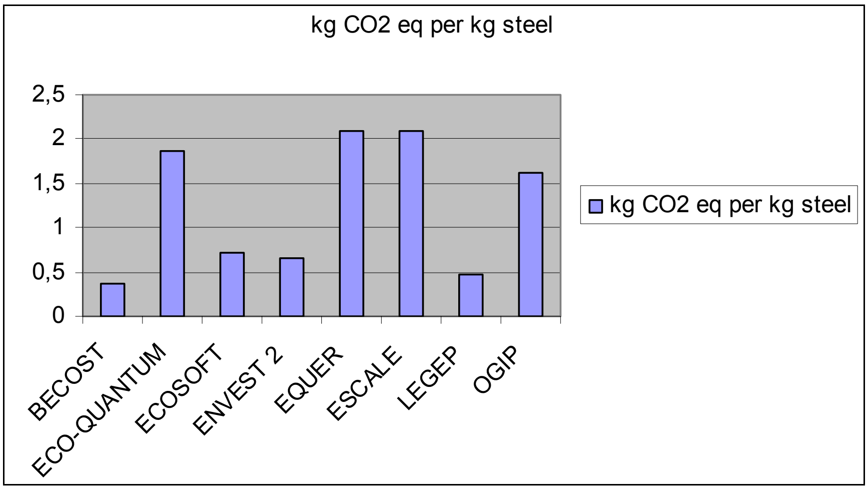



*Figure 31: Material data, contribution to global warming by the production of 1 kg steel*

Different percentages of recycled steel and different fabrication processes (e.g. blast furnace or electric arc furnace) may explain the large discrepancy between the tools in the results concerning ‘steel’. Even tools using the same LCI database may provide different values, because the database proposes different types of steel with different assumptions concerning the use of recycled steel.

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 used for the assessment, which partly explains the differing results. If we exclude BeCost from the comparison (the national Finnish electricity mix being very far from the European mix which was considered by the others), the overall discrepancy is +/- 10%.

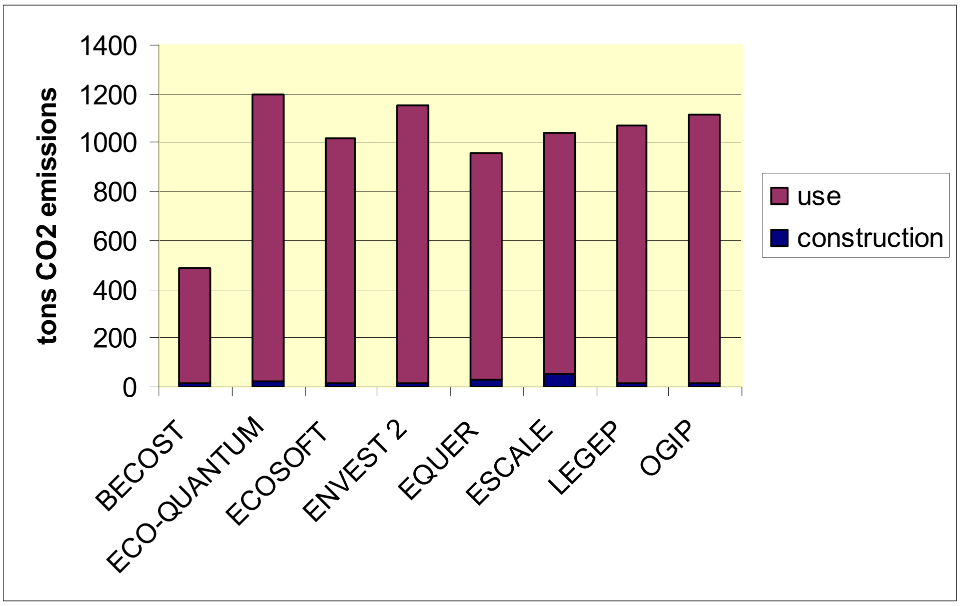



*Figure 32: building life cycle, contribution of the cube to global warming over 50 years*

The graph hereunder shows which data has been used in the different tools regarding the impacts of electricity production and distribution.

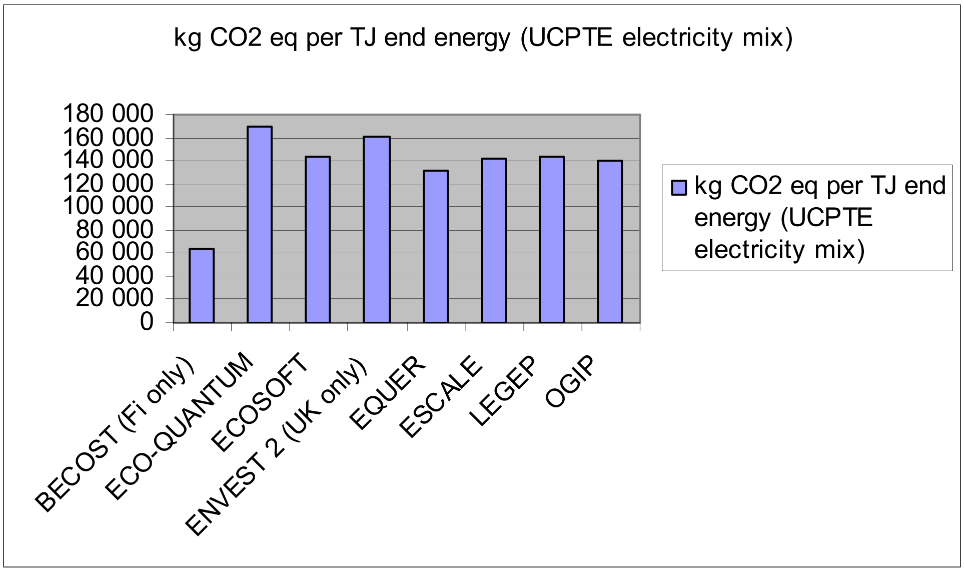



*Figure 33: Process data, contribution to global warming of providing 1 TJ electricity*

This graph confirms that the differences in the electricity production and distribution are a major cause for discrepancy. Some assumptions regarding the losses in the electricity grid also influence the results. Other causes for the discrepancy of the overall life cycle results of the cube are:

- different quantities of materials used (exact calculation or value derived from simplified geometric input),
- different material surpluses or wastes used during construction (from 0 to 10%),
- different steel content in the reinforced concrete (from 0.83 to 3%),
- different assumption concerning the use of recycled steel,
- different transport distances used (construction : from 0 to 50 km and end of life : from 0 to 20 km),
- different life spans of building components used
- different end of life processes included
- different global warming potential indicators (IPCC[5], CML[6]…) offered.

More information about the assumptions and the results are given in annex 1.

## 3.2. FUTURA

The 3 next case studies correspond to a low energy building in Switzerland, the FUTURA prefabricated house  Three alternatives were considered: a wooden, brick and concrete structure.

In a first step, the greenhouse gases emissions related to materials production and gas heating have been compared. This indicator has been selected because it is the only common indicator between all tools (except OGIP). It is expressed as a weight of equivalent $CO_2$ emission (kg). The results are illustrated by the following graphs.

[5] Scientific assessment working group of IPCC, Radiative forcing of climate change, World meteorological organization and United nations environment programme, 1994, 28p
[6] R. Heijungs, Environmental life cycle assessment of products, Centre of environmental science (CML), Leiden, 1992.

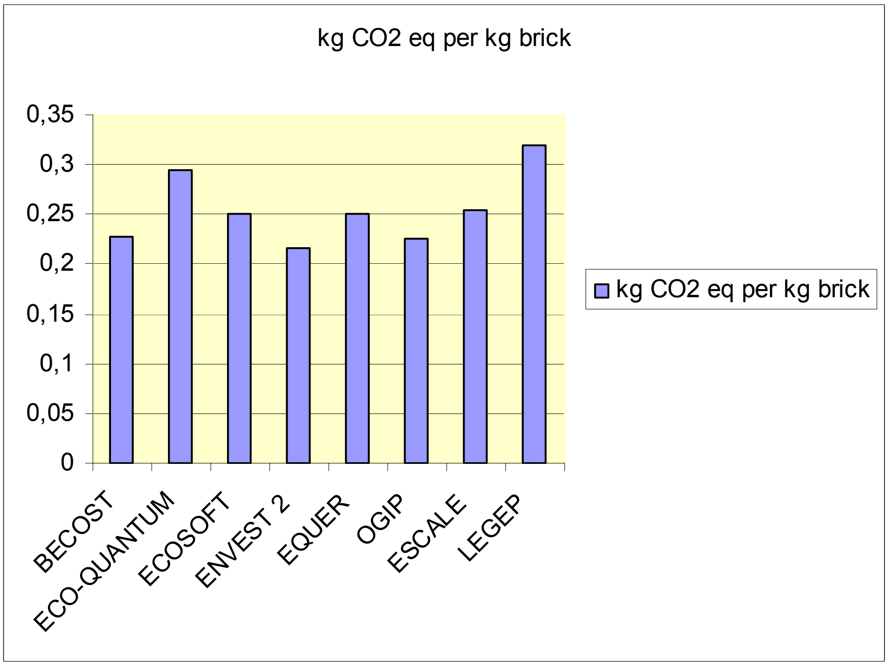



*Figure 34: Material data, contribution to global warming of producing 1 kg brick*

In the case of the wooden structure, some tools consider a $CO_2$ capture in the growth phase (because $CO_2$ is absorbed in the forest by photosynthesis) and a $CO_2$ and methane release at the end of the life cycle. Other methods take the neutrality as a starting point and therefore do not account for biogenic $CO_2$. The total $CO_2$ balance for the whole life cycle should be the same, however:

- the carbon stored in the wooden structure during the building life span is not in the atmosphere, and this contributes to protect the climate
- several processes may occur at the end of life : the wooden elements may be land filled, incinerated with or without heat recovery, re-used etc. The choice between these options has consequences on the $CO_2$ balance (e.g. recovering energy from incineration avoids the use of fossil fuels)
- problems can arise when an assessment is made without taking into account the disposal phase, which would not correspond to a complete LCA

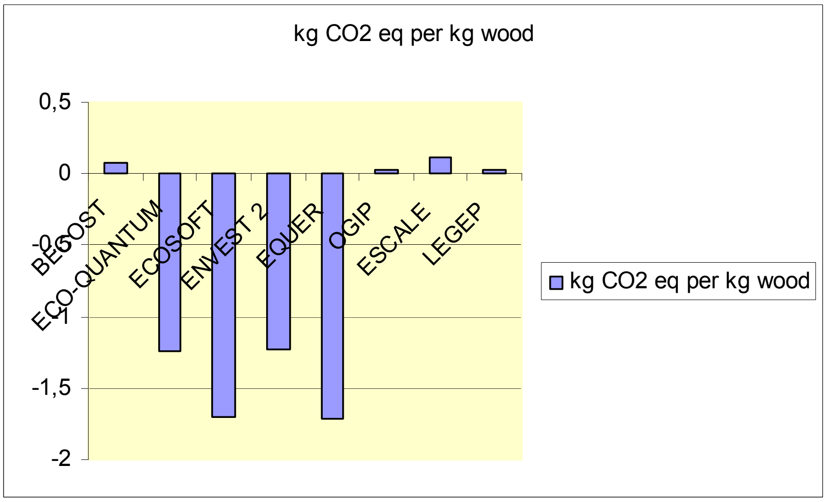



*Figure 35: Material data, contribution to global warming of producing 1 kg timber wood*

Even among tools using the same LCI database, the methodology considered to account for biogenic $CO_2$ can differ (e.g. ECOSOFT and EQUER account for $CO_2$ capture, OGIP and LEGEP do not).

Another discrepancy between the tools concerns the feedstock energy of wood as a material, which is included in some tools and not in others. Some tool developers consider that wood can be regarded as energy source and include its heating value in the energy mobilized to provide this material in a building. For others, the wood used for timber would not be used as a fuel so that its heating value is not included.

The following graph shows the impact of the gas energy used for space heating, and complements the data on electricity production presented in the previous section.

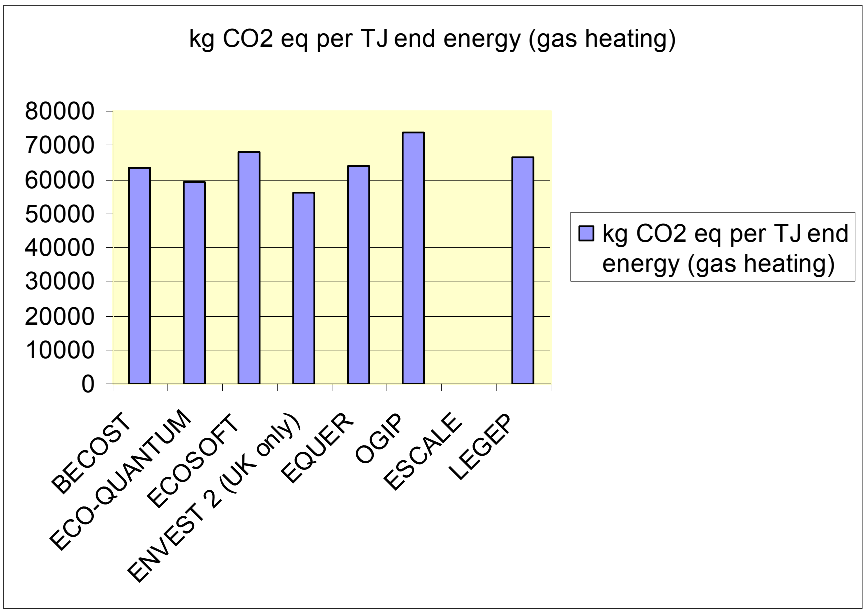



*Figure 36: Process data, contribution to global warming of providing 1 TJ gas heating*

Several causes may explain the differences:

- considering different boiler types (condensing/standard, low NOx, < or > 100 kW…)
- using different boiler efficiencies (space heating and domestic hot water)
- assuming different upstream processes (gas extraction , transport, distribution…)
- using different functional units - useful or end energy (i.e. related to heating load or heating consumption)

For the whole life cycle of the house, the results are similar to the results of the cube. The scattering is +/- 10% of the mean value between the tools (see Table 3 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% |

*Table 3: Discrepancy of results for the FUTURA house*

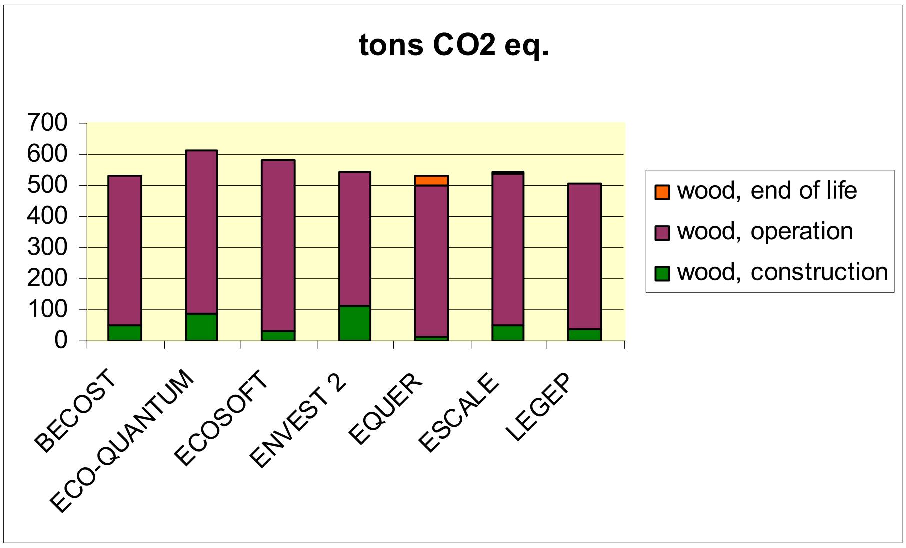



*Figure 37: : building life cycle, contribution to global warming of the wooden FUTURA house over 80 years*

Concerning the comparison between wood, brick and concrete structures, the global warming indicator is lower for wood in all tools except ENVEST. But the results differ when comparing brick and concrete, see Figure 38 below: brick leads to higher emissions according to 4 tools, whereas the 3 others provide an opposite result, the difference between brick and concrete being small in all tools.

An overall view of the CO2-Eq. emissions shows for all tools a domination of the operation phase. The emissions during this phase are very similar for the three alternatives, so only the case of wood is included in the figure. In most tools the same heating load has been considered for the three alternatives. EQUER being linked to a thermal simulation tool, the effect of thermal mass is accounted for, so that the heating load is slightly lower in the case of masonry structures (because the storage of solar gains is more efficient).

In the case biogenic $CO_2$ emissions (related to the wooden components) are included, some tools account for the release of greenhouse gases at the end of life. Therefore the demolition phase is also presented in the graph for the wooden alternative.

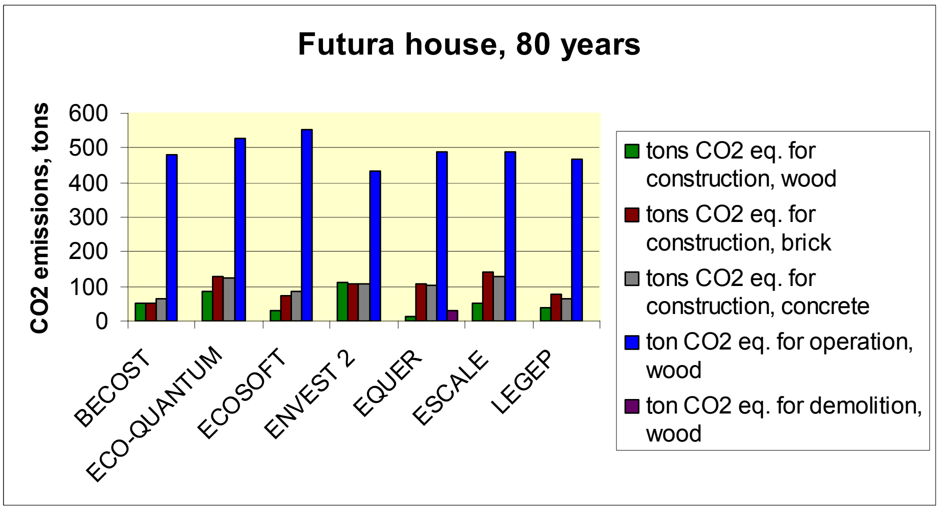



*Figure 38: building life cycle, comparison of wood, brick and concrete alternatives*

The indicator used for the discussion of the assessment results for the CUBE and the FUTURA house is related to global warming and expressed in kg $CO_2$-equivalent. Other indicators used in the tools are differing. The tools may address acidification, smog, waste (possibly indicating also radioactive waste), primary energy consumption, water consumption, exhaust of resources, eutrophication, ozone depletion, toxicity, eco-toxicity, cost, and some use also global indicators like eco-points or eco-scarcity. Therefore it is difficult to compare the multi-criteria ranking of the three alternatives considered (wood, brick and concrete). The following graphs present these results, for the whole life cycle in a first part, then for all phases except operation (which is similar for the three alternatives compared).

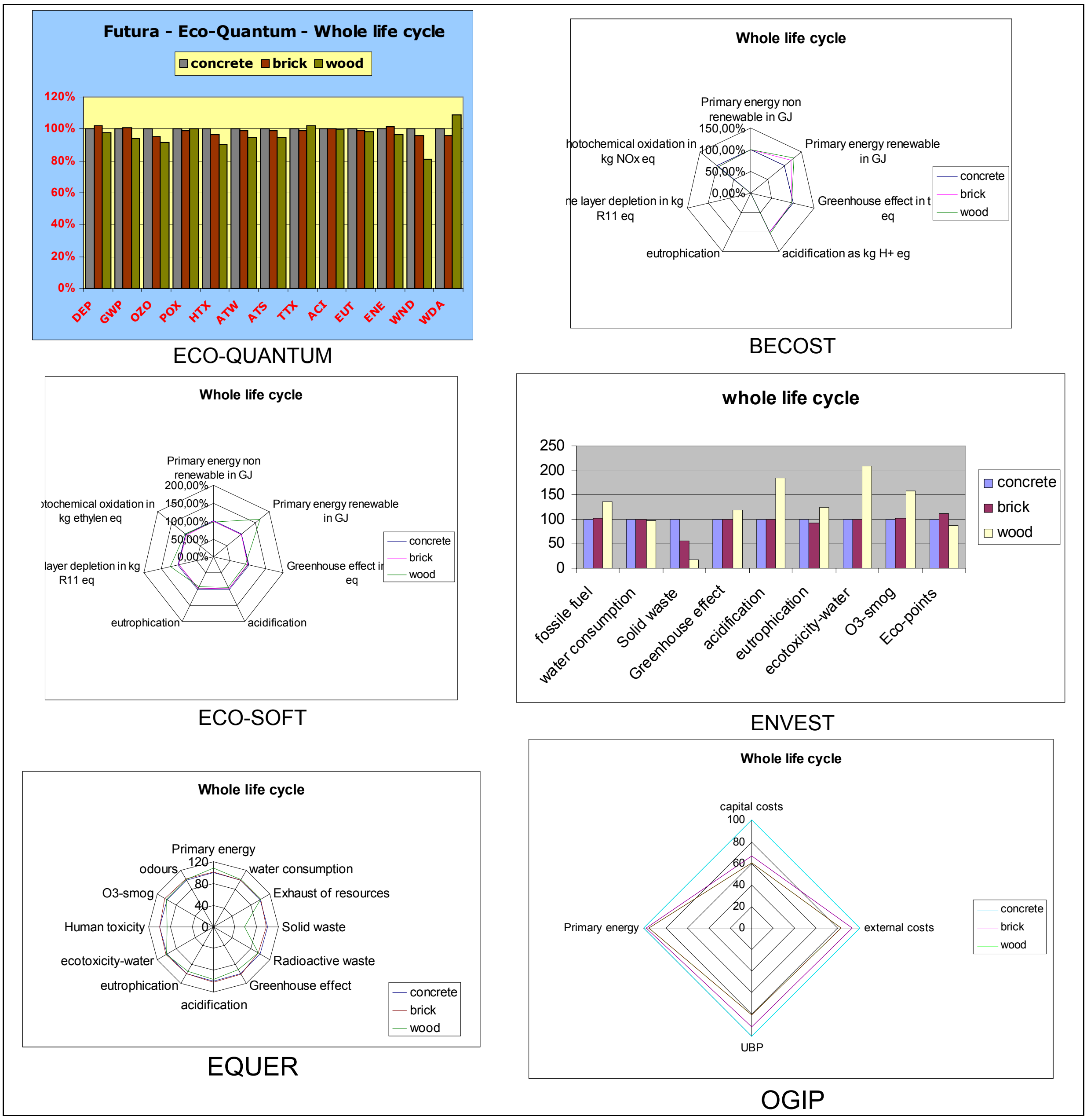



*Figure 39: Results of the different tools for the three alternatives (wood, brick and concrete structure) over the whole life cycle*

The impacts related to the operation phase are similar for the three alternatives, because the heating load for the different alternatives is almost the same. Therefore, it is interesting to compare the impacts for the rest of the life cycle (except operation), in order to increase the sensitivity of the results.

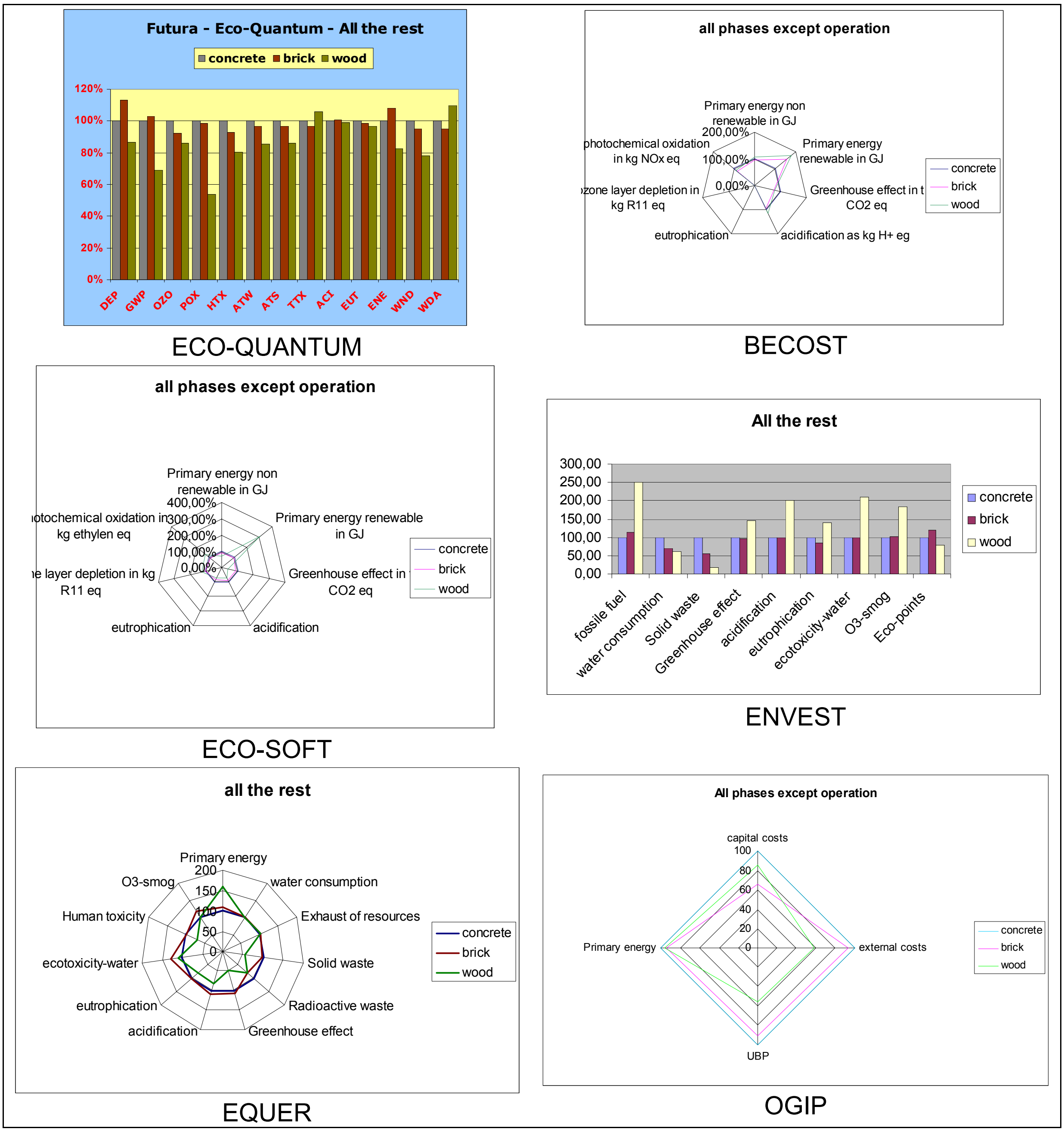



*Figure 40: Comparison of the three alternatives (wood, brick and concrete structure), all phases except operation*

These results illustrate the need of a careful interpretation of the LCA results: a multi-criteria approach is needed. A discussion is generally organised with the decision makers about possible priorities among the environmental issues of concern addressed by the tools. Aspects which are not integrated in LCA may of course play an important role in the choice of materials, e.g. choosing a material with a high thermal mass in order to improve thermal comfort.

More detailed results on these 3 cases are included in annex 2.

## 3.3. FUTURA + Recommendations

The last case study corresponds to the same house, but considering alternative designs which were derived by applying recommendations elaborated within the PRESCO network in WP1. Environmental quality is only a part of sustainability, therefore the LCA tools can deal with only a part of the PRESCO recommendations. The following recommendations were selected:

- Rec. n°134: Use renewable resource based materials.
- Rec. n°107: Use renewable resource.
- Rec. n°305: Choose an appropriate glazing type.
- Rec. n° 12 : Use environmental declarations on building products as an information source.
- Rec. n° 325: Use water saving appliances.
- Rec. n° 324: Install a system for the use of rainwater and/or greywater in the building.
- Rec. n° 77: Use locally sourced materials, including materials salvaged on site.

Each tool developer has selected a set of 3 to 5 recommendations (cfr. the following table). The indicators have been compared in the case of the concrete FUTURA house, with and without applying each recommendation.

Some recommendations have implications on the operation phase (e.g. choice of the glazing, using renewable energies) and others do not. If there is no implication (Rec. n°12 and 134), the operation phase has not been included in order to increase the sensitivity of the results and to make a comparison easier.

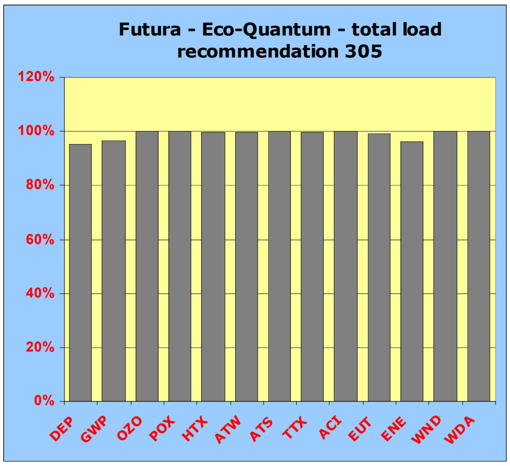
| Recommendation | Envest | Eco-quantum | Ecosoft | Ogip | Escale | Sima pro | Becost | Equer |
|---|---|---|---|---|---|---|---|---|
| 305 | x | x | x | x | x | x | x | x |
| 12 (except operation) | x | | x | | x (reverse) | | | |
| 325 | x | x | | | x | | | x |
| 77 | | | | | | x | | x |
| 324 | x | x | | | | | | |
| 134 (except operation) | x | x | x | x | x | x | x | x |
| 107 | | x | x | x | | | x | x |

*Table 4: Recommendations applied by the tools*

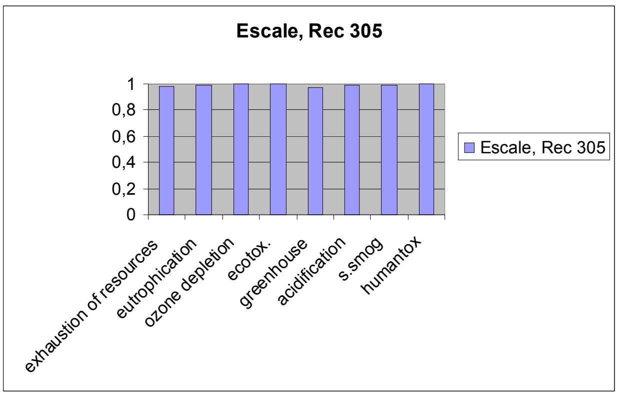
All tools have obtained reduced impacts when applying recommendations n°305 (selecting appropriate glazing, i.e. triple glazing in the considered case), n°325 (water saving), n°77 (reducing material transport) and n°107 (using renewable energy, solar domestic hot water).

**Recommendation 305 (select appropriate glazing)**

Replacing the initial double glazing by triple glazing reduces by 11 to 13% the heating load of the building, and lead to the following reduction of the assessed environmental impacts.




ECO-QUANTUM




ESCALE

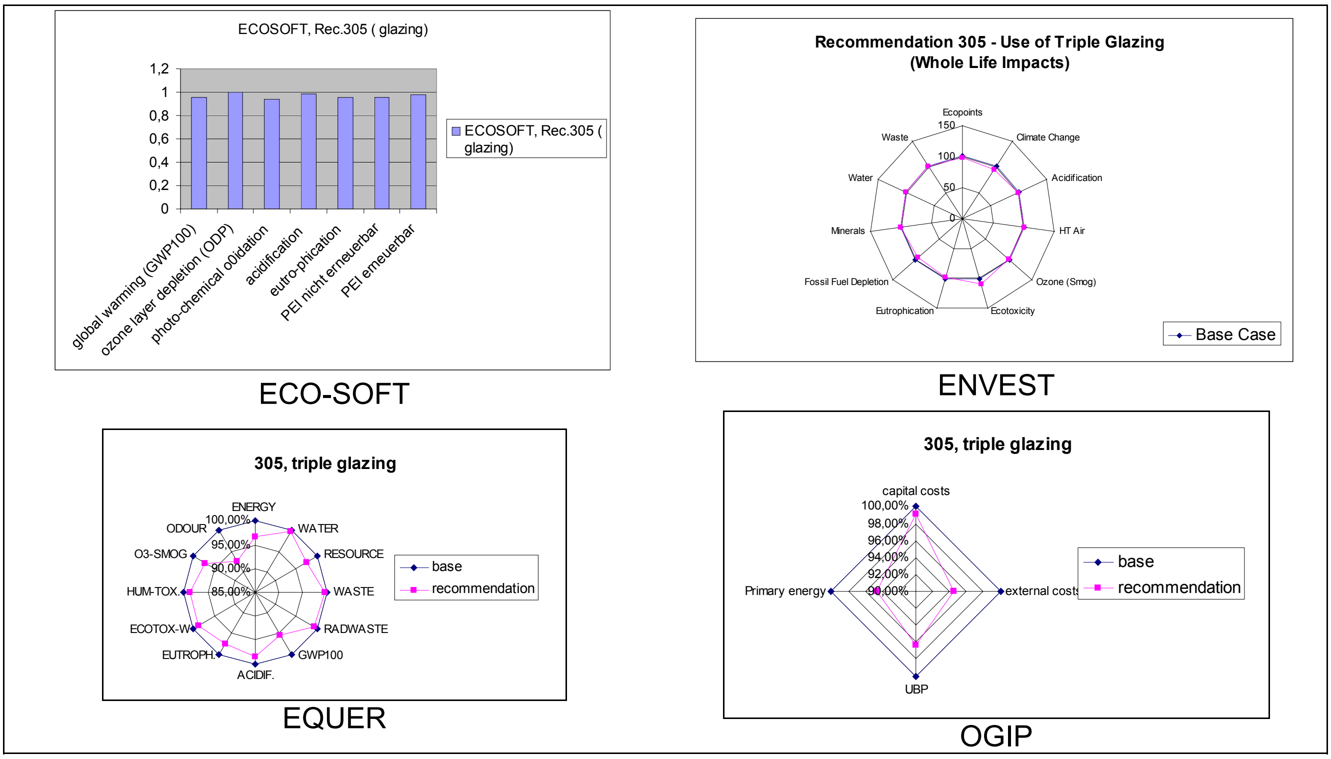
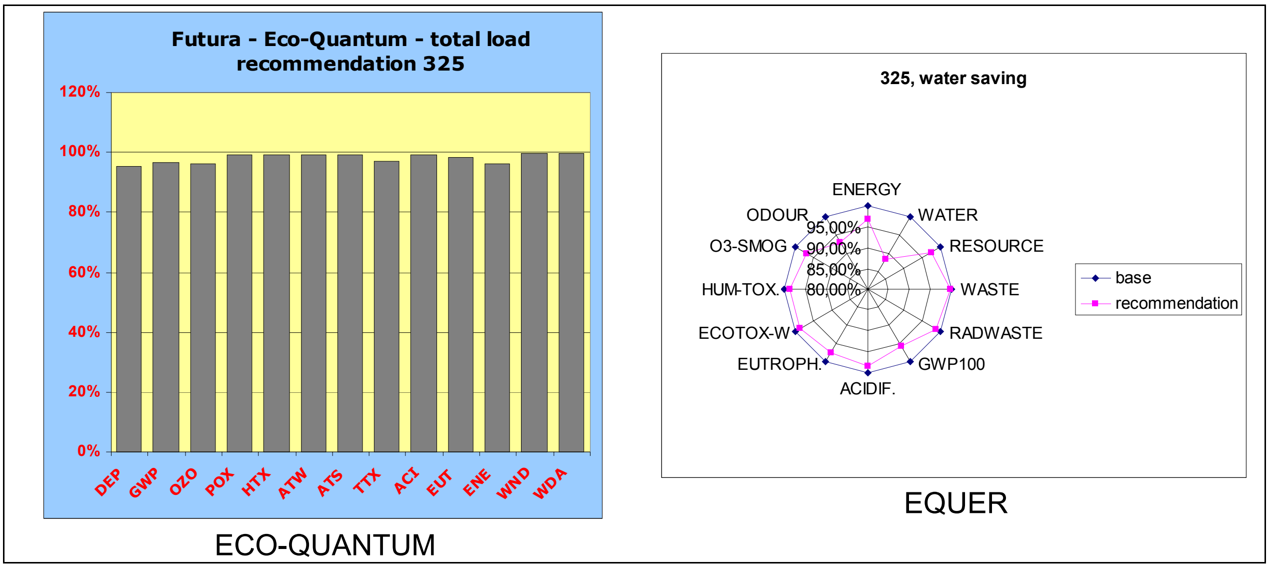



*Figure 41: Change of environmental impact after application of recommendation 305*

## Recommendation 325 (save water)

The use of water saving appliances leads to reduction of environmental impacts in all cases.



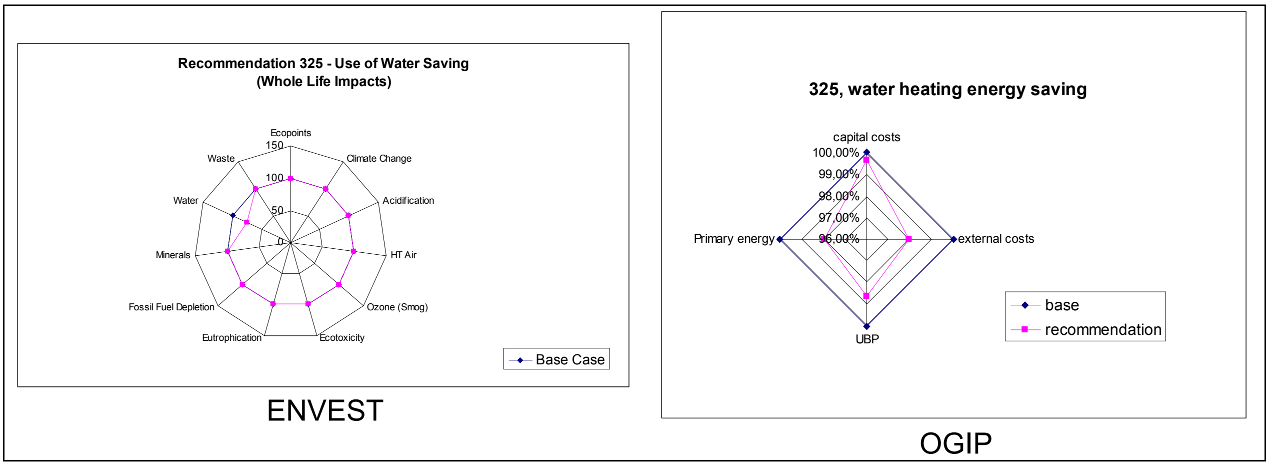



*Figure 42: Change of environmental impact after application of recommendation 325*

## Recommendation 77 (reduce material transport)

Only one tool (EQUER) applied this recommendation, replacing the transport distance of 50 km by 5 km or increasing it to 1,000 km. The result is the following.

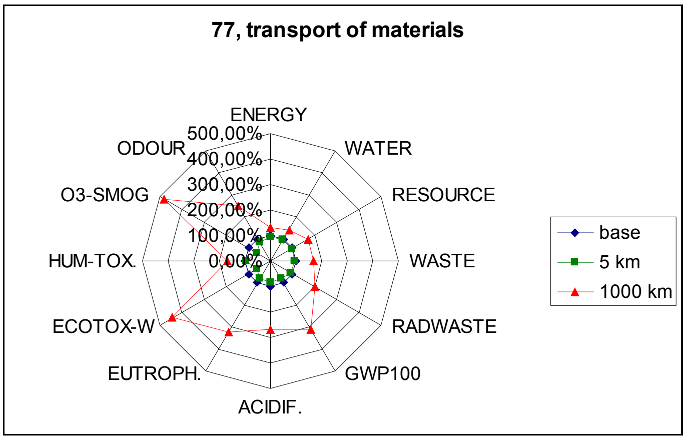



*Figure 43: Change of environmental impact after application of recommendation 77*

## Recommendation 107 (use renewable energies, solar water heating)

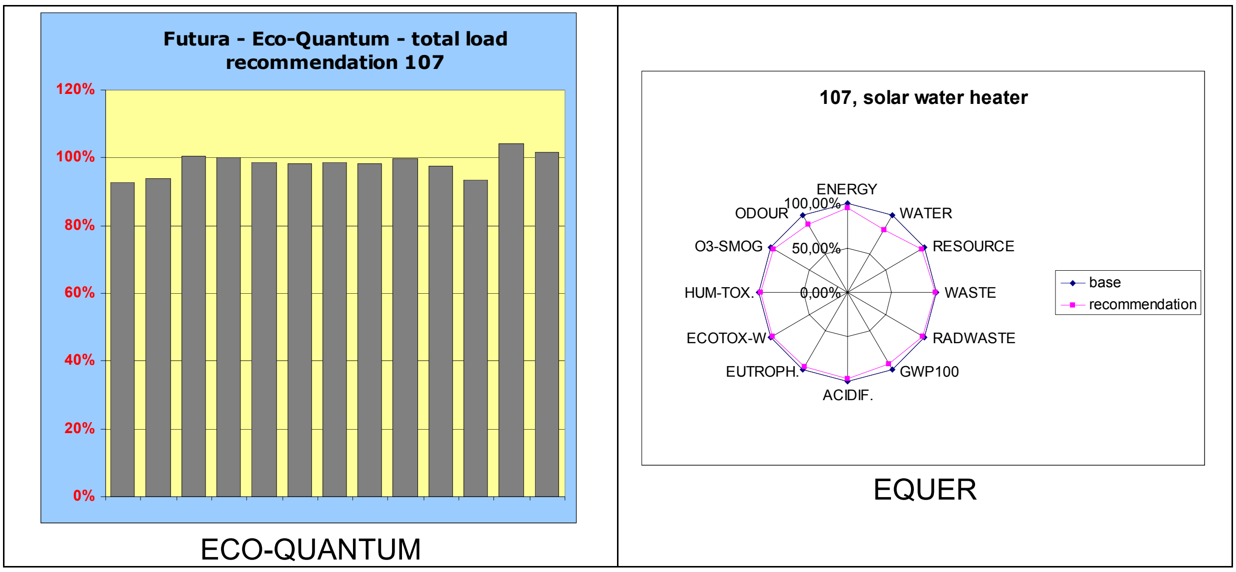
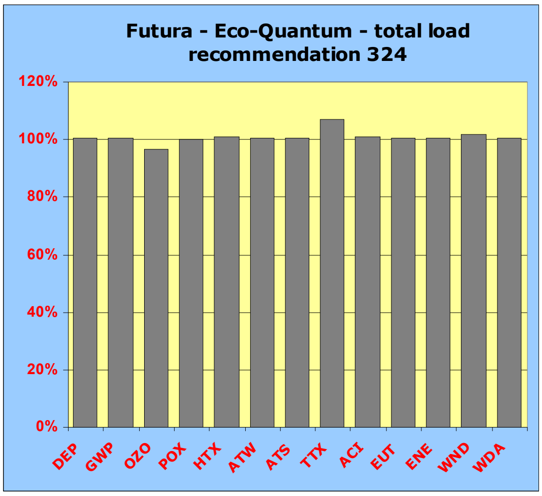


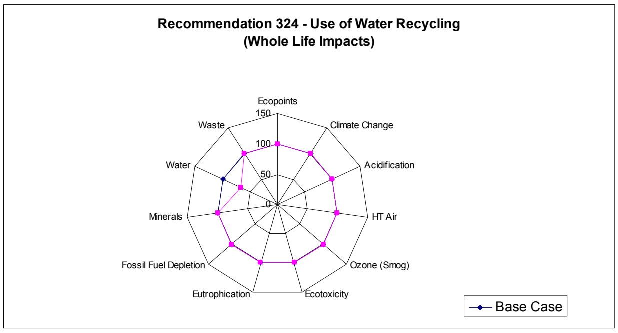

*Figure 44: Change of environmental impact after application of recommendation 107 (solar water heating)*

## Recommendation 324 (use rain water)

The results for the application of this recommendation are more contrasted because some impacts increase due to the additional installation of technical equipment.




ECO-QUANTUM

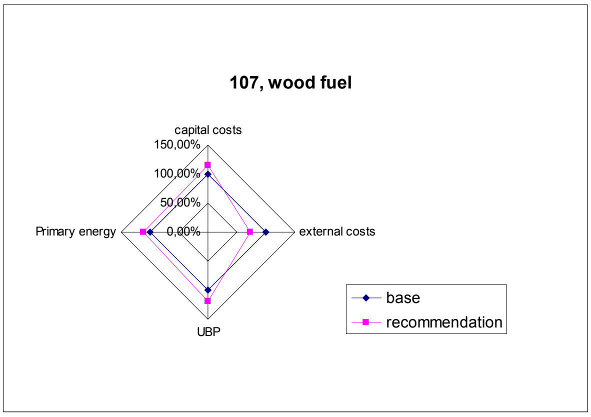



ENVEST

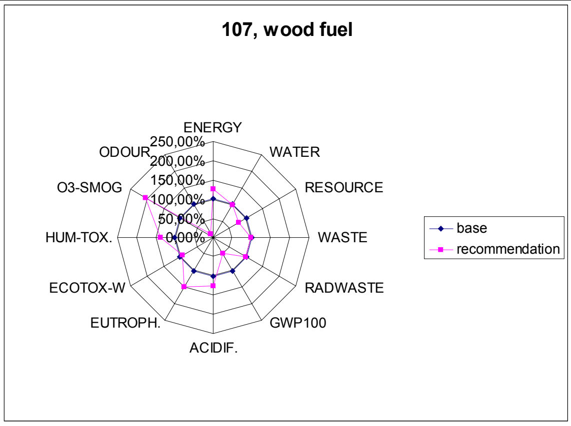
*Figure 45: Change of environmental impact after application of recommendation 324*

## Recommendation 107 (use renewable energies, wood fuel)

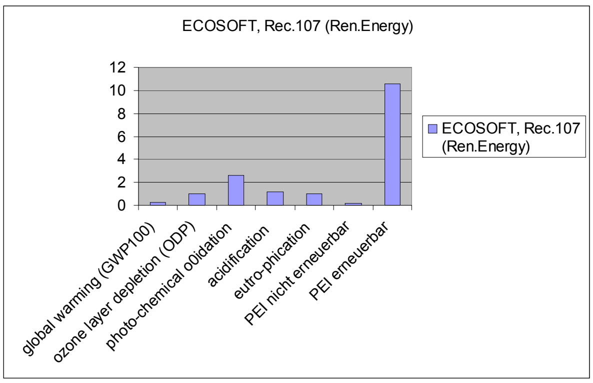
Not all impacts are reduced because pollutants are emitted during the combustion.




OGIP




EQUER

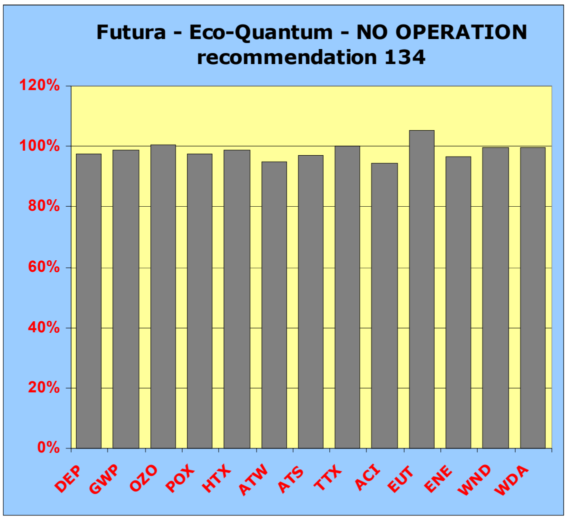



ECO-SOFT (including also solar water heating)

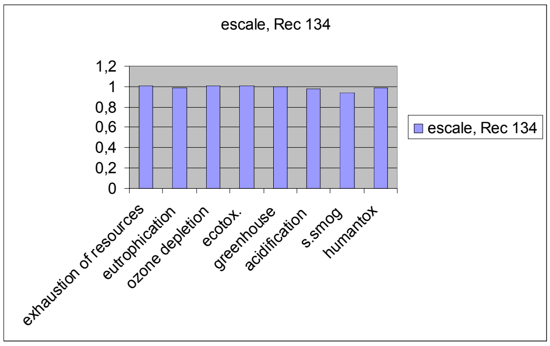
*Figure 46 : Change of environmental impact after application of recommendation 107 (wood fuel)*

## Recommendation 134 (use renewable materials)

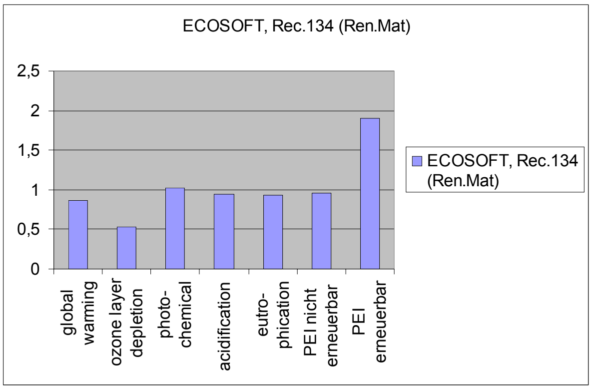
The use of renewable materials leads in general to reduced impacts except the feedstock energy indicator (if renewable energy is included), but there are some exceptions (cfr. ENVEST results).



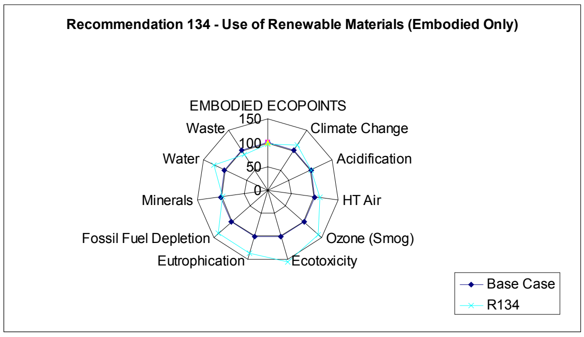

ECO-QUANTUM (mineral wool -> cellulose)



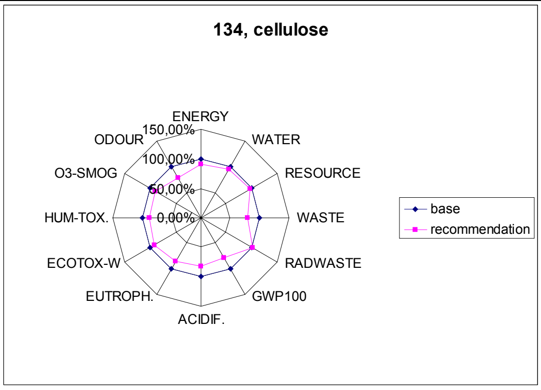

ESCALE (mineral wool -> cellulose)




ECO-SOFT (mineral wool -> cellulose)




ENVEST (concrete -> wood)




EQUER (mineral wool -> cellulose)

*Figure 47: Change of environmental impact after application of recommendation 107*

## Recommendation 12 (use materials with environmental declaration)

Only one tool (ENVEST) applied this recommendation, replacing rock wool by polyurethane. The results are the following.

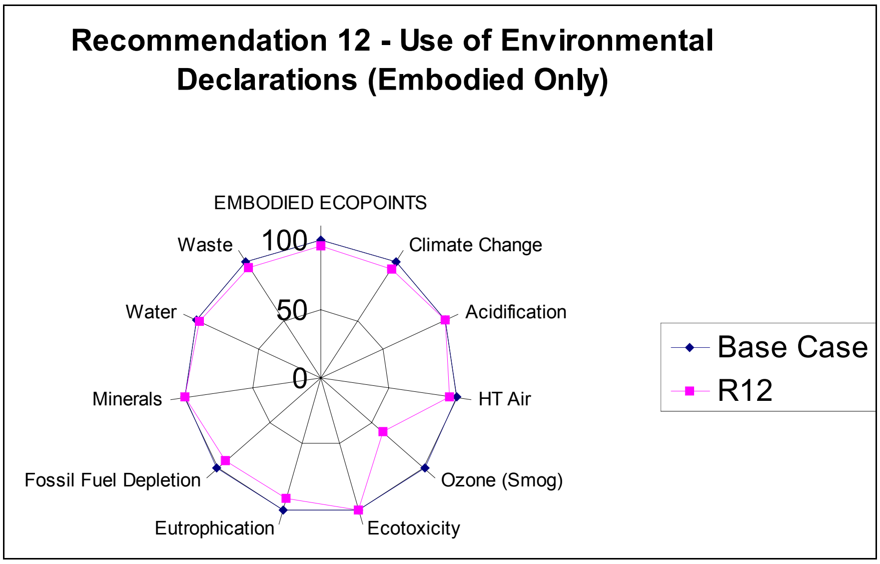



*Figure 48: Change of environmental impact after application of recommendation 107*

In general, all tools show in good agreement that each recommendation individually has a limited influence on the global life cycle indicators. To improve the environmental quality of a project in a significant way, eco-design should include several aspects together.

One of the tool developers stated that the sensitivity of the tools when applying each recommendation is lower than the uncertainty. This is true if the comparison is made against the uncertainty on the absolute value. But the uncertainty on relative values is much smaller. For instance the $CO_2$ emissions over the whole life cycle are differing by +/- 10%. But the relative impact when applying recommendation n°305 for instance varies between 95% and 98% of the base case impact, i.e. 96% +/- 2% : the discrepancy on the relative figure is 5 times lower than on the absolute figure. In this case, the difference with versus without the recommendation is 4% which is twice the uncertainty on the relative impact, and can be considered significant.

More detailed results are published in annex 3.

# 4. Discussions about the harmonisation of LCA tools

During the analysis of the results presented in the previous chapters, the assumptions and methods implemented in the different tools have been compared. This comparison has also addressed the input and output of the tools. Possibilities for harmonisation have been studied. The group has agreed on some proposals whereas there was no consensus on others. This chapter presents the state of this discussion.

## *4.1. Scope and system boundaries*

The main objective for performing a life cycle assessment of a building is to help the designers to reduce the environmental impacts related to this building over its life cycle. Therefore the building related LCA-based tools have been developed mainly as design tools. But they can also be used for other purposes, e.g. to choose a building site by comparing several possibilities, or to advise the users (inhabitants in a residential building, persons working in an office building etc.) on the management of a building.

The functional unit considered by the tools is the entire building over a certain time period (e.g. 80 years). The function of the building is indicated (e.g. residential, office) as well as the quality of this function (e.g. office building heated at 20°C during working hours and 16°C the rest of the time, with also possible cooling set points). Other comfort issues (lighting, noise protection, ventilation…) can be specified in the functional unit.

The system boundaries can be defined according to the objective of the assessment: if the objective is to choose a building site, the transport of persons should be included because it often has a considerable influence on the environmental impacts. Some other aspects may also be important (e.g. the solar access may be different in the compared sites, as well as the waste treatment processes). On the other hand if the objective of the LCA study is to help designing a building for a specific site, these aspects may have less importance.

Except in very particular cases, energy issues should be included in the studies: energy is needed for heating, domestic hot water, lighting and appliances, ventilation, possibly cooling. Upstream processes (production and distribution of gas, electricity, fuel…) should be accounted for. The design of a building has a large influence on its heating and lighting load. Linking energy and LCA makes the comparison of alternative designs more convenient. Different energy calculation methods are used throughout Europe. Dynamic simulation is more precise to evaluate space heating loads in low energy buildings, and cooling loads.

Water related impacts (impacts of drinking water production and sewage) are less influenced by the building design. Nevertheless features like low-consumption sanitary equipment and composting toilets may be taken into account in a building LCA. This is why this aspect is also addressed in some of the tools.

A larger kitchen and some space to store collected waste in a building may influence the sorting efficiency and the resulting impacts of waste treatment, but this is difficult to assess. Integrating a waste sorting scenario in a tool may be useful to evaluate the importance of such issues, but in general the municipal policy has more influence on these aspects than building design. Therefore operational waste is not included in most tools.

The question whether or not to include transport issues is rather similar: the existence of a bicycle garage may lead to reduce the use of cars. Again, this is difficult to assess and depends on the behaviour scenarios of the inhabitants which are assumed in the design phase. On the other hand this question can be more easily studied in an existing building if the purpose of the LCA is to study a renovation project.

Extending the system boundaries allows more possibilities of using the tools. On the other hand, including more aspects in a LCA reduces the sensitivity of the results to design choices. For instance replacing one material by another may lead to 4% difference in the result if only materials and energy are accounted for, but only 2% if water, waste and transport are also included. In the second case the choice of this material could be considered as having a negligible effect. This question is related to the interpretation of the results, and will therefore be addressed in a further paragraph.

Regarding cut off rules, some participants have proposed that:

- all input and output materials which constitute more than 2% mass of the end product must be included independently of their environmental effects
- if some effects can be proved also materials with less than 2% mass must be taken into account

Other partners account only for materials having a significant influence.

## *4.2. Data input*

A building is a complex object, including many different components (rooms, walls, materials, windows etc.). Besides an exact description of the geometry, all the different materials used in these components must be linked to corresponding LCI data. This chapter describes some recommendations concerning the data describing the building and its connection to the LCI data.

The detailed description of all the components of a building can be very time consuming if no user friendly interface is proposed. A graphic geometry input is in general more convenient, but may be less precise (e.g. wall may be defined by their internal or external area, and the derived quantity of materials can therefore be under or over-estimated).

Users have less difficulty if they use software more frequently; otherwise they often forget how to use a tool. Therefore it is advised either to develop one tool for all types of buildings (residential, offices, etc.) or to develop modules with a consistent interface (e.g. same way to input wall compositions etc.).

A user interface is in general the result of a compromise between precision and simplicity: more precision often requires more data, making the input more time consuming. The use of default values is in most cases a relevant solution. For instance in the early phase of a project, the designers do not know where building materials will be produced. Default values can therefore be considered, e.g. 50 km transport distance by truck. In a later phase of the design, it could be interesting a distinguish between e.g. locally produced concrete and other components like windows being produced far away from the building site. Also, it could be interesting to compare a locally produced material and an imported one. In such cases, the default values will have to be replaced by specific ones. The data is similar concerning the end of life transport of materials.

Default values may also be used for the life span of materials, and for the amount of construction waste: for instance at the end of the day some concrete is remaining and constitutes waste, some components can be broken (e.g. bricks) or a surplus can remain (e.g. insulation, tiles etc.). This means that a supplementary quantity of materials has to be produced, transported and disposed (e.g. land-filled, incinerated…). Default values may also be used for low impact building processes (e.g. construction, maintenance, dismantling).

Default values may be proposed for the electricity mix, but it may be useful to allow changes so that different electricity types from different producers may be compared (e.g. green electricity is proposed in some countries). If the user can choose between various energy sources for space heating and hot water, this will allow alternative energy sources to be compared (e.g. gas, fuel, electricity, wood, district heating including energy recovery from waste incineration or geothermal source, etc.). This possibility is particularly useful for low impact buildings. The possibility to provide part of this energy by a solar system (e.g. solar water heater, photovoltaic system) is also useful, but accounting for these alternative techniques requires appropriate data (which exist in some databases).

Walls, floors and ceilings can be described using pre-defined “building elements” (e.g. a set of materials with pre-defined quantities), which are linked to certain life cycle inventory data. Alternatively, the user can define a specific building element “manually”, e.g. defining a wall composition by giving a list of materials and thickness. The impacts related to the construction and disposal of such elements are then estimated by adding the impacts related to the included materials, neglecting assembling related impacts. It may be less precise but gives more possibilities to the user for customizing these elements.

LCA-based building assessment tools are usually connected to life cycle inventory databases, which relate either to regional, national, European or world contexts. Therefore it is essential to provide the users with as transparent data as possible. In general, it is advised to use the most recent and specific data, with the following remarks:

- the methodology for collecting this data should be consistent, it would not be relevant to compare two materials using different system boundaries, assumptions etc.
- some generic data can be used for an assessment at the beginning of the design phase (e.g. European brick, corresponding to a representative sample of European producers) and replaced by specific data (when available) in a later phase (e.g. data for a specific local brick producer)

End of life processes must be included in an LCA. Therefore certain disposal LCI-data must be collected and included (e.g. incineration or disposal of materials).

Harmonisation of LCI data is a pre-requisite for the harmonisation of LCA-based tools.

## *4.3. Output and interpretation of the results*

The output interface also corresponds to a compromise between precision and simplicity. Most tools provide a set of indicators corresponding to the main environmental issues of concern: e.g. climate change, acid rains, depletion of resources, waste production etc. The following table presents some examples of these indicators, sometimes complemented with several possible definitions: for instance the primary energy consumption may be expressed using a lower or upper heating value, including or not renewable energies and feedstock energy.

| | |
|---|---|
| **Resources** | |
| primary energy consumption | Lower or upper heating value<br>Renewable energies included? Feedstock energy included? |
| land use | Considering different types of land |
| water consumption | Quantity in $m^3$ |
| exhaust of abiotic resources | CML 1992[7] or 2000[8] |
| **Eco-systems** | |
| global warming, $CO_2$ eq | CML, 1992 or 2000, IPCC, 1994[9] or 2001 |
| acidification potential | CML, 1992 or 2000 |
| eutrophication potential | CML, 1992 or 2000 |

[7] R. Heijungs, Environmental life cycle assessment of products, Centre of environmental science (CML), Leiden, 1992, 96p

[8] J. B. Guinée et al., “Life Cycle Assessment – An operational guide for ISO Standards, operational annex, scientific background” (CML), Leiden, 2001

[9] IPCC, Scientific assessment working group of Intergovernmental Panel on Climate Change, *Radiative forcing of climate change*, World meteorological organization and United nations environment programme, 1994, 28p

| | |
|---|---|
| ozone depletion potential | CML, 1992 or 2000 |
| Photochemical oxydant (smog) | CML, 1992 or 2000 |
| human toxicity | CML, 1992 or 2000, DALY[10] |
| ecotoxicity | CML, 1992 or 2000 |
| inert waste production | tonnes or CML 2000 |
| radioactive waste production | Used only in very few tools, quantity in $m^3$ |
| dangerous waste production | Used only in very few tools, or included in waste with a higher weighting factor |
| **Economic** | |
| external cost | Used only in very few tools |
| Life cycle cost | Included in half of the tools |
| **Global** | |
| ecoscarcity points | Used only in very few tools |
| environmental footprint | Used only in very few tools |

*Table 5: Examples of environmental indicators*

Weighting factors allow several indicators to be aggregated in a single note (e.g. ecoscarcity points) but the meaning of this note is less clear.

Most tools provide the contribution of each life cycle phase - construction, operation, renovation and demolition - in the overall impacts.

Some tools provide the contribution of different building elements (e.g. walls, floors etc.) to the impacts. But this can only be evaluated for the construction, renovation and demolition phases. During the operation phase, the energy related impacts depend on interactions between several building elements (e.g. the solar radiation through windows can be stored in a slab and contribute to heat the building, depending on the control system). Due to these interactions it is not possible to allocate the global impact to each building element over the whole life cycle (in the previous example, would the energy saving be allocated to the windows or the slab?). Therefore the interpretation of these results must be performed carefully: for instance the construction related impacts of a heavy slab might be large but this slab may contribute to save energy by storing solar gains, resulting to an overall benefit compared to a lighter floor.

Using LCA in the design of a building consists in comparing the impact indicators corresponding to several alternatives. Sensitivity analysis may be needed to draw a conclusion from such studies: is the ranking of these alternatives modified if a different assumption is made e.g. concerning the use of the building? If the ranking remains the same, the selection of the alternative with the lowest impact is more reliable.

Further work is needed concerning some indicators, for instance:
- land use (accounting for qualitative aspects by defining different types of land),
- waste (integrating all downstream processes until final waste).

## 4.4. Methodology

The ISO 14040 standards provide a framework for life cycle assessment. However the tools may differ in some specific aspects, and it is useful to review them here and to propose some recommendations when it is relevant.

### 4.4.1. Recycling

[10] Mark Goedkoop et R. Spriemsma, *The Eco-Indicator 99, A dammage oriented method for life cycle impact assessment, methodology report, methodology annex, manual for designers*, avril 2000

The evaluation should account for recycling at both "ends" of the building life cycle: when recycled material is used for the construction, and when material is recycled at the end of life. But the possible benefit of recycling should not be accounted twice. Several methods are possible to model recycling, for instance the following approaches are implemented in some tools.

### a) the "Cut-off"-approach

Most materials on LCI-level are modelled with generic supply mix and "cut-off" approach. Individual recycling lies outside system boundary.

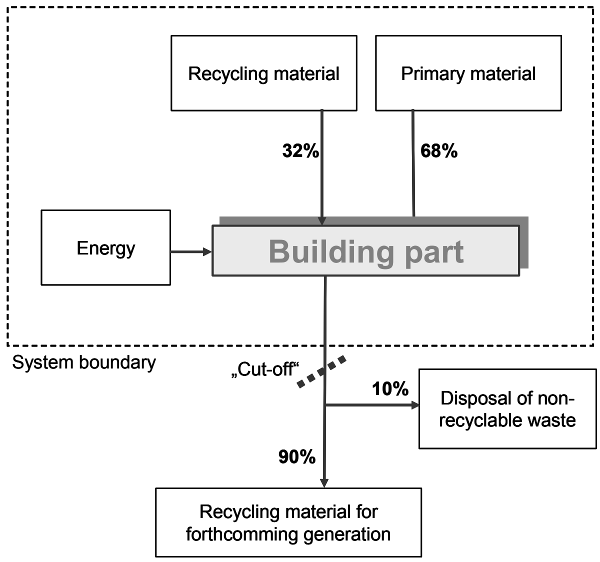



*Figure 49: graphical presentation of the "Cut-off" approach*

The building part is regarded as a blend consisting of primary (virgin) and secondary (recycling) materials with a fixed ratio reflecting the average global or regional production. At the end of the life time the part leaves the system without environmental burdens ("cut-off") as secondary materials source for forthcoming generations (compare figure 48). With this mental model, no difference is made between a part with e.g. 80% recycling potential and a compound with no recycling potential.

### b) the "bonus" method

If the impact of recycling $I_r$ is lower than the impact corresponding to the fabrication of the equivalent new material $I_n$ (for the same functional unit, e.g. 1 kg), the "bonus" is defined by:

$$I_n – I_r$$

If $I_r > I_n$, the "bonus" would be negative because recycling would increase the impact. If the recycling rate is not 1 (100%) but r, the bonus is reduced accordingly: $r \,.\, (I_n – I_r)$

If recycled material is used at the construction phase, half the bonus is accounted: the impact of using 1 kg of this recycled material is $I_n$ – ½ bonus =1/2 ($I_n + I_r$).

If the material is recycled at the end of life, half the bonus is also accounted for. The impact when recycling the same functional unit is evaluated by: – ½ bonus. In total, if 100% recycled material is used during the construction and if the material is also 100% recycled at the end of life, the impact is $I_r$.

If the recycling rate at the end of life is not 100% but r, and if the impact corresponding to the waste treatment (landfill, incineration…) is noted $I_t$, the impact related to the non recycled fraction is (1-r) x $I_t$. In this case the impact over the whole life cycle is $(1-r)(I_n + I_t) + r\,I_r$. The approach is the same for down-cycling and reuse.

The advantage of this method is to reward both the use and the production of recycled materials: for instance if recycled concrete is used but mixed with polystyrene to produce light concrete, the recycling at the end of life will surely be very problematic. In this case, only half the bonus is accounted for.

#### c) the "value corrected substitution method"

This approach makes no distinction between recycling at the beginning and at the end of the life cycle. A recycling rate of the material at the end of life is assumed, e.g. 90% for aluminium. The impact of the rest is calculated like in the previous approach using $I_t$ (impact of waste treatment). The method also assumes that a certain proportion of the recycled material is down-cycled, so that 1 kg recycled material corresponds only to p kg of new material (e.g. p = 0.9) which can be substituted. The impact related to the down-cycled fraction is neglected. The balance is shown in the next figure.

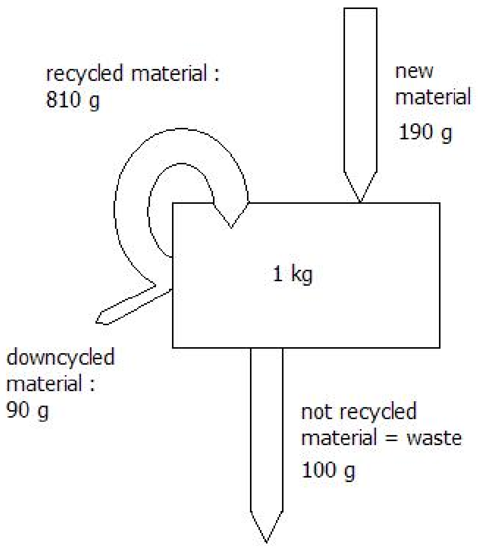



*Figure 50: graphical presentation of the "value corrected substitution method" for recycling*

Over the whole life cycle, the impact of the same functional unit as in the "case a" method (1 kg material, including fabrication and disposal) is:

$r \times I_r + (1 - r \times p)\, I_n + (1 - r)\, I_t$

This equation is equivalent to the previous method considering a recycling rate r x p and a down-cycling rate r x (1-p), and assuming the same impact for recycling and down-cycling. The second method assumes that the recycling rate is the same at the beginning and at the end of the life cycle.

#### d) IISI-method for metallic products

<u>Introduction</u>

Environmental pressures can be allocated for scrap from the industry that produces the original products only in such cases where the scrap has economical value and it is recycled. In addition, the ISO 14041 standard states "allocation procedures shall be uniformly applied to similar inputs and outputs of the system under consideration". A closed-loop allocation procedure applies to closed-loop product systems according to the standard. It also applies to open-loop product systems where no changes occur in the inherent properties of the recycled material. According to the ISO 14041 standard "an open-loop allocation procedure applies to open-loop product systems where the material is recycled into other product systems and the material undergoes a change to its inherent properties". Allocation should be based on physical properties, economic value (e.g. scrap value in relation to primary value) or the number of subsequent uses of the recycled material.

Scrap metal

This recycling model was originally developed by the International Iron and Steel Institute (IISI). The model is based on the concept that the original product and all products generated by the material in the original product should share the total environmental impact. Therefore the recycling model promotes the use of products with high recyclability and reusability. The recycling model should not be applied in such cases where the aim is for instance to describe real impacts for a certain area and time.

The recycling model is based on the closed-loop allocation. Recycling can be treated according to ISO 14041 as a closed-loop system when no changes occur in the inherent properties of the recycled material. Recycled steel, aluminum, zinc, copper and some other metals have practically identical physical properties to those produced from virgin materials.

The equation for all environmental parameters in the whole product system is (Brimacombe et al. 2001[11]):

$$X = X_{primary} + [ ( X_{recycled} - X_{primary} ) \times R \times Y ]$$

Where:

| | | |
|---|---|---|
| $X$ | = | LCI values for the whole system |
| $X_{primary}$ | = | LCI values for the virgin material route |
| $X_{recycled}$ | = | LCI values for the recycling route |
| $R$ | = | recycling ratio (the percentage of material which is recovered as scrap) |
| $Y$ | = | metallic yield ratio at the recycling process |

### 4.4.2. $CO_2$ storage

During the growth of plants, $CO_2$ is absorbed from the atmosphere in the photosynthesis process (around 1.85 kg $CO_2$ is absorbed to produce 1 kg cellulose for instance). At the end of life of the material, greenhouse gases are released (e.g. during incineration or landfill). Some of the tools assume a global $CO_2$ neutral process, assuming that a corresponding amount of CO2 is released after the end of life cycle as the original amount stored in the products. Other tools account for a $CO_2$ capture during the production phase, evaluated as a "negative" emission, and a $CO_2$ release at the end of life according to the process (e.g. heat may be recovered from the incineration and substitute the use of fossil fuel, methane can be collected on a landfill etc.). The second approach makes visible the $CO_2$ storage during the life span of the material in a building.

In any case, the method should be consistent: if $CO_2$ capture has been accounted for, the end of life processes should also be modelled, and a $CO_2$ release should be accounted for.

Three of the analysed tools do not take into account the disposal phase although the used methods takes the neutrality of wood as one's starting point and therefore do not consider

[11] Brimacombe, L., Schonfield, P. and Buriard, M. 2001. Sustainability and Steel Recycling. SAE Technical Paper Series 2001-01-3766. Society of Automotive Engineers. 4 pp.

the uptake and release of biogenic $CO_2$. Generally the tool developers and users must be aware that an overall life cycle shows a correct result but problems could arise when an assessment is made without taking into account the disposal phase.

One participant has proposed to distinguish the use of wood from certified forests, e.g. according to the forest stewardship council (FSC). If the forest is certified, the cleared trees will be replanted so that more $CO_2$ can be stored compared to a non certified forest. But this principle has been judged too difficult and complicated by another participant.

### 4.4.3. Renovation and demolition scenarios

In general, a life span is associated to each building element (default values can be used, cf. the paragraph on data input). This life span results from technical and economical aspects, possibly also changes in fashion, and interrelation with other components. If the default life span can be changed by the user, the benefit from long lasting components and good maintenance can be evaluated using the tool.

A theoretical renovation process is modelled in most tools, assuming that a component is replaced by an identical component and accounting for the related impacts. But we know that this rarely happens in practice. We may consider that this accounting method gives an estimate of the yearly impacts during the first years of the building life cycle, and the evaluation is less and less precise in a longer term.

The models should include the assumption that in practice, no replacement occurs in the final years of the building life span.

Studying a renovation project would require a specific interface. Using the tools as they are presently would require several calculations: one for the building before and one after renovation, and specific calculations if some elements have to be replaced (e.g. windows) so that the replacement related impacts are known. To avoid this multiple calculation, a specific interface would be more convenient in the case of refurbishment.

Concerning end of life processes after demolition, scenarios can be defined for different product categories (metals, masonry, wood…) assuming possible waste treatment processes (landfill, incineration, recycling…) according to the present state of the art.

# 5. Conclusions and recommendations

Compared to the previous exercises regarding the comparison of building LCA tools, this work allowed a deeper analysis to be performed, addressing particularly :

- the assumptions,
- the methodologies,
- the resulting indicators.

This exercise allowed to improve the software tools and aims at increasing the confidence in the tools : the discrepancy in the results between the studied tools remained in a reasonable range (+/- 10%) concerning the global warming indicator.

The analysis of the results of the three case studies has resulted in a long list of recommendations to be used for improving existing assessment tools or for designing new tools. Following sample shows some important ones:

- Try to have consistent LCI data with high transparency (same system boundary, clear allocation methods, no mixing of data from different sources, etc.).
- If possible use up to date specific product LCI data with a clear user area.
- Include all transports (also from upstream processes). If no exact data are available some country specific default values should be proposed for transport distances, to the building site in the construction phase and from the site at the end of life, for the different waste treatment processes (incineration, landfill, recycling, ...).
- Account for all materials having a significant influence.
- Account for both the use of recycled material in construction and for recycling at the end of life in a consistent and transparent way.
- If possible include the land-use in the whole process from cradle to gate.
- Include water consumption in the analysis although it is no indicator for the environmental impact.
- The choice of the impact assessment indicators is arbitrary but needs explanation. Be careful using cumulated indicators as different environmental impacts are calculated into one value.
- Substitutions of certain materials/constructions must be taken into account after their service life. Be aware that a certain time before demolition no substitution will be made.
- Upstream processes (production and distribution of gas, electricity, fuel…) must be accounted for.

Transparency is very important: the system boundary, the database, the system boundary, the assumptions and the calculation of the impact with different indicators (particularly if several indicators are combined using weighting factors) should be clearly described.

For the interpretation of the results the practitioners (architects, civil engineers, etc.) must be trained: building designers are no environmental experts and therefore some minimal knowledge should be provided to allow them to interpret the results of an LCA.

LCA based tools should also evolve according to the progress of knowledge (e.g. evolution of environmental indicators, progress in LCI data bases).

In terms of an outlook from this study, further work is 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 is available for the training of professionals. Therefore, impact reduction objectives could be integrated in the design briefs for low impact buildings. If a general target is to reduce the greenhouse gases emissions by 75% in the year 2050, it is necessary to integrate this objective in new buildings because they are likely to remain part of the building stock for a long time.

# Annex 1: Results of the first case study ("cube")

| | BECOST | ECO-QUANTUM | ECOSOFT | ENVEST 2 |
|---|---|---|---|---|
| **TARGET BUILDING TYPE(S)** | | | | |
| target building types | all | houses (new) | houses | offices |
| other types? | | is possible, but difficult, beacause component data are missing | also possible, but only design engineering included | appropriate for materials but not energy |
| time consumed (cube) | short (10 min) | 1h, without data collection and report | 1h, without data collection and report | less than one hour |
| **LCI DATA** | | | | |
| source of data | national base | IVAM-database | Eco-Invent 96 + IBO base for building materials | Mostly BRE Environmental Profiles, some other sources including Simapro |
| transparent (1) | the user can't see the LCI-data and can't add or change materials or other data | the user can't see the LCI-data an can't add or change materials or other data | user can see and change all data | Within the tool, users can only access Ecopoints scores for elements, with indicators provided for the whole building. Environmental Profiles data for key materials at indicator level can be seen on separate database tool |
| producer specific | LCI data mainly product-specific. Represent typical values in Finland. Energy and transportation data represent national average. | choice, mainly industry | average values | choice of producer specific materials within some elements. |
| system boundary (transport, energy…) | Extraction of raw materials, energy production, transport, manufacturing process, building (waste), replacement periods Use phase energy consumption should be calculated with a separate tool (Win Etana) | transport of raw materials and energy processes included | transport of raw materials and energy processes included, no transport to building site | transport of raw materials and energy processes included |
| concrete composition per m3 | 216 kg | ? | 120 g cement, 820 g gravel and 60 g water per kg concrete | 100% cement option: 300 kg cement |
| allocation for cement replacement (fly ash) | fly ash = by-product (no impact) | ? | Portland cement | economic |
| kg CO2 eq per kg concrete | 0,0863 | 0,151 | 0,13 | 0,134 |

| | | | | |
|---|---|---|---|---|
| type of steel | | 35% electric arc furnace 65% blast fiurnace | 99.9 scrap metal | electric arc furnace |
| Electricity mix for steel production | 0,362 | | European mix | |
| kg CO2 eq per kg steel | 228 130 | 1,86 | 0,71 | 0,657 |
| kg waste per kg steel | | | 0.1 kg slag | |
| kg CO2 eq per TJ end energy (UCPTE electricity mix) | 63 400 | 168900 | 143000 | UK only: 160648 |
| **QUANTITIES** | | | | |
| density of concrete | 2500 | 2400 | 2000 | 2400 |
| density of steel | 7800 | 7800 | 7800 | 7883 |
| customized densities | yes, choice among some product types with different densities | no | yes | |
| volume of concrete (used) | 40 | 40,26 | 40,26 | 41,93 |
| weight of concrete | 99 660 | 96 624 | 80528 | 100632 |
| % of steel | 3% volume (as agreed) | 0,83% | 3 % Volume | range 0, 80,100,115 kg/m3 - 115 kg/m3 used |
| weight of steel | 9 328 | 805 | 9420,84 | 4822 kg |
| dimensions | precise | precise | precise (user input) | asks for outside |
| construction waste | default value for all materials | reinforced concrete, in situ (10%) | neglected | neglected |
| transport | transport to building site excluded | transport to building site is neglected | transport building site optional, additional input | Average transport to site for individual materials included |
| construction site processes | neglected | neglected | neglected | neglected |
| elements | composition of structures predefined, administrator is able to change components or add new components | predefined components, no possibility tot change or add new components | partly predefined | Wide range of predefined materials and element specifications. Possibility to add new specifications on application to BRE. |
| tons CO2 eq. for construction | 12 | 19 | 18 | 17 |
| **OPERATION** | | | | |
| electricity mix | Finnish mix | ETH | Austria or UCPTE | UK mix |

| | | | | |
|---|---|---|---|---|
| types of heating energy (2) | average W,G,O | E (this was given in the case), in the Netherlands we mostly use gas | G,O,E,W, D | G |
| heating load calculation | no energy calculation, given amount of electricty is used | no energy calculation, given amount of electricty is used | no heating load calculation in "poor" ECOSOFT, Ecosoft has been combined with different local heating calculation software-tools (f.e. ecotech, zehetmayer, a0, PHPP EN 832) | benchmark for offices with adaptation depending on fabric and design |
| ton CO2 eq. For heating | 477 | 1182 | 1001 | 1134 |
| cooling load calculation | no energy calculation, given amount of electricty is used. Operation energy consumption should be calculated with a separate tool (Win Etana) | no energy calculation, given amount of electricty is used | no cooling load calculation | benchmark for offices with adaptation depending on fabric and design |
| domestic hot water, input data | national tool | idem | endenergy MJ | benchmark for offices |
| type of DHW energy | average W,G,O | idem | G,O,E,W, D | G,E |
| lighting load calculation | | idem | no | Based on office specification of lighting output and switching |
| electricity consumption, input data | defining equipment | idem | MJ end energy | benchmark for offices adapted for occupancy |
| cold water, input data | no | default values in EQ | no | based on specification of taps, toilets and showers |
| sewage | no | default values in EQ | no | range of toilet options including composting |
| domestic waste, input data | WinEtana | no issue in EQ | no | no |
| comuting, input data | no | no issue in EQ | no | No |
| maintenance (clean, check, repaint, repair) | renewal periods of building components | default values in EQ (eg. painting) | repaint, repare if userdefined | default service life for maintenance |
| replacement | default service life | default life span values in EQ, no possibility to change | default life span values, possible to change in the project | default service life + user |
| refurbishment | no | no issue in EQ | material input if user defined | default service life + user |
| **DEMOLITION** | | | | |

| | | | | |
|---|---|---|---|---|
| deconstruction processes | neglected | neglected | neglected | neglected |
| transport of waste | neglected | neglected | case scenarios too uncertain | neglected |
| "end" processes | neglected | incineration and landfill, recycling is taken into account in the production processes | case scenarios too uncertain | incin/land/rec |
| **INDICATORS** | | | | |
| life cycle phases (3) | | C,O,D,T | user defined; possibilities:C / C,O / C,R / C,O,R | C,O,R,D,T |
| primary energy : lower/upper heating value | HHV, including RE + NRE. including material and energy flows. | energy for water, energy and material flows | Higher heating value | Higher heating value |
| RE included ? | yes | | no, extra indicator | |
| feedstock energy included ? | yes | | yes | |
| global warming, CO2 eq | BECOST gives the result in terms of LCI data. National guidelines for converting to LCA data (DAIA-method). | CML 2000 | CML 2000 | IPCC 1995 |
| land use | no | no | not yet | no |
| external cost | | no | not yet | no |
| ecoscarcity points | | no | not yet | no |
| costs | yes. LCC | no | not yet | yes, capital and whole life costs |
| acidification potential | BECOST gives the result in terms of LCI data. National guidelines for converting to LCA data (DAIA-method). | CML 2000 | CML 2000 | CML1992 |
| eutrophication potential | | CML 2000 | CML 2000 | CML1992 |
| ozone depletion potential | | CML 2000 | CML 2000 | Montreal Protocol |
| Photochemical oxydant (smog) | BECOST gives the result in terms of LCI data. National guidelines for converting to LCA data (DAIA-method). | CML 2000 | CML 2000 | CML1992 |
| odours | no | no | not yet | no |
| human toxicity | no | CML 2000 | not yet | CML1992 |
| ecotoxicity | no | CML 2000, water, sedimental, terrestic | not yet | CML1992 |
| inert waste production | no | CML 2000 | not yet | tonne - total waste |
| radioactive waste production | no | no | not yet | no |
| dangerous waste production | no | CML 2000 | not yet | no |
| exhaust of abiotic resources | no | CML 2000 | not yet | no |
| water consumption | no | m3 | not yet | m3 |
| **NOTES** | | | | |

| | | | | | |
|---|---|---|---|---|---|
| (1) How the LCI data can be accessed by the user : whole inventory, profile (including e.g. a dozen of indicators) | | | | | |
| (2) G=gas, O=oil, D=district heating, E=electric, W=wood | | | | | |
| (3) C=construction, O=operation, R=renovation, D=demolition, T=total | | | | | |

| | EQUER | ESCALE / INIES / SimaPro | LEGEP | OGIP |
|---|---|---|---|---|
| **TARGET BUILDING TYPE(S)** | | | | |
| target building types | all except factories | all | houses (new and used), offices, schools, kindergarden, | all |
| other types? | | | factories | |
| time consumed (cube) | 1h, including energy calculation | | 1 h, including energy calculation, costs, lc-costs | 10h (I'm not a proficient user, including effort to make the result transparent) |
| **LCI DATA** | | | | |
| source of data | Eco-invent96 | **(S)** IVAM LCA Data 3.0 **(I)** French industrialists data | Eco-invent 96/Material moduls Weimar/Karlsruhe | mostly Eco-invent96 |
| transparent (1) | profile including 12 indicators for all materials and processes | **(S)** complete inventary | complete inventary profile | The step from LCI-Data to e+s components (assessed energy- and material-flows) is not comprehensible, from e+s components up to the building it is transparent but not user friendly. Easiest usage by choosing the building components included in OGIP. |
| producer specific | not presently | | not at present , different electricity mix under work | Data of Eco-invent 96 are not producer specific |
| system boundary (transport, energy…) | transport of raw materials and energy processes included | **(S)** transport of raw materials and energy processes included | transport of raw materials and energy processes included | no transports of raw material to building site are included, energy processes included |

| | | | | |
|---|---|---|---|---|
| concrete composition per m3 | 120 g cement, 820 g gravel and 60 g water per kg concrete | **(S)** 150 g cement, 385 g gravel, 95 g concrete granular, 330g sand, 40g water | 292 kg cement, 4 kg fly-ash | poor concrete as bed: 150kg/m3 and higher quality concrete 300kg/m3 |
| allocation for cement replacement (fly ash) | Portland cement is considered | **(I)** CEM II is considered | fly ash = by-product (no impact) | no; portland cement without replacement components is used; in general the secondary raw material for cement within Eco-invent 96 have no burdens from upstream processes. |
| kg CO2 eq per kg concrete | 0,133 | **(S)** 0,35 (prefabricated) 0,116 for concrete only | 0,095 | 0,12 |
| type of steel | 20% electric arc furnace 80% blast fiurnace | **(S)** 20% electric arc furnace 80% blast fiurnace | electric arc furnace | Concrete steel S 500, steel unalloyed, 20% electric steel 80% converter steel |
| Electricity mix for steel production | European mix | | | |
| kg CO2 eq per kg steel | 2,09 | **(S)** 2,1 | 1,293 | 1,61 |
| kg waste per kg steel | 0,74 | | | |
| kg CO2 eq per TJ end energy (UCPTE electricity mix) | 132100 | **(S)** 137 000 / **(E)** 142 000 | 144400 | 140 000 |
| **QUANTITIES** | | | | |
| density of concrete | 2100 | 2100 | 2400 | Poor concrete Concrete B35/25 CEM 42.5, minimum amount of cement z=150kg/m3: density: 2'190kg/m3, Concrete B35/25 CEM 42.5, minimum amount of cement z=300kg/m3: density: 2'380kg/m3 |
| density of steel | 7800 | 7850 | 7850 | 7850 |
| customized densities | yes | yes | no | some products are offered in different types with different densities |
| volume of concrete (used) | 36,3 m3 | 40,26 | 40,28 | 40.26m3 (plus additional poor concrete: 3.978 m3, plus additional concrete (unknown application): 0.308m3 |
| weight of concrete | 76184 kg | 82 018 kg | 96190 kg | without additional concrete: 95'828.68 kg (additional concrete: 9'445.39 kg) |
| % of steel | 0,03 | 3% in volume | 3% Volume as wanted, 45 kg/ m2 | 0.5%: base plate, 0.96%: roof, 0.76%: walls |
| weight of steel | 8808 kg | 9 483 kg | 9063 kg | 547.01kg: base plate, 932.40kg: roof, 924kg: walls |
| dimensions | inside | inside | precise | precise |
| construction waste | 5%, single value for all materials, user defined, default value proposed (5%) | 2,5 % for all materials (user defined) Cube : neglected | 3%, single value for all materials, default value proposed 3%) | not taken into account |

| | | | | |
|---|---|---|---|---|
| transport | single value for all materials, user defined, default proposed : 20 km | 50 km between factory and building site | transport to building site is defined for Materials with bigger volumes, like stones, concrete wood, for other work is neglected | no transports included but could be added manually |
| construction site processes | transport and treatment of the 5% construction waste | neglected | machines and needed materials (nails, wood) are calculated | included by: crane, loading equipment, vibrating needle, transformer and formwork panels |
| elements | both materials and elements | predefined components, possibility to change or add new components | predefined components, possibility to change or add new components | materials and predefined construction elements; possible to change and create new ones (with quite high expenditure) |
| tons CO2 eq. for construction | 32 | 51 | 14 | 17 |
| **OPERATION** | | | | |
| electricity mix | user defined, default value proposed | **(S)** UCPTE | UCPTE | UCPTE |
| types of heating energy (2) | G,O,E,W | E as it was predefined by PRESCO | E (chosen), G,O,W,D | G,O,E,W |
| heating load calculation | simulation, combined external tool : COMFIE (same building description as for LCA) | regulation tool or simulation tool Cube : EMPA data used | own programm, ENEV (EN832) | can be included when external calculated or internal calculation based on SIA 380/1 |
| ton CO2 eq. For heating | 924,5 | **(S)** 1020t / **(E)** 991 t | 1059 | 1095 |
| cooling load calculation | simulation, cf. heating | no | neglected | calculation of cooling load not possible, energy demand must be calculated separately and included |
| domestic hot water, input data | l/day/p, user defined, default value proposed (40 l), energy load calculated | regulation tool or simulation tool | benchmark for houses and offices l/day/pers user defined standard | only heating load for heating of water (water not taken into account) |
| type of DHW energy | G,O,E,W | **(S, E)** G,O,E,W | G,O,E,W,D | G,O,E,W |
| lighting load calculation | not yet implemented | Mixte software for commercial buildings | no | not taken into account |
| electricity consumption, input data | Wh/day/p, user defined | **( S,E)** user defined | benchmark for houses and offices kWh/day/pers user defined standard | MJ/m2/year |

| | | | | |
|---|---|---|---|---|
| cold water, input data | l/day/p, user defined, default value proposed (100 l) | **( S,E)** user defined Cube : neglected | benchmark for houses and offices l/day/pers user defined standard | not taken into account |
| sewage | composting/standard toilets | no | no | not taken into account |
| domestic waste, input data | kg/day/p, user defined, default value proposed (1 kg) + recycling % (paper, glass) | no | no | not taken into account |
| comuting, input data | distance + number of persons + type (train, bus…) | no | no | not taken into account |
| maintenance (clean, check, repaint, repair) | repaint | **(E)** check list Cube : neglected | elements for cleaning, check,repaint, repair | not taken into account |
| replacement | user defined life span, default value proposed (10 y for paint/finish, 30 y for windows) | **( S,E)** user defined life span Cube : neglected | default life span values, possibility to change in the project | default life span and possibility to overwrite by user (only with big effort) |
| refurbishment | 2 calculations needed | **?** | yes | not taken into account |
| **DEMOLITION** | | | | |
| deconstruction processes | neglected | **( S,E)** user defined Cube : neglected | in preparation | included in the basic elements |
| transport of waste | 1 distance for all materials, user defined, default proposed (20 km) | **( S,E)** user defined Cube : neglected | neglected | not taken into account |
| "end" processes | incineration/landfill option for each material | **( S,E)** user defined Cube : landfill | incineration/landfill defined for each material | not taken into account |
| **INDICATORS** | | | | |
| life cycle phases (3) | C,O,R,D,T | **(S)** C, O, R, D, T<br>**(E)** : C,O<br>Cube : C,O | C,O,R.D.T | C, O |
| primary energy : lower/upper heating value | Higher heating value | According the French experimental Standard : feedstock + process energy | ETH | Compare (***) on the bottom of the page, primary energy not consistent within different e+s components |
| RE included ? | yes | | | |
| feedstock energy included ? | yes | yes | | |
| global warming, $CO_2$ eq | IPCC 100 | **(S)** CML 1992 / **(E)** IPCC 100 | **CML**, ETH, Eco 95 | $CO_2$ for energy and material flow for the elements are included but can't be easily presented (must be calculated manual) |
| land use | no | no | ETH | not included |
| external cost | no | no | no | yes |
| ecoscarcity points | no | no | no | yes |
| costs | no | no | yes, for construction and lifecycle | yes |

| | | | | |
|---|---|---|---|---|
| acidification potential | CML 1992 | **(S)** CML 1992 | **CML**, ETH, Eco95 | not included |
| eutrophication potential | CML 1992 | **(S)** CML 1992 | **CML**, ETH, Eco95 | not included |
| ozone depletion potential | calculated but not visualized | **(S)** CML 1992 | **CML**, ETH, Eco95 | not included |
| Photochemical oxydant (smog) | CML 1992 | **(S)** CML 1992 | **CML**, ETH, Eco95 | not included |
| odours | CML 1992 | no | ETH | not included |
| human toxicity | CML 1992 | **(S)** CML 1992 | CML | not included |
| ecotoxicity | CML 1992 | **(S)** CML 1992 | CML | not included |
| inert waste production | ton | no | CML | not included |
| radioactive waste production | dm3, all types included | **( E )** dm3, EDF 99 data | ETH | not included |
| dangerous waste production | dm3, all types included | no | CML | not included |
| exhaust of abiotic resources | CML 1992 | no | ETH | not included |
| water consumption | m3 | **(S, E)** m3 | no | not included |
| **NOTES** | | | | |
| (1) How the LCI data can be accessed by the user : whole inventory, profile (including e.g. a dozen of indicators) | | | | |
| (2) G=gas, O=oil, D=district heating, E=electric, W=wood | | | | |
| (3) C=construction, O=operation, R=renovation, D=demolition, T=total | | | | |

# Annex 2: results for the FUTURA house (three alternatives)

| | BECOST | ECO-QUANTUM | ECOSOFT | ENVEST 2 |
|---|---|---|---|---|
| **TARGET BUILDING TYPE(S)** | | | | |
| time consumed | Several days, because construction and material adjustments | Input and calculation 0,5 day, datacollection much longer | 3 h, no energy calculation, no analyzing of the data | 1.5 hours to enter into program, several hours to calculate non-standard components. |
| **LCI DATA** | | | | |
| kg CO2 eq per kg wood | 0,072 | -1,24 hardwood, -1,06 softwood | * -1.8 to -1.63 | -1,231 |
| kg CO2 eq per kg brick | 0,228 | 0,295 | 0,25 | 0,217 |
| kg CO2 eq per kg massive concrete block / concrete | 0,084 | | 0,13 | 0.134 RC35 concrete 0.046 Dense Concrete Block |
| kg CO2 eq per TJ end energy (gas heating) | 63 486 | 59000 | 68000 (natural gas furnace low Nox>100kW Europe) | 56200 |
| useful or end energy ? | end energy | end energy | end energy | end energy |
| boiler efficiency | | | | |
| **QUANTITIES** | | | | |
| tons CO2 eq. for construction, wood | 52 | 87 | 32 | 98 |
| tons CO2 eq. for construction, brick | 51 | 130 | 73 | 95 |
| tons CO2 eq. for construction, concrete | 66 | 126 | 86 | 144 |
| **OPERATION** | | | | |
| ton CO2 eq. for operation, wood | 478 | 526 | 552 | 432,5 |
| **DEMOLITION** | | | | |
| process considered | not considered | landfill, incineration and reuse, but no demolition | not considered | not considered |
| kg CO2 eq per kg wood incinerated | not considered | 0,903 | not considered | 1,525 |
| ton CO2 eq. for demolition, wood | not considered | - | not considered | 1,487 |
| ton CO2 eq. for demolition, brick | not considered | - | not considered | 0 |
| ton CO2 eq. for demolition, brick | not considered | - | not considered | 0 |

| | EQUER | ESCALE / INIES / SimaPro | LEGEP | OGIP |
|---|---|---|---|---|
| **TARGET BUILDING TYPE(S)** | | | | |
| time consumed | 4h, including energy calculation | | | |
| **LCI DATA** | | | | |
| kg $CO_2$ eq per kg wood | --1,72 (massive wood) or -0,64 (plywood) | **0,551** | 0,026 | 0,0265 |
| kg $CO_2$ eq per kg brick | 0,25 | **0,254** | 0,32 | 0,226 |
| kg $CO_2$ eq per kg massiv concrete block / concrete | 0,133 | **0,12** | | 0,104 |
| kg $CO_2$ eq per TJ end energy (gas heating) | 83950 | | 66321 | 74000 |
| useful or end energy ? | useful energy | | | |
| boiler efficiency | 87% | | | |
| **QUANTITIES** | | | | |
| tons $CO_2$ eq. for construction, wood | 13 | 51 | 40 | |
| tons $CO_2$ eq. for construction, brick | 108 | 143 | 104 | |
| tons $CO_2$ eq. for construction, concrete | 101 | 129 | 91 | |
| **OPERATION** | | | | |
| ton $CO_2$ eq. for operation, wood | 488 | **489** | 467 | |
| **DEMOLITION** | | | | |
| process considered | landfill, incineration for wood | landfill | not considered | |
| kg $CO_2$ eq per kg wood incinerated | 1,47 | | not considered | |
| ton $CO_2$ eq. for demolition, wood | 32 | **1,9** | not considered | |
| ton $CO_2$ eq. for demolition, brick | 3,3 | 2,9 | not considered | |
| ton $CO_2$ eq. for demolition, brick | 3,4 | 2,8 | not considered | |

# Annex 3: results for the FUTURA house (recommendations)

ECO-QUANTUM

| Base case : FUTURA house, concrete | | | |
|---|---|---|---|
| Impact (Eco-Quantum) | All the rest | Operation phase | Total load |
| Abiotic depletion (kg Sb) | 12 833 | 75 305 | 88 138 |
| Global warming (kg CO2) | 125 730 | 537 158 | 662 888 |
| Ozon layer depletion (kg CFK11) | 0,0170 | 0,0113 | 0,0283 |
| Photoch. oxidation (kg ethyl) | 125,61 | 33,73 | 159,34 |
| Human. toxicity (kg 1,4DB) | 20 994 | 21 814 | 42 808 |
| Aquatic tox. water (kg 1,4DB) | 2 441 | 4 414 | 6 855 |
| Aquatic tox. sediment (kg 1,4DB) | 3 835 | 6 760 | 10 595 |
| Terrestrial tox. (kg 1,4DB) | 353,20 | 526,70 | 879,90 |
| Acidification (kg SO2) | 558,10 | 542,60 | 1 100,70 |
| Eutrophication (kg PO4) | 89,03 | 80,64 | 169,67 |
| Energy (kg MJ) | 1 601 600 | 8 233 777 | 9 835 377 |
| Waste, non dangerous (kg) | 157 163 | 21 748 | 178 911 |
| Waste, dangerous (kg) | 9 475 | 1 179 | 10 654 |

| Base case : FUTURA house, concrete | | | |
|---|---|---|---|
| Impact (EQuer) | All the rest | Operation phase | Total load |
| Primary energy | 1 601 600 | 8 233 777 | 9 835 377 |
| Water consumption | not in Eco-Quantum | | |
| Exhaust of resources | 12 833 | 75 305 | 88 138 |
| Solid waste | 157 163 | 21 748 | 178 911 |
| Radioactive waste | not in Eco-Quantum | | |
| Greenhouse effect | 125 730 | 537 158 | 662 888 |
| Acidification | 558,10 | 542,60 | 1 100,70 |
| Eutrophication | 89,03 | 80,64 | 169,67 |
| Ecotoxicity-water | 2 441 | 4 414 | 6 855 |
| Human toxicity | 20 994 | 21 814 | 42 808 |
| O3-smog | 125,61 | 33,73 | 159,34 |
| Odours | not in Eco-Quantum | | |
| | | | |

**Assumptions recommenation 107**

Solar waterheating collector: 2,8 m2 collector + 1 x storage, pump (6.160 MJ/year)
2,8 m2: water heating 14.271 MJ/year => 8.110 MJ/year (gas)
PV-system: 4 m2 panel + 4x inverter (3.200 MJ/year)
4 m2: lighting 41.231 MJ/year => 38.231 MJ/year (electricty)

| FUTURA house, concrete + recommendation 107 | | | |
|---|---|---|---|
| Impact (Eco-Quantum) | All the rest | Operation phase | Total load |
| Abiotic depletion (kg Sb) | 13 501 | 68 307 | 81 808 |
| Global warming (kg CO2) | 132 858 | 489 844 | 622 702 |
| Ozon layer depletion (kg CFK11) | 0,0177 | 0 | 0,0284 |
| Photoch. oxidation (kg ethyl) | 128,70 | 31 | 159,70 |
| Human. toxicity (kg 1,4DB) | 22 096 | 20 197 | 42 293 |
| Aquatic tox. water (kg 1,4DB) | 2 649 | 4 095 | 6 744 |
| Aquatic tox. sediment (kg 1,4DB) | 4 226 | 6 244 | 10 470 |
| Terrestrial tox. (kg 1,4DB) | 374,00 | 492 | 866,40 |
| Acidification (kg SO2) | 593,00 | 504 | 1 096,50 |
| Eutrophication (kg PO4) | 91,39 | 74 | 165,52 |
| Energy (kg MJ) | 1 703 165 | 7 500 978 | 9 204 143 |
| Waste, non dangerous (kg) | 166 204 | 20 187 | 186 391 |
| Waste, dangerous (kg) | 9 726 | 1 087 | 10 813 |

| FUTURA house, concrete + recommendation 107 | | | |
|---|---|---|---|
| Impact (EQuer) | All the rest | Operation phase | Total load |
| Primary energy | 1 703 165 | 7 500 978 | 9 204 143 |
| Water consumption | not t in Eco-Quantum | | |
| Exhaust of resources | 13 501 | 68 307 | 81 808 |
| Solid waste | 166 204 | 20 187 | 186 391 |
| Radioactive waste | not in Eco-Quantum | | |
| Greenhouse effect | 132 858 | 489 844 | 622 702 |
| Acidification | 593,00 | 503,50 | 1 096,50 |
| Eutrophication | 91,39 | 74,13 | 165,52 |
| Ecotoxicity-water | 2 649 | 4 095 | 6 744 |
| Human toxicity | 22 096 | 20 197 | 42 293 |
| O3-smog | 128,70 | 31,00 | 159,70 |
| Odours | not in Eco-Quantum | | |
| | | | |

| FUTURA house, concrete + recommendation 107, compared with base | | | |
|---|---|---|---|
| Impact (Eco-Quantum) | All the rest | Operation phase | Total load |
| Abiotic depletion (kg Sb) | 105% | 91% | 93% |

| FUTURA house, concrete + recommendation 107, compared with base | | | |
|---|---|---|---|
| Impact (EQuer) | All the rest | Operation phase | Total load |
| Primary energy | 106% | 91% | 94% |

| | | | |
|---|---|---|---|
| Global warming (kg CO2) | 106% | 91% | 94% |
| Ozon layer depletion (kg CFK11) | 104% | 95% | 100% |
| Photoch. oxidation (kg ethyl) | 102% | 92% | 100% |
| Human. toxicity (kg 1,4DB) | 105% | 93% | 99% |
| Aquatic tox. water (kg 1,4DB) | 109% | 93% | 98% |
| Aquatic tox. sediment (kg 1,4DB) | 110% | 92% | 99% |
| Terrestrial tox. (kg 1,4DB) | 106% | 93% | 98% |
| Acidification (kg SO2) | 106% | 93% | 100% |
| Eutrophication (kg PO4) | 103% | 92% | 98% |
| Energy (kg MJ) | 106% | 91% | 94% |
| Waste, non dangerous (kg) | 106% | 93% | 104% |
| Waste, dangerous (kg) | 103% | 92% | 101% |

| | | | |
|---|---|---|---|
| Water consumption | not in Eco-Quantum | | |
| Exhaust of resources | 105% | 91% | 93% |
| Solid waste | 106% | 93% | 104% |
| Radioactive waste | not in Eco-Quantum | | |
| Greenhouse effect | 106% | 91% | 94% |
| Acidification | 106% | 93% | 100% |
| Eutrophication | 103% | 92% | 98% |
| Ecotoxicity-water | 109% | 93% | 98% |
| Human toxicity | 105% | 93% | 99% |
| O3-smog | 102% | 92% | 100% |
| Odours | not in Eco-Quantum | | |
| | | | |

| FUTURA house, concrete + recommendation 107, solar heating collector (recom 300) | | | |
|---|---|---|---|
| Impact (Eco-Quantum) | All the rest | Operation phase | Total load |
| Abiotic depletion (kg Sb) | 12 985 | 69 886 | 82 871 |
| Global warming (kg CO2) | 127 375 | 508 084 | 635 459 |
| Ozon layer depletion (kg CFK11) | 0,0172 | 0,0112 | 0,0284 |
| Photoch. oxidation (kg ethyl) | 126,87 | 32,66 | 159,53 |
| Human. toxicity (kg 1,4DB) | 21 494 | 21 596 | 43 090 |
| Aquatic tox. water (kg 1,4DB) | 2 526 | 4 388 | 6 914 |
| Aquatic tox. sediment (kg 1,4DB) | 4 022 | 6 727 | 10 749 |
| Terrestrial tox. (kg 1,4DB) | 357,70 | 522,00 | 879,70 |
| Acidification (kg SO2) | 571,84 | 537,86 | 1 109,70 |
| Eutrophication (kg PO4) | 89,65 | 77,95 | 167,60 |
| Energy (kg MJ) | 1 627 034 | 7 740 978 | 9 368 012 |
| Waste, non dangerous (kg) | 164 233 | 21 667 | 185 900 |
| Waste, dangerous (kg) | 9 600 | 1 153 | 10 753 |

| FUTURA house, concrete + recommendation 107, PV (recom. 362) | | | |
|---|---|---|---|
| Impact (Eco-Quantum) | All the rest | Operation phase | Total load |
| Abiotic depletion (kg Sb) | 13 349 | 73 726 | 87 075 |
| Global warming (kg CO2) | 131 213 | 518 918 | 650 131 |
| Ozon layer depletion (kg CFK11) | 0,0175 | 0,0108 | 0,0283 |
| Photoch. oxidation (kg ethyl) | 127,44 | 32,07 | 159,51 |
| Human. toxicity (kg 1,4DB) | 21 596 | 20 415 | 42 011 |
| Aquatic tox. water (kg 1,4DB) | 2 564 | 4 121 | 6 685 |
| Aquatic tox. sediment (kg 1,4DB) | 4 039 | 6 277 | 10 316 |
| Terrestrial tox. (kg 1,4DB) | 369,50 | 497,10 | 866,60 |
| Acidification (kg SO2) | 579,26 | 508,24 | 1 087,50 |
| Eutrophication (kg PO4) | 90,77 | 76,82 | 167,59 |
| Energy (kg MJ) | 1 677 731 | 7 993 777 | 9 671 508 |
| Waste, non dangerous (kg) | 159 134 | 20 269 | 179 403 |
| Waste, dangerous (kg) | 9 601 | 1 113 | 10 715 |

| FUTURA house, concrete + recommendation 107,collector, compared with base | | | |
|---|---|---|---|
| Impact (Eco-Quantum) | All the rest | Operation phase | Total load |
| Abiotic depletion (kg Sb) | 101% | 93% | 94% |
| Global warming (kg CO2) | 101% | 95% | 96% |
| Ozon layer depletion (kg CFK11) | 101% | 99% | 100% |
| Photoch. oxidation (kg ethyl) | 101% | 97% | 100% |
| Human. toxicity (kg 1,4DB) | 102% | 99% | 101% |
| Aquatic tox. water (kg 1,4DB) | 103% | 99% | 101% |
| Aquatic tox. sediment (kg 1,4DB) | 105% | 100% | 101% |
| Terrestrial tox. (kg 1,4DB) | 101% | 99% | 100% |
| Acidification (kg SO2) | 102% | 99% | 101% |
| Eutrophication (kg PO4) | 101% | 97% | 99% |
| Energy (kg MJ) | 102% | 94% | 95% |
| Waste, non dangerous (kg) | 104% | 100% | 104% |
| Waste, dangerous (kg) | 101% | 98% | 101% |

| FUTURA house, concrete + recommendation 107, PV, compared with base | | | |
|---|---|---|---|
| Impact (Eco-Quantum) | All the rest | Operation phase | Total load |
| Abiotic depletion (kg Sb) | 104% | 98% | 99% |
| Global warming (kg CO2) | 104% | 97% | 98% |
| Ozon layer depletion (kg CFK11) | 103% | 95% | 100% |
| Photoch. oxidation (kg ethyl) | 101% | 95% | 100% |
| Human. toxicity (kg 1,4DB) | 103% | 94% | 98% |
| Aquatic tox. water (kg 1,4DB) | 105% | 93% | 98% |
| Aquatic tox. sediment (kg 1,4DB) | 105% | 93% | 97% |
| Terrestrial tox. (kg 1,4DB) | 105% | 94% | 98% |
| Acidification (kg SO2) | 104% | 94% | 99% |
| Eutrophication (kg PO4) | 102% | 95% | 99% |
| Energy (kg MJ) | 105% | 97% | 98% |
| Waste, non dangerous (kg) | 101% | 93% | 100% |
| Waste, dangerous (kg) | 101% | 94% | 101% |

**Assumptions recommenation 134**

Cellulose fibre: insulation of external walls (Rc:4,0,  only in stead of the Rockwool part) and pitched roof  (not in the FUTURA case)

Shells: bottom sealing and pavement (not in the
FUTURA case)
Flax: gypsum board with a core of flax for the non-bearing innerwalls
(not in the FUTURA case)
Linseed oil based paint:outdoor paintwork

| FUTURA house, concrete + recommendation 134 | | | |
|---|---|---|---|
| Impact (Eco-Quantum) | All the rest | Operation phase | Total load |
| Abiotic depletion (kg Sb) | 12 517 | 75 307 | 87 824 |
| Global warming (kg CO2) | 124 088 | 537 159 | 661 247 |
| Ozon layer depletion (kg CFK11) | 0,0171 | 0,0113 | 0,0284 |
| Photoch. oxidation (kg ethyl) | 122,51 | 33,69 | 156,20 |
| Human. toxicity (kg 1,4DB) | 20 766 | 21 815 | 42 581 |
| Aquatic tox. water (kg 1,4DB) | 2 318 | 4 417 | 6 735 |
| Aquatic tox. sediment (kg 1,4DB) | 3 723 | 6 762 | 10 485 |
| Terrestrial tox. (kg 1,4DB) | 354,10 | 526,67 | 880,77 |
| Acidification (kg SO2) | 527,50 | 542,70 | 1 070,20 |
| Eutrophication (kg PO4) | 93,68 | 80,62 | 174,30 |
| Energy (kg MJ) | 1 547 997 | 8 233 778 | 9 781 775 |
| Waste, non dangerous (kg) | 156 596 | 21 749 | 178 345 |
| Waste, dangerous (kg) | 9 427 | 1 179 | 10 606 |

| FUTURA house, concrete + recommendation 134 | | | |
|---|---|---|---|
| Impact (EQuer) | All the rest | Operation phase | Total load |
| Primary energy | 1 547 997 | 8 233 778 | 9 781 775 |
| Water consumption | not in Eco-Quantum | | |
| Exhaust of resources | 12 517 | 75 307 | 87 824 |
| Solid waste | 156 596 | 21 749 | 178 345 |
| Radioactive waste | not in Eco-Quantum | | |
| Greenhouse effect | 124 088 | 537 159 | 661 247 |
| Acidification | 527,50 | 542,70 | 1 070,20 |
| Eutrophication | 93,68 | 80,62 | 174,30 |
| Ecotoxicity-water | 2 318 | 4 417 | 6 735 |
| Human toxicity | 20 766 | 21 815 | 42 581 |
| O3-smog | 122,51 | 33,69 | 156,20 |
| Odours | not in Eco-Quantum | | |

| FUTURA house, concrete + recommendation 134, compared with base | | | |
|---|---|---|---|
| Impact (Eco-Quantum) | All the rest | Operation phase | Total load |
| Abiotic depletion (kg Sb) | 98% | 100% | 100% |
| Global warming (kg CO2) | 99% | 100% | 100% |
| Ozon layer depletion (kg CFK11) | 101% | 100% | 100% |
| Photoch. oxidation (kg ethyl) | 98% | 100% | 98% |
| Human. toxicity (kg 1,4DB) | 99% | 100% | 99% |
| Aquatic tox. water (kg 1,4DB) | 95% | 100% | 98% |
| Aquatic tox. sediment (kg 1,4DB) | 97% | 100% | 99% |
| Terrestrial tox. (kg 1,4DB) | 100% | 100% | 100% |
| Acidification (kg SO2) | 95% | 100% | 97% |
| Eutrophication (kg PO4) | 105% | 100% | 103% |
| Energy (kg MJ) | 97% | 100% | 99% |
| Waste, non dangerous (kg) | 100% | 100% | 100% |
| Waste, dangerous (kg) | 99% | 100% | 100% |

| FUTURA house, concrete + recommendation 134, compared with base | | | |
|---|---|---|---|
| Impact (EQuer) | All the rest | Operation phase | Total load |
| Primary energy | 97% | 100% | 99% |
| Water consumption | not in Eco-Quantum | | |
| Exhaust of resources | 98% | 100% | 100% |
| Solid waste | 100% | 100% | 100% |
| Radioactive waste | not in Eco-Quantum | | |
| Greenhouse effect | 99% | 100% | 100% |
| Acidification | 95% | 100% | 97% |
| Eutrophication | 105% | 100% | 103% |
| Ecotoxicity-water | 95% | 100% | 98% |
| Human toxicity | 99% | 100% | 99% |
| O3-smog | 98% | 100% | 98% |
| Odours | not in Eco-Quantum | | |

**Assumptions recommenation 305**

Glazing: double => triple

Heating load: 9.696 kWh/year => 8.689 kWh/year

Heating load: 44.622 MJ/year => 39.988 MJ/year

| FUTURA house, concrete + recommendation 305 | | | |
|---|---|---|---|
| Impact (Eco-Quantum) | All the rest | Operation phase | Total load |
| Abiotic depletion (kg Sb) | 12 933 | 71 229 | 84 162 |
| Global warming (kg CO2) | 126 532 | 515 287 | 641 818 |
| Ozon layer depletion (kg CFK11) | 0,0170 | 0,0113 | 0,0283 |
| Photoch. oxidation (kg ethyl) | 126,66 | 32,84 | 159,50 |
| Human. toxicity (kg 1,4DB) | 21 032 | 21 650 | 42 683 |

| FUTURA house, concrete + recommendation 305 | | | |
|---|---|---|---|
| Impact (EQuer) | All the rest | Operation phase | Total load |
| Primary energy | 1 611 137 | 7 863 058 | 9 474 194 |
| Water consumption | not in Eco-Quantum | | |
| Exhaust of resources | 12 933 | 71 229 | 84 162 |
| Solid waste | 157 378 | 21 687 | 179 064 |
| Radioactive waste | not in Eco-Quantum | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Aquatic tox. water (kg 1,4DB) | 2 449 | 4 395 | 6 844 | | Greenhouse effect | 126 532 | 515 287 | 641 818 |
| Aquatic tox. sediment (kg 1,4DB) | 3 846 | 6 736 | 10 581 | | Acidification | 563,82 | 538,22 | 1 102,04 |
| Terrestrial tox. (kg 1,4DB) | 353,77 | 523,20 | 876,97 | | Eutrophication | 89,57 | 78,65 | 168,22 |
| Acidification (kg SO2) | 563,82 | 538,22 | 1 102,04 | | Ecotoxicity-water | 2 449 | 4 395 | 6 844 |
| Eutrophication (kg PO4) | 89,57 | 78,65 | 168,22 | | Human toxicity | 21 032 | 21 650 | 42 683 |
| Energy (kg MJ) | 1 611 137 | 7 863 058 | 9 474 194 | | O3-smog | 126,66 | 32,84 | 159,50 |
| Waste, non dangerous (kg) | 157 378 | 21 687 | 179 064 | | Odours | not in Eco-Quantum | | |
| Waste, dangerous (kg) | 9 479 | 1 159 | 10 639 | | | | | |

| FUTURA house, concrete + recommendation 305, compared with base | | | |
|---|---|---|---|
| Impact (Eco-Quantum) | All the rest | Operation phase | Total load |
| Abiotic depletion (kg Sb) | 101% | 95% | 95% |
| Global warming (kg CO2) | 101% | 96% | 97% |
| Ozon layer depletion (kg CFK11) | 100% | 99% | 100% |
| Photoch. oxidation (kg ethyl) | 101% | 97% | 100% |
| Human. toxicity (kg 1,4DB) | 100% | 99% | 100% |
| Aquatic tox. water (kg 1,4DB) | 100% | 100% | 100% |
| Aquatic tox. sediment (kg 1,4DB) | 100% | 100% | 100% |
| Terrestrial tox. (kg 1,4DB) | 100% | 99% | 100% |
| Acidification (kg SO2) | 101% | 99% | 100% |
| Eutrophication (kg PO4) | 101% | 98% | 99% |
| Energy (kg MJ) | 101% | 95% | 96% |
| Waste, non dangerous (kg) | 100% | 100% | 100% |
| Waste, dangerous (kg) | 100% | 98% | 100% |

| FUTURA house, concrete + recommendation 305, compared with base | | | |
|---|---|---|---|
| Impact (EQuer) | All the rest | Operation phase | Total load |
| Primary energy | 101% | 95% | 96% |
| Water consumption | not in Eco-Quantum | | |
| Exhaust of resources | 101% | 95% | 95% |
| Solid waste | 100% | 100% | 100% |
| Radioactive waste | Not in Eco-Quantum | | |
| Greenhouse effect | 101% | 96% | 97% |
| Acidification | 101% | 99% | 100% |
| Eutrophication | 101% | 98% | 99% |
| Ecotoxicity-water | 100% | 100% | 100% |
| Human toxicity | 100% | 99% | 100% |
| O3-smog | 101% | 97% | 100% |
| Odours | Not in Eco-Quantum | | |
| | | | |

**Assumptions recommenation 324**

Rainwater: used for toilet, washing machine, garden (in Eco-Quantum you can choose)
System: pump and storage tank (in Eco-Quantum you can choose between pump system and a system based on gravity)
Energy demand of pump: 532 MJ/year (automatically calculated by Eco-Quantum)
Roof surface: 100,5 m2 (projection), whole surface is used for the catch of water.
Quantity of rainwater: 800 mm/m2*year (centre of the Netherlands)
Capacity polyethene storage tank: 3000 liter (Eco-Quantum calculates the minimal needed capacity: 2879 liter)
Extra materials: storage tanks (3 x 1000 liter), pump, piping.

Grey water: used for toilet (first destination, no water demand for flushing left), washing machine, garden
System: pump and storage tank (in Eco-Quantum you can choose between pump system and a system based on gravity)
Energy demand of pump: 416 MJ/year (automatically calculated by Eco-Quantum)
Capacity polyethene storage tank: 2000 liter
Extra materials: storage tanks (2 x 1000 liter), pump, piping.

| FUTURA house, concrete + recommendation 324, rainwater and grey water | | | |
|---|---|---|---|
| Impact (Eco-Quantum) | All the rest | Operation phase | Total load |
| Abiotic depletion (kg Sb) | 13 091 | 75 363 | 88 454 |
| Global warming (kg CO2) | 127 164 | 538 332 | 665 496 |
| Ozon layer depletion (kg CFK11) | 0,0170 | 0 | 0,0274 |

| FUTURA house, concrete + recommendation 324 | | | |
|---|---|---|---|
| Impact (EQuer) | All the rest | Operation phase | Total load |
| Primary energy | 1 629 444 | 8 247 866 | 9 877 310 |
| Water consumption | Not in Eco-Quantum | | |
| Exhaust of resources | 13 091 | 75 363 | 88 454 |

| | | | |
|---|---|---|---|
| Photoch. oxidation (kg ethyl) | 126,05 | 34 | 159,69 |
| Human. toxicity (kg 1,4DB) | 21 195 | 21 956 | 43 152 |
| Aquatic tox. water (kg 1,4DB) | 2 456 | 4 441 | 6 897 |
| Aquatic tox. sediment (kg 1,4DB) | 3 859 | 6 806 | 10 665 |
| Terrestrial tox. (kg 1,4DB) | 430,80 | 509 | 940,20 |
| Acidification (kg SO2) | 567,79 | 543 | 1 110,90 |
| Eutrophication (kg PO4) | 89,54 | 81 | 170,30 |
| Energy (kg MJ) | 1 629 444 | 8 247 866 | 9 877 310 |
| Waste, non dangerous (kg) | 160 280 | 21 860 | 182 140 |
| Waste, dangerous (kg) | 9 502 | 1 186 | 10 688 |

| | | | |
|---|---|---|---|
| Solid waste | 160 280 | 21 860 | 182 140 |
| Radioactive waste | Not in Eco-Quantum | | |
| Greenhouse effect | 127 164 | 538 332 | 665 496 |
| Acidification | 567,79 | 543,11 | 1 110,90 |
| Eutrophication | 89,54 | 80,76 | 170,30 |
| Ecotoxicity-water | 2 456 | 4 441 | 6 897 |
| Human toxicity | 21 195 | 21 956 | 43 152 |
| O3-smog | 126,05 | 33,64 | 159,69 |
| Odours | Not in Eco-Quantum | | |
| | | | |

| FUTURA house, concrete + recommendation 324, rainwater and grey water | | | |
|---|---|---|---|
| Impact (Eco-Quantum) | All the rest | Operation phase | Total load |
| Abiotic depletion (kg Sb) | 102% | 100% | 100% |
| Global warming (kg CO2) | 101% | 100% | 100% |
| Ozon layer depletion (kg CFK11) | 100% | 92% | 97% |
| Photoch. oxidation (kg ethyl) | 100% | 100% | 100% |
| Human. toxicity (kg 1,4DB) | 101% | 101% | 101% |
| Aquatic tox. water (kg 1,4DB) | 101% | 101% | 101% |
| Aquatic tox. sediment (kg 1,4DB) | 101% | 101% | 101% |
| Terrestrial tox. (kg 1,4DB) | 122% | 97% | 107% |
| Acidification (kg SO2) | 102% | 100% | 101% |
| Eutrophication (kg PO4) | 101% | 100% | 100% |
| Energy (kg MJ) | 102% | 100% | 100% |
| Waste, non dangerous (kg) | 102% | 101% | 102% |
| Waste, dangerous (kg) | 100% | 101% | 100% |

| FUTURA house, concrete + recommendation 324, compared with base | | | |
|---|---|---|---|
| Impact (EQuer) | All the rest | Operation phase | Total load |
| Primary energy | 102% | 100% | 100% |
| Water consumption | Not in Eco-Quantum | | |
| Exhaust of resources | 102% | 100% | 100% |
| Solid waste | 102% | 101% | 102% |
| Radioactive waste | Not in Eco-Quantum | | |
| Greenhouse effect | 101% | 100% | 100% |
| Acidification | 102% | 100% | 101% |
| Eutrophication | 101% | 100% | 100% |
| Ecotoxicity-water | 101% | 101% | 101% |
| Human toxicity | 101% | 101% | 101% |
| O3-smog | 100% | 100% | 100% |
| Odours | Not in Eco-Quantum | | |
| | | | |

| FUTURA house, concrete + recommendation 324, only rainwater | | | |
|---|---|---|---|
| Impact (Eco-Quantum) | All the rest | Operation phase | Total load |
| Abiotic depletion (kg Sb) | 12 987 | 75 292 | 88 279 |
| Global warming (kg CO2) | 126 579 | 537 520 | 664 099 |
| Ozon layer depletion (kg CFK11) | 0,0170 | 0,0105 | 0,0275 |
| Photoch. oxidation (kg ethyl) | 125,86 | 33,59 | 159,46 |
| Human. toxicity (kg 1,4DB) | 21 112 | 21 887 | 42 999 |
| Aquatic tox. water (kg 1,4DB) | 2 450 | 4 428 | 6 877 |
| Aquatic tox. sediment (kg 1,4DB) | 3 849 | 6 784 | 10 633 |
| Terrestrial tox. (kg 1,4DB) | 399,73 | 510,46 | 910,19 |
| Acidification (kg SO2) | 563,77 | 541,80 | 1 105,57 |
| Eutrophication (kg PO4) | 89,34 | 80,61 | 169,95 |
| Energy (kg MJ) | 1 618 123 | 8 236 608 | 9 854 731 |
| Waste, non dangerous (kg) | 158 927 | 21 792 | 180 719 |
| Waste, dangerous (kg) | 9 491 | 1 182 | 10 673 |

| FUTURA house, concrete + recommendation 324, only grey water | | | |
|---|---|---|---|
| Impact (Eco-Quantum) | All the rest | Operation phase | Total load |
| Abiotic depletion (kg Sb) | 12 938 | 75 410 | 88 348 |
| Global warming (kg CO2) | 126 314 | 538 345 | 664 659 |
| Ozon layer depletion (kg CFK11) | 0,0170 | 0,0110 | 0,0280 |
| Photoch. oxidation (kg ethyl) | 125,79 | 33,76 | 159,55 |
| Human. toxicity (kg 1,4DB) | 21 078 | 21 924 | 43 002 |
| Aquatic tox. water (kg 1,4DB) | 2 447 | 4 438 | 6 885 |
| Aquatic tox. sediment (kg 1,4DB) | 3 845 | 6 797 | 10 642 |
| Terrestrial tox. (kg 1,4DB) | 384,30 | 521,81 | 906,11 |
| Acidification (kg SO2) | 562,10 | 544,30 | 1 106,40 |
| Eutrophication (kg PO4) | 89,24 | 80,85 | 170,09 |
| Energy (kg MJ) | 1 612 921 | 8 250 946 | 9 863 867 |
| Waste, non dangerous (kg) | 158 516 | 21 850 | 180 366 |
| Waste, dangerous (kg) | 9 487 | 1 184 | 10 671 |

| FUTURA house, concrete + recommendation 324, only rainwater | | | |
|---|---|---|---|
| Impact (Eco-Quantum) | All the rest | Operation phase | Total load |
| Abiotic depletion (kg Sb) | 101% | 100% | 100% |
| Global warming (kg CO2) | 101% | 100% | 100% |
| Ozon layer depletion (kg CFK11) | 100% | 93% | 97% |

| FUTURA house, concrete + recommendation 324, only grey water | | | |
|---|---|---|---|
| Impact (Eco-Quantum) | All the rest | Operation phase | Total load |
| Abiotic depletion (kg Sb) | 101% | 100% | 100% |
| Global warming (kg CO2) | 100% | 100% | 100% |
| Ozon layer depletion (kg CFK11) | 100% | 97% | 99% |

| | | | |
|---|---|---|---|
| Photoch. oxidation (kg ethyl) | 100% | 100% | 100% |
| Human. toxicity (kg 1,4DB) | 101% | 100% | 100% |
| Aquatic tox. water (kg 1,4DB) | 100% | 100% | 100% |
| Aquatic tox. sediment (kg 1,4DB) | 100% | 100% | 100% |
| Terrestrial tox. (kg 1,4DB) | 113% | 97% | 103% |
| Acidification (kg SO2) | 101% | 100% | 100% |
| Eutrophication (kg PO4) | 100% | 100% | 100% |
| Energy (kg MJ) | 101% | 100% | 100% |
| Waste, non dangerous (kg) | 101% | 100% | 101% |
| Waste, dangerous (kg) | 100% | 100% | 100% |

| | | | |
|---|---|---|---|
| Photoch. oxidation (kg ethyl) | 100% | 100% | 100% |
| Human. toxicity (kg 1,4DB) | 100% | 101% | 100% |
| Aquatic tox. water (kg 1,4DB) | 100% | 101% | 100% |
| Aquatic tox. sediment (kg 1,4DB) | 100% | 101% | 100% |
| Terrestrial tox. (kg 1,4DB) | 109% | 99% | 103% |
| Acidification (kg SO2) | 101% | 100% | 101% |
| Eutrophication (kg PO4) | 100% | 100% | 100% |
| Energy (kg MJ) | 101% | 100% | 100% |
| Waste, non dangerous (kg) | 101% | 100% | 101% |
| Waste, dangerous (kg) | 100% | 100% | 100% |

**Assumptions recommenation 325**

Bath: 120 => 100 liter

Toilet: 6 liter and flush stop => vacuum toilet (special device for enough flow)
Tap washing: class S (11,5 - 8,7 liter) => class Z (6,6 - 4,3 liter)
Tap kitschen: S (11,5 - 8,7 liter) => class Z (6,6 - 4,3 liter)
Shower: class B (14,4 - 11,5 liter) => class Z (6,6 - 4,3 liter)
The use of rainwater or greywater is not taken into account because of recommendation 324
The changes diminishes the amount of hot and cold water of 12.815 m3 to 8.604 m3 (33%)
The general assumption of a reduction of energy demand for hot water of 30% is taken. (70% of 14.271 is 9.990 MJ/year) => this is the main cause of the better results

| FUTURA house, concrete + recommendation 325 | | | |
|---|---|---|---|
| Impact (Eco-Quantum) | All the rest | Operation phase | Total load |
| Abiotic depletion (kg Sb) | 12 840 | 71 255 | 84 095 |
| Global warming (kg CO2) | 125 758 | 514 160 | 639 918 |
| Ozon layer depletion (kg CFK11) | 0,0170 | 0,0102 | 0,0272 |
| Photoch. oxidation (kg ethyl) | 125,61 | 32,49 | 158,10 |
| Human. toxicity (kg 1,4DB) | 20 995 | 21 501 | 42 496 |
| Aquatic tox. water (kg 1,4DB) | 2 441 | 4 358 | 6 799 |
| Aquatic tox. sediment (kg 1,4DB) | 3 835 | 6 683 | 10 518 |
| Terrestrial tox. (kg 1,4DB) | 355,26 | 499,31 | 854,57 |
| Acidification (kg SO2) | 558,20 | 532,21 | 1 090,41 |
| Eutrophication (kg PO4) | 89,04 | 78,08 | 167,12 |
| Energy (kg MJ) | 1 602 149 | 7 853 672 | 9 455 821 |
| Waste, non dangerous (kg) | 157 164 | 21 481 | 178 645 |
| Waste, dangerous (kg) | 9 475 | 1 153 | 10 628 |

| FUTURA house, concrete + recommendation 325 | | | |
|---|---|---|---|
| Impact (EQuer) | All the rest | Operation phase | Total load |
| Primary energy | 1 602 149 | 7 853 672 | 9 455 821 |
| Water consumption | Not in Eco-Quantum | | |
| Exhaust of resources | 12 840 | 71 255 | 84 095 |
| Solid waste | 157 164 | 21 481 | 178 645 |
| Radioactive waste | Not in Eco-Quantum | | |
| Greenhouse effect | 125 758 | 514 160 | 639 918 |
| Acidification | 558,20 | 532,21 | 1 090,41 |
| Eutrophication | 89,04 | 78,08 | 167,12 |
| Ecotoxicity-water | 2 441 | 4 358 | 6 799 |
| Human toxicity | 20 995 | 21 501 | 42 496 |
| O3-smog | 125,61 | 32,49 | 158,10 |
| Odours | Not in Eco-Quantum | | |

| FUTURA house, concrete + recommendation 325, compared with base | | | |
|---|---|---|---|
| Impact (Eco-Quantum) | All the rest | Operation phase | Total load |
| Abiotic depletion (kg Sb) | 100% | 95% | 95% |
| Global warming (kg CO2) | 100% | 96% | 97% |
| Ozon layer depletion (kg CFK11) | 100% | 90% | 96% |
| Photoch. oxidation (kg ethyl) | 100% | 96% | 99% |
| Human. toxicity (kg 1,4DB) | 100% | 99% | 99% |
| Aquatic tox. water (kg 1,4DB) | 100% | 99% | 99% |
| Aquatic tox. sediment (kg 1,4DB) | 100% | 99% | 99% |

| FUTURA house, concrete + recommendation 325, compared with base | | | |
|---|---|---|---|
| Impact (EQuer) | All the rest | Operation phase | Total load |
| Primary energy | 100% | 95% | 96% |
| Water consumption | Not in Eco-Quantum | | |
| Exhaust of resources | 100% | 95% | 95% |
| Solid waste | 100% | 99% | 100% |
| Radioactive waste | Not in Eco-Quantum | | |
| Greenhouse effect | 100% | 96% | 97% |
| Acidification | 100% | 98% | 99% |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Terrestrial tox. (kg 1,4DB) | 101% | 95% | 97% | Eutrophication | 100% | 97% | 98% |
| Acidification (kg SO2) | 100% | 98% | 99% | Ecotoxicity-water | 100% | 99% | 99% |
| Eutrophication (kg PO4) | 100% | 97% | 98% | Human toxicity | 100% | 99% | 99% |
| Energy (kg MJ) | 100% | 95% | 96% | O3-smog | 100% | 96% | 99% |
| Waste, non dangerous (kg) | 100% | 99% | 100% | Odours | Not in Eco-Quantum | | |
| Waste, dangerous (kg) | 100% | 98% | 100% | | | | |

ECO-SOFT

| | | absolute value | | | |
|---|---|---|---|---|---|
| **Whole Life** | unit | base: concrete | Rec.134 (Ren.Mat) | Rec.305 ( glazing) | Rec.107 (Ren.Energy) |
| global warming (GWP100) | kg CO2 eq. | 635985 | 552011 | 605598 | 156926 |
| ozone layer depletion (ODP) | kg CFC-11 eq | 6,168 | 3,278 | 6,165 | 6,116 |
| photo-chemical o0idation | kg C2H2 | 62 | 64 | 58 | 163 |
| acidification | kg SO2 eq. | 2169 | 2044 | 2141 | 2609 |
| eutro-phication | kg PO4--- eq | 151 | 140 | 144 | 155 |
| PEI nicht erneuerbar | MJ | 1162537<br>0 | 11179007 | 11070049 | 2258224 |
| PEI erneuerbar | MJ | 603418 | 1150391 | 591672 | 6367418 |

| relative value | | | |
|---|---|---|---|
| base: concrete | Rec.134 (Ren.Mat) | Rec.305 ( glazing) | Rec.107 (Ren.Energy) |
| 100,00% | 86,80% | 95,22% | 24,67% |
| 100,00% | 53,15% | 99,95% | 99,16% |
| 100,00% | 102,99% | 93,91% | 263,97% |
| 100,00% | 94,25% | 98,69% | 120,27% |
| 100,00% | 92,86% | 95,70% | 103,00% |
| 100,00% | 96,16% | 95,22% | 19,42% |
| 100,00% | 190,65% | 98,05% | 1055,23% |

ENVEST

| | **FUTURA House Concrete** | **FUTURA House Con 12 declaration** | **FUTURA House Con 324 water recyc** | **FUTURA House Con 134 renewable** | **FUTURA House Con 325 water sav** | **FUTURA House Con 305 glazing** |
|---|---|---|---|---|---|---|
| Recommendation | Standard for compariso n | **12**: Use Environmental Declarations on building products as an information source. | **324**: Install a system for the use of rainwater and/or greywater in the building. | **134**: Use renewable resource based materials | **325**: Apply (drinking) water saving measures. Use water saving appliances. | **305**: Choose an appropriate glazing type |

| | | | | | | |
|---|---|---|---|---|---|---|
| Implementation | N/A | Referring to Product declaration (Environmental Profile), select Kingspan PU insulation in place of Rockwool for roof insulation | Use rainwater recovery system on 100% of roof to supply water for flushing wcs. | Use timber and OSB based internal wall rather than in situ concrete structure. | Use WCs with 4.5 litre flush and taps with flow regulation. | Use triple glazing rather than double glazing. |
| Embodied Impact (Ecopoints) | n/a | -5 ecopoints (-0.5%) | No change | -71 ecopoints (-6.8%) | No change | +2 ecopoints (+0.2%) |
| Operational Impact | n/a | No change | - 26 ecopoints (-2000 $m^3$ water) | No change | -18 ecopoints (-1400 $m^3$ water) | Reduces gas use from 9696 kWh per year to 8689 kWh. |
| | | | | | | |
| | | | | | | |
| | FUTURA House Concrete | FUTURA House R12 Declaration | FUTURA House R324 water recycling | FUTURA House R134 renewable materials | FUTURA House R325 water saving | FUTURA House R305 triple glazing |
| EMBODIED IMPACTS (80 YEARS) | | | | | | |
| EMBODIED ECOPOINTS | 1247 | 1193 | 1247 | 1204 | 1247 | 1258 |
| Climate Change (tonnes $CO_2$ eq. (100yr)) | 98 | 92 | 98 | 111 | 98 | 100 |
| Acid Deposition (tonnes $SO_2$ eq.) | 1 | 1 | 1 | 1 | 1 | 1 |
| Ozone Depletion (kg $CFC_{11}$ eq.) | 0 | 0 | 0 | 0 | 0 | 0 |
| Human Toxicity Air (kg tox.) | 1063 | 1001 | 1063 | 1178 | 1063 | 1092 |
| Ozone Creation (kg ethene eq.) | 30 | 18 | 30 | 42 | 30 | 31 |
| Human Toxicity Water (kg tox.) | 0 | 0 | 0 | 0 | 0 | 0 |
| Eco Toxicity Water ($m^3$ tox.) | 467377 | 467377 | 467377 | 723087 | 467377 | 509906 |
| Eutrophication (kg $PO_4$ eq.) | 48 | 43 | 48 | 66 | 48 | 50 |
| Fossil Fuel Depletion (tonnes of oil eq.) | 22 | 20 | 22 | 30 | 22 | 23 |
| Minerals Extraction (tonnes) | 303 | 303 | 303 | 292 | 303 | 305 |
| Water Extraction ($m^3$) | 258 | 252 | 258 | 321 | 258 | 258 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Waste Disposal (tonnes) | 226 | 216 | 226 | 204 | 226 | 226 |
| OPERATIONAL IMPACTS (80 YEARS) – Gas and Water only | | | | | | |
| Gas (kWh) | 775680 | 775680 | 775680 | 775680 | 775680 | 695120 |
| Water ($m^3$) | 5723,2 | 5723,2 | 3723,2 | 5723,2 | 4323,2 | 5723,2 |
| Gas (Ecopoints) | 753 | 753 | 753 | 753 | 753 | 675 |
| Water (Ecopoints | 74,2 | 74,2 | 48 | 74,2 | 55,8 | 74,2 |
| Total (Ecopoints) | 827 | 827 | 801 | 827 | 809 | 749 |
| | | | | | | |
| | | | | | | |
| **Comparison to Concrete House Base Case** | **FUTURA House Concrete** | **FUTURA House R12 Declaration** | **FUTURA House R324 water recycling** | **FUTURA House R134 renewable materials** | **FUTURA House R325 water saving** | **FUTURA House R305 triple glazing** |
| EMBODIED IMPACTS (80 YEARS) | Base Case | R12 | R324 | R134 | R325 | R305 |
| EMBODIED ECOPOINTS | 100 | 95,67 | 100,00 | 96,55 | 100,00 | 100,88 |
| Climate Change | 100 | 93,88 | 100,00 | 113,27 | 100,00 | 102,04 |
| Acidification | 100 | 100,00 | 100,00 | 100,00 | 100,00 | 100,00 |
| HT Air | 100 | 94,17 | 100,00 | 110,82 | 100,00 | 102,73 |
| Ozone (Smog) | 100 | 60,00 | 100,00 | 140,00 | 100,00 | 103,33 |
| Ecotoxicity | 100 | 100,00 | 100,00 | 154,71 | 100,00 | 109,10 |
| Eutrophication | 100 | 89,58 | 100,00 | 137,50 | 100,00 | 104,17 |
| Fossil Fuel Depletion | 100 | 90,91 | 100,00 | 136,36 | 100,00 | 104,55 |
| Minerals | 100 | 100,00 | 100,00 | 96,37 | 100,00 | 100,66 |
| Water | 100 | 97,67 | 100,00 | 124,42 | 100,00 | 100,00 |
| Waste | 100 | 95,58 | 100,00 | 90,27 | 100,00 | 100,00 |
| OPERATIONAL IMPACTS (80 YEARS) – Gas and Water only | | | | | | |
| Gas (kWh) | 100 | 100,00 | 100,00 | 100,00 | 100,00 | 89,61 |
| Water (m3) | 100 | 100,00 | 65,05 | 100,00 | 75,54 | 100,00 |
| Gas (Ecopoints) | 100 | 100,00 | 100,00 | 100,00 | 100,00 | 89,64 |
| Water (Ecopoints | 100 | 100,00 | 64,69 | 100,00 | 75,20 | 100,00 |
| Total (Ecopoints) | 100 | 100,00 | 96,86 | 100,00 | 97,82 | 90,57 |
| | | | | | | |
| | concrete | | | | | |
| Operation | Concrete | | R324 | | R325 | R305 |
| Ecopoints | 2054,67225 | | 2054,67225 | | 2054,67225 | 1953,36207 |
| climate | 368597,162 | | 368597,162 | | 368597,162 | 347451,276 |
| acid | 2159,89472 | | 2159,89472 | | 2159,89472 | 2134,67585 |
| htox | 2546,93174 | | 2546,93174 | | 2546,93174 | 2518,67969 |
| smog | 25,6038023 | | 25,6038023 | | 25,6038023 | 23,9019988 |
| ecotox | | | | | | |
| eutro | 106,378505 | | 106,378505 | | 106,378505 | 101,829713 |
| toe | 137,104345 | | 137,104345 | | 137,104345 | 127,133685 |
| minerals | | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| litres | 5736000 | | 3767978,4 | | 4313472 | 5736000 |
| waste | | | | | | |
| | | | | | | |
| Whole Life | Base Case | R12 | R324 | R134 | R325 | R305 |
| Ecopoints | 3301,67225 | | 3301,67225 | | 3301,67225 | 3211,36207 |
| Climate Change | 368695,162 | | 368695,162 | | 368695,162 | 347551,276 |
| Acidification | 2160,89472 | | 2160,89472 | | 2160,89472 | 2135,67585 |
| HT Air | 3609,93174 | | 3609,93174 | | 3609,93174 | 3610,67969 |
| Ozone (Smog) | 55,6038023 | | 55,6038023 | | 55,6038023 | 54,9019988 |
| Ecotoxicity | 467377 | | 467377 | | 467377 | 509906 |
| Eutrophication | 154,378505 | | 154,378505 | | 154,378505 | 151,829713 |
| Fossil Fuel Depletion | 159,104345 | | 159,104345 | | 159,104345 | 150,133685 |
| Minerals | 303 | | 303 | | 303 | 305 |
| Water | 5736258 | | 3768236,4 | | 4313730 | 5736258 |
| Waste | 226 | | 226 | | 226 | 226 |
| | | | | | | |
| Whole Life | Base Case | R324 | R325 | R305 | | |
| Ecopoints | 100 | 100 | 100 | 97,2647139 | | |
| Climate Change | 100 | 100 | 100 | 94,265212 | | |
| Acidification | 100 | 100 | 100 | 98,8329434 | | |
| HT Air | 100 | 100 | 100 | 100,020719 | | |
| Ozone (Smog) | 100 | 100 | 100 | 98,7378498 | | |
| Ecotoxicity | 100 | 100 | 100 | 109,099506 | | |
| Eutrophication | 100 | 100 | 100 | 98,3489984 | | |
| Fossil Fuel Depletion | 100 | 100 | 100 | 94,361776 | | |
| Minerals | 100 | 100 | 100 | 100,660066 | | |
| Water | 100 | 65,6915432 | 75,2011154 | 100 | | |
| Waste | 100 | 100 | 100 | 100 | | |

EQUER

| Base case : FUTURA house, wood | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |
| Impact | Unit | Construction | Utilisation | Renovation | Demolition | Total | | |
| ENERGY | GJ | 2689,84 | 11882,60 | 132,02 | 37,44 | 14741,89 | | |
| WATER | m3 | 898,00 | 14451,76 | 1757,83 | 358,04 | 17465,62 | | |
| RESOURCE | E-9 | 0,49 | 4,25 | 0,98 | 0,01 | 5,74 | | |
| WASTE | t eq | 40,14 | 59,29 | 1,53 | 492,18 | 593,14 | | |
| RADWASTE | dm3 | 3,32 | 15,54 | 0,38 | 0,13 | 19,38 | | |
| GWP100 | t CO2 | 25,22 | 487,89 | 8,16 | 34,66 | 555,92 | | |
| ACIDIF. | kg SO2 | 349,66 | 1439,49 | 23,74 | 33,01 | 1845,90 | | |
| EUTROPH. | kg PO4 | 42,10 | 103,65 | 3,18 | 5,10 | 154,04 | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| ECOTOX-W | m3 | 510648,63 | 7648042,26 | 262866,47 | 104211,42 | 8525768,79 | | |
| HUM-TOX. | kg | 1070,33 | 1947,67 | 81,10 | 38,35 | 3137,45 | | |
| O3-SMOG | kg C2H4 | 170,53 | 661,08 | 13,06 | 30,90 | 875,57 | | |
| ODOUR | Mm3 | 41,24 | 6556,91 | 6,39 | 5,86 | 6610,41 | | |
| | | | | | | | | |
| Recommendation 305, triple glazing : heating load = 8803 kWh/year | | | | | | | | |
| whole life cycle | | | | | | | | |
| Impact | Unit | base | recommendation | Impact | base | recommendation | | |
| ENERGY | GJ | 14741,89 | 14258,18937 | ENERGY | 100,00% | 96,72% | | |
| WATER | m3 | 17465,62 | 17433,45983 | WATER | 100,00% | 99,82% | | |
| RESOURCE | E-9 | 5,74 | 5,60E+00 | RESOURCE | 100,00% | 97,62% | | |
| WASTE | t eq | 593,14 | 591,0199561 | WASTE | 100,00% | 99,64% | | |
| RADWASTE | dm3 | 19,38 | 19,2146948 | RADWASTE | 100,00% | 99,16% | | |
| GWP100 | t CO2 | 555,92 | 529,8597794 | GWP100 | 100,00% | 95,31% | | |
| ACIDIF. | kg SO2 | 1845,90 | 1814,998596 | ACIDIF. | 100,00% | 98,33% | | |
| EUTROPH. | kg PO4 | 154,04 | 150,3632355 | EUTROPH. | 100,00% | 97,61% | | |
| ECOTOX-W | m3 | 8525768,79 | 8409748,39 | ECOTOX-W | 100,00% | 98,64% | | |
| HUM-TOX. | kg | 3137,45 | 3095,936264 | HUM-TOX. | 100,00% | 98,68% | | |
| O3-SMOG | kg C2H4 | 875,57 | 849,4121454 | O3-SMOG | 100,00% | 97,01% | | |
| ODOUR | Mm3 | 6610,41 | 6115,837313 | ODOUR | 100,00% | 92,52% | | |
| | | | | | | | | |
| Recommendation 325, water saving (-30%) | | | | | | | | |
| whole life cycle | | | | | | | | |
| Impact | Unit | base | recommendation | Impact | base | recommendation | | |
| ENERGY | GJ | 14741,89 | 14281,99466 | ENERGY | 100,00% | 96,88% | | |
| WATER | m3 | 17465,62 | 15431,14354 | WATER | 100,00% | 88,35% | | |
| RESOURCE | E-9 | 5,74 | 5,60E+00 | RESOURCE | 100,00% | 97,64% | | |
| WASTE | t eq | 593,14 | 591,1026225 | WASTE | 100,00% | 99,66% | | |
| RADWASTE | dm3 | 19,38 | 19,1868236 | RADWASTE | 100,00% | 99,02% | | |
| GWP100 | t CO2 | 555,92 | 531,5752157 | GWP100 | 100,00% | 95,62% | | |
| ACIDIF. | kg SO2 | 1845,90 | 1813,967686 | ACIDIF. | 100,00% | 98,27% | | |
| EUTROPH. | kg PO4 | 154,04 | 150,5170592 | EUTROPH. | 100,00% | 97,71% | | |
| ECOTOX-W | m3 | 8525768,79 | 8404708,947 | ECOTOX-W | 100,00% | 98,58% | | |
| HUM-TOX. | kg | 3137,45 | 3094,57274 | HUM-TOX. | 100,00% | 98,63% | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| O3-SMOG | kg C2H4 | 875,57 | 850,6963259 | O3-SMOG | 100,00% | 97,16% | | |
| ODOUR | Mm3 | 6610,41 | 6157,957599 | ODOUR | 100,00% | 93,16% | | |
| | | | | | | | | |
| Recommendation 77, transport of materials | | | | | | | | |
| construction | | | | | | | | |
| Impact | Unit | base | 5 km | 1000 km | Impact | base | 5 km | 1000 km |
| ENERGY | GJ | 2689,84 | 2597,06 | 3568,77 | ENERGY | 100,00% | 96,55% | 132,68% |
| WATER | m3 | 898,00 | 856,96 | 1286,86 | WATER | 100,00% | 95,43% | 143,30% |
| RESOURCE | E-9 | 0,49 | 0,46 | 0,84 | RESOURCE | 100,00% | 92,60% | 170,14% |
| WASTE | t eq | 40,14 | 37,31 | 67,01 | WASTE | 100,00% | 92,94% | 166,93% |
| RADWASTE | dm3 | 3,32 | 2,98 | 6,56 | RADWASTE | 100,00% | 89,70% | 197,61% |
| GWP100 | t CO2 | 25,22 | 19,59 | 78,48 | GWP100 | 100,00% | 77,70% | 311,25% |
| ACIDIF. | kg SO2 | 349,66 | 286,56 | 947,43 | ACIDIF. | 100,00% | 81,95% | 270,95% |
| EUTROPH. | kg PO4 | 42,10 | 32,31 | 134,88 | EUTROPH. | 100,00% | 76,74% | 320,36% |
| ECOTOX-W | m3 | 510648,63 | 325928,38 | 2260629,96 | ECOTOX-W | 100,00% | 63,83% | 442,70% |
| HUM-TOX. | kg | 1070,33 | 994,27 | 1790,84 | HUM-TOX. | 100,00% | 92,89% | 167,32% |
| O3-SMOG | kg C2H4 | 170,53 | 102,33 | 816,70 | O3-SMOG | 100,00% | 60,00% | 478,91% |
| ODOUR | Mm3 | 41,24 | 34,74 | 102,80 | ODOUR | 100,00% | 84,24% | 249,26% |
| | | | | | | | | |
| Recommendation 134, cellulose insulation (walls + roof) | | | | | | | | |
| except operation | | | | | | | | |
| Impact | Unit | base | recommendation | Impact | base | recommendation | | |
| ENERGY | GJ | 2859,29 | 2592,92 | ENERGY | 100,00% | 90,68% | | |
| WATER | m3 | 3013,87 | 2889,67 | WATER | 100,00% | 95,88% | | |
| RESOURCE | E-9 | 1,48 | 1,44 | RESOURCE | 100,00% | 96,93% | | |
| WASTE | t eq | 533,85 | 425,90 | WASTE | 100,00% | 79,78% | | |
| RADWASTE | dm3 | 3,84 | 3,85 | RADWASTE | 100,00% | 100,43% | | |
| GWP100 | t CO2 | 68,04 | 53,16 | GWP100 | 100,00% | 78,14% | | |
| ACIDIF. | kg SO2 | 406,42 | 335,32 | ACIDIF. | 100,00% | 82,51% | | |
| EUTROPH. | kg PO4 | 50,39 | 42,58 | EUTROPH. | 100,00% | 84,51% | | |
| ECOTOX-W | m3 | 877726,53 | 799798,64 | ECOTOX-W | 100,00% | 91,12% | | |
| HUM-TOX. | kg | 1189,78 | 1055,19 | HUM-TOX. | 100,00% | 88,69% | | |
| O3-SMOG | kg C2H4 | 214,50 | 191,52 | O3-SMOG | 100,00% | 89,29% | | |
| ODOUR | | 53,49 | 41,36 | ODOUR | 100,00% | 77,33% | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Mm3 | | | | | | | |
| | | | | | | | | |
| Recommendation 107, renewable energy (50% solar water heater) | | | | | | | | |
| whole life cycle | | | | | | | | |
| Impact | Unit | base | recommendation | Impact | base | recommendation | | |
| ENERGY | GJ | 14741,89 | 14006,05608 | ENERGY | 100,00% | 95,01% | | |
| WATER | m3 | 17465,62 | 14210,45532 | WATER | 100,00% | 81,36% | | |
| RESOURCE | E-9 | 5,74 | 5,52E+00 | RESOURCE | 100,00% | 96,23% | | |
| WASTE | t eq | 593,14 | 589,8819899 | WASTE | 100,00% | 99,45% | | |
| RADWASTE | dm3 | 19,38 | 19,07256551 | RADWASTE | 100,00% | 98,43% | | |
| GWP100 | t CO2 | 555,92 | 516,9664058 | GWP100 | 100,00% | 92,99% | | |
| ACIDIF. | kg SO2 | 1845,90 | 1794,806988 | ACIDIF. | 100,00% | 97,23% | | |
| EUTROPH. | kg PO4 | 154,04 | 148,4038172 | EUTROPH. | 100,00% | 96,34% | | |
| ECOTOX-W | m3 | 8525768,79 | 8332073,042 | ECOTOX-W | 100,00% | 97,73% | | |
| HUM-TOX. | kg | 3137,45 | 3068,849204 | HUM-TOX. | 100,00% | 97,81% | | |
| O3-SMOG | kg C2H4 | 875,57 | 835,7691534 | O3-SMOG | 100,00% | 95,45% | | |
| ODOUR | Mm3 | 6610,41 | 5886,488279 | ODOUR | 100,00% | 89,05% | | |
| | | | | | | | | |
| Recommendation 107, wood fuel | | | | | | | | |
| whole life cycle | | | | | | | | |
| Impact | Unit | base | recommendation | Impact | base | recommendation | | |
| ENERGY | GJ | 14741,89 | 18761,12102 | ENERGY | 100,00% | 127,26% | | |
| WATER | m3 | 17465,62 | 17403,14865 | WATER | 100,00% | 99,64% | | |
| RESOURCE | E-9 | 5,74 | 4,44E+00 | RESOURCE | 100,00% | 77,47% | | |
| WASTE | t eq | 593,14 | 586,0034447 | WASTE | 100,00% | 98,80% | | |
| RADWASTE | dm3 | 19,38 | 19,28224009 | RADWASTE | 100,00% | 99,51% | | |
| GWP100 | t CO2 | 555,92 | 271,9002482 | GWP100 | 100,00% | 48,91% | | |
| ACIDIF. | kg SO2 | 1845,90 | 2309,885568 | ACIDIF. | 100,00% | 125,14% | | |
| EUTROPH. | kg PO4 | 154,04 | 228,8435365 | EUTROPH. | 100,00% | 148,56% | | |
| ECOTOX-W | m3 | 8525768,79 | 7814674,471 | ECOTOX-W | 100,00% | 91,66% | | |
| HUM-TOX. | kg | 3137,45 | 4347,361345 | HUM-TOX. | 100,00% | 138,56% | | |
| O3-SMOG | kg C2H4 | 875,57 | 1779,448967 | O3-SMOG | 100,00% | 203,23% | | |
| ODOUR | Mm3 | 6610,41 | 794,6654267 | ODOUR | 100,00% | 12,02% | | |

ESCALE

| | | | | | Rec12/normal | Rec134/normal |
|---|---|---|---|---|---|---|
| | Unit | FUTURA | FUTURA with rec12 | FUTURA with rec.134 | | |
| exhaustion of resources | e-12/kg | 4,89E+03 | 4,81E+03 | 4,94E+03 | 98% | 101% |
| eutrophication | kg PO4 eq. | 148 | 146 | 147 | 99% | 99% |
| ozone depletion | kg CFC11 eq | 0,0529 | 0,0528 | 0,0535 | 100% | 101% |
| ecotox. | m3/mg | 1,04E+07 | 1,04E+07 | 1,05E+07 | 100% | 101% |
| greenhouse | kg CO2 eq. | 6,20E+05 | 6,00E+05 | 6,18E+05 | 97% | 100% |
| acidification | kg SO2 eq. | 2,12E+03 | 2,11E+03 | 2,07E+03 | 100% | 98% |
| s.smog | kg ethene eq | 180 | 179 | 170 | 99% | 94% |
| humantox | kg/kg | 3,13E+03 | 3,12E+03 | 3,08E+03 | 100% | 98% |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| Rec.12 application | | | | | | |
| Low-e 4/16/4 repalced by triple glazing | | | | | | |
| | | | | | | |
| Rec.134 | | | | | | |
| Floor above basement, Anhydride cast plaster floor replaced by OSB Panel (alternative 2) | | | | | | |
| Floor above ground floor glasswool replaced by wood fibreboard (alternative1) | | | | | | |
| External walls above ground, polystyrène replaced by wood fibreboards. | | | | | | |
| No recent data available for cork, wool, insulation cellulose... | | | | | | |
| | | | | | | |
| CONCLUSION | | | | | | |
| No major differences due to recommandations. | | | | | | |
| Uncertainties are higher than the calculated differences. | | | | | | |

OGIP

**Base case : FUTURA house, concrete**

| **Impact** | **Unit** | **operation phase** | **all the rest** | | | **Total** |
|---|---|---|---|---|---|---|
| Capital costs | CHFr. | 333 440,00 | 242 773,00 | | | 576 213,00 |
| External costs | CHFr. | 61 276,00 | 7 941,00 | | | 69 217,00 |
| UBP | UBP (*) | 295 605 989,00 | 74 071 898,00 | | | 369 677 887,00 |
| Primary energy (**) | MJ | 11 560 430,00 | 1 005 744,00 | | | 12 566 174,00 |

**Recommendation 305, triple glazing : corrected heating load = 8'596 kWh/year**

operation phase

| **Impact** | **Unit** | **base** | **recommendation** | **Impact** | **base** | **recommendation** |
|---|---|---|---|---|---|---|
| Capital costs | CHFr. | 333 440,00 | 330 266,00 | capital costs | 100,00% | 99,05% |
| External costs | CHFr. | 61 276,00 | 57 913,00 | external costs | 100,00% | 94,51% |
| UBP | UBP (*) | 295 605 989,00 | 284 732 157,00 | UBP | 100,00% | 96,32% |
| Primary energy (**) | MJ | 11 560 430,00 | 10 929 554,00 | Primary energy | 100,00% | 94,54% |

**Recommendation 325, water heating energy saving (-30%) caused by water saving**

operation phase

| Impact | Unit | base | recommendation | Impact | base | recommendation |
|---|---|---|---|---|---|---|
| Capital costs | CHFr. | 333 440,00 | 332 251,00 | capital costs | 100,00% | 99,64% |
| External costs | CHFr. | 61 276,00 | 60 016,00 | external costs | 100,00% | 97,94% |
| UBP | UBP (*) | 295 605 989,00 | 291 532 661,00 | UBP | 100,00% | 98,62% |
| Primary energy (**) | MJ | 11 560 430,00 | 11 324 104,00 | Primary energy | 100,00% | 97,96% |

**Recommendation 77, transport of materials**

OGIP uses average data either valid for Switzerland, Europe ot the world. The transportation from manufacturer or regional storage to the building site is not included and therefore can't be adapted to another situation

**Recommendation 134, renewable insulation (walls + roof)**

makes no sense because for the alternatives offered in OGIP (cellulose fibre) an additional construction is necessary

**Recommendation 107, wood fuel**

operation phase

| Impact | Unit | base | recommendation | Impact | base | recommendation |
|---|---|---|---|---|---|---|
| Capital costs | CHFr. | 333 440,00 | 383 229,00 | capital costs | 100,00% | 114,93% |
| External costs | CHFr. | 61 276,00 | 44 572,00 | external costs | 100,00% | 72,74% |
| UBP | UBP (*) | 295 605 989,00 | 349 800 567,00 | UBP | 100,00% | 118,33% |
| Primary energy (**) | MJ | 11 560 430,00 | 12 923 311,00 | Primary energy | 100,00% | 111,79% |

**Recommendation 12, use environmental declaration on building products**

not clear...

**Recommendation 324, rainwater system**

not possible to be modelled in OGIP, because the use of water and the disposal of waste water during the use phase of the building is not taken into account

(*) The calculation of the environmental impact is made with the method of the ecological scarcity based on environmental factors. The unit of the environmental impact is ecoscarcity points (UBP). It is a fully aggregated method which means that all the environmental effects are declared in one number. The method of ecological scarcity is based on the basic assumption that the amount of the yearly total flow of a substance or the just still tolerable flow is determining the ecological relevance.

(**) Primary energy includes all energy carriers which can be dealt with on the marked. It includes all non-renewable and renewable primary energy carrier as well as energetic usable fossil fuel and biomass, water power and 50% of the energetic recoverable waste. Not counted are the passiv-solar gains and the solar energy from small installations which are used at the same place as the energy is produced.