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Deliverable D2.1
State of the art report

and

Deliverable D2.2
Collection of published material

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Introduction

The building sector contributes largely in the global environmental load of human activities: for instance around 40% of the total energy consumption in Europe corresponds to this sector. It represents also a major potential for improvement, and is generally addressed by most environmental policies.

The Energy Performance of Buildings Directive includes environmental information in energy certificates, particularly CO_2 emissions. Environmental performance is a major driving force to energy saving (climate change, exhaust of resources, nuclear waste, toxicity aspects etc.).

Reducing environmental impacts in the building sector requires appropriate evaluation methods allowing:

- environmental performance levels to be integrated in programmes (clients brief) by the demand side (e.g. requirements in municipal policy and building programmes),
- advice to be provided to designers, Architects and consultants, in order to reach such targets,
- guidance for efficient operation and management of buildings, so that actual performance corresponds to design performance,
- life cycle costing methods and tools do evaluate the most cost effective measures (actions) for energy savings and reduced environmental impacts over the whole life cycle..

Life cycle assessment (LCA) constitutes an important part of such evaluation methods. Previous studies allowed building LCA tools to be reviewed (e.g. International Energy Agency annex 31, European thematic network PRESCO, European projects REGENER and LENSE). Some gaps are addressed in the ENSLIC Building project regarding environmental indicators, easily understandable presentation of LCA results to users, simplification and adaptation of LCA to various purposes (e.g. early design phases).This report presents a state of the art regarding the application of this method in the building sector and provides:

- a list of existing tools,
- a description of environmental indicators,
- example presentation of results according to the users,
- practice regarding simplification of LCA and adaptation to building design.

Life Cycle Costing gives information about most total costs over the whole life cycle. In combination with methods for environmental assessment and other assessment criteria, more support methods and tools are available for decision support during the design and construction process. Previous studies of existing LCC methods and tools, as well as the today's use and future needs, are done in earlier projects as LCC Refurb, LCC-DATA, Task Group 4 (TG4) (2003) Report of Task Group 4: Life Cycle Costs in Construction, the European Commission, and EU Commission project Life Cycle Costing (LCC) as a contribution to sustainable construction: a common methodology.

1 List and description of existing Building LCA tools

The life cycle assessment of a building can be performed using general LCA software, but it requires much time to quantify building materials, energy use etc. Therefore, specific tools have been developed to facilitate the use of LCA in the building sector: architects and engineers only have a few days to perform such a study, and appropriate interfaces are more convenient. Therefore this state of the art report focus on specific LCA tools for buildings.

1.1 Software Tools for general LCA studies

Due to the large amount of data required to perform a LCA it is recommended to avail of a software tool which facilitates the efficient undertaking of a study. At present various programs exist on the market and they allow the carrying out of LCA studies in different degrees of detail. In deciding which programs to use, it is necessary to consider several criteria.

One of the key points to note is the number of databases that the software incorporates, its origin, quality and scope. Also, it is convenient that the program allow editing of the existing databases and to easily import new databases that might be acquired later. In addition it is important to check the ease of use of the program based on the application that it will have, the possibility of using different impact evaluation methods, the traceability the results, the interface and the graphical possibilities that it offers and evidently its financial cost.
Next table is a compilation of the main programs currently available, indicating each one's contact e-mail address and its main characteristics.

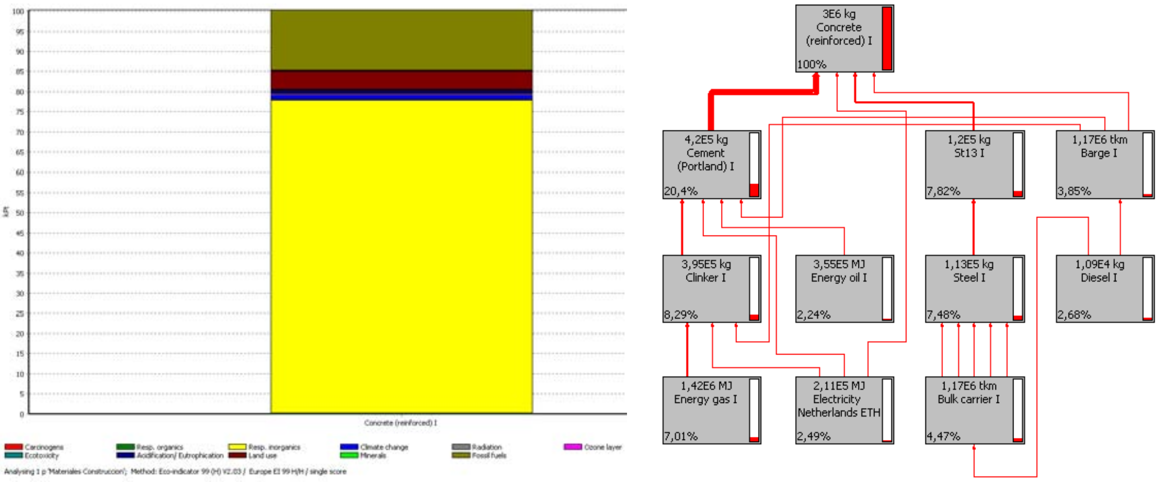
Program	Development Company	Contact	Comments
Boustead	Boustead Consulting (UK)	http://www.boustead-consulting.co.uk	Very complete tool suitable for LCA studies in the Steel, Chemical and Plastics Industry
Eco-it	Pré Consultants (NL)	http://www.pre.nl	Especially suitable for designers of products and containers. It uses Ecoindicator '99. It is easy to use.
Ecopro	Sinum AG. - EcoPerformance Systems (CH)	http://www.sinum.com	It allows simple life cycle studies of products to be realized. It uses BUWAL database.
Ecoscan	TNO Industrial Technology (NL)	http://www.ind.tno.nl	Can be used by technicians and those in charge of implementing eco-design of products. It has several databases and is easy to use.
Euklid	Fraunhofer-Institut (DE)	http://www.ivv.fhg.de	Program directed at LCA studies of industrial products.
KCL Eco	Finnish Pulp and Paper Research Institute (FI)	http://www.kcl.fi/eco	Possesses a very complete user interface. Uses Ecoindicator 95 or DAIA 98 and has good data for the paper industry.
GaBi 4	PE INTERNATIONAL GmbH and LBP, University of Stuttgart (DE)	http://www.gabi-software.com	Apart from conventional uses of LCA this program also includes the possibility of performing an economic analysis through the inclusion of the Life Cycle Costs (LCC) and social impacts through Life Cycle Working Environment (LCWE).
LCAit	Chalmers Industritenik (SE)	http://www.ekologik.cit.chalmers.se	Main application is in the area of containers and paper products.
Miet	Leiden University (NL)	http://www.leidenuniv.nl/cml/ssp/software	Works with MS Excel and is based on environmental data from USA. It is free to use
Pems	Pira International (UK)	http://www.piranet.com/pack/lca_software.htm	Can be used by experts or novices in the field, Possesses a flexible user interface.
Simapro	Pré Consultants (NL)	http://www.pre.nl	Allows LCAs to be carried out using multiple impact evaluation methodologies. Comes with several complete databases. Suitable for design or R&D departments
Team	Ecobilan (FR)	http://www.ecobilan.com	Very complete tool flexible and powerful although more complicated to use. Allows cost information to be entered.
Wisard	Pricewaterhouse Coopers (FR)	http://www.pwcglobal.com	Suitable for economic and environmental impact analysis for municipal solid waste.
Umberto	Ifeu-Institut (DE)	http://www.umberto.de	Gives high quality data and transparent results. Data libraries are complete and flexible. Suitable for performing business eco-balances.

Software programs for general LCA studies

In addition to these tools of wide applicability there exist other programs to perform more specific LCA studies for particular sectors and products. For example, for construction products EcoQuantum developed by Pré Consultants stands out, for electronic products the Japanese program JEM-LCA developed by NEC (New Global Statement), etc.

1.1.1 SimaPro (CIRCE)

SimaPro is a complete tool to develop LCA studies of wide range types of products, activities or services. Although it is not designed specifically to carry out LCA of buildings, the complete databases, and the flexibility of the impact assessment methodologies included, makes it suitable for this purpose.
SimaPro offers an intuitive user interface following ISO 14040 and it can be used to develop parameterized modelling with scenario analysis. This tool presents direct impact assessment calculations from each stage of the system studied and it can analyze complex waste treatment and recycling scenarios.



LCA of 3000 ton of concrete reinforced (SimaPro 7)

SimaPro offers interactive results analysis, tracing results back to their origins, in real time. It also presents a weak point analysis, using the process tree to identify any "hot spots". The table below briefly specifies the characteristics of the impact assessment methods in SimaPro 7. These methods are not specific to SimaPro, and the corresponding indicators used in Building LCA tools will be described in chapter 2.

Method	Characteristics
Impact 2002+	Damage approach; many similarities with Eco-indicator 99, but completely recalculated toxicity factors
TRACI 2002	Midpoint method developed by US EPA
CML 2 baseline 2000	Update of the 1992 method, more advanced models, and inclusion of fate analysis
EPS 2000	Damage approach, using monetarisation (willingness to pay) instead of weighting by a panel
Eco-indicator 99	Damage approach, uses category indicators at endpoint level. Three versions are included using different assumptions
Ecopoints 97 (UBP)	Distance to target based on Swiss policy targets (also referred to as Ecoscarcity method or UBP
EDIP/UMIP 97	Characterisation and Normalisation method developed for the Danish EPA See also 2003 version
Eco-indicator 95	Distance to target method based on scientific targets, includes damage approach
CML 92	Very widely used “midpoint” method, relatively simple characterisation, no fate or exposure, several normalisation sets

The IMPACT 2002+ is mainly a combination between IMPACT 2002 (Pennington et al. 2005), Eco-indicator 99 (Goedkoop and Spriensma. 2000, 2nd version, Egalitarian Factors), CML (Guinée et al. 2002) and IPCC. IMPACT 2002 factors mainly replace Human Health cancer and non-cancer factors and Aquatic and Terrestrial ecotoxicity factors. Eco-indicator 99 factors mainly replace Respiratory effects, Ionizing radiations, Terrestrial acid/nutri, Land use and Mineral extraction. CML factors mainly replace Aquatic acidification and Aquatic eutrophication. The Aquatic eutrophication CF implemented in this method are the one for a P-limited watershed. The impact categories are: Aquatic acidification and Aquatic eutrophication are midpoint indicators, and therefore are not included in the endpoint.

The TRACI 2002 method is a temporary implementation of the TRACI 2.0 method, based on preliminary data.

CML 2 baseline 2000 is an update of the CML 92 method and includes more advanced models. The impact categories considered are: abiotic resources, global warming, ozone layer depletion, toxicity (for people, aquatic and terrestrial ecosystems), photochemical oxidation, acidification and eutrophication. There are various sets of normalization for The Netherlands (1997), the West of Europe (1995) and World-wide (1990 or 1995).

EPS 2000 method considers the high-priority environmental strategies in product design, evaluating from an economic point of view the restoration of environmental damage caused by products. For this reason, it is particularly suitable as a tool for the development process of a product in a company. The numerous impact categories considered are grouped in four damage categories: human health, regeneration capacity of ecosystems, resource reserves and biodiversity.

Ecopoints ’97 is an update of a 1990 method elaborated by the Swiss Ministry of the Environment, in accordance with the established environmental policies of that country. It includes a reasonable number of impact categories, between which it is possible to emphasize the levels of NOx, SOx, CO_2, Pb, CD, Zn and Hg in the air, the levels of Cr, Zn, Cu, CD, Hg, Pb and Ni in water, pesticides, wastes, etc. Three versions of the method exist that differ in the normalization factors to apply.

EDIP/UMIP ‘97 method was developed by the Environmental Design Centre of Industrial Products (EDIP) of Holland, it is similar to CML 92 and in various aspects is updated and improved. The c impact categories of are: global warming, aquatic and terrestrial ecosystems, ozone layer depletion, human toxicity, acidification, eutrophication, photochemical smog, dangerous pollution, wastes, radioactive waste and resources.

Currently there are two impact evaluation methods based on Ecoindicators ’95 / ‘99, the latter being the most commonly used. Eco-indicators are numbers that represent the total environmental impact of a product or service, whose interpretation is relatively simple: the greater the indicator, the greater is the associated environmental impact.

The Ecoindicator ’95 method is the result of a R&D project between various institutions, research centres and businesses: PRé consultants, Philips Consumer Electronics, NedCar (Volvo/Mitshubishi), Océ Copiers, Schuurink, CML Leiden, TU-Delft, IVAM-ER (Amsterdam) and EC Delft. The method is adapted to strictly meet the methodology recommended by the SETAC. Ten impact categories are considered: the greenhouse effect, ozone layer depletion, soil acidification, eutrophication, heavy metals, carcinogenic substances, pollution, pesticides, energy resources and solid wastes. The normalization factors are based on European data from 1990. Two sets of normalization exist: Europe g and Europe e which use different hypotheses when extrapolating data.

The Ecoindicator ‘99 method is an update of the Ecoindicator '95 method. Three versions of the Ecoindicador´99 exist that employ different assumptions in the environmental models considered:

- Equalitative Perspective (E): The chosen time span is the extreme long term, substances are included if there is the least indication as to their effect. Damages cannot be avoided and could cause catastrophic effects. For fossil fuels it is assumed that they cannot easily be substituted.

- Individualistic Perspective (I): The time span is the short term (100 years or less), substances are included if there is clear evidence as to their effect. Damages can be recovered by technological and economic development. It is assumed that fossil fuels cannot be easily exhausted and they are thus omitted from the evaluation.

- Hierarchic Perspective (H): The time perspective is the long term, substances are including if there is consensus as to their effect. For fossil fuels it is assumed that they cannot easily be substituted. Usually the Hierarchic perspective (H) is chosen by default because it is the weighted average of the group of experts who designed the method. Other versions are used for more extensive analyses.

Finally, CML 92 was developed by the Environmental Training center (CML) of the University of Leiden (Holland). The impact categories that are considered are relatively easy to understand: Greenhouse effect conservatory, ozone layer, echo-toxicity and human toxicity, power eutrophication, acidification, pollution, resources and solid wastes. Various sets of normalization exist: The Netherlands (1993/94), the West of Europe (1990) and World-wide (1993).

None of these impact assessment methods assess the specific environmental problems of the Spanish building sector in Spain. Although it should be necessary to adapt and to validate these assessment methods in Spain, at present the most widely methodology used is the Eco-indicator 99. Also this methodology included in SimaPro 7 is usually used in the LCA studies developed by CIRCE Foundation.

1.1.2 GABI (CALCON)

The GaBi 4 software system was developed in a co-operation between the Department of Life Cycle Engineering (GaBi) at the Chair of Building Physics (LBP), University of Stuttgart (http://www.lbpgabi.uni-stuttgart.de) and PE INTERNATIONAL GmbH (http://www.pe-international.com). This fruitful co-operation started in 1990 with the first version of the software GaBi 1 and has been ongoing since then, being the software currently in its fourth version (GaBi 4).

It is a powerful, fully-featured software which supports the collection, organisation, analysis and monitoring of the environmental performance of products, processes and systems. Integrating the Life Cycle Costs (LCC) and Life Cycle Working Environment (LCWE), the software also offers additional sustainability-related criteria such as costs and social impacts as an option for the user. In this way, questions about the environmental performance of building products, building panels or entire buildings can also be answered in a highly efficient way.

GaBi 4 also supports:

- Life Cycle Assessment projects
- Carbon footprint calculation

- Life Cycle Engineering projects (technical, economic and ecological analysis)
- Life Cycle Costing studies
- Classical material and energy flow analysis
- Design for environment applications
- Greenhouse gas accounting
- Environmental Benchmarking studies
- Environmental management system support (ISO 14001 and EMAS)

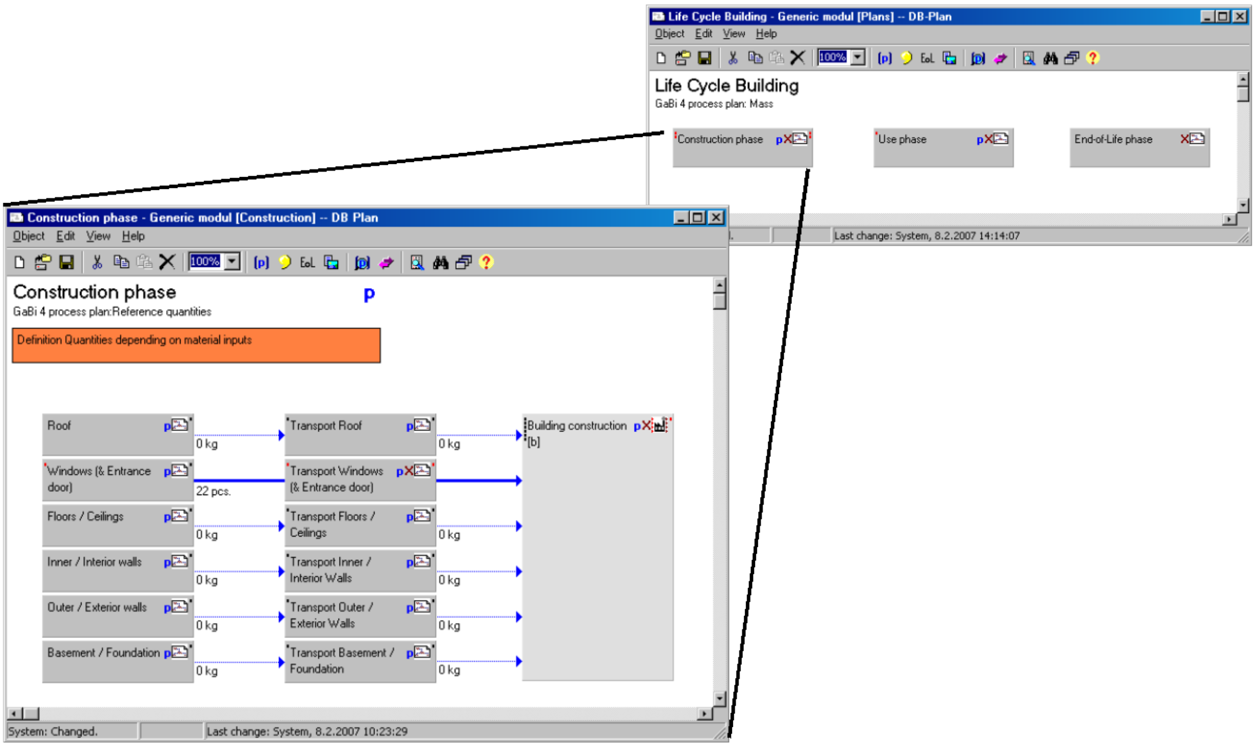
Apart from the professional or lean database included in the software, it also offers additional specific modules to compliment the databases. They can be differentiated as follows:

GaBi 4 Databases

	Database	Content	Number of processes and plans*
Professional	Professional (included in GaBi 4 Professional)	• Standard database used in industry • Includes complete ELCD database • Includes data from APME/PlasticsEurope Includes data from BUWAL	1000 processes and 17 plans
Lean	Lean (included in GaBi 4 Lean)	• Reduced database • Includes extracts from the ELCD database • Includes data from APME/PlasticsEurope	370 processes
Extension databases	Ia: Intermediates organic	• Organic intermediates, country specific	121 processes
	Ib: Intermediates inorganic	• Inorganic intermediates, country specific	74 processes
	II: Energy	• Power grid mix, energy carrier mixes, supply of steam, ,thermal energy sup-ply, country specific	307 processes and 20 plans
	III: Steel	• Sheets, alloyed steel, alloying elements	29 processes
	IV: Aluminium	• Profiles, sheets, castings, alloying elements	39 processes
	V: Non-ferrous metals	• Primary, secondary, alloying elements	15 processes
	VI: Precious metals	• Primary	8 processes
	VII: Plastics	• High performance plastics, compounds	70 processes
	VIII: Coatings	• Painting processes, paint, solvents, pigments, fillers	40 processes and 10 plans
	IX: End of life	• Disposal, recycling, dynamic process models	23 processes
	X: Manufacturing	• Single processes, material-specific processes, dynamic processes	50 processes
	XI: Electronics	• Average, representative components, soldering pastes, electro-mechanical parts, FR4 substrates, assembly lines and a generic model	129 processes and 1 plan
	XII: Renewable raw materials	• Fertilizers and pesticides, tractors & passes, agricultural equipment, several industrial intermediate products for e. g. producing Biopolymers or fuels, different crops	118 processes
	XIII: ecoinvent integrated (Ecoinvent 2.0 database)	• Energy supply, building materials and building processes, chemicals, deter-gent ingredients, graphic papers, transport, disposal, agricultural products and processes.	approx. 2500 unit and terminated processes each
	XIV: Construction materials	• Additives, glue, concrete, mortar, plaster, paints, lightweight aggregate concrete, brick, foam mortar, lime sand brick, building slabs, wood, insulating material, heat insulating bonding systems, metals, plastics, windows	178 processes and 10 plans
	XV: Textile finishing	• Pre-treatment (dry processes such as singeing, or wet processes such as desizing, bleaching and scouring), dyeing • and/or printing (e.g. acids, cationic, direct, disperse, and reactive dyes), finishing, fabrics	125 processes and 54 plans

* In GaBi plans are used to combine the individual processes into various stages of a product's life-cycle. In summary, the creation of a life-cycle balance is completed as follows: The processes necessary to manufacture a product are determined including their associated flows. The individual processes are connected on plans in order to produce a product.

An important feature offered by GaBi 4 is the use of parameters. They can be used to calculate flow quantities depending on other flow quantities (regardless of the process scaling), technical parameters or on flow properties. The major advantage it offers is possibility to use the same process in multiple locations in the modelling with different scenarios for each use.



Example of how a building could be modelled in GaBi 4

Over 100 impact categories, evaluation methods and types of indicators are included in GaBi 4:

- These cover environmental characterisation methods such as CML 96, CML 2001, CML 2007 (available soon), EDIP 97, EDIP 2003, EPFL 2002+, TRACI and also evaluation methods like Ecoindicator 95 & 99, Ecological Scarcity Method (UBP), etc. as well as related information on normalisation.
- They provide economical and social indicators such as qualified working time, health and safety and humanity of working conditions.
- They provide technical indicators such as energy, standard volume, chemical formulae and CAS numbers.
- Life Cycle Inventory data for integrating land use into LCA is currently implemented into the software and will be soon released as a free upgrade to all GaBi users.

Apart from that, the software enables analyse such as scenario analysis, parameter variation, sensitivity analysis and Monte Carlo Analysis.

GaBi 4 databases are available in German, English and Japanese. User-interface languages offered are: German, English, Danish, Portuguese, Spanish, Italian, Japanese and Chinese.

A very interesting additional module to the software is the GaBi i-report. Basically, it defines and applies report templates to existing LCA models and creates dynamic reports for internal and external communication. With these reports, the LCA expert can provide parameters that can be adjusted by non-LCA experts, while the results in the i-report directly reflect the modifications. These reports can then be exported to standard text-processing software life Microsoft Word. In the construction sector, it is an interesting tool, as LCA experts can create LCA building models, using key parameters. Through the use of the i-report, architects are able to vary these parameters and analyse the results immediately without changing the model itself and without necessarily having in-depth LCA expertise. Thus, LCA can find its way into the planning process of the construction sector, promoting sustainable construction.

The GaBi 4 software is used daily by about 50 consultants and researchers at LBP and PE INTERNATIONAL - the largest LCA-group worldwide. It is used in projects for industry, governments and other parties. Consequently, maximum feedback on user-friendliness and functionality needs is guaranteed, ensuring its practice-oriented development.
Regarding the building sector, examples of some projects that used this software can be mentioned:

- “Environmental Improvement Potentials of Residential Buildings (IMPRO-Building)”. Project funded by the European Commission, DG JRC (IPTS), 2006 – 2008.
- “LCA of insulating material made of hemp -Development of a completely biogenous insulation material”. Project, funded by the German DBU, 2005 – 2007.
- “ÖkoPot - Ecological market potentials of wood products”. Project, funded by the German Research Ministry BMBF, 2005 – 2007.
- Tool for creating different Environmental Product Declarations (EPDs), ongoing
- "Maximum use of renewable resources in buildings" (NaWaRo-Max). German Research Ministry BMBF, 1999-2001.

1.2 Building specific tools

1.2.1 ECOEFFECT (KTH)

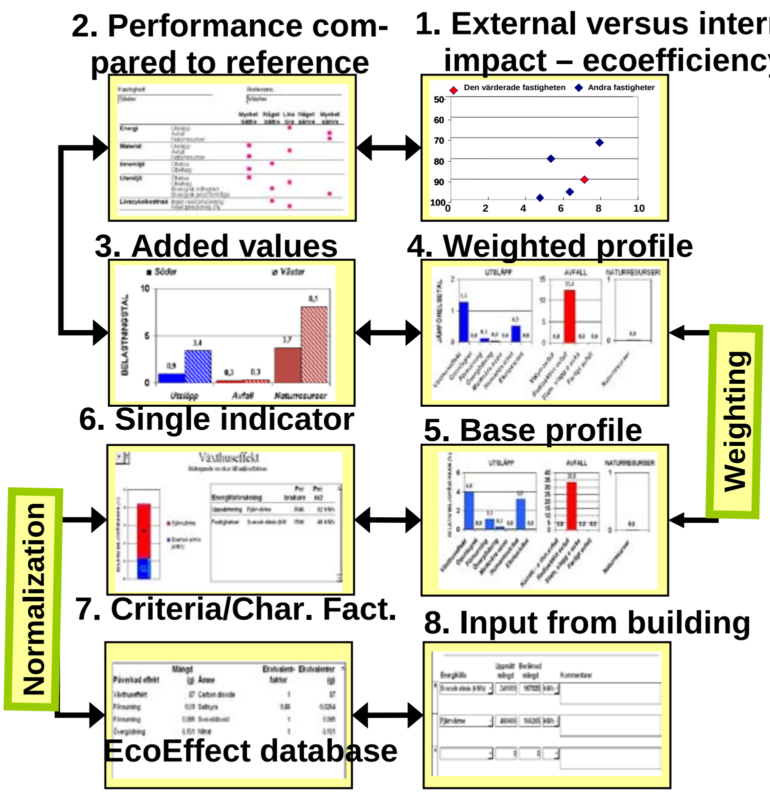
The objective of the EcoEffect method is to:

- Quantitatively describe environmental and health impact from real estate and the built environment
- Provide a basis for comparison and decision making that can lead to reduced environmental impact

The method primarily target decision makers within the planning, designing and, management of the built environment. The method is currently developed for multi-family residential houses, offices and schools. EcoEffect software has been developed consisting of an MS Access tool and an Input Data Sheet in MS Excel.

The EcoEffect cover the areas: Energy, Material, Indoor Environment, Outdoor Environment and Life Cycle Costs. Environmental assessment are carried out within each of these areas for a number of different impact categories e.g. climate change, acidification, noise, etc.

One goal has been that the EcoEffect results should be easy to understand and underlying assumptions and conditions should be easily accessible. For this reason a hierarchy of information levels has been elaborated. On the top is two aggregated indices presented, one for the external impact (from use of energy and materials) and one for the internal environment (indoor and outdoor issues). Together these two indices show the environmental efficiency of a building. The bottom level consists of input data sheets, see figure below.



Information levels that is very easy to move between

EcoEffect is also meant to be used for formulating quantitative environmental goals for each impact category e.g. a certain building shouldn’t contribute to the problem of climate change more than a certain amount. It is designed to be used both in the planning/designing of new buildings and at management of an existing building. For instance, the data on existing building’s indoor environment is collected through questionnaires to users and additional some measurements and inspections. In the planning situation, corresponding data is obtained by filling up the goals and performance requirements in a table in the Input Data Sheet.

In the EcoEffect method, a life cycle assessment methodology is used for calculation of environmental impacts from the use of energy and material in the real estates/buildings. The functional unit is defined differently depending on the type of real estate (family residential house, office or school) e.g. as “the provision a family house for 50 years".

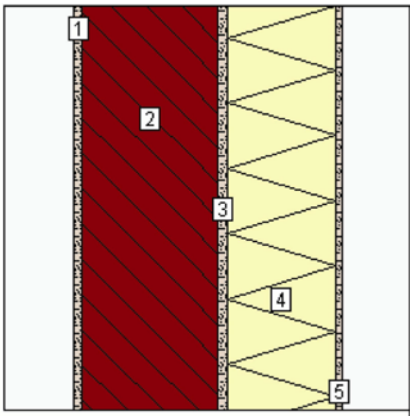
The environmental impact calculated for energy and material use is of three types: emissions, waste and natural resource depletion. The EcoEffect software contains a database with environmental data for different energy types, selected material groups, and reference values etc that are used in the calculations.

For the indoor environment, the impact on human health and wellbeing is assessed whereas for the outdoor environment, both the impact on human health as well as the impact on the ecosystem/biological diversity is included. For both areas, it is the actual characteristics and the circumstances of the indoor and outdoor environment that are essentially assessed. The input data for the assessment are calculated to load values according to established criteria that are based on relevant norms, threshold values etc.

The sum of investment, service (power, heating, water and wastewater, cleaning) and maintenance costs are aggregated over 50 years or another defined period is used as an environmental cost indicator. Costs that have no evident or obvious connection to the environmental impacts of a real estate are excluded from this indicator, e.g. capital costs.

1.2.2 ECOSOFT (IFZ)

ECOSOFT was developed by IBO (Österreichisches Institut für Baubiologie und Bauökologie) for the Austrian market. IBO is also responsible for management and distribution of the tool. In almost all Austrian provinces a simplified version, the so-called "OI3 – Index of the thermal building envelope" has been established as an assessment tool used for housing subsidy. This version is a rating system showing the ecological quality of the building materials, based on indicators PEIne (primary energy use from non-renewable), GWP (global warming potential), AP (acidification potential). The model works for new buildings and also for renovation projects, using the common software tools for the calculation of energy demand (calculation of energy demand is a must for legal and subsidy submission in Austria). ECOSOFT is based on the IBO database for building materials and calculates material, transport and energy inputs, as well as emissions on air, soil, water and waste. LCA of building materials is based on SimaPro using CML Baseline 2001. ECOSOFT can be linked with the official Austrian energy certificate (following the European Building Directive, EPBD), which offers broad range of application.
ECOSOFT is aimed at professionals, such as architects and building engineers working in private and public sectors. The tool is Excel based, and has a user-friendly design, with low operating expense.



Projekt, Auftraggeber:
Sanierung, EIV

Bauteil:
Kopie 3 von Bsp. HLZ AW nach Sanierung mit Kork

Bauteiltyp:
Wand: gegen Außen - nicht hinterlüftet ($R_{si}+R_{se}$ = 0,17)

Wärmedurchgangskoeffizient / U-Wert,
berechnet nach ÖNORM EN ISO 6946:
0,198 W/m²K

flächenspez. Masse: **381,0 kg/m²**

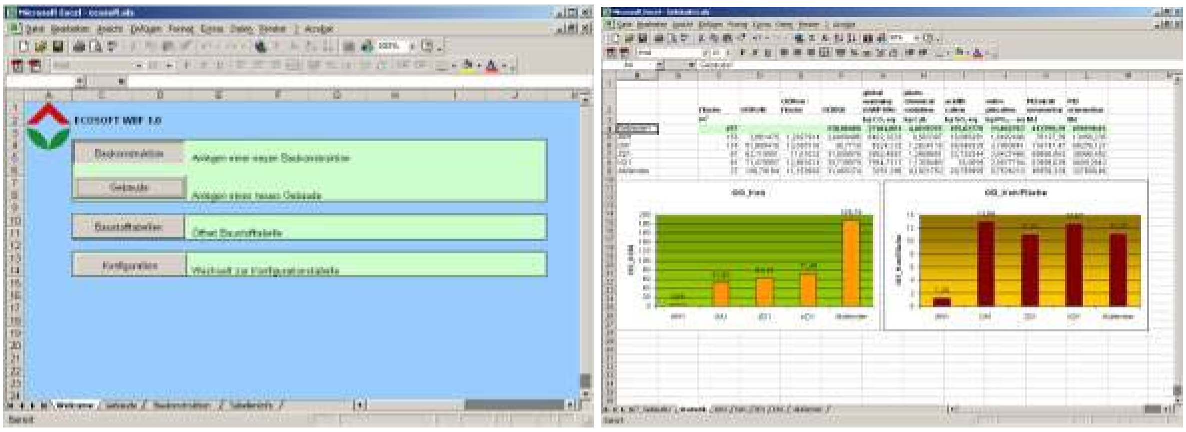
$OI3_{TGH}$: **38**

Gesamtdicke: **0,485 m**

von innen nach aussen

Nr.	Typ	Bezeichnung der Schicht	Dicke [m] d	Lambda [W/mK] λ	Durchlassw. [m²K/W] R = d / λ	MJ/m² PEI n. e.	kg CO_2 equ./m² GWP100	kg SO_2 equ./m² AP
1		Kalkputz	0,0150	0,700	0,021	32,51	3,9900	0,004725
2		Ziegel - Hochlochziegel 1200 kg/m³	0,2500	0,380	0,658	751,00	57,0324	0,162300
3		Kalk-Zementputz	0,0150	0,800	0,019	38,61	3,5370	0,01
4		Korkdämmplatten	0,2000	0,048	4,167	172,47	-35,0400	0,06 00
5		Silikatputz mit Kunstharzzusatz armiert	0,0050	0,800	0,006	34,74	1,9662	0,011268
		Gesamtes Bauteil (alle Schichten)				1029,33	31,4856	0,259800

Example of ECOSOFT based calculation for one m2 of an exterior wall



Example output window in ECOSOFT

The main strengths of ECOSOFT are its user-friendly design and a multi-level access for different users and goals. ECOSOFT is Excel based which enables access and integration to other applications. Furthermore parts of ECOSOFT (OI3-Index) are very common in Austria, because of the already mentioned compulsory application in the social housing sector.

The main weakness of ECOSOFT is the integration of energy consumption aspects (e.g. no links to dynamic thermal simulation programs) and the missing link to common tools used by architects and building engineers (e.g. CAD programs and tools for tendering). Furthermore there is no link to LCC data and LCC-tools.

1.2.3 EQUER (ARMINES)

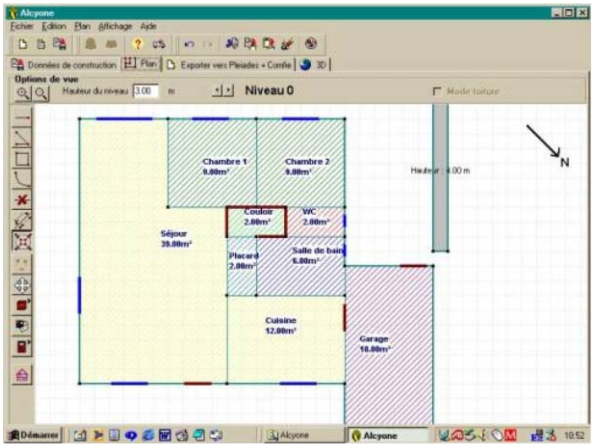
EQUER performs simulations of a building's life cycle, in order to provide designers with environmental indicators, allowing a project to be assessed from an environmental perspective (e.g. global warming, acidification and eutrophication potentials, exhaust of natural resources,…). The Swiss Oekoinventare 1996 database[1] and Ecoinvent 1.2[2] if the user has access to it 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.

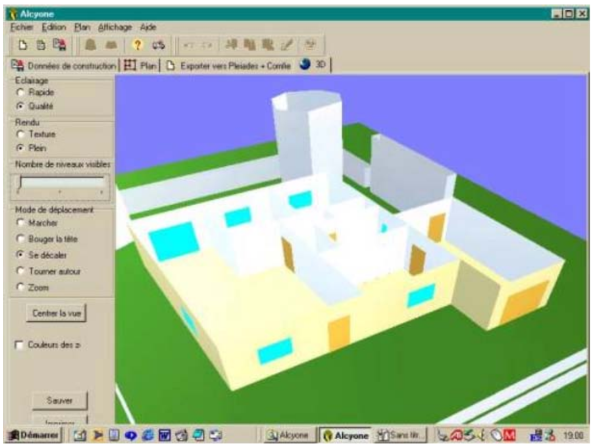
The tool requires input from the user about the building geometry, material characteristics, internal loads and schedules, climate, heating and cooling equipment characteristics. Water consumption, waste generation and transport issues may be taken into account, depending on the goal of the study. Readable,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

[1] R. Frischknecht et al., 'Ökoinventare für energie systeme' , Eidgenössische Technische Hochschule, Zürich, ENET Publications, Bern 1996

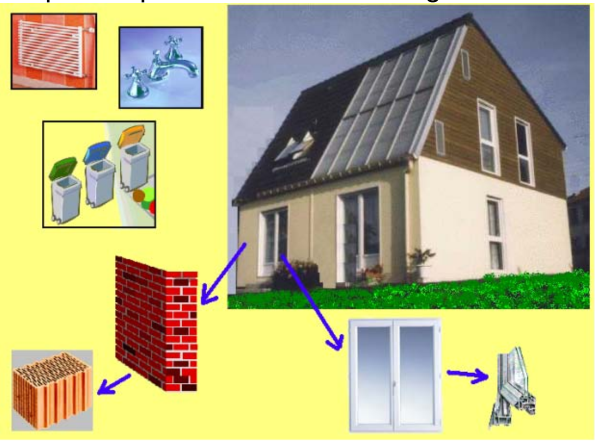
[2] Frischknecht R., Jungbluth N., Althaus H.-J., Doka G., Heck T., Hellweg S., Hischier R., Nemecek T., Rebitzer G., Spielmann M. (2004) "Overview and Methodology", ecoinvent report No. 1, Swiss Centre for Life Cycle Inventories, Dübendorf, 75 p. and www.ecoinvent.ch



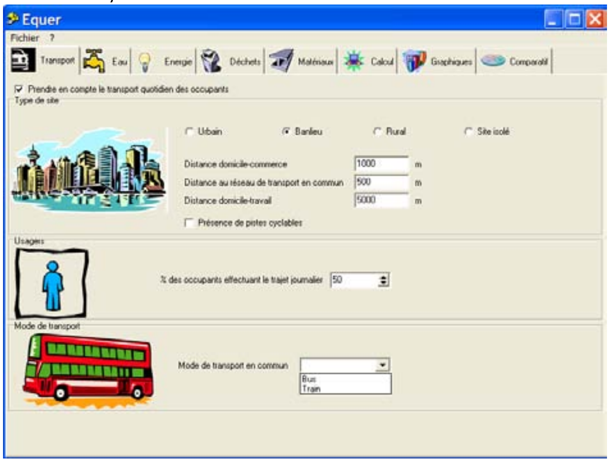
2D plan imported or created using ALCYONE



3D view, ALCYONE



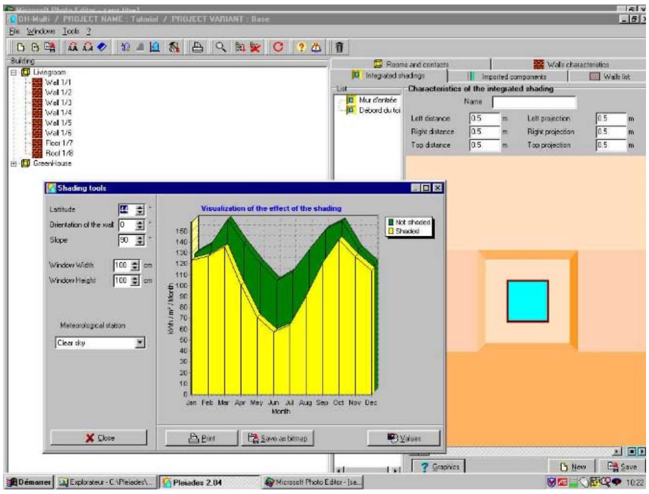
Object oriented model in PLEIADES-COMFIE



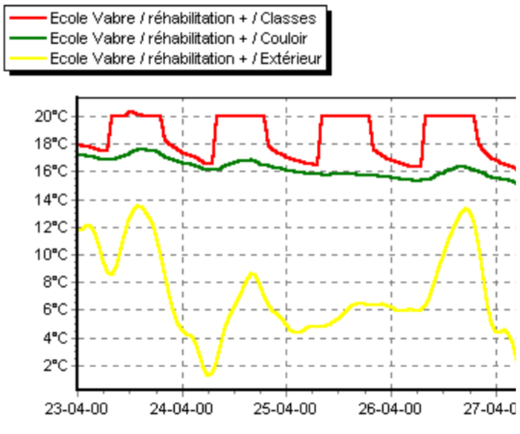
Supplementary input (transport, water, waste…) in EQUER

Data input in EQUER

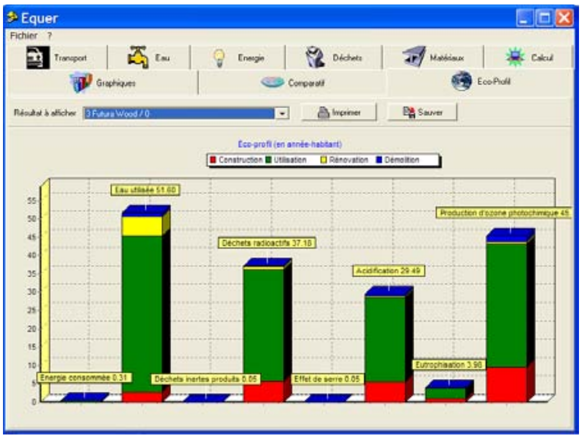
The assessment results are represented by means of environmental indicators such as contribution to global warming, acidification, eutrophication, exhaust of abiotic resources, human toxicity, ecotoxicity, smog and odours, primary energy and water consumption, radioactive and other waste production.



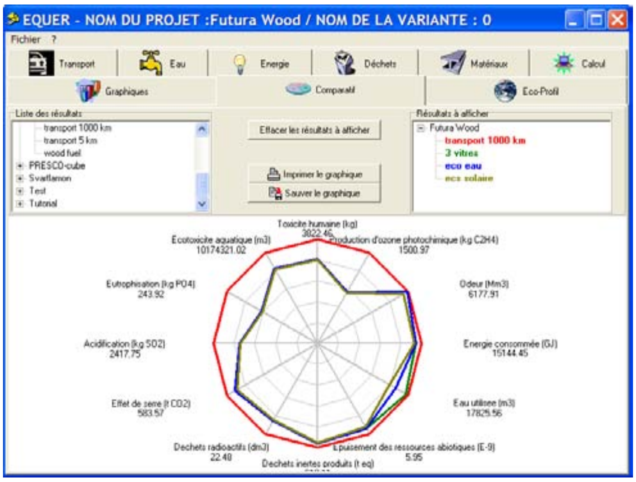
Calculation of solar gains, shading, energy load



Evaluation of temperature profiles using PLEIADES-COMFIE



Output of EQUER, Environmental indicators for construction, operation, renovation, and demolition



Comparison of alternatives using EQUER

Results of EQUER

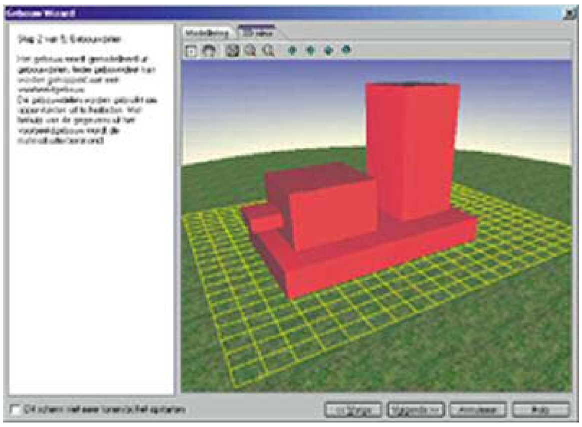
The main strengths of EQUER are the link with an energy simulation tool and a user friendly interface (PLEIADES, ALCYONE) that allows a more global assessment. Life cycle simulation reduces the risk of errors when taking renovation into account because the materials quantities are automatically calculated; focussing on the envelope allows for use by architects.

The main weaknesses are the missing link with cost calculation and the time required for an assessment (typically 2 to 5 days per building including energy calculation). Future improvements are under development regarding 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.

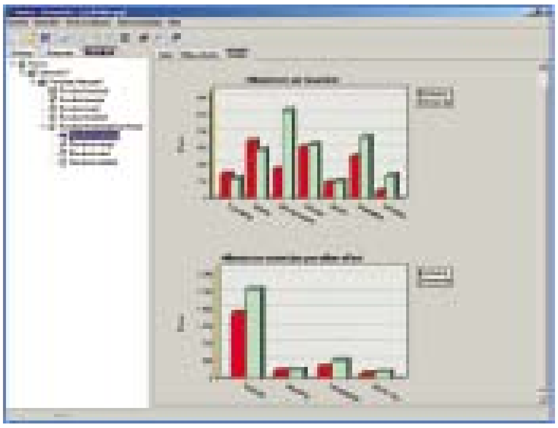
The calculations are developed by ARMINES and the user interface by IZUBA Energies. More information can be obtained on www.izuba.fr where a demonstration version of the software can be downloaded.

1.2.4 GreenCalc+ (ECOFYS)

GreenCalc is a tool to assess and compare the "environmental sustainability" of buildings. The GreenCalc method calculates what it would cost to prevent the environmental damage of buildings' construction and use based on the life cycle assessment methodology. Given that LCA analyses are often incomplete because of missing data this software introduces the TWIN concept, which combines available quantitative data with estimated qualitative data. Furthermore, it is not limited to energy, materials and water, but it also takes mobility aspects into account. Finally, it does not express the results in environmental effects, but in environmental costs and the environmental assessment is translated into costs per m2 for the total lifecycle of the building (construction, exploitation and demolition).
This tool can be used on several levels. Users are governmental organizations, architects and consultants. Decision makers on governmental levels for example use GreenCalc to set goals/ambitions. Architects use the software to make choices on installations and materials, to achieve ambitions and to compare different alternatives during the design process (a wizard can be used in order to easily create a model of the building). Consultants use the tool to give advice or to make calculations for other parties.



Creation of the model



How the results are displayed

Beside the environment index for the whole building the results can be also examined by sub-aspect, so that clear becomes how the building scores on what concerns materials or energy. Furthermore the environment impact is calculated explicitly like for example ozone layer infestation, acidification etc. Moreover it is possible export the results to Excel as a result of which they can be processed simply further.

Modules

The software consists of four modules:

1. Materials module;
2. Energy module;
3. Water module;
4. Mobility module.

1. The **materials module** calculates the environmental impact of the use of materials (including maintenance) during the lifetime of the building. To do this GreenCalc uses the TWIN model of the Dutch Institute for Building Biology and Ecology (NIBE). This can be done using quantitative data obtained from LCA studies or qualitative information taken from the international literature. In this way building products, building elements and buildings are evaluated as comprehensively as possible. In the GreenCalc calculation the module material is subdivided into raw materials, pollution, waste, environmental nuisance, ecological effect, energy, re-usability, reparability and lifespan. GreenCalc gives a clear view of the environmental cost over the different structural parts of the building and determines the total CO_2-production as a result of the material usage.

2. The **energy module** calculates the energy consumption during the lifetime of the building. GreenCalc also calculates the Energy Performance Norm as an extra option for predicting energy consumption. This module consists of different parameters: building use, heating-, cooling-, ventilation- and hot water system, type of artificial lighting, use of solar energy, etc. These parameters are on itself the base for the Energy performance Ratio (EPC), which is an energy efficiency calculation based on the energy consumption within the building.

3. The **water module** calculates the water consumption during the lifetime of the building.

4. The **mobility module** calculates the mobility-related hidden environmental costs associated with commuting during the lifetime of the building. The module is based on mobility scenarios that depend on location, access by public transport or road, and the number of parking spaces. The location selected for the building is determining for the results.

Choice

The environmental index makes it possible to establish as early as the initiative phase what the desired environmental index is and at what cost it can be achieved. This gives sustainability practical meaning. It has been found in practice that it is essential to define the environmental index before design and construction. Many projects start off with good intentions, but in many cases very little is left at the end. The environmental index can ensure that everyone makes a contribution to more sustainable building.

Sustainability quantified

In order to quantify sustainability the RGD (Dutch Government Buildings Agency) developed an environmental index that expresses the sustainability of a building in one number. The index is based on 1990 as the reference year. A building with a 1990 sustainability level has as environmental index of 100. The higher is the level of sustainability, the higher is the index. The environmental index has been calculated for more than a hundred projects. Most of the buildings are commercial or industrial, but the calculation method can also be used for homes. The environmental index of most projects is between 100 and 200. Leading projects achieve 250.

Different approach

Practical experience has shown that the environmental gains from technical measures, such as using environmentally friendly materials and renewable energy, are limited. At constant accommodation costs, these measures do not bring the environmental index beyond about 200. After that the costs rise rapidly. If we are prepared to pay the additional costs, an environmental index of around 500 is what can be achieved by utilizing all technical options. A different approach is therefore needed in order to achieve factor 20 (environmental index of 2000). The expression 'factor 20' is often used in connection with sustainability. This means that the efficiency with which environmental resources will be used in 2040 must be 20 times better than it was in 1990. In other words the environmental impact per unit of product or service must be 20 times lower. Factor 20 is based on a calculation by the American ecologist Barry Commoner.

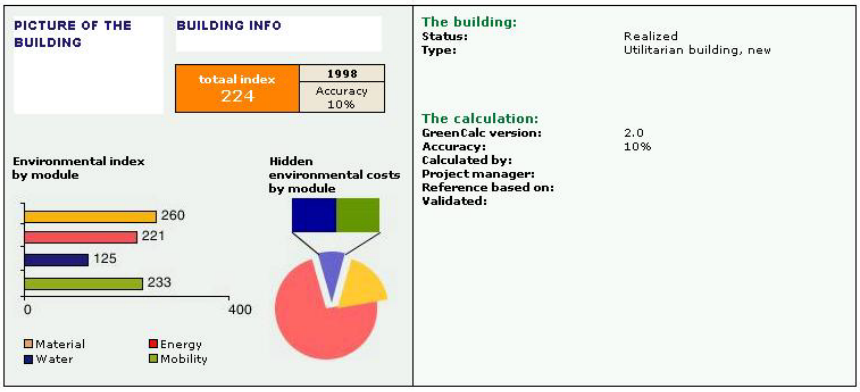
Calculating the environmental index

In order to calculate the environmental index (factor 20 = environmental index 2000) it's used a method that goes beyond evaluating the material and energy consumption. The intensity, with which the building is used, for example hot desking and/or multifunctional spaces, also counts. A higher intensity may mean that the floor area per user is smaller than the norm in 1990. The location is also important. Opting for a location at a railway station may mean that the environmental impact of mobility is less than was normal in 1990. The expected lifetime is also important. If a building is flexible enough that it can have several 'lives', the environmental impact is considerably less than that of a building that is demolished after 20 years. All these aspects of a sustainable concept are incorporated in the calculation.

Hidden environmental costs

Besides construction and operating costs there are also environmental costs. These are the costs incurred in a project for environmental provisions. The environmental costs reduce the burden on the environment, but in practice they do not reach the point that the environmental problems are completely solved. In other words the environmental costs are not enough to make the project sustainable.

The hidden environmental costs are the extra environmental costs that have to be taken into account to produce a 'really sustainable' building. These costs are not currently incurred because otherwise the projects would become too expensive. Usually the issue is not even raised. Nevertheless it is useful to calculate the hidden environmental costs because they reveal how great the distance is between current practice and sustainability. The hidden environmental costs are calculated for the building materials, the energy and water consumption, and the mobility (commuting). We obtain the environmental index by comparing the hidden environmental costs of the project with the hidden environmental costs in 1990.



Results' overview

The TWIN^{2002} model

The TWIN^{2002} model is update version of the TWIN model (Haas 1997).
It uses the CML2 method as much as possible. Some of the environmental categories which are not fully covered are covered with components from Eco-indicator 99 and the original TWIN module.

Table 1 TWIN^{2002} model

Emissions	CML2-baseline
Odors	CML2-baseline
Depletion	TWIN
Landuse	Eco-indicator 99
Hinder due to noise/light	TWIN
Hinder to road transport noise	Müller-Wenk

1.2.5 JOMAR (SINTEF)

JOMAR is a model developed as a basis for calculation of environmental profile for whole building constructions, based upon data from databases and general LCA software, in addition to the model structure (Cost classification system) from the Nordic project on LCC assessment of buildings (SBi 2005:01 LCC for byggverk). The model has been tested on three building constructions; timber based, flexible and heavy as well as heavy. As a first step yotal energy consumption and emissions contributing to climate change are calculated in a total life cycle perspective.
The developed model and exemplifying case assessments have shown that a holistic model including operation phase is both important and possible to implement. The project has shown that the operation phase causes the highest environmental loads when it comes to the exemplified impact categories.

The model will be further developed.

1.2.6 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 (Life Cycle Inventories) 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".

Elements at each level contain all necessary data for cost, energy, 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).

More information can be obtained from: http://www.legep.de/

1.2.7 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 areas 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).

For more information: http://virtual.vtt.fi/virtual/proj6/environ/ohjelmat_e.html

1.2.8 ENVEST 2

Envest 2 is a software tool that simplifies the otherwise very complex process of designing buildings with low environmental impact and whole life costs. Envest 2 allows both environmental and financial tradeoffs to be made explicit in the design process, allowing the client to optimise the concept of best value according to their own priorities.

Designers input their building designs (height, number of storeys, window area, etc) and choices of elements (external wall, roof covering, etc). Envest 2 identifies those elements with the most influence on the building's environmental impact and whole life cost and shows the effects of selecting different materials. It also predicts the basic environmental and cost impact of various strategies for heating, cooling and operating a building.

Having made comparisons between different buildings and specifications, designers can graphically demonstrate the environmental and financial credentials of different designs to clients. Envest 2 produces detailed and summary information that is readily transferred to the users own template to create a bespoke environmental report for a building.

Environmental data may be presented as a range of 12 impacts, from climate change to toxicity, as well as a single ‘Ecopoint’ score (where 100 EcoPoints equal the annual impact of one UK citizen), for ease of communication, especially in comparison with costs.

Costs are measured in Pounds Sterling according to Net Present Value, discounted at 2002 Treasury rates or a discounted rate set by the user.

Envest 2 is web based, allowing large design companies to store and share information in a controlled way, enabling in-house benchmarking and design comparison.

Two versions of the tools are available:

Envest 2 estimator uses default environmental and financial data about the whole life performance of the building. It is intended for use by design teams who are particularly interested in the environmental performance of a building but also find it useful to provide an estimate of relative whole life costs for different designs.

Envest 2 calculator provides default environmental data but allows the user to enter their own capital and lifetime financial cost information. This provides a powerful tool for design teams for whom the whole life costs are of prime importance, who have their own specific data available and who also find it useful to have access to the environmental performance of the design.

More information: http://envestv2.bre.co.uk/

1.2.9 ATHENA

Athena is a user-friendly software for the LCA of buildings developed by the Athena Sustainable Materials Institute in Canada. The tool allows architects and engineers to assess and compare building designs and material choices at an early stage. The conceptual building design is easily entered using preset building assembly dialogues. The database contains North American (primarily Canadian) inventory data on structural assemblies and building envelope materials. Operating energy calculated elsewhere can be converted to environmental impacts taking into account the upstream effects. The maintenance of building assemblies is also considered assuming a user-defined building lifetime. The results are presented by lifecycle stage or by assembly type in terms of primary energy use, global warming potential, solid waste emissions, pollutants to air and water, and natural resource use.

More information: http://www.athenasmi.ca/

1.2.10 BEES

BEES (Building for Environmental and Economic Sustainability) is an LCA based database focusing on building products, developed by the National Institute of Standards and Technology. BEES is a simple tool aimed at designers, builders, and product manufacturers. The tool enables direct product-to-product comparisons based on LCA and LCC. Environmental and economic performance are combined into a single score with weights specified by the user.

More information: http://www.bfrl.nist.gov/oae/software/bees.html

1.3 Data bases, Environmental product declaration

The ISO-standard ISO-21930 Environmental Product Declarations (EPD) sets the criteria for EPDs for building products.

1.3.1 General data bases

There exist many data bases providing life cycle inventories for processes and materials. A list of some important data bases, linked to e.g. the SimaPro software, is given in the following table

SimaPro 7 comes with a large set of data libraries that they cover 6000 different processes. It is important to note that in a given study it is possible to use data coming from a single data base or to combine information from various databases, based on the requirements of data quality that have been defined for the LCA study.

Database (year)	Content	Source	Process count
Danish IO database (1999)	Detailed Danish Input Output database for Denmark	2.0 LCA Consultants (Denmark) www.lca-net.com	793
Danish Food database (2003)	Database on food, using marginal approach	2.0 LCA Consultants (Denmark) www.lca-net.com	671
Ecoinvent v1.2 (2005)	2600 processes on energy, transport, materials, etc.	Ecoinvent centre (Switzerland) www.eco-invent.ch	+2700
USA input output (2003)	IO dataset for the USA	CML, University of Leiden (The Netherlands) www.leidenuniv.nl/interfac/cml	500
Industry data (2001)	Data published by industry associations, such as APME	Various, Association of plastics Manufacturers - Plastics Europe www.apme.org	74
Idemat (2001)	Dutch database, compiled from different sources	Delft Technical University (The Netherlands) www.io.tudelft.nl	508
Buwal 250 (1997)	General materials, energy, transport and waste, etc	Swiss Institute of Packaging www.umwelt-schweiz.ch/buwal/eng/index	248
ETH-ESU (1996)	All processes of the famous energy and transport database. ETH-ESU Zurich	ETH-ESU (Switzerland) www.uns.ethz.ch	+1100

Franklin (1996)	USA database, on materials, transport and energy	Franklin Associates (USA) www.fal.com	78

SimaPro 7 Databases

The Danish Input Output database is based on the Danish statistical data (NAMEA) for 1999. A number of modifications and improvements have been made to these basic data in order to make them more relevant for LCA purposes.

Ecoinvent is a generic database by the Swiss ecoinvent Centre, containing the inventory data of more than 2,500 products and services. The ecoinvent Centre is a joint initiative of institutes and departments of the Swiss Federal Institutes of Technology Zürich (ETH Zürich) and Lausanne (EPFL), of the Paul Scherrer Institute (PSI), of the Swiss Federal Laboratories for Materials Testing and Research (Empa), and of the Swiss Federal Research Station Agroscope Reckenholz-Tänikon (ART).
Existing data were collected, harmonised, and completed in the framework of the ecoinvent 2000 project. As a result, the database is of the highest quality in Europe covering the fields of energy production, resource extraction, chemicals, washing agents, paper, agriculture, transport services and waste management. Categories related to buildings are construction processes, building materials, wood, paints, glues, glass, metal, insulation, photovoltaic systems and solar collectors. The data source is primarily the Swiss and German industry, but they can be applied to the rest of Europe as well. Besides the detailed inventory data on each product, impact assessment results based on various models can also be obtained. Many LCA software tools, such as GaBi and SimaPro use ecoinvent data.
http://www.ecoinvent.ch/
US Input Output database is focused on 481 sectors of the US economy. The US input-output (IO) database consists of a commodity matrix from 1998, supplemented with data for capital goods. The IO commodity matrix is linked to a large environmental intervention matrix. Environmental data have been compiled using several data sources: Toxic Releases Inventory 98 (TRI), Air Quality Planning and Standard (AIRS) data of the US EPA, Energy information administration (EIA) data of the US dep. of energy, Bureau of economic analysis (BEA) data of the US Department of Commerce (DOC), National Center for Food and Agricultural Policy (NCFAP) and World Resource Institute (WRI).

Industry data is an inventory data provided by industry associations. Mostly cradle to gate data.Idemat 2001 is a database focused on engineering materials (metals, alloys, plastics, wood), energy and transport.Buwal 250 is a packaging materials database (plastic, carton, paper, glass, tin plated steel, aluminium), energy, transport, waste treatments.

ETH-ESU 96 is focused on electricity generation and related processes like transport, processing, waste treatment and includes 1200 unit processes and 1200 system (results) processes.

Franklin US is a North American inventory data for energy, transport, steel, plastics, processing collected by Franklin Associates, USA.

1.3.2 Spain

At the moment (with the exception of the database of the Catalonia Institute of Construction Technology-ITEC, available in: www.itec.es/nouBedec.e/presentaciobedec.aspx) there is no specific database for the impact of the building sector for Spain. Most of them are related to technologies and raw materials from the North of Europe. As there are substantial differences between UE countries in the climatology, city-planning norms, building techniques, etc., it should be necessary to adequate the existing databases. Due to its wide range of products, the Ecoinvent database included in SimaPro 7 is the most used database in the LCA studies developed by CIRCE Foundation.

1.3.3 Hungary

EMI uses the Swiss ecoinvent database. This database has been adapted to the Hungarian conditions where necessary. For the building materials produced in Hungary, the following changes were applied:

- The Swiss electricity modules were changed for Hungarian, since the composition of the Swiss electricity mix is very different from the Hungarian one.
- The natural gas modules were changed for Hungarian. The CED of Hungarian gas is about 15 % higher than that of the Swiss and the average European gas.
- The Swiss and Western European transport modules are different; here the average European modules were used.

1.3.4 ECOSOFT – Austria

ECOSOFT is based on the IBO (Österreichisches Institut für Baubiologie und -ökologie, a private research institute with focus on environmental performance of buildings) data base for building materials, which is an adaptation of the ECOINVENT data base for the Austrian situation. IBO data base includes more than 500 building materials (reference values). LCA of building materials is based on SIMA PRO using CML Baseline 2001. IBO data base is also the official data base (www.oebox.at) for the housing subsidy system in different Austrian provinces. Producers of building materials are given the opportunity to make a self declaration for their products in this data base. Declarations by producers are checked, managed and verified by IBO.

1.3.5 France

The Ecoinvent database is used, but the electricity mix can be varied according to the country for the electricity consumed in the building : a % of thermal (gas, fuel and coal), nuclear and hydro power has to be given by the user. This mix can be different for space heating, because this techniques induces peak demand during the cold winter days, and the use of different production (e.g. thermal plants during peak demand periods, compared to nuclear in standard periods). Transport distances for the materials can also be varied, from fabrication to construction sites but also at the end of life.

1.3.6 Norway

EcoProduct is a data base for material selection, based on EPDs or similar information. Later, when more EPDs are available, third parties verification is mandatory for all product in the data base. EPD-Norge has put effort into the work of producing PCRs (Product Catecory Rules) for building products, and hence intensify the work of producing EPDs.

EPD-Norge has also started the work of establishing relevant national data for electricity, transport and package for the Norwegian construction sector, to be used in EPDs.

As a part of the focus on use of open standards and information exchange between building information models, ICT-tools, and different data bases, environmental information (not necessary a total EPD) is some of the information available in the future building product data base (Norsk Byggtjeneste).

Also in Germany the work has started to make a national data base for building relevant EPDs, focusing on generic or averaged EPDs.

1.3.7 Other data bases

- Finland

New environmental declarations are compiled according to the publication "Methodology for Compiling Environmental Declarations for Building Products and Assessing Environmental Impacts of Buildings". The RT Environmental Declaration is based on the national methodology following the basic principles stated in the ISO standard series 14040 and 14020. The method considers also the preliminary results achieved within ISO CD 21930. It is developed in cooperation with the Confederation of Finnish Construction Industries RT, the Building Information Foundation RTS, VTT Technical Research Centre of Finland and companies in the construction business.
The RT Environmental Declaration is a voluntary and public document providing comparable and impartial information on the environmental impacts of building materials. It is a source of information for users, designers and constructors.
More information : http://www.rts.fi/ymparistoseloste/index_RTED.htm

- United Kingdom

Reliable and independent environmental information about building materials and components is in high demand. Environmental profiles are a useful way of providing this information in a standardised way – identifying and assessing the environmental effects of building materials over their entire life cycle, through their extraction, processing, construction, use and maintenance, and their eventual demolition and disposal.

More information : http://cig.bre.co.uk/envprofiles/document.jsp

1.4 Life cycle cost

The main goal for applying LCC and visualising the annuity costs is to assist in making well informed decisions. Instead of making decisions based on capital costs, the methodology facilitate decision making based on costs over the whole life time. This is a clear parallel to the Life Cycle Assessment principles: Instead of calculating the environmental loads from the construction elements, one takes into consideration the loads over the entire life cycle.

The ISO-standard ISO-15686-5 Life Cycle Costing describes Life Cycle Costing (LCC) as a valuable technique which is used for predicting and assessing the cost performance of constructed assets. The definition of constructed assets includes all building types and engineering works, both existing and new. LCC is also a tool used to facilitate choices where there are alternative means of achieving the Client's, or key stake holder's objectives and where those alternatives differ not only in their initial costs, but also in their subsequent operational and renewal costs over the service life time of their interest in the asset (service life planning of constructed assets).

Life Cycle Cost is defined as economic assessment considering all agreed projected significant and relevant cost flows relevant to the constructed asset over a period of analysis expressed in monetary value. The projected costs are those needed to achieve defined levels of performance, including reliability, safety and availability.

Life Cycle Costing is defined as a tool and technique which enables comparative cost assessments to be made over a specified period of time, taking into account all relevant economic factors both in terms of initial capital costs and future operational and asset replacement costs.

Typically LCC analysis covers a defined list of costs over the physical, technical, economic or functional life of a constructed asset, over a defined period of analysis. LCC will also be influenced by non construction and occupancy costs, as well as local, national or international policies, allowances, taxes etc. LCC analysis may include allowances for foreseeable changes, such as future occupancy levels or changing legislative or regulatory parameters. LCC analysis may also form part of a strategic review of procurement routes or objectives (such as enhancing sustainability or improving functionality).

In the early stage of a project, LCC forecasting may use ‘benchmark costs’ based on historical costs of previous projects. To simplify this and to ensure that used costs for benchmarking to be successfully achieved, definitions and cost structures need to be clear and comparable. This is handled by the LCC-DATA project, which also aims to develop a European Cost database with experience data (in fact information).

As design evolves and more detailed information becomes available, benchmarks should be substituted with first principle project-specific estimated costs. Often (but not always) life cycle costing will include a single lump sum which represents all the acquisition costs (e.g. the purchase cost) and may also take account of residual value/disposal costs.

Practice varies between users as to whether only costs borne by the customer for the analysis (typically the construction client) are taken into account, or whether customer/societal etc costs are also included. The terms “intangibles” and “externalities” have been used to describe included or excluded other costs respectively.

In Germany, LEGEP allows both LCA and LCC analyses to be performed.

Six LCC programs applied in the building sector exist in Sweden :
a) BELOK Clients for commercial localities - software free
b) The Swedish environmental management council - software free
c) Älvstrande utveckling AB - developer - software free
d) Swedish Energy agency - software free
e) Svenska bostäder (Public housing company) - software free
f) LCC energy – (Software 1200 SEK).

In Hungary, EMI currently does not have any life cycle cost databases and have not performed any studies on LCC yet.

There are no common tools and data base for Life Cycle Costs (LCC) in Austria. LCC aspects can be found in facility management tools, with main focus on operating costs, not considering end of life costs (e.g. disposal and recycling costs).

University of Applied Science in Kufstein are developing an Austrian database as a real estate benchmarking tool in cooperation with the most important building owner and facility management associations in Austria.
In Norway is LCProfit the most common LCC tool to be used for buildings.

ARMINES has worked on a very simple model in France, accounting only for investment and operation costs but not for renovation and demolition.

Nowadays, in Spain, LCCA methodologies and tools related to buildings are neither known enough nor used among potential building sector agents. Although there are some tools for life cycle cost analysis for specific products or activities, such as “DEEP Energy Efficient Tool kit” (supported by IEE Programme and designed to help local public authorities in tackling energy efficiency through procurement), there is no standard LCCA database or methodology for building sector.

CEN TC350 WG4 has started the work with a standard for economic assessment of buildings, and this standard will be a framework for LCC. Energy costs will here be a main part of the operation cost

1.5 Databases for LCC

There are many national data bases for investment costs (construction costs). For Norway Holte Byggsafes data bases are most used. Input to the data base is contractual costs from building projects (construction, maintenance, refurbishment, and demolition).

For operation and management costs many countries are lacking good data bases. Some countries (Norway, Denmark, and soon Austria) have national data bases used for benchmarking of costs. The costs have to follow a strict classification system (as NS 3454) to be comparable.

In Germany, LEGEP is linked to the SIRADOS database.

In France, the Batiprix database is available on the web (www.batiprix.com). Consultants have constituted a network in order to exchange cost information and constitute a database accounting for local contexts (e.g. costs are higher in Paris than in the rest of the country).

In Hungary, the King software is used for planning the investment costs of buildings, its database is updated regularly.

2 Environmental indicators

This report provides a list of most common environmental indicators used in the building LCA methods. The following table indicates which indicators are used by the project partners. Each indicator is referenced by a number, and its definition is given below. It is more convenient to structure the list, and the following structure has been used.

<u>1 Resources</u>
1.1 Depletion of abiotic resources, CML 1992
1.2 Depletion of abiotic resources (antimony equivalent), CML1995 and 2001
1.3 Cumulative energy demand a) total, and b) : non renewable part
1.4 Water consumption
1.5 Surplus energy to extract minerals and fossil fuels
1.6 Land use
1.7 Resource factor
1.8 Cumulative exergy demand

2 <u>Air pollution</u>
2.1 Global warming potential, IPCC, 1994 and 2001
2.2 Ozone depletion potential, CML 1992, 1995 and 2001
2.3 Acidification potential, CML 1992, 1995 and 2001
2.4 Winter smog, CML 1992 and 1995
2.5 Photochemical oxidant formation (summer smog), CML 1992, 1995 and 2001
2.6 Odours, CML 1992 and 2001

3 <u>Water pollution</u>
3.1 Eutrophication potential, CML 1992, 1995 and 2001
3.2 Aquatic Eco-toxicity, CML 1992 and 2001

4 <u>Soil pollution and waste</u>
4.1 Terrestrial ecotoxicity, CML 1992 and 2001
4.2 Amount of solid waste
4.3 Amount of radioactive waste

5 <u>Damages, health and biodiversity</u>
5.1 Human toxicity, CML 1992 and 2001
5.2 Heavy metals, CML 1995
5.3 Carcinogenics, CML 1995
5.4 Disability Adjusted Life Years, (DALY) Ecoindicator 1999
5.5 Ionising radiation, CML 2001
5.6 Depletion of biotic resources, CML 1992 and 2001
5.7 Impacts of land use, CML 2001
5.8 Potentially Disappeared Fraction (PDF), Ecoindicator 1999

Indicators	**CIRCE**	**ECOFYS**	**SINTEF (EPDs)**	**SINTEF (EcoProfile)**	**ARMINES**
1 Resources	1.5	1.3 a) 1.4	1.3 1.4 1.6	1.3 1.4 1.6	1.2 (2001) 1.3 a) 1.4
2 Air pollution		2.2 2.3a 2.5a 2.6	2.1 (2001) 2.2 (2001) 2.3 (2001) 2.5		2.1 (2001) 2.3a (2001) 2.5a (2001) 2.6 (1992)
3 Water pollution		3.1a 3.2a	3.1		3.1a (1992)
4 Soil pollution and waste		4.1 4.2	4.2		4.2 4.3
5 Damages, Health and biodiversity	5.4 5.8	5.1a 5.8			5.4a 5.8

Indicators	CalCon	KTH	IFZ	EMI	CEN
1 Resources	1.2 (2001) 1.3 a)	1.7	1.3 b)	1.3 b)	1.2 as Fe eq.[3] 1.3b and use of renewable primary energy 1.4
2 Air pollution	2.1 (CML 2001) 2.2 (2001) 2.3 (2001) 2.5 (2001)	2.1 (2001) 2.2 2.3b 2.5b	2.1 (2001) 2.3a 2.5a	2.1 2.2 2.3a 2.5a	2.1 2.2 2.3 2.5
3 Water pollution	3.1 (1996 and 2001)	3.1b 3.2b	3.1a	3.1a	3.1a
4 Soil pollution and waste	4.2				4.2 (non hazardous and hazardous) 4.3
5 Damages, Health and biodiversity		5.1b 5.4b		5.4a 5.8	

2.1 Resources

2.1.1 Depletion of abiotic resources, CML 1992

Abiotic resources are non-living natural resources, like iron ore or crude oil. The efficient use of these resources is one of the most important criteria of sustainability. Most abiotic resources are non-renewable (except, for example, wind).

In 1992 according to Heijungs [Heijungs et al, 1992] for a given resource *i*, abiotic depletion was defined as the ratio between the quantity of resource extracted (m_i) and the recoverable reserves of that source (Mi):

$$abiotic\ depletion = \sum_i \frac{m_i}{M_i} \qquad \text{(II.2)}$$

The units used for both extractions and reserves could thus be freely selected, as long as this was consistent for a given source. Ores were normally expressed in kg and natural gas in m^3, although MJ could be used as an alternative. Heijungs observed that this is a simplified method and that should ultimately be extended to include the extraction rate, expressed in kg/year or m^3/year.

2.1.2 Depletion of abiotic resources (antimony equivalent), CML1995 and 2001

Guinée and Heijungs [Guinée and Heijungs, 1995] proposed a characterisation factor called ADP (Abiotic Depletion Potential). The new characterisation factor was based on the resource state and the extraction rate, expressed in kg of a reference resource (antimony):

$$abiotic\ depletion = \sum_i ADP_i \times m_i \qquad \text{(II.3)}$$

ADP_i = Abiotic Depletion Potential of resource *i* [kg of antimony equivalent/kg];
m_i = mass of the substance *i*, inventoried in the process [kg].

[3] Using the abiotic conversion factor, or an alternative indicator in the present state of the standard project, complemented with the weight of renewable resources other than primary energy (in kg).

$$ADP_i = \frac{DR_i}{(R_i)^2} \cdot \frac{(R_{ref})^2}{DR_{ref}} \qquad (II.4)$$

R_i = ultimate reserve of resource *i*, [kg];
DR_i = extraction rate of resource *i*, [kg*year^{-1}]
R_{ref} = ultimate reserve of antimony, [kg];
DR_{ref} = extraction rate of antimony [kg*year^{-1}];

The model is considered operational for 84 elements and 30 configurations (resources composed of different elements fossil fuels excluded).

A development of this method was made [Van Oers et al, 2002] in order to extend the calculation to the fossil fuels category: fossil fuels can be considered equivalent to resources and then can be mutually replaced, so we can calculate a global ADP for all fossil fuels regarding the use of a 1 MJ of fuel, according to the following expression:

$$ADP_{fossil\ energy} = \frac{DR_i}{(R_i)^2} \cdot \frac{(R_{ref})^2}{DR_{ref}} = 4{,}81 \times 10^{-4} \qquad (II.5)$$

$ADP_{fossil\ energy}$= Abiotic Depletion Potential of fossil fuels [kg/MJ];
R_i = ultimate reserve of fossil fuel *i*, 4,72*10^{20} MJ;
DR_i = production of fossil energy, 3,03*10^{-15} MJ*year^{-1};
R_{ref} = ultimate reserve of antimony, 4,63*10^{15} kg;
DR_{ref} = extraction rate of antimony 6,06*10^{7} kg*year^{-1}

The ADP of each fuel is then obtained by multiplying the $ADP_{fossil\ energy}$ with the energy content *E* of each considered fuel:

$$ADP_{fuel} = ADP_{fossil\ energy} \times E_i \qquad (II.6)$$

ADP_{fuel}= Abiotic Depletion Potential specific of the fossil fuel [kg];
$ADP_{fossil\ energy}$= Abiotic Depletion Potential global of the fossil fuel [kg/MJ];
E = energy content of the fossil fuel *i,* [MJ];

Between 1992 and 1997 several research groups studied and proposed methods for abiotic depletion evaluation. In 1997 Heijungs made a distinction between resources that can be depleted and those that are competitively used: resources that are depleted should be assessed by a method based on depletion, as stated above and those that are competitively used should be assessed by a method based on competition. One implication of this is that the aggregation of abiotic measures into a single measure is not meaningful. Several solutions were proposed, but reviewing authors differ in their conclusions, and today there is no general consensus about what constitutes the best category indicator.

2.1.3 Cumulative energy demand

2.1.3 a)
The Cumulative Energy Demand (CED) has already been used since the seventies as an indicator for energy systems. The assessment of the environmental impacts related to a product or process is based on one parameter: the total energy demand for production, use and disposal expressed in primary energy. Energy resources that can be found in nature, such as coal, crude oil and natural gas are called primary energy resources. Their transformation into „secondary“ energy resources, such as gasoline, diesel or electricity involves losses, which depend on the efficiency and level of the transformation.

Every direct and indirect (e.g. construction of infrastructure) energy input is taken into account, obtained from process or input-output analysis. It is important to distinguish between non-renewable (fossil, nuclear) and renewable primary energy use (hydro, wind, solar, biomass etc.).

2.1.3 b)
ECOSOFT uses Primary Energy non-renewable (PEI_{ne}) as an indicator for the cumulative energy demand of building materials. This indicator is calculated as gross calorific value of all non-renewable resources used in the process chain. It is expressed in MJ/m^2 of construction area.

2.1.4 Water consumption

Desiccation refers to a group of related environmental problems caused by water shortages due to groundwater extraction for industrial and drinking water supply, enhanced drainage and water management. No method has been yet developed for incorporating desiccation in LCA under the form of a desiccation potential [Guinée et al, 2001]. As in the case of most potential impacts (GWP, AP, EP, POCP, ODP, etc.), an impact will not take place necessarily, but a potential indicator is useful in order to evaluate the potential risk of a real impact production.

In the building sector, the water consumption is nevertheless an important matter [Polster, 1995]. In the absence of a characterisation factor for desiccation, we propose an indicator also used by [Frischknecht et al, 1996], which regards simply the quantity of water used:

$$water\ used = Q \qquad \text{(II.68)}$$

Q = quantity of freshwater used [m^3].

This indicator uses the water consumption figures included in the inventories (e.g. materials and electricity production). Some types of water sources (e.g. sea water) are not accounted for.

2.1.5 Surplus energy to extract minerals and fossil fuels

Minerals:
Surplus energy per kg mineral as a result of the reduction of the mineral class. The geographic reach is global.

Fossil fuels:
Surplus energy to extract MJ, kg or m^3 of fossil fuel, like result of the lower quality of resources. Geographic reach is global.

The previous impact categories are grouped in three damage categories, applying the corresponding damage characterization factors. The intention of this grouping is to combine the impact categories that have the same indicator unit into damage categories and thus to simplify subsequent interpretation by reducing the number of impact categories. The results of the impact categories are grouped in the following types of damages:

Damage to Resources (Resources):
It is expressed as the energy required [MJ] for the future extraction of minerals and fossil fuels. Human activity will always extract the best resources first, leaving lower quality resources for future extraction. This damage will be experienced by future generations who will have to invest greater effort in extracting the remaining resources. This extra effort is

expressed as surplus energy. It includes the following impact categories: Minerals and Fossil Fuels.

2.1.6 Land use – land competition

There are many consequences of human use of land. Land is regarded in the subcategory „land competition“ as a resource, which is temporarily unavailable during its use [Guinée, 2002].
Land use is highly relevant for the building and construction sector from two different points of view:
direct land use of the building which occupies land;
land use and transformation for the production of building materials (mineral extraction, agriculture, silviculture)
These issues are currently not reflected in most LCAs. Several methods have been developed for including land use in LCA, but determining the effects on the ecosystem is a very complex task. It is not only the occupied area itself which is relevant, but also the degree of change. For example, one square metre of sealed ground cannot be compared to one square metre of plantation forest. The model in *Guinée* does not distinguish between the different types of use: the indicator results from an unweighted aggregation of all land uses related to the product life. Research on land use in general is currently undertaken by a number of organisations. However, direct land use of buildings is a largely new field in the area of LCA.

2.1.7 Resource factor

For EcoEffect we have designed a resource use factor based on an AHP process (Analytic Hierarchy Process). Resources were divided in four categories – metals, fuels, minerals and biomass. The weighting aspects were: supply horizon, exploitation rate, value (monetary), accessibility, regeneration rate and recovering energy.

2.1.8 Cumulative exergy demand

Exergetical life cycle assessment is a suitable tool for resource accounting. Exergy is the quality of energy or the work potential of energy with respect to environmental conditions [Szargut et al., 1988]. In energy conversion processes, energy is conserved, but exergy is consumed, as formulated by the second law of thermodynamics. While the exergy content of electrical, chemical, kinetic and potential energy is close to the amount of energy, low temperature heat is low quality energy. The exergy to energy ratio is described by the Carnot factor.
The exergy concept can be applied to energy forms, but also to material resources. Besides kinetic and potential exergy, physical and chemical exergy can be defined. The exergy value of a substance equals the work that can be extracted when the substance is brought to equilibrium with the surrounding environment by reversible processes. Generally, average global conditions are applied to express the physical exergy (298 K temperature and 101325 Pa atmospheric pressure). Chemical exergy can be calculated based on the chemical composition of the atmosphere, seawater and the earth’s crust and describes to what extent the substance stands out from the environment from a chemical point of view.
Based on the work of *Szargut* [Szargut et al., 1988], the exergy content of energy and material resources were calculated by *De Meester and Dewulf* and included in the software tool eXoinvent [De Meester and Dewulf, 2006]. eXoinvent is based on the Swiss ecoinvent database. With the help of eXoinvent, it is possible to convert the reference flows of ecoinvent into exergy and calculate the cumulative exergy content of products.

Exergy is a suitable indicator to account for resource consumption. The advantage of exergy vs. the traditionally used energy is – besides taking into consideration the quality of energy –, that energy and material use are accounted for on the same scale. In LCA, for instance, oil is considered either as material or energy consumption, depending on its use as energy carrier or feedstock for plastic production. With exergy, these energy-material trade-off problems can be resolved.
Exergetical life cycle assessment can be applied to evaluate the cumulative resource consumption of building materials, building elements or whole buildings. Exergetical LCA of buildings is a relatively new field and only few case studies have been done so far.

2.2 Air pollution

2.2.1 Global warming potential, IPCC, 2001 or 2007

The anthropogenic greenhouse effect caused by the emissions of human activities has to be distinguished from the natural greenhouse effect. The natural greenhouse effect is of vital importance for living beings on the Earth. But the human emission of so-called greenhouse gases, such as carbon dioxide and methane enhances the heat radiation absorption of the atmosphere, which results in the rise of the earth's surface temperature. During the 20th century, the average global temperature increased by about 0.6 °C due to the enhanced greenhouse effect. The consequences might involve a change in climate patterns, the shift of vegetation zones and of the precipitation distribution, and the rise of the sea level due to the melting ice caps. The impact of an emitted gas is expressed in terms of its global warming potential (GWP) in CO_2-equivalents [Guinée, 2002].

A Global Warming Potential indicator (GWP) can be evaluated based on the 2001 or 2007 IPCC characterisation factors[4] :

$$\textit{climate change} = \sum_i GWP_i \times m_i$$

GWP_i = Global Warming Potential of substance *i* [kg of CO_2 equivalent/kg];
m_i = mass of the substance *i*, inventoried in the process [kg];
The time horizon can be 20, 100 or 500 years..

2.2.2 Ozone depletion potential, CML 1992, 1995 and 2001

Stratospheric ozone depletion is the thinning of the stratospheric ozone layer as a result of anthropogenic emissions, such as CFCs and halons [Guinée, 2002]. This causes a greater fraction of solar UV-B radiation to reach the Earth's surface, with a potential damage to human health, ecosystems, biochemical cycles and materials. The natural seasonal Antarctic 'ozone hole' has been growing since the early 1980s. On a global scale, the decline of ozone in the stratosphere has recently slowed. The depletion is mainly caused by CFCs which are used in aerosols, air conditioning, and refrigerators. Halon, which is a fire retardant, is one of the key ozone-depleting gases. However, the use of this substance has been reduced significantly and will soon be phased out completely due to the successful implementation of the Montreal Protocol. It is therefore important to state in the impact assessment how much of the Ozone Depletion Potential (ODP) is due to halon.

[4] Albritton D. L. and Meira-Filho L. G. : Technical Summary. In: Climate Change 2001: The Scientific Basis - Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) (ed. Houghton J. T., Ding Y., Griggs D. J., Noguer M., van der Linden P. J. and Xiaosu D.). IPCC, Intergovernmental Panel on Climate Change, Cambridge University Press, The Edinburgh Building Shaftesbury Road, Cambridge, UK, retrieved from: www.ipcc.ch/pub/reports.htm

ODP is the ratio between the amount of ozone destroyed by a unit of a substance “x” and a reference substance, normally taken as CFC-11. The unit of the ODP is therefore kg CFC-11 equivalent.

$$ODP(x) = \frac{Global\,loss\,of\;ozon\,(x)}{Global\,loss\,of\;ozone\,by\,(CFC-11)}$$

Source: US EPA (2003) Class II Ozone-Depleting Substances. U.S. Environmental Protection Agency. Accessed at < http://www.epa.gov/ozone/ods2.html> on October 6, 2003.

2.2.3 Acidification potential

a) CML 1992, 1995 and 2001
The acidity of water and soil systems can be increased due to acid deposition from the atmosphere, mainly in the form of rain. Sulphur dioxide (SO_2) and nitrogen oxides (NO_x) emitted by combustion processes are responsible for most acid deposition, commonly called “acid rain”. Potential consequences are forest decline, soil acidification and damage to building materials. The effect of substances is expressed in terms of acidification potential (AP) in kg SO_2-equivalents [Guinée, 2002]. At the interpretation of the indicator result regional differences have to be considered, since a basic soil, for instance, can neutralise the effects.

b) Haushild

AP(SO_2^- equivalents) = [n/(2*M_w)]*64,06 = (n/ M_w)*32,03

M_w is mol mass of the emitted substance (g/mol)

n is the number of hydrogen ions emitted to the recipient
64,06 g/mol is the mol mass of SO_2
Source:
Haushild M et al (1996). *Bakgrund for miljøvurdering av produkter UMIP.* Instittuet for Produktutvikling DTU, DTU,Miljø- og energiministeriet, Miljøstyrelsen, Dansk Industri

Wenzel H., Hauschild M. and Alting L. 1997. Environmental Assessment of Products. Volume 1: Methodology, tools and case studies in product development. Chapman & Hall, ISBN 0-412-80800-5

2.2.4 Winter smog, CML 1992 and 1995

The main contributors to winter smog are the particles (dust) and sulphur emissions. These aspects are accounted for in toxicity and acidification indicators, therefore a specific indicator for winter smog is not commonly used.

2.2.5 Photochemical oxidant formation (summer smog)

a) CML 1992, 1995 and 2001
This indicator describes the formation of reactive chemical compounds from certain air pollutants by the action of sunlight. Ethylene, carbon monoxide, sulphure dioxide, methane and NMVOC, for example, are important emissions. Ozone (O_3), a form of oxygen, is the most important chemical compound in this group. In contrast to the protecting role of the ozone layer in the stratosphere, ozone in the troposphere is toxic. Ozone formation, sometimes referred to as “summer smog” is mainly an issue on sunny days in larger cities with a lot of traffic. Ethylene is the reference substance for the assessment.

b) Jenkin

Photochemical Ozone Creation Potentials, POCP for a specific VOC is defined as the ratio between the ozone formation by an additional release of the VOC and the additional ozone formation by the same release of the reference substance eten.

$$POCP_i = \frac{\text{ozon increase from the i:th VOC}}{\text{Ozonincrease from eten}}$$

Source:
Michael E. Jenkin 1 , Sandra M. Saunders 2 and Richard G. Derwent. (2000). Photochemical Ozone Creation Potentials for Aromatic Hydrocarbons: Sensitivity to Variations in Kinetic and Mechanistic Parameters. "Chemical Behaviour of Aromatic Hydrocarbons in the Troposphere" in Valencia, Spain, February 27 - 29, 2000. Accessed at < http://www.physchem.uni-wuppertal.de/PC-WWW_Site/pub/valencia2000/proceedings/Jenkin.pdf > on June 8, 2003

2.2.6 Odours, CML 1992 and 2001

The odour threshold value of a substance is defined as the concentration of that substance under defined standard conditions at which 50% of a representative sample of the population can detect the difference between a sample of air mixed with that substance and a sample of clean air [Heijungs et al, 1992].

Heijungs developed a simple method in 1992, which is still used today. In his approach substances were classified using a critical volume approach, by dividing the emission of a potentially malodours substance by the odour threshold value (OTV) of that substance. A distinction must be made between emissions of potentially malodorous substance to the atmosphere and to water. Each is associated with a different odour threshold value, as defined in the following expressions:

$$malodorous\ air = \sum_i \frac{m_{i,air}}{OTV_{i,air}} \qquad \text{(II.54)}$$

$$malodorous\ water = \sum_i \frac{m_{i,water}}{OTV_{i,water}} \qquad \text{(II.55)}$$

$OTV_{i,air}$, $OTV_{i,water}$ = the odour threshold value in *air*, *water* of substance *i* [kg*m^{-3}];
$m_{i,air}$, $m_{i,water}$ = the quantity of substance *i* emitted in *air*, *water* [kg].

2.3 Water pollution

2.3.1 Eutrophication potential

a) CML 1992, 1995 and 2001
Eutrophication occurs when there is an increase in the concentration of nutrients, mainly nitrogen (N) and phosphorus (P) in a body of water or soil, occuring both naturally and as a result of human activity [Guinée, 2002]. It may be caused by the run-off of synthetic fertilisers from agricultural land, or by the input of sewage or animal waste. It leads to a reduction in species diversity as well as changes in species composition, often accompanied by massive growth of dominant species such as “algae bloom”. In addition, the increased production of dead biomass may lead to depletion of oxygen in the water or soil since its degradation consumes oxygen. This contributes to changes in species composition and death of organisms. The reference substance for the calculation of the eutrophication potential for each emission is phosphate (PO_4^{3-}), which has a eutrophication potential of 1.

b) EDIP

EcoEffect uses the Danish EDIP concept. EDIP claims that the general formula for aquatic organisms is $C_{106}H_{263}O_{110}N_{16}P$, which means that phosphorus will contribute to eutrophication 16 times more than nitrogen. A substance with formula $C_aH_bN_cO_dS_eP_f$ and the molar weight M_W then have the following eutrophication ability when NO_3^- is taken as the reference:

$EP(NO_3^-$ equivalents$) = [(c+16f)*62,0]/ M_W$

M_W = molar weight of the compound

c and f refers to the number of N and P atoms in the compound

Source:

Haushild M et al (1996). *Bakgrund for miljøvurdering av produkter UMIP.* Instittuet for Produktutvikling DTU, DTU,Miljø- og energiministeriet, Miljøstyrelsen, Dansk Industri

Wenzel H., Hauschild M. and Alting L. 1997. Environmental Assessment of Products. Volume 1: Methodology, tools and case studies in product development. Chapman & Hall, ISBN 0-412-80800-5

2.3.2 Aquatic Eco-toxicity

a) CML 1992 and 2001

The CML impact assessment method considers o.a. the aquatic eco-toxicity category. This impact category covers the impacts of toxic substances on aquatic ecosystems. The area of protection is the natural environment (and natural resources).

Aquatic eco-toxicity can be dived into fresh water and marine aquatic eco-toxicity.

Fresh Water Aquatic Eco-toxicity (FAETP)

Fresh water aquatic eco-toxicity refers to the impact of toxic substances emitted to freshwater aquatic ecosystems.

$$fresh\ water\ aquatic\ eco\ toxicity = \sum_i \sum_{ecom} FAETP_{ecom,\,i} \times m_{ecom,1}$$

m is the emission of substance *i* to the medium *ecom*

Fresh water aquatic eco-toxicity: the characterisation factor is the potential of fresh water aquatic toxicity of each substance emitted to the air, water or/and soil. The unit of this factor is kg of 1,4-dichlorobenzene equivalents (1,4-DCB_{eq}) equivalents per kg of emission.

Marine Aquatic Eco-toxicity (MAETP)

Marine aquatic eco-toxicology refers to the impact of toxic substances emitted to marine aquatic ecosystems.

$$marine\ aquatic\ eco\ toxicity = \sum_i \sum_{ecom} MAETP_{ecom,\,i} \times m_{ecom,1}$$

Marine aquatic ecotoxicology: the characterisation factor is the potential of marine aquatic toxicity of each substance emitted to the air, water or/and soil. The unit of this factor is kg of 1,4-dichlorobenzene equivalents (1,4-DCB_{eq}) equivalents per kg of emission.

b) EDIP

Eco toxicity in EcoEffect is also based on the Danish EDIP work, which is based on the volume (m^3) of air, soil and water which is needed to dilute a gram of the hazardous substance to make it harmless to man and ecosystems.

Eco toxicity

$$CF(et) = f \times BIO \times \frac{1}{PNEC} = f \times BIO \times ETF$$

f = Distribution factor to air, soil and water
BIO = Biodegradable factor.
PNEC or LOEC= Predicted No Effect Concentration and Lowest Observed Effect Concentration
ETF = Eco toxicity factor =1/PNEC

2.4 Soil pollution and waste

2.4.1 Terrestrial ecotoxicity, CML 1992 and 2001

Terrestrial eco-toxicity refers to the impact of toxic substances emitted to terrestrial ecosystems.
The characterisation factor is the potential of terrestrial toxicity of each substance emitted to the air, water or/and soil. The unit of this factor is kg of 1,4-dichlorobenzene equivalents (1,4-DCB_{eq} equivalents per kg of emission).

2.4.2 Amount of solid waste

The building sector generates large quantities of inert waste and this issue must be considered in a LCA study regarding this field [Polster, 1995]. In this context, we propose an indicator also used by [Frischknecht et al, 1996], which evaluates the quantity of inert waste:

$$waste\ creation = W \qquad \text{(II.70)}$$

W = mass of waste [kg].
This definition implies to model all waste treatment processes until the ultimate landfill, and to account for all corresponding impacts.

2.4.3 Amount of radioactive waste

There are several types of radioactive waste according to their activity and their time of storing (e.g. the time of storing may vary from 30 to 10,000 years). The quantity of radioactive waste is a useful indicator in the absence of an indicator for ionizing radiation, because the process of nuclear energy production may be advantaged if we regard only the main environmental impacts: e.g. considering only CO_2 emissions we may get the impression that the nuclear energy is a “clean” way to produce electricity.

60% of Europe's electricity use is associated with buildings (residential and tertiary sector) [EC-DGTREN, 2004] and according to UCTE (Union for the Coordination of Production and Transmission of Electricity), in Europe nuclear plants are the first source of electricity delivering, approximately 32% of the electricity [EC-DGTREN, 2004]. Therefore the radioactive waste issue cannot be neglected in a LCA referring to the building sector and an indicator regarding this category was proposed by Polster [Polster, 1995]. This indicator took into account the Oekoinventare database approach [Frischknecht et al, 1996], which evaluates the volume of radioactive waste in order to define the storing capacity needed:

$$radioactive\ waste = V_{rw} \qquad \text{(II.65)}$$

V_{rw} = radioactive waste volume (including all types, provided by inventories).

The further use of a characterization factor corresponding to the waste radioactivity may complement this view.

2.5 Damages, Health and biodiversity

2.5.1 Human toxicity

a) CML 1992 and 2001
This impact category covers the impacts on human health of toxic substances present in the environment. The effect is induced by the dose of pollutant received (inhaled or ingested) by an individual person and not by its concentration in the environment.

The real impact on humans depends also on the population density around the emission point, thus in the deserted zones the human toxicity should be neglected. In reality it is impossible to determine exactly the real magnitude of a local impact, especially in the present global context, when the life cycle phases of a product can take place on different continents. E.g. a product can be conceived and tested on a continent, produced on another continent using raw materials from a third continent, and afterwards used on a fourth. In these conditions, the use of planetary reference was preferred for human toxicity.

Heijungs defined in 1992 the human toxicity as sums of impacts of toxic substances into 3 compartments of air, water and soil, potentially threatened by pollution.

$$human\ toxicity = \sum_i (HCA_i \times m_{ai}) + (HCW_i \times m_{wi}) + (HCS_i \times m_{si}) \qquad \text{(II.27)}$$

HCA_i, HCW_i, HCS_i = characterisation factors for human toxicological impacts resulting from emissions to air, water, soil of substance *i* [kg body weight/kg substance];
m_{ai}, m_{wi}, m_{ws}= emissions of substance *i* to air, water or soil [kg].

Heijungs considers as references for the three compartments:
the volume of air in the troposphere for a 6 km height at 1 atmosphere,
the volume of water for 10 m deep, calculated for 70% of globe area,
the weight of 15 cm of soil for 30% of globe area.

In this approach, the same substance emitted in air or water or soil has 3 different characterisation factors:

$$HCA_i = \frac{VI_a \times W}{V_a \times ADI_i} \qquad \text{(II.28)}$$

$$HCW_i = \frac{VI_w \times W}{V_w \times ADI_i} \qquad \text{(II.29)}$$

$$HCS_i = \frac{M \times W \times N}{Vs \times Cvalue_i} \qquad \text{(II.30)}$$

VI_a, VI_w=daily intakes of air and water: 20 m^3 air/day/person, 2 l water /day/person;
W = world population, considered $5*10^9$ persons at that time;
V_a, V_w,V_s= volume of air, water and mass of the soil of the global model: $3*10^{18}$ m^3 air, $3*10^{18}$ l water and $2.7*10^{16}$ kg dry soil;
ADI_i = acceptable daily intake for substance *i* [kg of substance i /day/kg body weight]:
M = human body weight, 70 kg body weight;
N = uncertainty factor for the acceptable daily intake;
$Cvalue_i$ = human toxicological intervention value [kg of substance *i* /kg of soil].

Acceptable Daily Intake is defined in two ways:

for substances with a threshold value (i.e. an environmental concentration or intake value below which no harmful effects have been observed on human, plants or animals), it represents the daily intake that can be sustained life-long without adverse effects;
for substances with no such threshold, it is the daily intake resulting in a risk of 1 extra case of cancer per 1000 life-long exposures.

A similar method to that employed for air and water calculation was used to calculate the toxicity for soil, but taking into account that the substances present in soil are taken up by humans indirectly. The toxic substances are transported by groundwater and accumulate in vegetation. Humans may ingest these toxic substances directly through vegetables, fruits, etc., or indirectly through meat, milk, and other animal origin products. The relevant intake routes and the magnitude of the resulting intakes have been modelled, and as a result, provisional human toxicological C values were developed on the acceptable daily intake basis. The C value is a measure of the substance concentration in soil, which, if exceeded, poses a serious threat to the public health.

Since 1992 several authors complemented the human toxicity definition in order to take into account the fate, the effects and the substance transfer. Hereunder we give the general formula of Heijungs in 1999, which takes into account fate, exposure/intake and effect [Guinée et al, 2001]:

$$HTP_{i,ecomp} = \sum_{fcomp} \sum_{r} F_{i,ecomp,fcomp} \times T_{i,fcomp,r} \times I_r \times E_{i,r} \qquad \text{(II.31)}$$

$HTP_{i,ecomp}$= the Human Toxicity Potential, the characterisation factor for the human toxicity of substance *i* emitted to emission compartment *ecomp*. In some methods the contributions via exposure routes *r* are not summed, yielding several HTPs;
$F_{i,ecomp,fcomp}$= a fate factor, representing intermedia transport of substance *i* from emission compartment *ecomp* to final (sub)compartment *fcomp*, and degradation within compartment *ecomp*; in some methods intermedia transport is indicated separately by $f_{i,ecomp,fcomp}$ and biodegradation by BIO (see "rule of the thumb" model hereunder);
$T_{i,fcomp,r}$= the transfer factor, the fraction of substance *i* transferred from *fcomp* to exposure route *r*, i.e. air, drinking water, fish, plants, meat, milk, etc.;
I_r= an "intake factor", representing human intake via exposure route *r*, thus, a function of daily intake of air, drinking water, fish, etc.;
$E_{i,r}$= an "effect factor" representing the toxic effect of intake of substance *i* via exposure route *r*.

HTP is often defined in relation to a reference substance (*ref i*):

$$HTP_{i,ecomp} = \frac{\sum_{fcomp} \sum_{r} F_{i,ecomp,fcomp} \times T_{i,fcomp,r} \times I_r \times E_{i,r}}{\sum_{fcomp} \sum_{r} F_{refi,ecomp,fcomp} \times T_{refi,fcomp,r} \times I_r \times E_{refi,r}} \qquad \text{(II.32)}$$

Three types of characterisation models defining the degradation and intermedia transport for human toxicity, superseded the provisional method developed by Heijungs in 1992:
models based on the "rules of the thumb", like the one developed by Hauschild and Wenzel in 1998, yields three separate not aggregated indicators for each principal exposure routes *r* (air, water, soil) [Hauschild and Wenzel, 1998]:

$$human\ toxicity = \sum_{i} \sum_{ecomp} m_{i,ecomp} \times HTP_{i,ecomp,r} \qquad \text{(II.33)}$$

$$HTP_{i,ecomp,r} = \sum_{fcomp} f_{i,ecomp,fcomp} \times BIO_i \times T_{i,fcomp,r} \times I_r \times E_{i,r} \qquad \text{(II.34)}$$

$HTP_{i,ecomp,\ r}$= the Human Toxicity Potential, the characterisation factor for the human toxicity of substance *i* emitted to emission compartment *ecomp* and leading to exposure via router *r*;
$f_{i,ecomp,fcomp}$= the intermedia transport factor, the fraction of substance *i* emitted to emission compartment *ecomp*, that reaches the final compartment *fcomp*. This factor is based on the rule of thumb and not to a fate model. It is not a continuous value, but assumes a limited number of values as 0.2 and 1;
BIO_i= the biodegradability factor of substance *i*.

models based on empirical relation derived from measurement data and single medium models, summarized in the following formula yielding a single indicator result for human toxicity, related to toxic effect of lead emissions into air [Huijbregts, 1999b]:

$$human\ toxicity = \sum_i \sum_{ecomp} m_{i,ecomp} \times HTP_{i,ecomp} \qquad \text{(II.35)}$$

$$HTP_{i,ecomp} = \sum_{fcomp} \left[\frac{E_{i,fcomp} \times F_{i,ecomp,fcomp}}{E_{Pb,air} \times F_{Pb,air,air}} \right] \qquad \text{(II.36)}$$

$E_{i,fcomp}$= the “effect factor”, representing the human-toxic impact of substance *i* in the final compartment *fcomp* and there defined as the reciprocal of the total acceptable annual dose per m^2: for air the NEC (No Effect Concentration in kg m^{-3}) times the total volume of air inhaled by human beings per year and per m^2, and for water and soil the ADI (in kg*kg body weight^{-1}*day^{-1}) times total body weight per m^2 and number of days per year (365).

iii) model simulated on the computer, Guinée et al in 1996 and afterwards Huijbregts in 1999 [Huijbregts, 1999b] developed characterisation factors for human toxicity including degradation and intermedia transport using the USES model, Uniform System for Evaluation of Substances. The first USES model [Guinée et al in 1996] incorporated as a separate module, the multimedia model Simplebox [Van de Meent, 1993]. Simplebox calculates the Predicted Environmental Concentration (PEC) in four environmental compartments, represented as “boxes”: air, water, agricultural soil, industrial soil due to a constant flux, taking into account six exposure routes (air, fish, drinking water, crops, cattle meat and milk), allowing substance fate to be modelled including degradation and immobilisation.

Huijbregts modified the second version of the USES model in order to calculate characterisation factors for human toxicity (as well as for aquatic sediment and terrestrial ecotoxicity, see next paragraph) using the same method as Guinée [Guinée et al, 1996] but allowing the model of the substances fate at global level. In USES 2.0 there are five spatial scales (regional, continental, global tripartite to reflect the arctic, temperate and tropical climate zones of the northern hemisphere). For regional and continental scales, Huijbregts divided the water into freshwater and seawater. Therefore 6 compartments are defined (air, freshwater, seawater, natural soil, agricultural soil and industrial soil). At global scale, modelled as a closed system, only three main compartments (air, water, soil) are regarded. The dependence between substances properties and temperature in this model is accounted for, as well as their dependence with soil depth.

The measuring unit of HTP is the equivalent quantity of 1,4 dichlorobenzene: the indicator can be expressed as the quantity of 1,4 DCB giving, in the same conditions (compartment ecomp and for scale s), the same effect as the emitted quantity of substance *i* [Huijbregts, 1999b].

$$HTP_{i,ecomp} = \frac{\sum_r \sum_s PDI_{i,ecomp,r,s} \times E_{i,r} \times N_s}{\sum_r \sum_s PDI_{1,4-dichlorbenzene,air,r,s} \times E_{1,4-dichlorbenzene,air,r,s} \times N_s} \qquad \text{(II.37)}$$

N_s = the population density at scale *s*;
$PDI_{i,ecomp,r,s}$= the predicted daily intake via exposure route *r* at scale *s* for substance *i* emitted to emission compartment *ecomp* [day-1];
$E_{i,r}$= the "effect factor", representing the human-toxic impact of substance *i*, here representing the acceptable daily intake via exposure route *r* [day].

In order to better evaluate the potential short-term impacts of product systems and the model sensitivity to the choice of spatial horizons, Huijbregts ran a number of scenarios to assess the influence of these choices for horizons of 20, 100 and 500 years by integrating over these periods the amount of substance present in compartment *fcomp* after an emission pulse released to the compartment *ecomp*, and compared that with the value obtained by integration to infinity. The indicator result for human toxicity and a specific time horizon *t* can also be calculated using the formula:

$$human\ toxicity = \sum_i \sum_{ecomp} m_{i,ecomp} \times HTP_{i,ecomp,t} \qquad \text{(II.38)}$$

As a conclusion, fate is a particularly important consideration for human toxicity and it would not be appropriate to neglect it. Huijbregts models the fate more realistically compared to the rule of the thumb or empirical models. Although this method presents uncertainties regarding the model and its constituent parameters, it can be recommended as a baseline characterisation method for human toxicity [Guinée et al, 2001].

The impact category results are subject to a high degree of uncertainty because there is an ongoing discussion about the characterisation models and factors of these categories and the scientific basis is still very much under development [Guinée, 2002]. Therefore, the significance of the category results is questionable.

b) EDIP
Toxicity in EcoEffect is also based on the Danish EDIP work, which is based on the volume (m^3) of air, soil and water which is needed to dilute a gram of the hazardous substance to make it harmless to man and ecosystems.

Human toxicity
Characterisation factor = CF

$$CF(ht) = f \times BIO \times I \times T \times {}^{1}\!/_{HRD} = f \times BIO \times I \times T \times HTF$$

f = Distribution factor to air, soil and surface water. Depends on where the poisonous substance is released.
BIO = Biodegradable factor. Numbers are taken from experiments.
I = The amount poisonous substance in water, soil or food which is consumed per kg bodyweight and day, g/kg
T = Transport- and transfer factor. The ability of the substance to be transferred from the source to a human body.
HRD/HRC = Tolerable daily dose in g per kg body weight and day
HTF = Human toxicity factor = 1/HRD.

2.5.2 Heavy metals, CML 1995

More global indicators are now generally preferred regarding toxicity, see 2.5.4.

2.5.3 Carcinogenics, CML 1995

More global indicators are now generally preferred regarding toxicity, see 2.5.4.

2.5.4 Disability Adjusted Life Years (DALY)

a) Ecoindicator 1999

The eco-indicator 99 is an LCA weighting method, elaborated by Dutch and Swiss research organisations under the leadership of the PRé Consultants [Goedkoop and Spriensma, 2001]. Unlike the CML-method, Eco-indicator looks at the end-point of the cause and effect chain: it is a damage-oriented, distance-to-target approach. The aim of the method is to aggregate LCA results into easily understandable and user-friendly units, the so-called eco-points. According to their definition of environment, three damage categories (endpoints) were chosen: Human Health, Ecosystem Quality and Resources. Damage to Human Health is expressed as Disability Adjusted Life Years (DALY). Damage to Ecosystem Quality is based on the percentage of species that have disappeared in a certain area due to the environmental load. Damage to resources is measured in “surplus energy” per kg extracted material: this corresponds to the idea that the extraction of the remaining resources will result in increasingly higher energy requirements in the future. The weighting of the three categories is based on the Cultural Theory, which distinguishes three main attitudes: *hierarchists* have a balanced time perspective, based on a consensus among scientists (this is the default approach), *egalitarians* have a long time perspective, here even a minimum of scientific proof is satisfactory, whereas *individualists* have a short time perspective and only proven effects are included.

Carcinogenic Substances:
The scope of this indicator is global and local. The damage is expressed in DALY /kg emitted. The DALY (Disability Adjusted Life Years) is an index also used by the World Bank that represents the sum of the years of life lost by premature mortality and the lost years of productive life due to incapacity.

Respired Organic matter:
Respiratory effects result due to the emission of organic substances to the air. The indicator of this category is Photochemical Ozone Creation Potential (POCP). For the calculation of emissions of substances to the air the UNECE Trajectory model is used (it includes final destination), and its units are kg ethane equivalent/kg emission. The scope of this indicator is global, regional and local. Damage is expressed as DALY/kg emission.

Respired Inorganic matter:
Respiratory effects caused by particulate emissions of SOx and NOx to the air. Damage is expressed as DALY/kg emission. The scope is similar to that of the previous indicator.

Climatic Change:
The characterization factors are based on the models developed by the Intergovernmental Panel for Climate Change (IPCC) and expressed as global warming potential in the time span from 100 years to the long term. The equivalence factor has been divided into three groups: gases with an atmospheric life of less than 20 years that are assumed to behave like methane; gases with an atmospheric life of between 20 and 100 years that behave like CO_2; gases with atmospheric life longer than 100 years that behave like N_2O. Damage is

expressed as DALY/kg emission - result of an increase or decrease in the occurrence of diseases and deaths caused by climate change.

Radiation:
Based on studies for the German nuclear industry. Damage is expressed as DALY/kg emission, as a result of radioactivity. The scope of the indicator is regional and local.

Ozone layer depletion:
The values of ozone depletion potential (ODP) have been established for hydrocarbons that contain chlorine, flourine and bromine combined or CFCs. This indicator has been developed by WMO (World Meteorological Organization) for different substances. Damage is expressed as DALY/kg emission, due to the increase of UV radiation as a result of ozone damaging substances to the air. The geographic reach for this indicator is at a global scale.

Damages to Human Health (Human Health):
It is expressed as the sum of the number of lost years of life and the number of years lived incapacitated (DALY). In this damage category the following impact categories are included: Carcinogenic Substances, breathed Organic substances, breathed Inorganics, Climatic Change, radioactivity and Ozone layer.

b) Nuclear waste and ionising radiation

For use of electric energy produced from nuclear power EcoEffect uses a specific characterisation. It is assumed that all produced nuclear energy is related to risks throughout the life cycle of the uranium fuel and that these risks are proportional to the amount of electricity produced. The risk is calculated for different stages of the life cycle with DALYs, as for other indicators in EcoEffect, and then added to a damage factor (see weighting). So it is enough to know the used amount of electricity and the fraction of this electricity which is coming from nuclear power to be able to calculate the potential external load value for nuclear energy use (the indicator in EcoEffect).

2.5.5 Ionising radiation, CML 2001

The impact related to the ionising radiation includes the effects of releases of radioactive substances as well as direct exposure to radiation. In some cases we may speak of a daily radiation, like in the case of inhabitants who are exposed to building materials radiation. Exposure to this type of radiation is both harmful for humans and animals.

Ionising radiation is expressed in terms of the number of atoms disintegrating per unit of time (one Bq corresponds to one disintegration per second). Radioactivity declines in the course of time. The half-life of a substance is the time taken for the radioactivity of a given substance to decline by half.

2.5.6 Depletion of biotic resources, CML 1992 and 2001

More global indicators are now generally preferred regarding eco-toxicity, see 2.5.8.

2.5.7 Impacts of land use, CML 2001

More global indicators are now generally preferred regarding eco-toxicity, see 2.5.8.

2.5.8 Potentially Disappeared Fraction (PDF), Ecoindicator 1999

Ecotoxicicity:

Damages to ecosystem quality as a result of the emission of toxic substances to the air, water and earth. The main ones are heavy metals, with chromium being the reference substance. Damage is expressed as Potentially Affected Fraction (PAF) m^2 year /kg emission. The scope is global, regional and local.

Land Use:
Land use has impact on the diversity of species depending on the type of use and the characteristics of the area, based on observations. Damages as a result of the conversion of or occupation of land is expressed as PDF m^2 year/m^2.

Acidification - Eutrophication:
Acidification is caused by the emission of protons in terrestrial and aquatic ecosystems. In terrestrial systems the effects are observed as a reduction in forest growth and finally their disappearance; in aquatic systems the consequences are acidic lakes no type of wild life. Eutrophication or excess nutrients (nitrification) in aquatic and terrestrial systems can be caused by an excess of nitrogen, phosphorus and biodegradable organic matter. Nutrient enrichment of aquatic ecosystems increases the production of plankton algae and higher aquatic plants that deteriorate water quality and diminish the utility of the ecosystem. The decomposition of organic matter is a process that consumes oxygen sometimes causing anaerobic conditions. The damage to the atmosphere as a result of the emissions of acidifying substances to the air is expressed as Fraction Potentially Disappeared (FPD) m^2 year/kg emission. The geographic reach is similar to that of the previous indicator.

Damage to the Ecosystem (Ecosystem Quality):
It is expressed as the loss of species in a certain area over a specific time period PDF m^2 year) It includes the following impact categories Ecotoxicity, Acidification, Eutrophication and Land Use.

2.6 Comparison of indicators

2.6.1 Resources

Indicators like the abiotic depletion potential use data regarding raw material or fuel reserves, and such data is very uncertain. For instance the CML 2001 indicator considers a Uranium reserve of 62,500 billion tonnes (ultimate reserve), which is not the same order of magnitude as many other sources, e.g. CML 1992 (1.7 million tonnes), U.S. Bureau of Mines (13.4 million tonnes), French Energy Observatory (4.7 million tonnes). The use of ultimate reserves is problematic, particularly in the case of energy reserves: if a fuel is too diluted, exploitation does not pay back because more energy is needed to extract this fuel than what can be obtained from the fuel. As a consequence, consuming 1 kWh nuclear electricity contributes around 100 times less to resource depletion compared to 1 kWh electricity produced by a gas plant, though the extraction rate is similar.

The indicator “Surplus energy to extract mineral of fossil fuels” may be more adapted for fuels than for minerals, for which the problem is not an energy pay back. Surprisingly, uranium is not accounted for in this indicator.

The cumulative energy demand indicator may include renewables. May be a distinction could be done between several types of renewables. For instance if a building is heated using wood or geothermal heat, this consumed energy is no more available for other buildings. On the other hand, installing solar collectors on a roof does not reduce the available energy for other consumers.

The evaluation of water resource depletion requires to define which type of water is accounted (not only potable but also rivers, underground water…) and if only the net consumption is considered (a part is returned to wastewater treatment or rivers).

2.6.2 Air pollution

Several durations can be considered for the evaluation of the global warming potential. A 100 years period is generally used in the building sector, but some authors state that short term effects have more influence than impacts in a far future. For instance the GWP100 being the same, emitting methane could be more harmful than emitting a long lasting gas because the effect of methane will occur sooner and could cause a faster climate evolution, with more impacts on plants.
Another question regards accounting for biogenic CO_2. Some methods do not account for it, stating that the CO_2 stored during vegetation growth will be emitted to the atmosphere at end of life. No difference is made between timber from a certified forest, assuming new trees are planted. No difference is neither made between different end of life processes (incineration versus re-use in another building). Also, carbon storage during the life span of the timber is not considered.
The present indicators do not depend on the location of the emissions, but it is questionable if a substance emitted in a cold European climate of a hot and sunny South European zone has the same effect because both temperature and radiation influence the decomposition of many gases in the atmosphere.

2.6.3 Water pollution

The geographic location problem is also true for emissions into water, particularly regarding eco-toxic effects because plants and animals differ according to the location.

2.6.4 Soil pollution and waste

Besides geographic localisation which regards more eco-toxicity aspects, waste is an important issue in the construction sector. There are different types of waste: inert, banal and dangerous. Some waste is further processed and only a part –called ultimate waste- is stored (landfill). Several indicators corresponding to the different types of waste can be used, or a weighted value of the different types. The same is true for nuclear waste, because several types are defined according to their activity and their life span.

2.6.5 Damages, health and biodiversity

The indicator based on critical volume presented in an informative annex of the CEN method is not justified by a model including e.g.:
- the degradation of pollutants,
- their transport in ecological compartments,
- their transfer to potable water and food,
- the risks for human health and biodiversity.

On the other hand, the very global DALY and PDF indicators include some very uncertain assumptions like the consequences of global warming on health.

The discussion regarding the comparison of indicators will continue in WP3 during the elaboration of guidelines. Obviously the evaluation of these complex environmental issues still requires extensive research activities.

2.7 Normalisation and weighting

According to the standard Environmental management-Life Cycle assessment-Life cycle impact assessment (ISO 14042) are weighting and normalisation optional. These elements may use information from outside the LCIA framework, which should be justified and reported. Normalization employs baselines and/or reference information. Grouping and weighting employ value-choices.(ISO 14042).

The following table provides synthetic information on normalisation in different tools.

Tool	References used for normalisation
ECO-EFFECT	Impacts are normalised relative to per capita emissions/use per year in Sweden.
ECO-SOFT	Benchmarks available for PEI, GWP, AP and energy demand for heating
EQUER	National statistics available for : primary energy, GWP, water consumption, acidification, eutrophication, summer smog, waste production, radioactive waste production
GABI	
GREENCALC	A comparison is made to a reference building from 1990. Only for energy there is a national requirement.
SimaPro	There are some references of energy and water consumption for residential and tertiary buildings. No solid references about other environmental impact.

Data is available at a European scale[5].

Indicator	Value per inhabitant and per year
Depletion of abiotic resources	32.6 kg eq. Sb[4]
Primary energy consumption	In 1999 : 168,400 MJ[6]
GWP	14,600 kg eq. CO_2[4]
Acidification potential	84.2 kg eq. SO_2[4]
Eutrophication potential	38.4 kg eq. PO_4^{3-}[4]
Summer smog	25.4 kg eq; C_2H_4[4]
Ozone depletion potential	0.256 kg eq. CFC11[4]
Human toxicity	0.0068 DALY[7]
Eco-toxicity	13,700 PDF.m^2.year[6]

5 **Guinée** J. B., (final editor), Gorrée M., Heijungs R., Huppes G., Kleijn R., de Koning A., van Oers L., Wegener Sleeswijk A., Suh S., Udo de Haes H. A., de Bruijn H., van Duin R., Huijbregts M. A. J., Lindeijer E., Roorda A. A. H., Weidema B. P. : *Life cycle assessment; An operational guide to the ISO standards;* Ministry of Housing, Spatial Planning and Environment (VROM) and Centre of Environmental Science (CML), Den Haag and Leiden, The Netherlands, **2001**, 704 p

6 RECORD study, valeurs de normalisation pour les indicateurs environnementaux, 2002, 32p, n°01-1009/1A

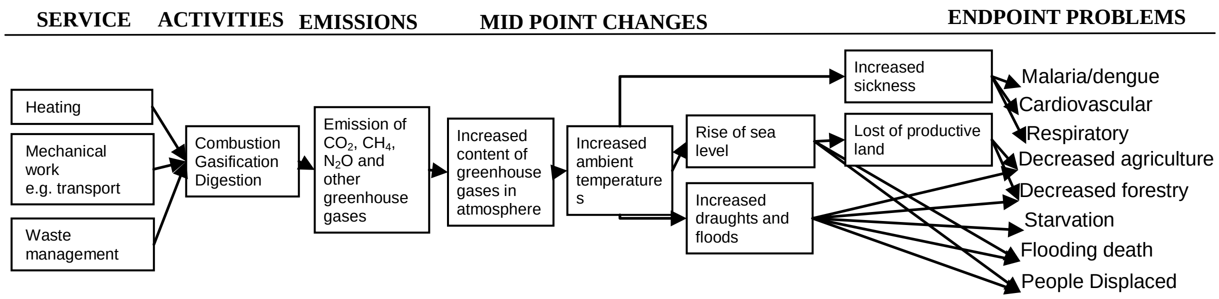
7 Jolliet Olivier, Saadé Myriam et Crettaz Pierre, Analyse du cycle de vie, comprendre et réaliser un écobilan Presses Polytechniques et Universitaires Romandes, Lausanne, 2005

Dangerous waste	107 kg[5]

2.7.1 ECO-EFFECT (KTH)

Within the EcoEffect project a new system for weighting external impacts from buildings, i.e. impacts caused by use of a building contributing to local, regional and global problems. After comparing different approaches, the use of the consequential implication of emissions and depletion of natural resources on human beings was considered to be the most relevant basis for weighting. A simplification used is that damage to nature also is transferred to end-problems on human-beings. The principles of the DALY (Disability Adjusted Life Years) system are adopted to qualify damage and annoyance to man. This was further complemented with a development of the EuroQol (European Quality of Life Scale) system for facilitating production of new disability weights covering also issues like discomfort and loss of employment.

Overall, the weighting system for each impact category includes: definition of endpoint problems, finding disability weights and duration of disability for each end-problem, estimating potential number of people affected today, estimating duration of the impact and finally calculating a damage value. These factors are estimated for the global level. The relations between these damage values are used as weights. Although current lack of data poses a problem data availability and quality is continuously improving. This concept is also used for assessment of the indoor environment but then the weight represents the potential harm to a single user of the building. The method is very transparent and open for updating and sensitivity analyses.



A cause effect chain for climate change illustrating the links between a demanded service and end point problems for which damage values are calculated.

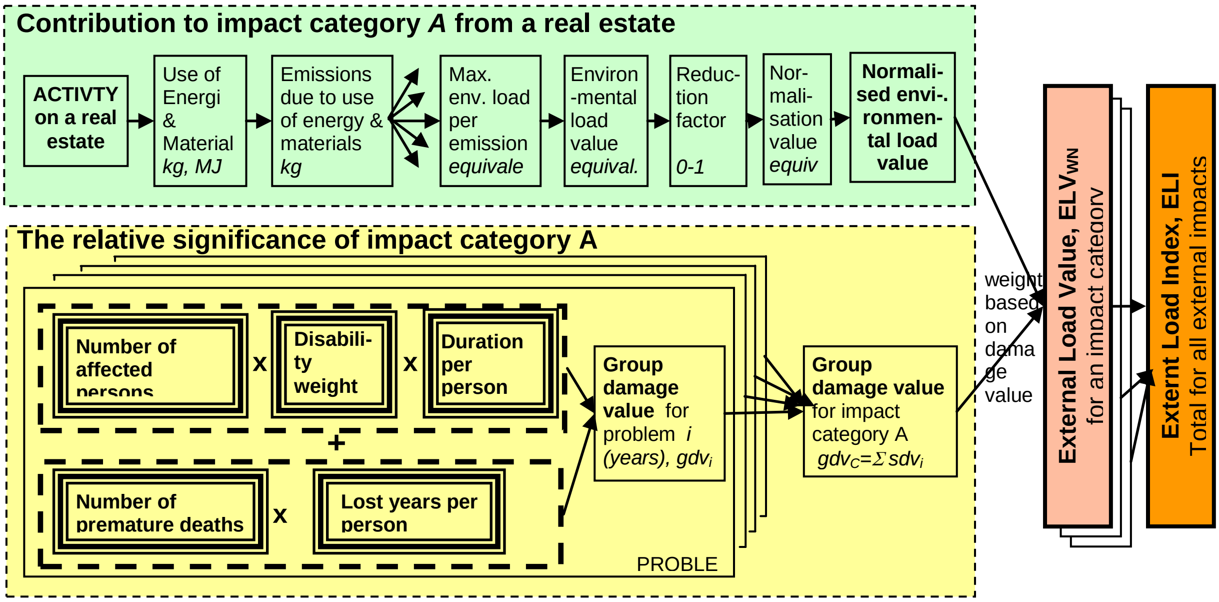


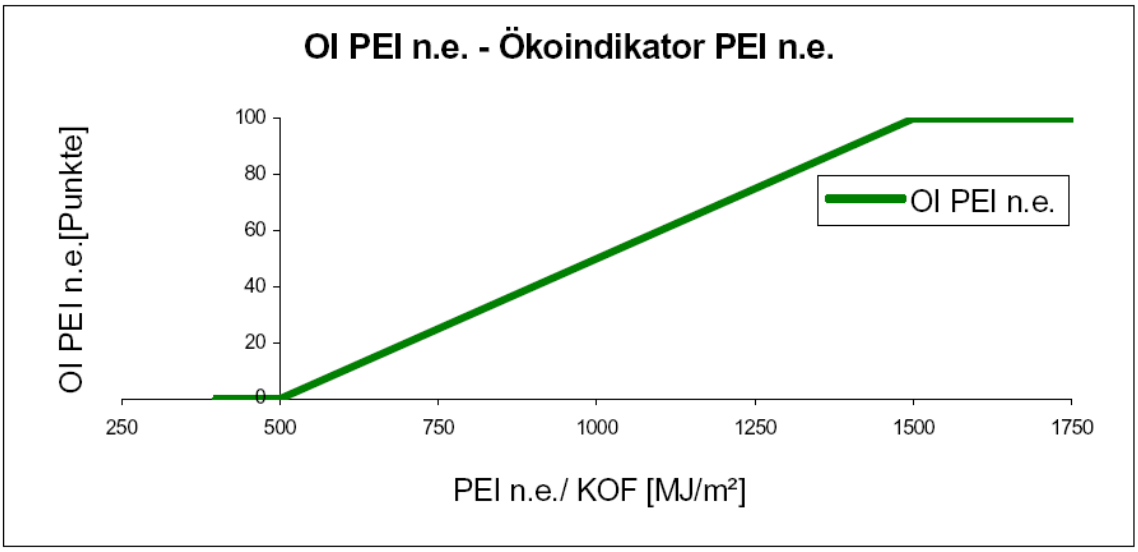
Illustration of how calculations and aggregation are performed in EcoEffect.

2.7.2 ECO-SOFT (IFZ)

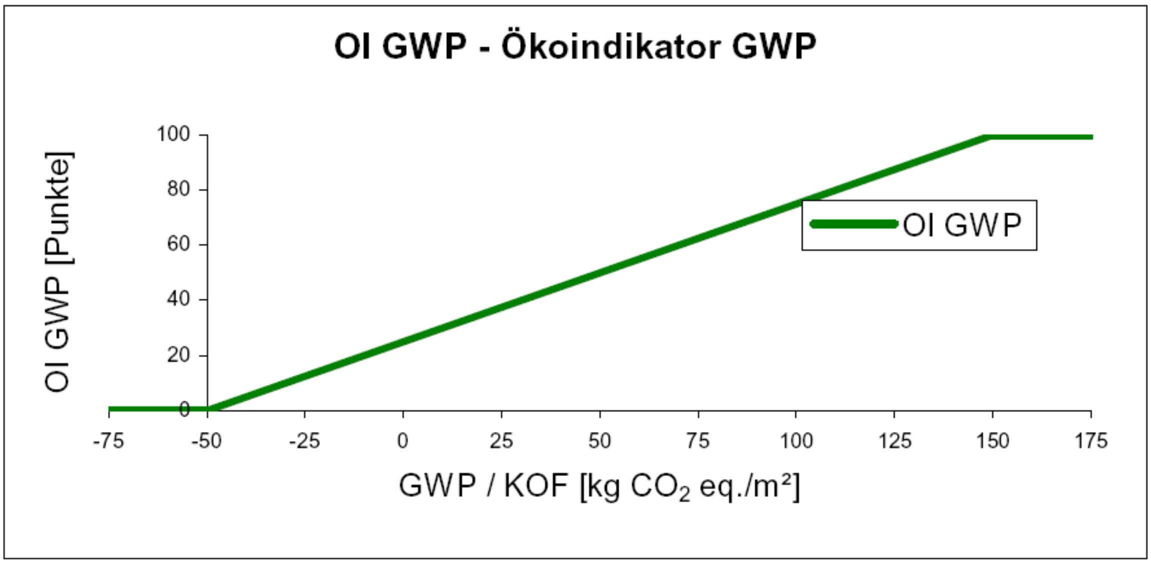
ECOSOFT offers a weighting system for building materials called "OI3-Index". This Index is based on three indicators: Primary Energy non-renewable (PEI_{ne}), Global Warming Potential (GWP) and Acidification Potential (AP). Case studies of buildings with different construction systems (light weight construction, solid buildings, e.g.) have generated benchmarks for this weighting system. Depending on the values for PEI_{ne}, GWP and AP points from 0 -100 can be achieved, functional unit is 1 m^2 construction area. Final result is the OI3-index calculated as below-mentioned:

$\text{OI3-Index} = 1/3\ OI_{PEIne} + 1/3\ OI_{GWP} + 1/3\ OI_{AP}$

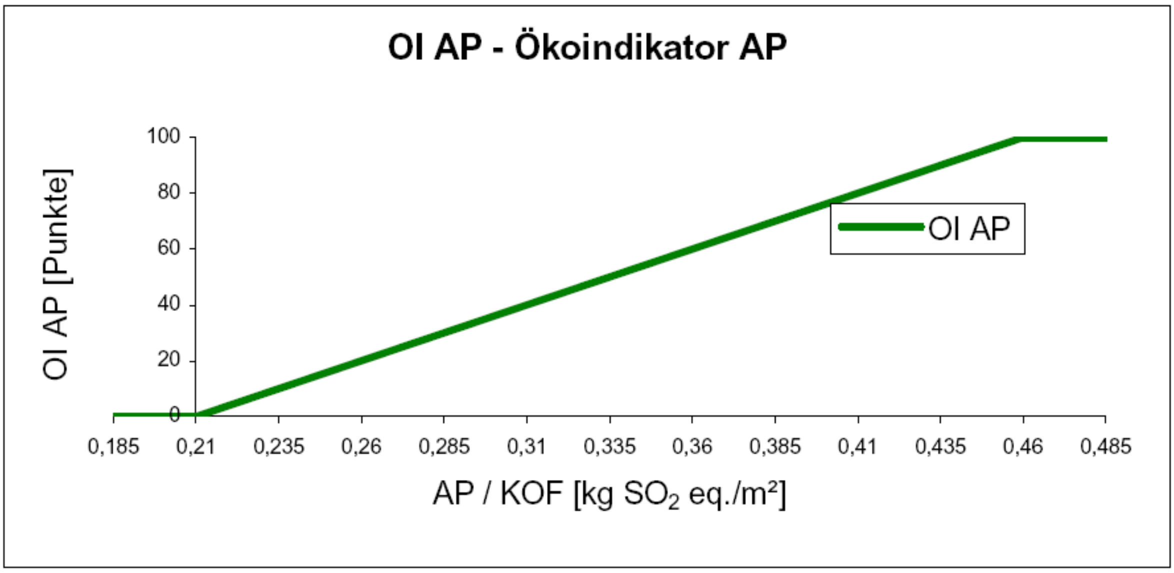
For the housing subsidy system in most of the Austrian provinces the OI3-Index has to be calculated for construction areas of the thermal building envelope ($OI3_{TGH}$), sometimes under inclusion of a correction factor for the shape/volume ratio ($OI3_{TGH,\ lc}$). $OI3_{TGH,\ lc}$ – values under 20 points represent a very high ecological standard.



Point system for Primary Energy non-renewable ($OI_{TGH}PEI_{ne}$)



Point system for Global Warming Potential ($OI_{TGH}GWP$)



Point system for Acidification Potential ($OI_{TGH}AP$)

2.7.3 EQUER (ARMINES)

No weighting is proposed at the moment : the normalisation phase helps to identify to which indicators correspond the highest impacts of the studied project. Ranking priorities among the indicators depend on the location, the use of the building, and the opinion of the client.

2.7.4 GABI (CALCON)

GaBi 4 software provides the user the possibility with a wide range of weighting and normalisation methods:

- CML 2001 and 1996: normalisation for different countries and weighting from experts, policy, survey and population
- EDIP 1997 and 2003: Ressources, Toxicity and Waste
- EcoIndicator 99 and 95: egalitarian, hierarchist and individualist approach
- Impact 2002+
- Ecological Scarcity Method (UBP)

2.7.5 GREEN CALC (ECOFYS)

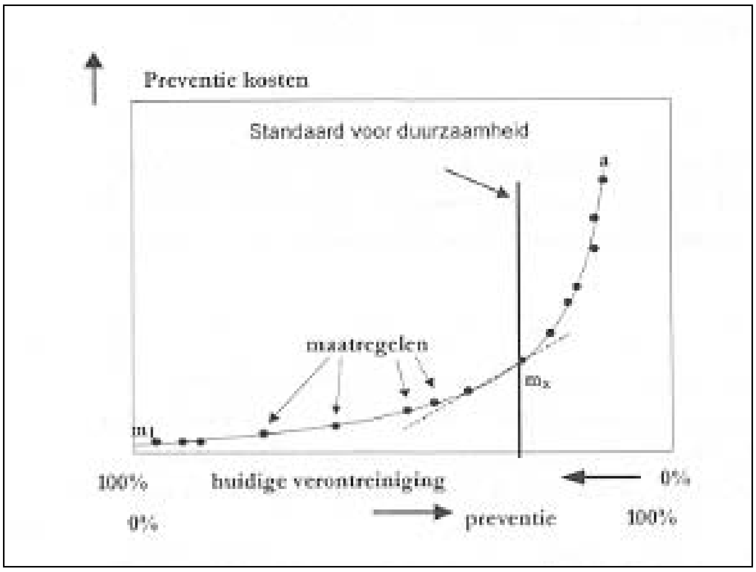
Weighting within GreenCalc is done on the basis of hidden environmental costs. The hidden environmental costs give the distance between the present environmental burden and a sustainable environmental burden. A sustainable environmental burden or impact can be sustained infinitely without any significant negative effect on human health, biodiversity and the Life Support System.
These are measured by calculation the costs for prevention. The prevention costs are the costs that would have to be made for provisions in order to reduce the present pollution a sustainable level.
But these costs have now not yet been made and are not included in the production/building costs but have eventually to be made by society. Usually the issue is not even raised. Hence the name hidden environmental costs. The hidden environmental costs reveal how great the distance is between current practice and sustainability.These costs are calculated on the basis of technical and 'social' measures

As a practical standard it is assumed that the Life Support System remains undamaged when:

- Substances do no accumulate;
- Species do not extinct on world level;
- Human health does not decline by the environmental burden.

For each environmental theme an environmental model is compiled. The costs and measurements are scaled for the contribution and effort of the Netherlands. This method of hidden environmental cost is for Dutch/ Western European buildings. The costs are calculated per environmental equivalent. A cost curve can be made in which the cheapest measures are in the left hand side of the curve.

Cost effectiveness
By grouping the measurtewmtn form the rising yearly costs per kg equivalent the minimum prevention osts canbe found to elicmint the burde on the wenvirenmnet by the source.
Aonluy technical measue are used.



Pollution versus prevention costs.

The number of measures from m1 to mx are necessary to reach the require level of sustainability.
The formula is as follows:

Total emissions to be prevented:
TTVE = $\sum_{(m1-mx)}(prevented\_emissions)$

Total costs that have to be made to reach a sustainable level:
TK = $\sum_{(m1-mx)}(\cos ts\_measurements)$

Hidden environmental costs: VMK = TK / TTVE.

For all environmental indicators sustainability levels are determined.
Examples:
Climate change (greenhouse gas emission CO_2)
- Reduction of CO2 emissions by 50% compared to 19990.

Acidification
- A reduction to 165 million kg SO_2 eq. per annum (from 970 million in 1992).

The hidden environmental costs are calculated for the building materials, the energy and water consumption, and the mobility (commuting). An environmental index is obtained by comparing the hidden environmental costs of the project with the hidden environmental costs in 1990.

2.7.6 SIMA PRO (CIRCE)

CIRCE generally uses the damage assessment, normalization and weighting factors defined in the Ecoindicator ’99 included in SimaPro 7.

In order to obtain the damage assessment, the characterisation factors considered for each damage category are:

- Human Health (DALY):
  - Carcinogenic Substances: 1 DALY/DALY
  - Respired Inorganic matter: 1 DALY/DALY
  - Respired Organic matter: 1 DALY/DALY
  - Climatic Change: 1 DALY/DALY
  - Radiation: 1 DALY/DALY
  - Ozone layer depletion: 1 DALY/DALY
- Ecosystem Quality (PDF m^2 year):
  - Ecotoxicity: 0,1 PDF m^2 year / PAF m^2 year
  - Acidification – Eutrophication: 1 PDF m^2 year / PAF m^2 year
  - Land use: 1 PDF m^2 year / PAF m^2 year
- Resources (MJ surplus):
  - Minerals: 1 MJ surplus / MJ surplus
  - Fossil fuels: 1 MJ surplus / MJ surplus

The normalization factors considered to obtain the degree of contribution to the global environmental problem of each damage category are:

- Human Health: 65,1
- Ecosystem Quality: 1,95 e-04
- Resources:1,19 e-04

The units of the Ecoindicator'99 are the milli-points (mPt). The absolute value of the points is not very relevant as the main purpose is to compare relative differences between products. The scale is chosen in such a way that the value of 1 Pt is representative for one thousand of the yearly environmental load of one average European inhabitant. This value is calculated dividing the total environmental load in Europe by the number of inhabitants and multiplying it with 1000 (scale factor).

In order to obtain the indicator value (expressed in mPt), the weighting factors considered are:

- Human Health: 300
- Ecosystem Quality: 400
- Resources:300

2.7.7 (EMI)

For CML-categories we use normalisation to identify the relative significance of the impact assessment categories. No weighting is proposed.
For eco-indicator 99, the three end-categories are used, based on the Hierarchist default weights.

3 Adaptation and simplification of LCA

The main potential users of LCA results are not environmentalists (e.g. architects, building owners, property developers, municipal services…). The interpretation phase is an essential issue in LCA. It is therefore needed that LCA results are well understood by end users in order to influence correctly the decision making process. Information has been collected about the use of the tools (who are the users, at which stage of a building project is LCA used, how often, for what purpose) and possible barriers. Different aspects have been studied to make the interpretation phase easier, for instance :

normalization (e.g. relating CO_2 emissions of a building to an average emission per inhabitant and year, at a national or European level),

comparison of the performance of a project with references (standard construction, best practice…),

comparison of different design alternatives for the same project.

3.1 Identification of users

Type of user	Stage of the process	Purpose of LCA use
Consultants advising municipalities, urban designers	Preliminary phases	Setting targets at municipal level Defining zones where residential/office building is encouraged or prohibited Setting targets for development areas
Property developers and clients	Preliminary phases	Choosing a building site Sizing a project Setting environmental targets in a programme
Architects	Early design (sketch) and detailed design in collaboration with engineers Design of a renovation project	Comparing design options (geometry / orientation, technical choices)
Engineers / Consultants	Early design in collaboration with architects, and detailed design Design of a renovation project	Comparing design options (geometry, technical choices)

3.2 Identification of barriers against the use of LCA

3.2.1 Cost and complexity of an LCA

Country	Duration of an LCA for e.g. a 1,000 m2 office building
Austria	Assuming that all data are available: 2 days
France	1 day + 2 days thermal calculations
Germany	Approx. 2 days if all data are available (what is really seldom)

Hungary	2 days + 2 days thermal simulation
Norway	Depending of the use of Building information models, more simplified transfer of information/update of information reduces the time needed Energy demand calculations 1-2 days depending on complexity and need for defining different parameter. Life Cycle costing 1-2 days depending on complexity LCA not sufficiently in use Product decision based on EPDs or other LCA based information, short time for products in EcoProduct, 2-4 hours for other products
Spain	2 days (LCA of building construction) + 1-2 days (LCA of building operation and maintenance) depending on the complexity of the geometry, energy systems, zonification, etc.
Sweden	Assuming that amount of energy and basic material use are available - 1/2 day
The Netherlands	Basically 2-3 days but it depends on the complexity of the building that has to be analyzed. The costs are variable (naturally, the rates charged are different). Part if the information is in most cases available for energy performance calculations. The Dutch Green Building Council promotes the use of a rating tool BREEAM. Property developers seem to be more in favour of such a scheme than a LCA calculation (www.DGBC.nl).

Some possible solutions to reduce costs and complexity of applying LCA in the building sector are proposed in § 3.3.

3.2.2 Uncertainty of an LCA

Tool	**Validation or verification activities**
ECO-EFFECT	Limited comparison with Beat (DK) and ELP (Environmental Load Profile, SE).
ECO-SOFT	PRESCO exercise, intercode comparison with 7 other tools
EQUER	REGENER, intercode comparison with ECO-QUANTUM and ECO-PRO IEA Annex 31 exercise PRESCO exercise, intercode comparison with 7 other tools
GABI	
GREENCALC	No comparison is made. A standard has been drafted in order to have the same calculation methods between similar software (to be able to compare results; ECO-QUANTUM, GreenCalc and GPR Building) This is the Dutch standard NEN 8006:2004/A1:2008 nl ‘Environmental data of building materials, building products and building elements for application in environmental product declarations - Assessment according to the Life Cycle Assessment (LCA) methodology’.
SIMA PRO	Look for more specific data regarding the high impact phases in the building construction. Comparison of at least two different databases and two different impact assessment methods to analyze the dispersion on results.

Inter-comparison of tools could help to increase the confidence in Building LCA.

3.2.3 Low link with labelling and subsidy schemes

Country	Green labelling scheme	Link with LCA
Austria	Social housing subsidy schemes in different Austrian provinces	Energy performance, choice of building materials
Bulgaria		
France	HQE	1 over 14 target regarding the choice of materials
Germany	DGNB certificate (DGNB stands for Deutsche Gesellschaft fuer Nachhaltiges Bauen and is the German part of the World Green Building Council)	Certain indicators within the DGNB certificate are based on LCA application
Hungary	No common green labelling system for buildings yet, labelling is only based on the operational energy use	
Norway	Nordic Ecolabelling "Svanen" of residential building (single family houses) 10 products are labelled. EcoProfile – environmental assessment of buildings. Criteria based. No labelling.	Life Cycle approach is used when defining the criteria. List all products and materials used in the Swan-labelled house, with appropriate units of quantity, is mandatory. Simplify the LCA. Criteria for materials are is partly LCA based.
Spain	Spanish Building Energy Label (Royal Decree 47/2007)	In the Spanish Energy Label, only the emissions caused by the energy consumption during the use of the building are evaluated (by means of CALENER software). There is no reference on the energy involved in the building construction.
Sweden	No commonly labelling scheme for buildings yet	
The Netherlands	Link to the "Energielabel" (Dutch energy label system). Link to the EPC calculation (energy) and WPC (Dutch standard NEN6922 'Water performance of dwellings and residential buildings - Determination method' The operational energy use of new building is maximised by the Building Act (calculation). Following a sustainable building scheme is only voluntary	GreenCalc+ calculates the EGG, EPC, EPL and WPC (Water Performance Coefficient) It also calculates the Energy Building Index by comparing the project with a reference building. The Environmental Management Index, that shows how the user deals with the building on annual base, is calculated as well.

Country	Incentives	Link with LCA
Austria	Higher subsidy for energy-efficient green buildings	Energy performance, choice of building materials
Bulgaria		

France	reduction of local taxes with HQE label	1 over 14 target regarding the choice of materials
Germany	Special interest rates depending on the final energy demand. Local/municipal funding for certain "green" actions	No link known
Hungary	No special incentives for green buildings, only energy efficiency measures (additional insulation, change of windows, renewable energy)	
Norway	Regulations – buildings and products have to have low environmental impact. Extra housing loans when building environmental friendly. Support for energy savings – both new and existing buildings	In general, no requirements for documenting the environmental impact, but documentation can be done by use of LCA
Spain	Possible reduction of local taxes depending on the energy label.	CALENER software
Sweden	No incentives exists apart from for certain measures e.g. installation of solar collectors	
The Netherlands	No incentives exists apart from certain subsidies for the installation of PV modules or solar water heaters and heat pumps.	No link known

Sensibilisation of European, national and local authorities to environmental protection could help to support the practice of LCA by appropriate grants.

3.2.4 Difficulty to formulate and follow up measurable environmental goals

Country	**Example environmental goals in a building programme**	**Follow up**
Austria	Housing subsidy province of Styria: Eco-points for energy demand, use of renewable energy sources and choice of ecological building materials	Energy certificate, Calculation of OI3-Index, computer aided (online) energy book-keeping for multi story buildings in the social housing sector
Bulgaria		
France	Lyon Confluence (CONCERTO project) : kg CO2/m2/year G radioactive waste / m2 / year	Calculations derived from energy bills
Germany	Law ENEV2009 that sets environmental goals limited to energy demand and CO2-emissions	Regulations can follow as soon as CEN standardisation and according EU-regulations are clear
Hungary	SOLANOVA: CO2, primary energy demand	Monitoring, energy bills

Norway	Regulations – max theoretical energy demand, KWh/m2 Larger building projects have environmental programmes. Norwegian standard for Environmental programme is under development. Larger contractors have usually their own environmental programmes as part of their quality system. Environmental goal is a part of public procurement document (buildings, rental).	Monitoring throughout building process. Energy consumption
Spain	Reference indicators: kg CO_2/m^2/year; kWh/m^2/year (final energy) Examples: Renaissance - CONCERTO project- in the new district of Valdespartera and the old district Picarral in Zaragoza; application of the sustainable building guide in Basque Country	No standard follow up methodology defined. Only some regions have defined the process to obtain the energy label and the follow up procedures.
Sweden	Skanska: CO2 and primary energy targets	
The Netherlands	As follow up on the EPBD a labelling scheme has been introduced. Existing building have to have an certificate when sold (>1000m2 floor space). New building have to fulfil the energy requirement set in the Building Act. For dwellings now an EPC = 0.8 is required. (In 2011 EPC = 0.6; in 2015 EPC = 0.4). This gives a maximum energy use for certain types of buildings. Examples: City of Almere CRrescendo (CONCERTO project) low energy houses Several examples of zero-energy buildings WWF dwellings: Solar dwellings, a certificate scheme with the use of FSC wood	

Some experience has been gained in the frame of e.g. European CONCERTO projects regarding the requirement of environmental targets in development programmes. For instance in the Lyon Confluence urban renovation project in France, environmental performance targets were required, see table below.

Emission reduction targets in the Lyon Confluence project	Greenhouse gases	Radioactive waste
dwelling	7 kg eq. CO_2 / m^2 / year	2 g rad. waste / m^2 / year
offices	5 kg eq. CO_2 / m^2 / year	2 g rad. waste / m^2 / year

3.3 Simplification of LCA

Studies report that, depending on the energy performance of a building, up to 90% of the building impacts are related to the main building elements (walls, floor and foundation, roof, windows, equipment), and to the operation phase (heating, cooling, lighting, ventilation, water consumption). The decisions influencing the most the environmental performance of buildings are made at an early phase (sketch) where no detailed data exist. Simplifying the building description is therefore essential. The state of the art addresses :
studies comparing simplified and detailed models,
the user interface and easy data input.

3.3.1 Simplification of LCA

Austria
Successful implementation of LCA-tools in building process depends on a strong link to common practice (Adaptation to typical planning and design phases, requirements by subsidy and building law) and adequate efforts for landlords and professionals involved. Linking LCA activities with the energy certificate (as required by the EPBD) might be a passable strategy for Austria. Calculations and data (geometry of the building, thermal surface area, building materials for the thermal envelope, calculation of the energy performance) required for this energy certificate can be the base for LCA, by generating only low additional efforts. Furthermore a limitation of indicators (e.g. PEI, GWP, AP) facilitates dissemination of LCA. If possible, LCA tools should be integrated in common tools used by professionals (CAD and tendering programs), extra tools (software programs) for LCA have proved to be a strong hurdle for dissemination in Austria.

France
Link with CAD and thermal simulation, the tool being used for energy certification, makes the use of LCA more convenient among practicioners. A PhD is in progress and will include a chapter regarding the effect of simplification on the precision of the evaluation.

Germany
Currently in the framework of the German sustainability certificate system several simplification projects are ongoing.

Hungary
A recent Ph.D. dissertation concluded that cumulative energy demand is a suitable screening indicator for conventional residential buildings in Hungary [Szalay, 2007]. For typical building systems and heating fuels, energy was highly correlated with the global warming potential, the resource use in eco-indicator 99 and with the non-renewable cumulative exergy demand. The normalisation of the results, i.e. comparing the magnitude of the other indicator results to a reference value (the annual interventions in Western Europe) showed that the relative significance of the other environmental indicators, such as acidification, ozone depletion, photochemical oxidation, eutrohication is far less than that of global warming. The analysis was done for six building categories, four building systems and ten environmental impact categories and 1,000 building geometries per building category.

If the main target of the LCA is to optimise the architectural design, the non-building related components should not be taken into account. The impacts caused by the operation of the building can be divided into predominantly building-related components, such as the heating demand covering the algebraic sum of the transmission losses of the envelope and the utilised fraction of the solar gains, and predominantly user-related components, such as the heating demand covering the algebraic sum of the ventilation losses and the internal gains; the domestic hot water demand and the lighting.

The analysis also showed that from the total building related impacts, building envelope is responsible for 80 % and the other building elements (internal walls, floors etc.) for 20 % of the specific non-renewable cumulative energy demand in single-family houses, and 70 % and 30 % in multi-family houses. As these other elements do not influence the operational energy demand, these elements do not have to be taken into account in the energetic optimisation of the building. However, these elements can be taken into account in a labelling system, for example.

Norway

Focus on Environmental Product Declarations (EPDs). EPDs will be used as input for LCA for the whole building, adding the operation phase (energy for operation, maintenance…)
Simplified method is under development, focusing on a few indicators. EcoProduct is a database with EPDs or similar information enabling architects or purchasers to compare the environmental impact of different products, where the information in the tool is LCA based.

Statsbygg (Public Construction and Property Management) has as a goal that EPDs or similar information is delivered for all main product in their building projects.

Many municipalities are making their climate programme, and are looking for tools to use following up the programme. CO2 emission is most important.

Several larger research project is looking at how to ensure reliable sustainability assessment, aiming at both improving the available information (making more EPDs available) and to link assessment tools to tools already in use by architects, engineers and designers. Use of building information model and information exchange by use of IFC format are higly emphasised.

Laws on public procurement demands that LCC and environmental impact are taken into account in all public procurement, and LCA of building and use of EPDs are both means to enable the process.

Spain

National Renewable Energies Centre is developing a building environmental quality guarantee that involves an energy consumption analysis by means of the energy labelling according to the RD.47/2007 and a life cycle assessment of the construction materials with own software.
In the Autonomous Community of the Basque Country has been developed a guide for sustainable building that contains an extensive catalogue of good environment practice in the construction sector applied throughout all its life cycle. It includes the city planning, the management and the architecture process development, the management of material and waste, the performance, the demolition and the use and maintenance of the building.Sweden
At least two simplified methods exist, “ELP”(Environmental Load Profile, consultant product) and “Sustainable Buildings”(IVL).

Sweden

There are at least three kind of LCA application problems in buildings which might be simplified. They concern simplification of acess to building data, building product data and reduction of impact categories. Simplification of access to building data have been done based on CAD drawing with a tool called Anavitor. Devlopment and use of BIM (Building Information Modelling) based CAD programs will anable this for many aplications. Regarding building product data no large efforts have been done. LCA for building are still dependent on either a Swedish version of Building Product Declarations developed by the Swedish Eco Cycle Council (poor regarding LCI data), compilation of own databases or use of foreign European databases. Regarding impact categories some appications are restricted to climate change, acidification, eutrification, stratospehric ozone layer and ground ozone. Some work has been done on weighting based on damaged (EcoEffect), The Swedish National Environmental targets (IVL), environmental taxes (Ecotax), etc. EPDs for building products have not been developed to any significant extent.

The Netherlands
Effort is put in harmonising the existing tools like ECO-Quantum, GreenCalc and GPR Building. These programs already use users friendly wizards and data can be imported.

There is competition with rating schemes (like BREEAM).

Many municipalities are making their climate programme, and are looking for tools to use following up the programme. CO2 emission reduction is most important.

By the Ministry of Environment focus is on implementing the EPBD requirements (labelling schemes).
The topic of sustainable buildings i however on the agenda.

3.3.2 Users interface

Tool	Users interface	Links with other calculations
ECO-EFFECT	Inputs are environmental targets, building size, amounts of energy, materials and design actions to prevent indoor problems. The excel program gives material amounts, U-values etc.	Energy use is taken from other programs – there is a number that could be used. Simulations are always done for new buildings so there is no need to incorporate it in EcoEffect.
ECO-SOFT	MS Excel based	Link to the Austrian Energy Certificate is possible
EQUER	Graphic geometry input	Thermal simulation
GABI	available	Export to other databases of certain results possible
GREENCALC	It is a Windows program. A simple wizard is available to quickly fill in the building details. The building can be divided in standard building blocks to determine the material use. A 3D view of the building is generated. Energy and water concepts can be selected.	Results from the obligatory calculation of energy performance for new buildings on the basis of NPR 5129 or NPR 2917 can be imported. Results can also be exported to Excel. For existing building the EPA model (energy performance advice) is included in GreenCalc. The energy-index of a existing building is calculated.
SimaPro	Main inputs are the amount of construction materials used in the building and the energy consumption.	Energy consumption must be calculated with an additional soft (e.g. CALENER) and the list of materials involved in the

		construction is inserted in SIMA PRO.

3.3.3 Presentation of results

The way to present results is essential to help users during the interpretation phase of an LCA. Normalisation allows all indicators to be expressed using the same scale. Weighting reduces the number of indicators. But a question generally asked is : how does the studied project performs in comparison to a standard building, or to best practice ? References have to be defined in order to answer such a question. Such references depend on the type of building, and if the studied project is a new construction or a retrofit project. This problematic will be further studied in the next Enslic work packages, and particularly the case studies.

- references for new constructions

Country	**Standard practice**	**Best practice**
Austria	For social housing projects: > Low energy standard for heating > Exclusion of some materials (FKW, FCKW, HFKW, HFCKW, PVC) For other building categories: > no requirements for the energy consumption, mainly definition of minimum u- values > no requirements for the ecological performance of building materials	Passive house standard, water saving sanitary equipment, solar hot water, soar heating and cooling, energy efficient lighting and equipment, ecological insulation materials (mineral foam board, straw, hemp)
Bulgaria		
France	Thermal regulation level Most frequent building materials according to the statistics institute: concrete blocks + polystyrene + gypsum inside, clay tiles roof, concrete floor + polystyrene, PVC windows with low emissivity double glazing	Passive house standard External insulation Water saving sanitary equipment Solar hot water
Germany	Energy regulations, regulations that ban some materials.	Reduced energy consumption up to energy-producing houses
Hungary	Energy performance regulation based on EPBD Most common building elements: porous insulating brick without additional insulation, or with external polystyrene, clay tiles, floors with prefabricated beams or concrete floors with polystyrene, PVC windows, low-e double glazing. Gas heating.	Passive house standard (very few examples yet)

Norway	Energy regulations Total energy demand by use of standardised calculation method: Houses 125 +1600/Area (kWh) Apartment buildings 120 kWh Offices 165 kWh	Low energy houses Passive house standard
Spain	Good passive design of building (assisted by thermal simulations). Limitation of energy losses and promotion of energy gains in winter. Promotion of energy losses and limitation of energy gains in summer. High efficiency heating, cooling and lighting systems. Use of renewable energies, such as PV or solar thermal or systems.	Low emission buildings or ZEB (zero emission buildings) Positive-energy buildings (more energy produced tan consumed). Bio-construction (natural & healthy materials vs. synthetic high energy consuming construction materials)
Sweden	Energy Code: without household electr. Max 110 kWh/m2,yr - South Max 130 kWh/m2,yr - North Um (dwellings)< 0,5 W/m2,K Um (localities) > 0,7 W/m2,K	Preliminary standard for passive house
The Netherlands	Energy regulations Total energy demand by use of standardised calculation method: EPC (Energy Performance coeffi-cient) No requirements are set on individual components or parts of a building. The total (calculated) energy use is assessed. Some regulations that ban the use of substances are found in the Environmental protection Act.	

- references for existing buildings

Country	**Standard practice**	**Best practice**
Austria	In comparison to new buildings (standard practice) energy demand for heating is 2 – 3 times higher, mainly fossil energy sources for heating and cooling.	Low energy standard and sometimes passive house standard, water saving sanitary equipment, solar hot water, soar heating, energy efficient lighting and equipment
Bulgaria		
France	Building before renovation used as a reference	U values of passive house standard for walls, windows and roof Heat recovery on exhaust air, air tight envelope (passive house standard) Condensing gas boiler

		Water saving sanitary equipment Solar hot water
Germany	Energy regulations, regulations that ban some materials.	Energy reduction up to passive houses
Hungary	Typical retrofit includes: External polystyrene additional insulation, change of windows for low-e PVC, controllable heating	Extra insulation, special windows Condensing gas boilers Mechanical ventilation with heat recovery Water saving sanitary equipment Solar hot water
Norway	Building requirements valid also for refurbishment, but other requirements (aesthetics, cultural heritage, economy), might have higher value.	Extra insulation – new U-value depending on type of building and construction. Windows/doors with low U-value (1,0 W/m2K) Balanced ventilation with heat recovery (85 %). Water saving sanitary equipement Energy efficient lightning
Spain	Improvement of building skin by better insulation and reduction of air leakage (new windows). Maintenance or substitution of old energy systems. Use of renewable energies, such as PV or solar thermal or systems.	External insulation if it is a regularly used building (keeping a better thermal inertia). Use of natural materials (e.g. a commercial solution with cork + lime). Check the building before and after refurbishment (blower door for air leakage, infrared camera for insulation & energy bills for the systems). It is also recommended to check thermal comfort by sensors and real efficiency of systems by energy counters.
Sweden	Building before renovation used as a reference	Extra insulation, exchange of windows with U-value about 1,5 W/m2K, installation of heat pump on exhausted air and exchange fuels to district heating.
The Netherlands	Good insulation, (f.i. R_c>3) Insulated double glazing and solar water heater or district heating or heat pump or solar PV is necessary to reach the obligatory energy performance.	Low energy houses or zero-energy houses. Combination of high insulation and balanced ventilation (heat recovery) with the application of renewable energy (solar) and for instance a heat pump combined with low temperature heating. A number of energy concepts are possible.

Conclusions

Building LCA and LCC tools with corresponding data bases have been reviewed and analysed, mostly at a European level but also including North American tools. A list of environmental indicators has been derived, and each indicator has been presented. Weighting has also been addressed. Some indicators have been compared and some limits in the present knowledge have been identified.

Potential users of LCA have been listed according to the life cycle phases of a project. The main barriers against the use of LCA in the building sector have been addressed (uncertainties, low link with labelling/certification, difficulty to formulate and follow up measurable goals, cost and complexity) and some solutions have been proposed: inter-comparison of tools, sensibilisation of public authorities, integration of environmental targets in development programmes, simplification of input-output.

This state of the art constitutes a basis for the elaboration of guidelines for the application of LCA in the building sector.

Deliverable D2.2 : Collection of published material

1 Environmental assessment tools

1.1 Data bases on materials and processes
Ecoinvent www.ecoinvent.ch
Gemis www.gemis.de
European data base ELCD : http://lca.jrc.ec.europa.eu/lcainfohub/datasetArea.vm

1.2 Building life cycle assessment tools
ECO-QUANTUM : www.ecoquantum.nl
LEGEP : http://www.legep.de/
EQUER : www.izuba.fr
ATHENA : http://www.athenaSMI.ca
OGIP : http://www.ogip.ch/
ECO-SOFT : http://www.ibo.at/de/ecosoft.htm
ENVEST 2: http://envestv2.bre.co.uk/
BECOST : http://www.vtt.fi/rte/esitteet/ymparisto/lcahouse.html
BEES : http://www.bfrl.nist.gov/oae/software/bees.html
GREENCALC: www.greencalc.com
ECOEFFECT : www.ecoeffect.se

1.3 Building rating systems and existing labels
GB Tool : http://www.iisbe.org/
BREEAM : http://www.bre.co.uk/sustainable/breeam.html
LEED : http://www.ibec.or.jp/CASBEE/english/overviewE.htm
ESCALE : http://www.cstb.fr/departements/ddd.asp
CASBEE : http://www.ibec.or.jp/CASBEE/english/index.htm
GPR Gebouw® : http://www.grpgebouw.nl/
NATURE PLUS : http://www.natureplus.org/
ECOProfil : www.byggsertifisering.no
Code for Sustainable homes :
http://www.planningportal.gov.uk/england/professionals/en/1115314116927.html
Nordic Ecolabelling – Svanen: http://www.ecolabel.nu/nordic_eco2/welcome/
Ecolabelling of Small houses:
http://www.svanen.nu/Default.aspx?tabName=CriteriaDetailEng&menuItemID=&pgr=89

1.4 Energy labels
CALENER (Spanish Building Energy Label):
http://www.mityc.es/Desarrollo/Seccion/EficienciaEnergetica/CertificacionEnergetica/Reconocidos/CalenerVYP/

1.5 General life cycle assessment tools
Boustead: www.boustead-consulting.co.uk
Eco-it: www.pre.nl
Ecopro: www.sinum.com
Ecoscan: www.ind.tno.nl
Euklid: www.ivv.fhg.de
KCL Eco: www.kcl.fi/eco
Gabi: www.gabi-software.com
LCAit: www.ekologik.cit.chalmers.se
Miet: www.leidenuniv.nl/cml/ssp/software
Pems: www.piranet.com/pack/lca_software.htm
SimaPro: www.pre.nl

Team: www.ecobilan.com
Wisard: www.pwcglobal.com
Umberto: www.umberto.de

1.6 Other environmental assessment tools
studies regarding external costs : http://www.externe.info/
Ecological scarcity
Sustainable Process Index
MIPS (Material Input Per Service unit)
Ecological footprint
Miljøprogrammering
EcoProduct

2 Cost calculation tools

Life cycle cost calculation
Elements method : Swiss standard SN 506 502, Cost classification by elements
DEEP Energy Efficient Procurement Toolkit - LCCA Tool: www.iclei-europe.org/deep
NS3454 Cost classification
LCprofit www.statsbygg.no

3 Existing review reports

International Energy Agency, Annex 31 : Energy related environmental impact of buildings, technical synthesis report, http://www.iisbe.org/annex31/index.html
Sustainable urban environment – metrics, models and toolkits :
Assessment of sustainability tools, BRE, July 2004
analysis of sustainability / social tools, Levett – Therivel Consultants, June 2004
Åsa Jönsson, *Tools and methods for environmental assessment of building products—methodological analysis of six selected approaches*. Building and Environment, Volume 35, Issue 3, April 2000, Pages 223-238
Martin Erlandsson and Mathias Borg, *Generic LCA-methodology applicable for buildings, constructions and operation services—today practice and development needs*. Building and Environment, Volume 38, Issue 7, July 2003, Pages 919-938
Ding, Grace K.C. (2008). Sustainable construction - The role of environmental assessment tools. Journal of Environmental Management, 86, pp 451-464.
Todd, Joel Ann, Crawley, Drury, Geissler, Susanne and Lindsey, Gail. (2001). Comparative assessment of environmental performance tools and the role of the Green Building Challenge. Building Research & Information, 29, 5, pp 324-335.
ABDELGHANI-IDRISSI, M. A., BIROT, J.-J., SEGUIN, D., MILLER, A., IP, K. (2004), DURABUILD project, Environmental assessment tools report **:**
http://www.durabuild.org/html/French/publications/EAT%20Report.pdf
Building environmental quality evaluation for sustainability through time (BEQUEST) (2000). Projet Européen. Site internet : http://research.scpm.salford.ac.uk/bqpart/

Department of Environment and Heritage. (2001). *Projet Greening the building life cycle : Life cycle assessment tools in building and construction (Building LCA)*. Australian Government. Disponible en ligne. URL : http://buildlca.rmit.edu.au/

Task Group 4 (TG4) (2003) Report of Task Group 4: *Life Cycle Costs in Construction*, the European Commission, http://ec.europa.eu/enterprise/construction/suscon/tgs/tg4/lccreport.pdf.

4 Previous European projects

PRESCO : http://www.etn-presco.net/

CRISP : http://crisp.cstb.fr/
EXTERNE : http://www.externe.info/
ECO-HOUSING : www.eco-housing.org
HQE2R : http://hqe2r.cstb.fr/
SUREURO : http://www.sureuro.com/
BEQUEST : http://research.scpm.salford.ac.uk/bqpart/
ANSEA : http://www.taugroup.com/ansea/
SPARTACUS : http://www.trttrasportieterritorio.it/spartacus_eng.htm
LENSE : http://www.lensebuildings.com/
DEEP : http://www.iclei-europe.org/deep

5 Standards and standard drafts

EN ISO 14040, 1997 and 2006, Environmental management - Life cycle assessment - Principles and framework
EN ISO 14041, 1998, Environmental management – Life Cycle Assessment – Goal and Scope Definition – Inventory Analysis.
EN ISO 14042, 2000, Environmental management - Life cycle assessment - Life cycle impact assessment.
EN ISO 14043, 2000, Environmental management - Life cycle assessment - Life cycle interpretation.
EN ISO 14044, 2006, Environmental management - Life cycle assessment -- Requirements and guidelines
EN ISO 14047 Examples of application of ISO 14042 European standard, Geneva, 2003, 93 p.
EN ISO 14048, 2002, Data documentation format European standard, Geneva, 47 EN ISO 14049, 2000, Examples of application of ISO 14041 European standard, Geneva, 49 p.
ISO 15686-5 Buildings and constructed assets – Service life planning Part 5 – Life cycle costing
ISO 21931 Building construction Sustainability in building construction Framework for assessment of environmental performance of buildings and constructed assets Part 1: Buildings
ISO/AWI 15392 Building construction Sustainability in building construction General principles
ISO/CD 21932 Building construction Sustainability in building construction. Terminology
ISO 21929 Building construction Sustainability in building construction. Sustainability indicators Part 1 – Framework for development of indicators for Buildings
ISO 21930 Building construction Sustainability in building construction Environmental declaration of building products".
SPOLD (1996). SPOLD data format (rev. 1996.04.10). Society for the Promotion of LCA Development (SPOLD). Brussels.
Documents from CEN TC 350 Sustainability of construction works and TC 351 Construction products : assessment of release of dangerous substances
SETAC-Europe (1992). Life-cycle assessment. LCA Workshop, Leiden 2-3 December 1991. Society of Environmental Toxicology and Chemistry (SETAC) - Europe. Brussels.
AFNOR, Pr NF P 01-020-1, Qualité environnementale des produits de construction et des bâtiments

6 Scientific and technical documents about LCA

DE MEESTER, BRAM; DEWULF, J.; VAN LANGENHOVE, H. (2006): eXoinvent. The exergy of ecoinvent reference flows, version 1.0, software tool. University of Gent.
FRISCHKNECHT R., et al. , 1996, Oekoinventare von Energiesystemen, 3. Auflage, ETH Zürich / PSI Villigen
FRISCHKNECHT R., JUNGBLUTH N., ALTHAUS H.-J., DOKA G., HECK T., HELLWEG S., HISCHIER R., NEMECEK T., REBITZER G., SPIELMANN M. (2004) "Overview and

Methodology", ecoinvent report No. 1, Swiss Centre for Life Cycle Inventories, Dübendorf, 75 p. and www.ecoinvent.ch

GOEDKOOP M. and SPRIENSMA R. (2000) "The Eco-indicator 99 : A damage oriented method for life cycle impact assessment", PRé Consultants, Amersfoort, The Netherlands, 142 p.

GUINEE J. B., (final editor), GOREE M., HEIJUNGS R., HUPPES G., KLEIJN R., de KONING A., van OERS L., WEGENER SLEESWIJK A., SUH S., UDO de HAES H. A., de BRUIJN H., van DUIN R., HUIBREGTS M. A. J., LINDEIJER E., ROORDA A. A. H., WEIDEMA B. P. (2001) "Life cycle assessment; An operational guide to the ISO standards", Ministry of Housing, Spatial Planning and Environment (VROM) and Centre of Environmental Science (CML), Den Haag and Leiden, The Netherlands, 704 p.

GUINEE J. (Ed.) (2002): Handbook on Life Cycle Assessment. Operational guide to the ISO standards. Kluwer Academic Publishers Dordrecht, The Netherlands.

HABERSTATTER K., 1992, Bilan écologique des matériaux d'emballage, Etat en 1990, Office fédéral de l'environnement, des forêts et des paysages (OFEFP), Switzerland

HEIJUNGS R., Environmental life cycle assessment of products, 1992, Centre of environmental science (CML), Leiden, 96p

Intergovernmental panel on Climate Change (IPCC), Scientific assessment working group of IPCC, 1994, Radiative forcing of climate change, World meteorological organization and United nations environment programme, 28p.

Intergovernmental panel on Climate Change (IPCC), Climate change 2001 : the scientific basis, J.T. Houghton, Y. Ding, D.J. Griggs, M. Nogger, P.J. van der Linden, X. Dai, K. Maskel, C.A. Johnson, Cambridge University Press, 2001, 881 p

KOHLER N. and KLINGELE M., 1996, Simulation von Energie- und Stoffflüssen von Gebäuden während ihrer Lebensdauer, 1996 International Symposium of CIB W67, Vienna

MAK John Mak, ANINK David, KORTMAN Jaap et al., March 1996, ECO-QUANTUM, design of an LCA based method on building level, W/E Consultants sustainable building / IVAM Environmental research, Gouda / Amsterdam (in Dutch)

PEUPORTIER B., September 2002, Assessment and design of a renovation project using life cycle analysis and Green Building Tool, Sustainable Building 2002 Conference, Oslo

PEUPORTIER Bruno, KELLENBERGER Daniel, ANINK David, MÖTZL Hildegund, ANDERSON Jane, VARES Sirje, CHEVALIER Jacques, and KÖNIG Holger, October 2004, Inter-comparison and benchmarking of LCA-based environmental assessment and design tools, Sustainable Building 2004 Conference, Warsaw

POLSTER Bernd, PEUPORTIER Bruno, BLANC SOMMEREUX Isabelle, DIAZ PEDREGAL Pierre, GOBIN Christophe and DURAND Eric, 1996, Evaluation of the environmental quality of buildings - a step towards a more environmentally conscious design, Solar Energy vol. 57 n°3

POPOVICI E. and PEUPORTIER B., September 2004, Using life cycle assessment as decision support in the design of settlements, PLEA Conference, Eindhoven

REGENER final reports, January 1997, C.E.C. DG XII contract n° RENA CT94-0033, 563 p

SZALAY Z., 2007, Life cycle environmental impacts of residential buildings, PhD, Budapest University of Technology and Economics, Budapest

SZARGUT. J. et al (1988): Exergy analysis of thermal, chemical and metallurgical processes. Hemisphere/Springer. New York/Berlin.

Annex : Life Cycle Assessment in Spain: Background

1. The Catalonia Institute of Construction Technology (ITEC)

ITEC has developed a construction data bank of prices and documents called BEDEC PR/PCT ITEC. As it is explained in its web www.itec.es/nouBedec.e/presentaciobedec.aspx the data bank contains the prices of 300.000 construction elements, urbanization, civil engineering, refurbishment, security and health, control tests and indirect costs, with reference prices for all Spanish provinces, commercial products and environmental data. Also it is included a directory with the manufacturing plants as well as the technical characteristics and company product certificates and a list with the current regulations. Therefore, it is a construction general prices base that incorporates environmental data referred to 100 raw materials or basic materials used in the construction. These materials combined, from one another, are referenced according to the construction components to get the following environmental data:

- ✓ Weight (quantity of material used according to the budget)
- ✓ Waste in weight (unnecessary material quantity of the carrying out process)
- ✓ Waste in volume (unnecessary material volume of the carrying out process)
- ✓ Packaging in weight (unnecessary material quantity corresponding to carrying out process packaging)
- ✓ Packaging in volume (unnecessary material volume corresponding to carrying out process packaging)
- ✓ Material energy cost (energy consumption in the material production that composes the budget)
- ✓ Machinery energy cost (energy consumption in the use of machinery during the carrying out process)
- ✓ Material CO_2 emission (CO_2 emission in the materials manufacturing that composed the budget)
- ✓ Machinery CO_2 emission (CO_2 emission using the machinery during the carrying out process)
- ✓ Summary (information of different impacts in each level that composes the budget)

In some cases the materials data have been obtained according to studies and life cycle assessment, in others are agreements between manufacturers and producers of the material studied.

2. CENER: Building Environmental Quality Guarantee

National Renewable Energies Centre is developing a building environmental quality guarantee that involves an energy consumption analysis by means of the energy labelling according to the RD.47/2007, carried out with software CALENER, a life cycle assessment of the construction materials with own software, just as an environmental study concerning several indicators of building sustainability (best practices guide)

3. Colegio de Arquitectos de Valencia

The web of the Colegio de Arquitectos de Valencia www.ctav.es has available a building material directory organized by categories where there is a list of sustainability materials with an ecology valuation compared with an economy valuation. Everything is valued from 1 to 10 according to the following ecology and economy criteria.

- Ecology Valuation
  - ✓ Renewable raw material (MPR) or none (MPNR)

- ✓ Recyclable material (RCB) or none (NRCB)
- ✓ Recycled material (RCD) or none (NRCD)
- ✓ High or low energy content (ENRG) in production and transport
- ✓ Purity grade or mixture with different raw materials(%AÑ)
- ✓ Important or insignificant use factor (FIND) in production and installation
- ✓ Long or short Life Cycle (VUTIL)

- Economy Valuation
  - ✓ High or low product merchandising grade
  - ✓ Equivalent price (PHOM) in the market if it's an inconvenient for its application or not
  - ✓ Business policy (PEMP) that shows consideration for the environment in all products or only in some of them
  - ✓ High or low installation added cost (CCOL)
  - ✓ Respecting human conditions in the companies (CHUM) (volatile elements, toxics or social security system)

The elements have been valued according the above criteria with a value 1 (positive case) or 0 (negative case). It has been applied a correction factor in the valuation according to the following table:

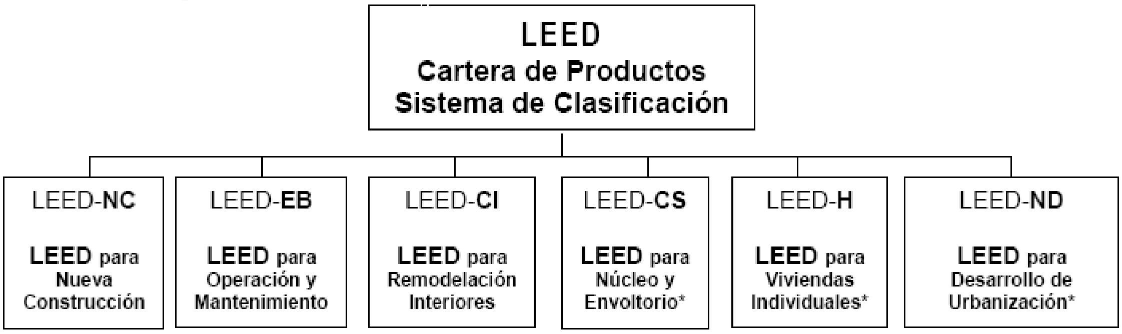
x 2 : MPR y FCOM
x 1.5 : RCB, RCD y PHOM
x 1 : ENRG, AÑO, FIND, VUTIL, PEMP, CCOL y CHUM

The sum of its ecology values in relation to the sum of the economic values shows its position in the general valuation.
For facilities and construction systems there has been applied a standard ecology vale of 3, because it is supposed that all elements have an energy consumption (1), its purity cannot be valued (0), the elements are industrialized (1) and the life cycle is long (1). The elements are not renewable (0), they are not recyclable on its whole (0), and neither recycled (0).

For the research elements which are not in the market yet, it has been applied a standard economy value of 2, due to the supposition that the elements have been developed by companies interested in the environment (1), respecting human conditions in its production (1) but an opinion cannot be given about its equivalent price (0), neither about its installation price (0).

4. Spanish Green Building Council

Spanish Green Building Council is a spanish national association of companies promoting sustainability in contruction by using the northamerican tool called LEED (Leadership in Energy and Environmental Design) based on a check list system for evaluation of the enviromental impact on buildings.
www.spaingbc.org
www.leedbuilding.org



En desarrollo desde Octubre 2005

Extracted from the web: www.usgbc.org

What is LEED®?

The Leadership in Energy and Environmental Design (LEED) Green Building Rating System™ encourages and accelerates global adoption of sustainable green building and development practices through the creation and implementation of universally understood and accepted tools and performance criteria.

LEED is the nationally accepted benchmark for the design, construction and operation of high performance green buildings. LEED gives building owners and operators the tools they need to have an immediate and measurable impact on their buildings' performance. LEED promotes a whole-building approach to sustainability by recognizing performance in five key areas of human and environmental health: sustainable site development, water savings, energy efficiency, materials selection and indoor environmental quality.

Who Uses LEED?

Architects, real estate professionals, facility managers, engineers, interior designers, landscape architects, construction managers, lenders and government officials all use LEED to help transform the built environment to sustainability. State and local governments across the country are adopting LEED for public-owned and public-funded buildings; there are LEED initiatives in federal agencies, including the Departments of Defense, Agriculture, Energy, and State; and LEED projects are in progress in 41 different countries, including Canada, Brazil, Mexico and India.

How is LEED Developed?

LEED Rating Systems are developed through an open, consensus-based process led by LEED committees. Each volunteer committee is composed of a diverse group of practitioners and experts representing a cross-section of the building and construction industry. The key elements of USGBC's consensus process include a balanced and transparent committee structure, technical advisory groups that ensure scientific consistency and rigor, opportunities for stakeholder comment and review, member ballot of new rating systems, and a fair and open appeals process.

5. Spanish Green Building Challenge

The Green Building Challenge is a consortium of nineteen countries, which are developing, implementing and verifying an evaluation methodology, based on the environmental quality of buildings. The project began in 1998 and has taken various steps that have been completed to coincide with the celebration of the Sustainable Building Conference in 2000, 2002 and 2005 (see Newsletter 56).

International links:

www.sb05.com
www.iisbe.org

Spain joined the project in 2000 and since then a team of experts has been developing the tool VERDE. It has also been tested in various buildings already built or under construction, introducing various environmental improvements. The project is led by iiSBE (internationally).

GBTool is a tool that makes the evaluation and user interface. The program is based on standard Excel spreadsheet, so that any user can download demo versions and evaluate capabilities of the tool.

The results obtained are compared with baseline data which have been obtained on buildings in the country, unlike many other tools that work with local references from the place of origin of the tools. The fact that the project is developing in the international sphere, with the synergy created between the different teams and adaptation to different local realities, is one of the great contributions of the GBC.

Spanish link www.e-sostenible.es does not work at the moment. No recent news about the development of VERDE tool.

6. The Building Sustainable Agency

iiSBE

The Building Sustainable Agency involves workshops from the Environmental and Sustainability Unit of Architectural technicians and Architects Association of Barcelona (Colegio de Aparejadores y Arquitectos Técnicos de Barcelona), from the Vallés Higher Technical School of Architecture and Geo-biology studies Association GEA. (www.csostenible.net) It has a data base of eco-materials based on RD 21/2006 which regulates the adoption of environmental and eco-efficient measures in buildings. To comply with the article 6.2, it will be necessary to use at least a building materials' family including an ecolabel according to the environmental quality guarantee from the Government of Catalonia, European Union Ecology's label, brand AENOR Environment or any other ecology's label type I, in accordance with the rule UNE 150.025/2005 IN. The data base shows the following products' family:

- Pavement and flooring materials.
- Faucets and other toilet accessories.
- Paints and varnishes.

Moreover, the Building Sustainable Agency allows the search of building materials according to sustainable parameters which are included in the categories of waste, water, energy, emissions or resources.
www2.csostenible.net/es_es/productos/guiadaproductos/Pages/sostenibilitat.aspx.
The product search can also be carried out according to specific building elements.

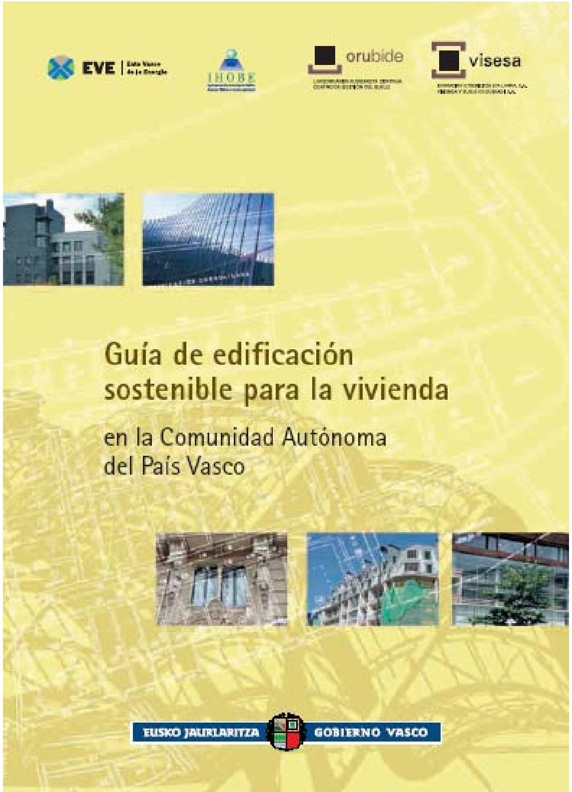
7. The Sustainable Building guide for the housing in the Autonomous Community of the Basque Country

This guide contains an extensive catalogue of good environment practice in the construction sector applied throughout all its life cycle. It includes the city planning, the management and the architecture process development, the management of material and waste, the performance, the demolition and the use and maintenance of the building. The guide includes a valuation code about the application of this guide along all analyzed process, from the Partial plan preparation to the city project redaction, preliminary plan, basic project, performance project, the building construction and the performance finished.

http://www.gizaetxe.ejgv.euskadi.net/r40-2168/es/contenido/informacion/guia_edificacion/es_15292/adjuntos/guiac.pdf

http://www.canalconstruccionsostenible.com/interior.asp?MP=5&idnoticia=1579

This last link has available the download of the valuation code for the sustainable building (Foundation Entorno).



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