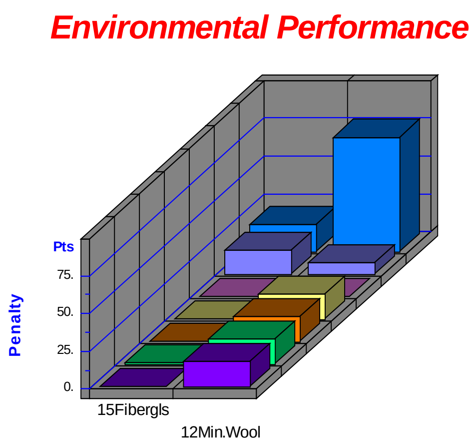
International Energy Agency

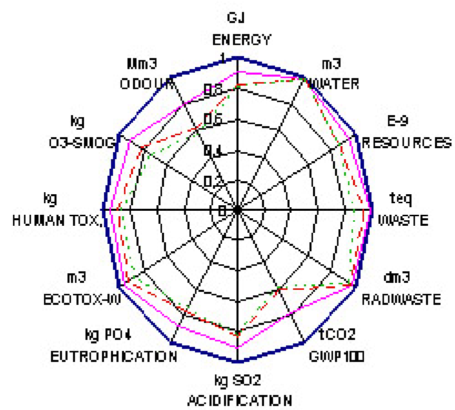
Energy Conservation in Buildings and Community Systems

ANNEX 31

Comparative Applications

A Comparison of Different Tool Results on Similar Residential and Commercial Building





Annex 31
Energy-Related Environmental Impact of Buildings

October 2001

CONTENTS

Principal Author

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Annex 31 representatives in each participating country completed the tool applications and wrote up results.

APPLICATION OF TOOLS

Introduction

The environmental impact of a single dwelling and an office was quantitatively or qualitatively determined with tools from the participating countries. The tools are mentioned in Table 1. This table is not a complete overview of the existing tools, but shows the tools used for application in IEA BCS Annex 31. All the tools are intended to assist in quantifying or qualifying the environmental profile of a building, or to assist decision-makers in improving the environmental performance of a building design.

Some tools have both functions: to quantify and improve. EQUER, Eco-Quantum and Ecopro are examples of this group of tools. They quantify the environmental impact and give the designer possibilities to improve the environmental impact of a building by offering the designer environmental improvement options.

E2000 Oeko bau and BEES 1.0 are examples of qualitative tools, they are meant to improve the environmental performance of a building but not to quantify the environmental impact of the building.

BREEAM'98 for offices is a mixture of a quantitative and qualitative tool. For some criteria BREEAM defines quantitative criteria; after a calculation, which is not necessarily LCA-based, credits are given.

Country*		Tool	Energy calculation
Australia	r	LCA-based tool	-
Canada	r	Optimize	HOT 2000
Denmark	r	SBI tool	BV95
Germany	o	Ecopro	-
England	o	BREEAM'98 for offices	Esicheck
Finland	o	BEE 1.0	-
France	r	EQUER	COMFIE
	r	TEAM for buildings	Th-C and DEL2 methods
Japan	r,o	BRI-LCA	-
The Netherlands	r	Eco-Quantum	Energy Performance Calculation
Norway	r	LCA-based tool	-
USA	r	BEES 1.0	Energy 10
Sweden	r	EcoEffect	-
Switzerland	r	E2000 Oeko bau Standard	-

Table 1. Tools in application in IEA BCS Annex 31. The energy calculation program is mentioned if applied.

***r** - signifies a residential building**: o** signifies an office building*

Life Cycle Assessment

Most tools used for the application in the annex are based on the environmental life cycle assessment methodology developed by Heijungs et al. (1992). The LCA is applied to determine the environmental profile of materials of the building. But also taken into account is the environmental impact of a building. This is, of course, more than adding the environmental impact of the various materials. That's what makes building LCA tools different from LCA for building materials.

Non LCA

BREEAM'98 and E2000 Oeko bau are the two tools of table 1 which are not LCA based. BREEAM'98 is a questionnaire with which the designer can earn credits. Improvement options are made clear during the design proces by the BREEAM'98 assessor. Finally, when the environmental performance is sufficient, meaning a certain amount of credits is obtained; the building gets a certificate that indicates the environmental performance, for example Excellent or Good. E2000 Oeko bau is also a questionnaire that provides the owner a quick scan of the environmental performance of a building and its improvement options.

The application study has been mainly LCA oriented. Countries have therefore used their LCA-based tools. This application part may therefore not be a correct view of the use of tools in the respective countries. This application exercise provides insight into the application of LCA-based tools and their possibilities but not in the use of tools in countries as an overview.

Energy in Use

For some tools energy during use is determined by a separate energy calculation program. Table 1 shows these programs. The output of these programs is then filled in in the environmental assessment tool. Tool developers state that the goal is to have both integrated in the near future, e.g. in the tool Ecopro exists an integrated energy calculation. Energy in use is at this moment responsible for a large part of the environmental impact of buildings. However, with reducing the energy in use, the environmental impact of building materials is becoming more and more important for the environmental impact of building.

The elaboration of the application of the tools on the dwelling shows this line of development. Making the dwelling highly energy efficient reduces the proportion of the environmental impact of energy consumed during use and increases the proportion of the environmental impact of the building materials. To further reduce the environmental impact of buildings more focus is necessary on the building materials and building concepts. Currently the energy in use is responsible for about 80-90% of the environmental impact - consumption of resources and emissions- of a building during its lifetime. New technology and energy efficiency can reduce this to about -an estimated- 50%.

Objective of the Application Exercise

By applying the tools to common building types it is intended to demonstrate how they work. Questions that are being addressed are:

- What is the output of the tool?
- In what way do the tools contribute to showing how to reduce the environmental impact of a building?

Other questions which can be answered by performing the application of so many different tools are:

- Trend analysis and qualitative analysis of the results: show which tools have comparable results and : which are different?
- Why do quantitative data differ, this is elaborated by an example, the CO_2 emissions?
- Which aspects are beyond discussion, i.e. are equal for all; which aspects have need to be widely discussed?
- In what units do the different tools express the environmental performance?
- Most tools are LCA-based. What is to be expected for the future?

It was never the intention to compare results or analyse tools thoroughly. Different kinds of studies are necessary to perform that kind of research. From the application performed in this Annex trends and rough conclusions are drawn.

Other interesting questions, but not necessarily to be answered in this study, are:

- Which weighting factors do they use? At what level is aggregation carried out?
- What can be concluded of differences in allocation and system boundaries of the tools?
- What are the normalisation data each tool or country uses? What differences do exist?
- Which recommendations can be met? Such as: do most tools give one indicator and is this going to be indicative of future development; which procedures can be developed to create more equity in the European countries?

Method

Three Steps

Tools have been applied in the member countries of Annex 31. The result is a demonstration of how tools work, what local situations are and how tools guide designers, consultants or researchers into more environmentally sound buildings.

All tool users or developers received information on the Dutch, Novem reference building and a reference residential dwelling. With these data environmental impact of the building was calculated in three steps:

1. without energy in use
2. with energy in use and after adapting the building to local circumstances (such as local climatic data)
3. after improving the environmental impact of the building, that is, after the tool guided the designer to environmental improvements options and had him/her choose the best from an environmental point of view.

Figure 1 shows the three steps.

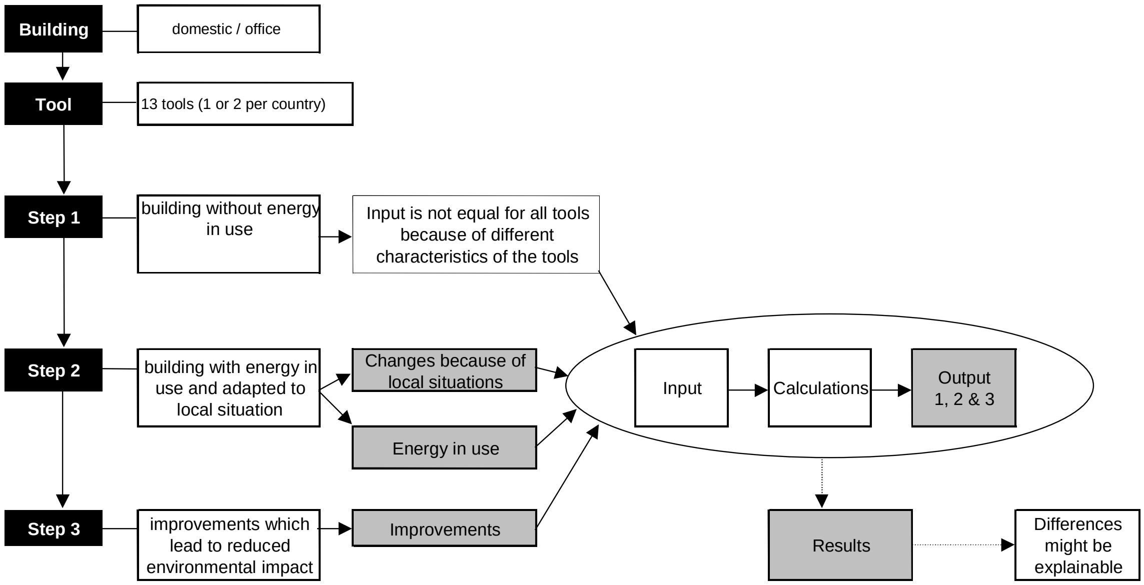


Figure 1: Plan of action for the application.

Results

With the tools mentioned in table 1 the environmental performance of the building is calculated and the three steps are carried out. The results are presented in an executive overview report. This article presents a summary of the application and answers the above mentioned research questions.

Step 1: Table, graphic or spider

All tools are meant for researchers, architects or consultants. This implicates the demands to the input, the way of calculation and the output. These three depend on the target group. The input for the application was equal for each tool: a dwelling and an office were presented in sketches, quantities of materials and insulation values. It appeared that nearly all tools needed this information. Non LCA tools did ask for other input data, totally or partially.

A clear and direct readable output is important for the users of the tools. However, a lot of tools are still under development and their output is still under construction. User interfaces are not yet optimal for most tools.

The output as presented now by the different tools shows roughly three kinds of output: table, graphic or spider. The kind of output presented differs more widely. Table 2 presents the different ways of expressing the environmental performance of buildings: it varies between the environmental effects as given by LCA and newly constructed environmental indicators (with normalisation and weighting).

TOOL		OUTPUT										
Optimize	1.	resources	initial energy	CO_2	SO_2	waste						
	unit	kg	MJ	kg	kg	kg						
SBI-tool	1.	acidification potential	GWP	ODP	human toxicity	ecotoxicity	persistent toxicity	nutrification	bulk waste	hazardous waste	slagg and ashes	radioactive waste
	unit	PE (personal equivalents)	PE	PE	PE	PE	PE	PE	PE	PE	PE	PE
		POCP	recources									
		PE	PE									
EcoPro	1.	resources	primary energy	nutrification	acidification	greenhouse effect	eco-indicator	(six criteria can be chosen)				
	unit	kg	TJ	kg P-eq.	kg SO_2-eq.	kg CO_2-eq.	ecopoints					
BEE 1.0	1.	primary energy	GWP	AP	POCP	construction waste						
	unit	GJ	kg CO_2-eq.	kg SO_2-eq.	g NO-eq.	kg						
EQUER	1.	energy	water	resources	waste	rad waste	GWP100	acidificiation	odour	ecotox-w	human tox	O_3 - smog
	unit	GJ	m^3	E-9	t eq	dm^3	t CO_2	kg SO_2	Mm^3	m^3	kg	kg
		eutrophication		And per building phase: construction, renovation, demolotion								
		kg PO_4										
TEAM for buildings	1.	water used	waste	total primary energy	air acidification	eutro-phication	depletion non renewable resources	greenhouse effect	aquatic ecotoxicity	human toxicity	terrestrial eco-toxicity	depletion of ozone layer
	unit	liter	kg	MJ	kg H^+ eq.	kg PO_4-eq.	frac. of reserve	kg CO_2-eq.	g eq. dichlorobenzene	g eq. dichlorobenzene	g eq. dichlorobenzene	g eq. CFC11
BRI-LCA	1.	energy	CO_2									
	unit	GJ	kg CO_2-eq.									
Eco-Quantum	1.	resources	emissions	energy	waste							
	unit	none	none	none	none							
	2.	exhaustion of resources	fuel depletion	greenhouse effect	depletion ozone layer	summer smog	human toxicity	ecotoxicity	acidifi-cation	nutri-fication	energy non re-newables	waste
	unit	none	none	kg CO_2-eq.	kg CFC11-eq.	kg etheen-eq.	kg body weight	m^3 water	kg SO_2-eq.	kg PO_4-eq.	MJ	kg
		hazardous waste	radio-active waste									
		kg	kg									
Norwegian LCA tool	1.	resources	total energy	CO_2	SO_2	waste						
	unit	kg	kWh	kg	kg	kg						
EcoEffect	1.	GWP	AP	POCP	NP	ODP	hazardous waste	nuclear waste	resource depletion	human toxicity	eco toxicity	waste / slag and ashes
	unit	kg CO_2-eq.	kg SO_2-eq.	kg C_2H_4-eq.	kg NO_3-eq.	kg CFC11-eq.	kg	kWh	copper equivalents	m^3 media (soil, water, air)	m^3 media (soil, water)	kg
	2.	Energy use	Materials use	Indoor environment - health	Outdoor environment - env. health and ecosystems		Life cycle costs					
BEES 1.0	1.	economic performance	fuel vs. feedstock energy	environmental performance	life-cycle stage	global warming	overall performance					
	unit	\$/.09sq.m. or \$/sq.ft	MJ/0.09 sq.m. or MJ/sq.ft	relative points	relative points	relative points	relative points					

AP : Acidification Potential
GWP : Global warming potential
NP : Nutrification Potential
ODP : Ozone Depletion Potential
PE : Personal equivalent
POCP : Photochemical Ozone Creation Potential

Table 2: Output of the tools (IEA Annex 31).

Examples of output are shown below. EQUER presents the results in different ways. In table 3 the environmental performance is presented per phase in the life span of a building: construction, renovation and demolition

Impact	Unit	Construction	Renovation	Demolition
ENERGY	GJ	691	353	11
WATER	m^3	767	237	5
RESOURCES	E-9	0.0	0.0	0.0
WASTE	t eq	18	6.2	152
RADWASTE	dm^3	0.2	0.0	0.0
GWP100	t CO_2	37	5.2	0.7
ACIDIFICATION	kg SO_2	215.3	45.8	7.9
EUTROPHICATION	kg PO_4	22.0	2.7	1.2
ECOTOX-W	m^3	1,635,087	8,316	9463
HUMAN TOX.	kg	368	764	11
O3-SMOG	kg	95	11	1.5
ODOUR	Mm^3	513	990	0.8

Table 3: Output of step 1 of EQUER, for the domestic building.

One of the outputs of the Dutch tool Eco-Quantum is presented in figure 2.

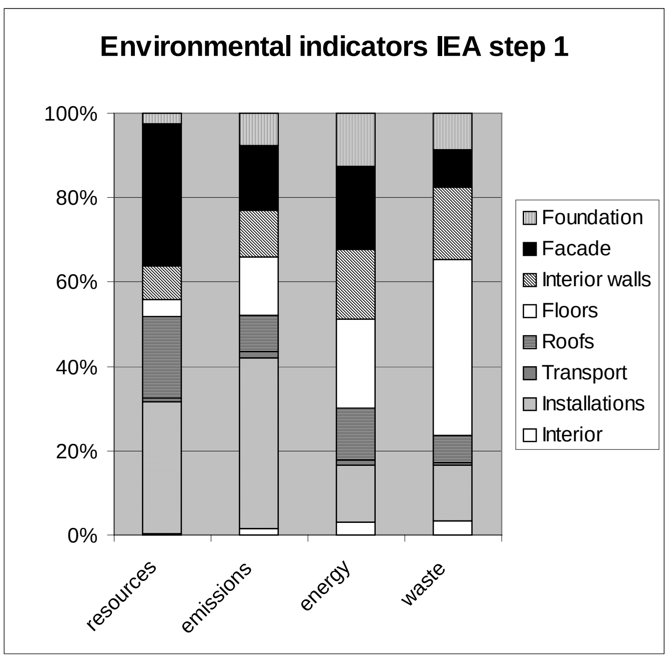


Figure 2: Environmental indicators by Eco-Quantum of domestic building step 1 IEA case study.

The kind of output of Optimize and the Norwegian tool is about the same. Figure 3 shows the results of step 1 concerning embodied energy carbon dioxide emissions and sulphur dioxide emissions. While the initial embodied energy of the Canadian building is higher, the carbon dioxide and sulphur emissions are lower. This is due, in large part to the predominance of hydro-electricity in the production of Canadian goods and services.

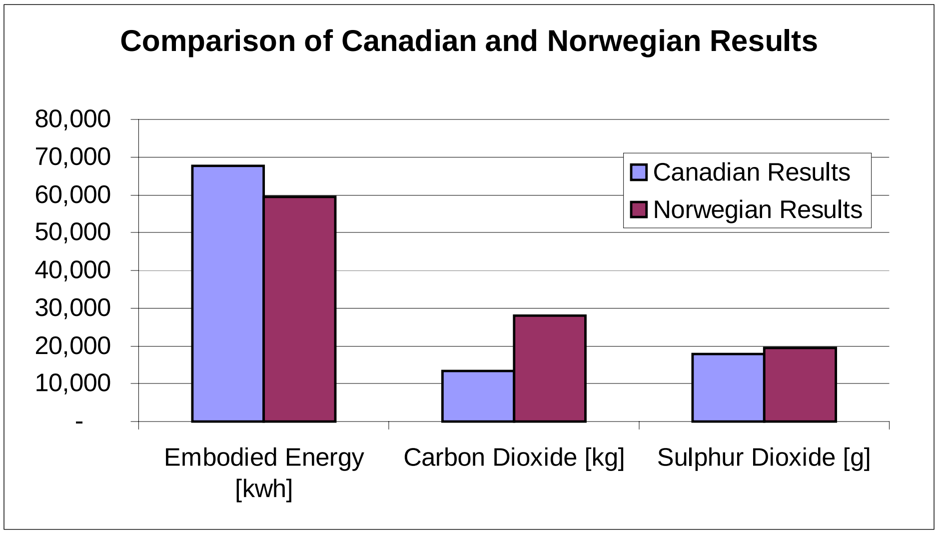


Figure 3. Comparison of Canadian and Norwegian results , step 1 IEA31.

Table 4 shows the results of an analysis of the trends of the output. Do the floors and roofs for example have about the same environmental performance after calculation with all tools? Of course each country and each tool is different. However, the results of 'exhaustion of resources' or 'resources' are presented in the table.

Resources	Foun-dation	Facade	Interior walls	Floors	Roofs	Instal-lation	Interior design	Mainte-nance	Transport
Optimize	14%	14%	20%	40%	4%	2%	6%		
SBI-tool	13%	29%	-	18%	32%	8%	-		
EcoPro	-	4%	20%	44%	3%	6%	-	24%	
BEE 1.0	*total building*								
EQUER	*resources is no part of output*								
TEAM for bldgs	1%	10%	1%	4%	1%	60%	20%		1%
BRI-LCA	*no part of output*								
Eco-Quantum	2%	48%	21%	5%	1%	20%	0%	-	2%
LCA tool Norw	13%	14%	21%	40%	5%	1%	7%		
EcoEffect	*not shown*								

Table 4: Output of step 1 concerning Resources for all tools per building component: the results of the domestic building are shown.

SBI-tool shows that floors, roofs and external walls are primarily responsible for the environmental effects. Changing the materials of these components to more environmentally sound options improves the environmental performance of the buildings. Interior walls have about the same percentage in the exhaustion of resources. Concerning floors the percentage is much lower for the tools TEAM and Eco-Quantum. For these two tools installations and/or interior design contribute largely to the environmental performance concerning resources.

In the Eco-Quantum tool the environmental impact is relatively large because of the use of copper, zinc and lead: the exhaustion of these resources contributes largely to the indicator 'resources' and also to the indicators Emissions and Energy. The installations (heating unit and pipes) are mostly made of metals. These explain the high environmental impact on the indicator Resources.

Maintenance

Ecopro shows a figure exclusive for maintenance (24%). For tools like EQUER and Eco-Quantum maintenance is included in the environmental performance. Default figures on maintenance and life span of materials or building elements are part of the tool. A conclusion of the Optimize tool study indicates that sufficient data regarding the life span of components is not available. The significance of recurring energy is therefore difficult to estimate with a high level of confidence. One of the remaining questions to be answered is how to deal with maintenance, what maintenance data is available, which is used and what is its accuracy?

Embodied energy

All tools calculate embodied energy (EE) of the building materials, during construction and the embodied energy during operation. Figures on embodied energy differ greatly. One of the explanations is the transport of materials which is responsible for a part of the embodied energy. Dutch aluminium comes for example from Finland. Transport from Finland to The Netherlands is included in the embodied energy. For Finland the situation is completely different and so is the embodied energy. The same for CO_2 emissions, which are also related to, amongst others, transport. Regional differences make comparisons impossible. Table 5 contains the figures of embodied energy as presented in the output of the tools after performing

STEP 1	Initial Embodied energy	unit	Life cycle embodied energy	unit	years	Maintenance included in appl.	Initial embodied energy [MJ/building]	Initial embodied energy [MJ/sq m]	Life cycle embodied energy [MJ/ sq m/year]
Optimize	243.000	MJ	183	MJ/m2/ year	40	yes	243.000	2.960	183
SBI-tool	2.711.570	MJ	2.711.570	MJ/40 years	40	no	2.711.570	23.786	595
BEE 1.0	1.448.000	MJ			na	no	1.448.000	12.702	188
EQUER	691.900	MJ	1.056.800	MJ/50 years		yes	691.900	6.069	185
TEAM	335.015	MJ	394.649	MJ/50 years	50	yes	335.015	2.939	69
ECOPRO	549.000	MJ	583.000	MJ/80 year	80	yes	549.000	4.816	64
BRI-LCA	6.940	MJ/year	6.940	MJ/year	50	no	6.940	3.044	61
Eco-Quantum	363.128	MJ/ building	427.236	MJ/building/ 50 years	50	yes	363.128	3.185	75
LCA-tool	59.450	kWh (10.9MJ)					648.005	5.684	114
EcoEffect	41	MJ/m2/ year	3.644	MJ/building/ year		no	182.189	2.061	41

step 1.

Table 5: Embodied energy after step 1 of the application of IEA 31 for different tools. All results are for the domestic building.

As the last column in the table indicates, the EE values per square metre range a full order of magnitude. The SBI-tool shows the highest embodied energy, EcoEffect the lowest. The low scores of EcoEffect can be explained by the lack of data: not all materials are incorporated, so the energy figures are rather low. Embodied energy is not an “input” indicator in EcoEffect: where emissions and waste from all processes in a material’s or fuel’s life cycle are recalculated in terms of specific environmental impacts.

Figure 4: Ecopro Summary screen

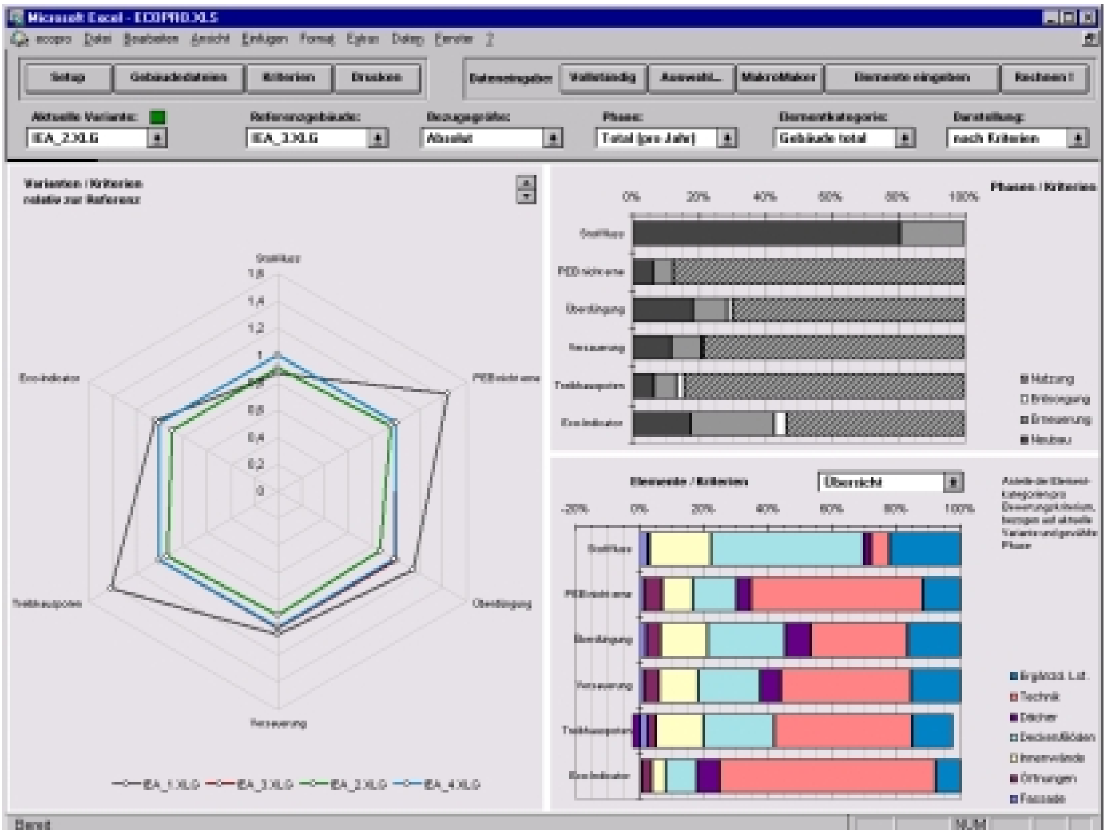


Figure 4 is an Ecopro output screen that shows how it allows for a comparison between a reference building and three variances on the left side of the graphic with more or less optimated criteria per variance. In the top of the right side a conclusion is presented per phase in the life span of a building (construction, renovation, maintenance and demolition) and the criteria. At the bottom there is a relative valuation of the single elements with criteria. All results are presented on the desktop. By clicking the single drop-down you can select special values of criteria (26), phases (5), etc. That is the main-reason, we can’t make a difference between step 1 and 2. After filling in the input data, such as elements, climate etc. we get the complete information and results at graphics and tables.

Step 2: With operating energy

The domestic building and office are adapted: building materials in the national context are used if necessary, i.e. commonly used materials, and the national climatic data are applied. Energy during the lifetime of the building is included in the calculations of the environmental performance of the building.

The changes are, in short:

- Canada: wall construction changed from brick envelope with concrete structure to stucco siding with stick frame structure.
- Denmark: only operating energy is added, no further changes
- Finland: external walls, roofs, ground floor and windows are changed: thicker insulation material and triple glazing
- France (Equer): external walls (external layer of mineral rendering), roof (thickness of insulation is 20 cm instead of 8cm) and ground slab (6 cm polystyrene is added) are changed. Electricity is produced by 78% nuclear, 14% hydro and 8% thermal. A standard occupancy pattern is defined and included.
- France (Team for buildings): external walls in brick and concrete with 20 cm width concrete blocks, thickness of mineral wool is increased (12 cm instead of 8 cm), 1 cm coating is added on external wall to improve tightness. The energy is natural gas.
- Germany: no changes.
- Japan: Structure was changed to Japanese building code: quantity of concrete and reinforcement increased substantially. Concrete doubled (from 50 m3 to 102 m3), reinforcement changed from 2,500 kg to 14,000 kg.
- The Netherlands: in regranulate concrete as a replacement of gravel (20%) is used, insulation of roof, facade and floor is improved (U-values changed from 0.4 W/m2K to 0.33 W/m2K), wood is FSC approved, interior frames are made of wood instead of steel, painting contains les VOC's (high solids or acrylate).
- Norway: external construction is insulated according to the Norwegian building code. The heat gain is according to the Norwegian Standard.
- Sweden: concrete is replaced by wood and mineral insulation.
- Switzerland: no adaptations are made. Step 1 was impossible because without energy in use there is no outcome. So step 2 provides the results.
- United Kingdom: No material change, energy in use is calculated.
- USA: with Energy 10, energy in use is calculated. Material changes are done in step 3.

The results of step 2 show that energy in use is responsible for 75% (Canada, to 95% (Finland) of the environmental impact (exhaustion of resources and emissions) of buildings during the whole life cycle. The percentage depends of course on the environmental parameter considered.

The developer of EQUER explains: 'In the local adaptation, more insulation is used (+6 cm polystyrene in the slab, +11 cm mineral wool in the roof) so that the impacts during the production phase are higher. The use of polystyrene in walls instead of mineral wool increases the smog indicator (POCP). The nuclear waste is also more important in the " French house ". But the interpretation of this graph could be misleading: one may conclude that the house defined in step one would lead to lower impacts, which is not necessarily true if considering the whole life cycle: the supplementary impacts for the production of insulation in the step 2 house is certainly balanced by the energy saving during use, so that the overall impacts are certainly lower compared to the step 1 house.'

The developer of TEAM for buildings concludes:

1. The global life cycle of the building should be considered. The environmental analysis should not be limited merely to the use phase but should also include the construction and maintenance stages.

2. Energy indicators are not sufficient to sum up the environmental impacts of a building life cycle, as several impact indicators are not correlated to energy consumption.

For the Japanese building the quantity of energy consumption increased by 70%, the CO_2 emissions increased by 55% in comparison to step 1, because the structure was changed to Japanese building code: quantity of concrete and reinforcement increased substantially. Concrete doubled (from 50 m3 to 102 m3), reinforcement changed from 2,500 kg to 14,000 kg.

Contributions to the environmental impact of energy in use ranges from 75% (for Resources) to 85% (for Energy). For waste the contribution is of course much lower.

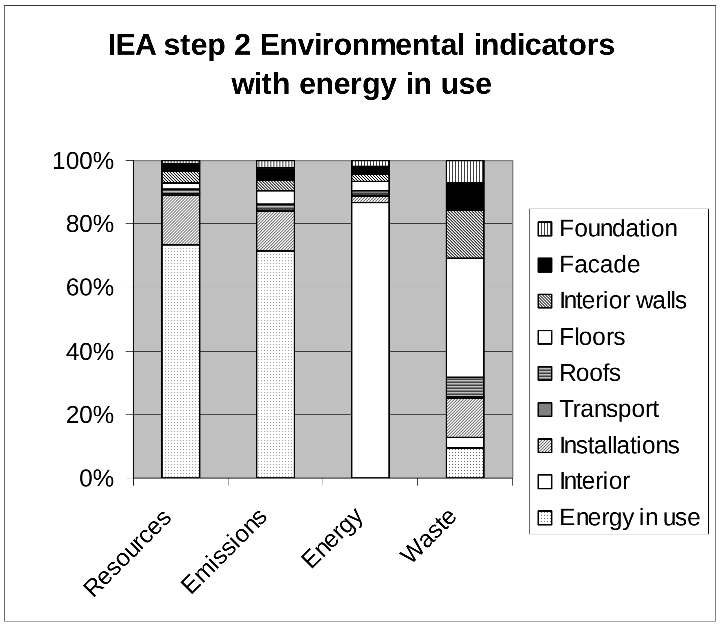


Figure 5:. Output of Eco-Quantum after step 2. The lowest bars are the result of energy in use, during a life time of 50 years.

The same pattern is shown with all tools. Reducing the energy in use therefore provides the highest environmental profit. For highly energy efficient buildings, building materials are becoming more and more important. Better environmental performance can be gained by reducing energy during use and by reducing the environmental impact of building materials. Step 3 shows some of these improvements.

Step 3: Improvement of environmental performance

Some tools are designed to show areas for improvement, such as EQUER, Ecopro and Eco-Quantum. The target group differs. Eco-Quantum is developed for designers and is therefore very user friendly. Ecopro and EQUER are used by tool developers, researchers and consultants and need expertise to use the tool and improve a design. BREAAM and E2000 oeko bau are specially developed to improve the environmental performance of buildings. BREEAM is used by an especially educated assessor, E2000 oeko bau can be used by architects, planners and building owners. A formula is filled in, and the rating is simple. The building gets a certificate in both cases (BREAAM and E2000).

Other tools are not especially developed to show improvements, such as BEE 1.0. They are meant to assess the environmental performance, not to improve.

Figure 6 shows the improvements assessed with EQUER. Three options are assessed:

1. More insulation
2. Increased solar contribution and more insulation
3. 'Green' materials, increased solar contribution and more insulation

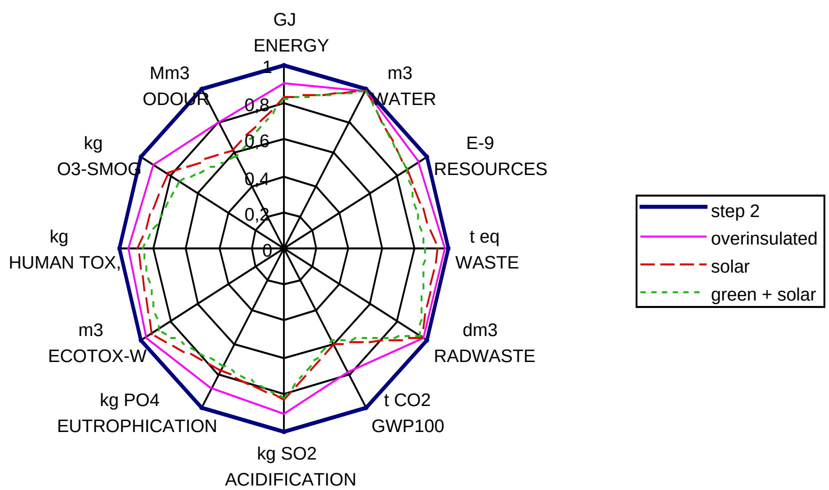


Figure 6: Results of improvements with the tool EQUER.

BEES helps the user optimize in a different way: the environmental impact is shown in a 3D graph together with other parameters like costs. Figure 7 illustrates this. BEES 1.0 compares the environmental performance of materials for one function.

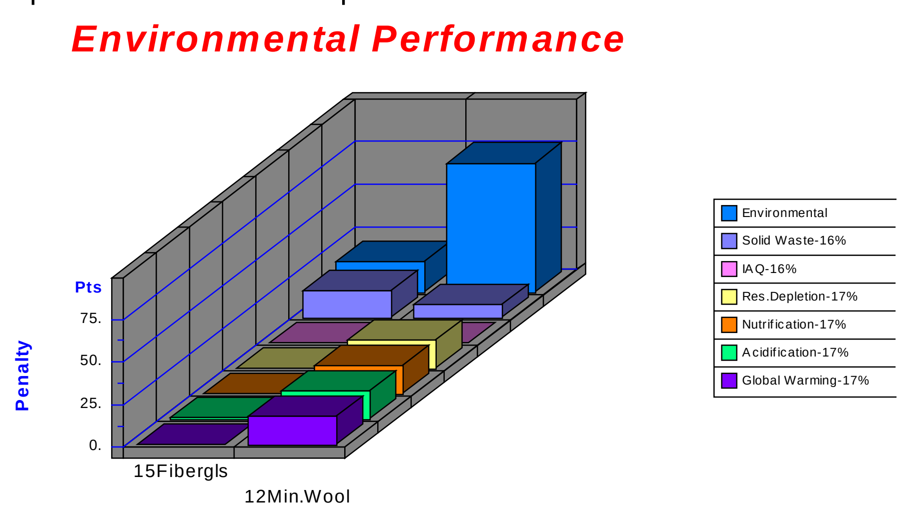


Figure 7: Improvement options as shown by BEES1.0.

Eco-Quantum and Optimize are user friendly and especially designed to improve the environmental performance of buildings. Their structure differs highly from the others. Figure 8 shows how Eco-Quantum guides the user into more environmentally sound options. For each material the environmental indicators of alternatives for that building component are shown, when clicking on it. Ecopro has a separate application (element-maker) to describe single elements, based at material databases. The user can then choose. The architect keeps the freedom of designing and choosing materials.

Most tools are still under development. More user-friendly tools continue to be developed. Tools have gone through stages of development. At first researchers were glad to be able to calculate the environmental performance of buildings as a whole, taking into account their whole life cycle and all their materials. The next step is of course making them more user friendly and making them accessible to their respective markets.

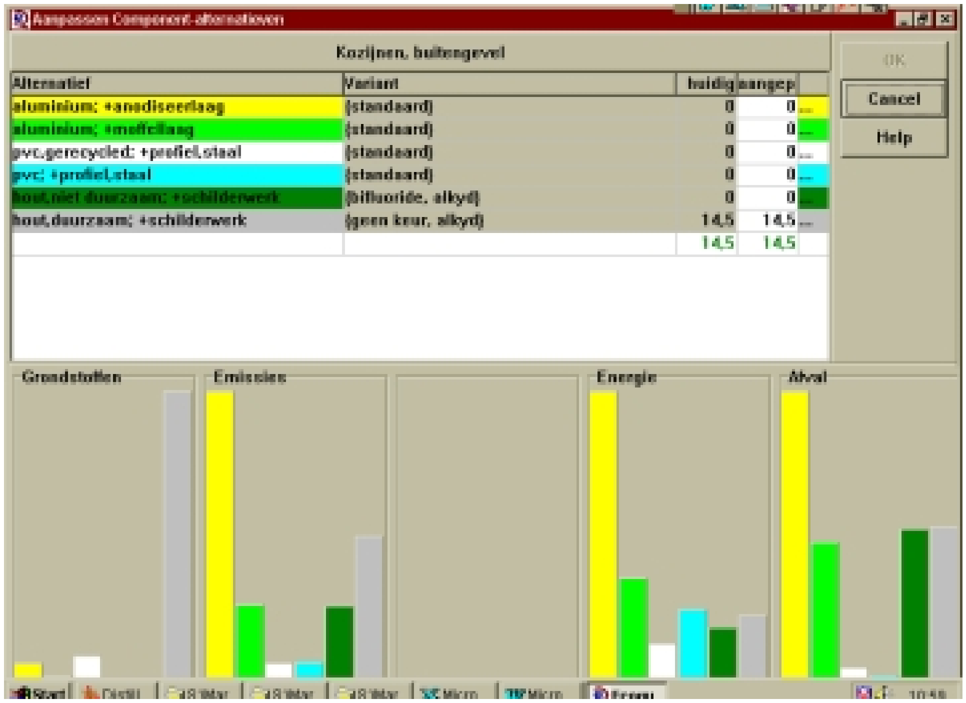
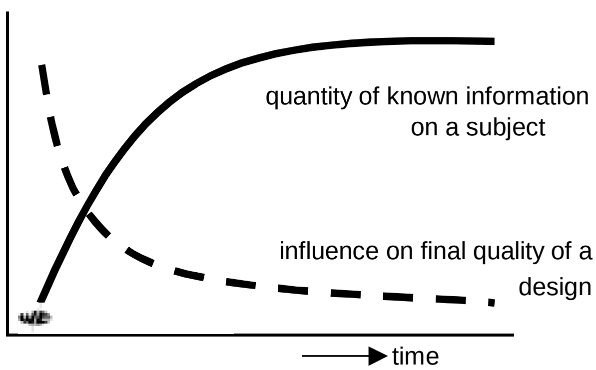


Figure 8: Improving the environmental performance by Eco-Quantum.

Early design tools

The next step will be to design tools which can assess the environmental performance early in the design and throughout the whole design, since the highest environmental profit can be gained by taking into account environmental performance very early in the design and throughout the whole process of designing. Figure 9 shows this.

Figure 9. Early in the design: high influence on final quality



(W/E consultants, 1995)

Another next step in development of most tools is to indicate uncertainties in the results. Due to the use of LCA methods uncertainty and variability can be distinguished (Huijbregts, 1998). Uncertainty is divided in: 1) Parameter uncertainty, 2) model uncertainty and 3) uncertainty due to choices. Variability covers: 4) spatial variability, 5) temporal variability and 6) variability between objects and sources.

The source and the quality of the data, the system boundaries, the allocation, the environmental profiles and the normalisation data are highly important for the significance of the results. So far, Eco-Quantum and SBI tool are the only two tools which show uncertainties in the results; if the user requests it Eco-Quantum calculates an indication of uncertainties: the influence of a longer or shorter life span (20%), and the influence of a different waste scenario can also be shown. These are the uncertainties due to choices and help put the results into perspective. SBI-tool presents the standard deviation of the results (see paper on sensitivity analysis).

Another development is the demand for tools which help building owners and designers in the process of deciding whether to demolish or refurbish buildings or building blocks.

CONCLUSIONS

Demonstrating the generation Environmental Assessment tools gives a first glimpse of the tools: do they have LCA as a basis, what output is generated? The differences for example in data, allocation of data, differences in energy-mix, show that the results from using the different tools produce different results for the same inputs. By doing so nothing is said about the correctness of each of the methods. The exactness or the correctness of the results cannot be verified because there is no datum.

Uncertainty analysis and **variability analysis** are very important to interpret the results of the tools. In this generation of tools these analyse do hardly play a role or do not appear to the user. This is a major point of attention.

The tools do demonstrate that thinking about environmental assessment converges towards LCA methods. LCA methods can be used for certain types of impacts like the impacts of materials; however, not for all. For aspects like comfort, health or quality of the contextual integration LCA is not appropriate. These aspects are hardly addressed in this application, but are also important for a sustainability assessment of a building.

Also the presentation of results for some groups can be seen: from LCA–based results to other results that are easier to communicate. However, the relevance of weighting is becoming more recognized, with weighting factors that have to be determined in a political/scientific way, and, what is even more important, in a transparent way.

From this application of tools can be concluded that **transparency** of a tool is one of the most important characteristics. Without it, the value of a tool diminishes. Not every user has to be able to see the details of a tool, but experts need that information to be able to draw conclusions.

The results of the application show that further research of data infrastructure, system boundaries, data allocation and weighting factors is necessary to compare the quality of tools and to judge the quality of tools. For example, the energy mix is very important for the results of the tool. By not being able to switch energy mixes, it is not possible to use a tool in another country. Comparison is also impossible.

Literature

- IEA BCS Annex 31, Energy Related Environmental Impact of buildings, Application of tools, Draft final report. May 1999. W/E consultants sustainable building, Marjo Knapen & Chiel Boonstra

- W/E consultants sustainable building, 1995. Environmental consultancy (in Dutch), Gouda, The Netherlands.
- Huijbregts, M.A.J., Application of uncertainty and variability in LCA, The international journal of LCA, vol. 3, no. 5, pages 273-280, 1998.

APPENDIX 1 - AUSTRALIA

Domestic building
Analysis Tool: Boustead Model for Life Cycle Inventory Calculations, version 3
By: Matthew Janssen, Environmental and Energy Services
Date: October 1998

Introduction

The results are a presented in the form of a text dump from the model. The final results will be delivered in March 1999. Some of the major results (see attached) for the energy use are graphed. The modelling was carried out on Version 3 of the Boustead Model for Life Cycle Inventory Calculations using Australian data researched by the NSW Department of Public Works and Services.

Some assumptions are made:

- the building is assumed to be constructed in Australia of Australian building materials.
- only the manufacturing of the building materials is considered. No construction, operation, maintenance or demolition is included
- all energy sources are assumed to be Australian and reflect Australia's fuel mix and production characteristics
- note that the results are the total for the building. There are many ways in which the results can be reported. The model can be set up to break the results into each building system or material. For example some model results for the percentage contribution of each building material to the total energy use are included
- this example doesn't demonstrate the full capabilities of the model, but gives an example of the type of input it can produce.

Step 1

Raw results (text file dump)

Code	9570					
Operation:						
IEA domestic house example - procure						
Units:						
House						
Country:						
AUS						
Region:						
AVERAGE						

Year:						
October '98						
GROSS ENERGY						
Fuel type	Fuel prod'n	Energy content	Energy use	Feedstock	Total	
	& delivery	of delivered	in	energy	energy	
	energy	fuel	transport			
	(MJ)	(MJ)	(MJ)	(MJ)	(MJ)	
Electricity	91198.1	37679.7	1384.61	3.95	130266.36	
Oil fuels	6366.89	21486.73	13486.82	10388.82	51729.26	
Other fuels	9195.27	207451.74	748.28	33136.76	250532.04	
Totals	106760.26	266618.16	15619.71	43529.53	432527.67	
PRIMARY FUELS & FEEDSTOCKS						
Fuel type	Fuel prod'n	Energy content	Fuel use	Feedstock	Total	
	& delivery	of delivered	in	energy	energy	
	energy	fuel	transport			
	(MJ)	(MJ)	(MJ)	(MJ)	(MJ)	
Coal	53035.36	98495.08	426.52	28.24	151985.2	
Oil	6185.53	22225.13	14987.14	10394.6	53792.4	
Gas	16008.55	122493.08	97.85	6073.25	144672.73	
Hydro	3316.55	1466.4	13.33	-	4796.27	
Nuclear	1909.62	1257.27	15.75	-	3182.64	
Lignite	25684.16	9058.73	78.82	-	34821.72	
Wood	-	12341.87	-	26771.64	39113.51	
Sulphur	-	74.08	0.29	66.14	140.51	
Biomass	7.03	3.12	6.00E-02	194.84	205.05	
Hydrogen	3.00E-02	111.21	<0.01	-	111.24	
Recovered energy	-	-329.38	-0.32	-	-329.7	
Unspecified	23.59	11.39	0.19	-	35.17	
Peat	0.37	0.27	<0.01	-	0.64	
Totals	106170.79	267208.26	15619.63	43528.71	432527.39	
FUELS & FEEDSTOCKS						
Fuel type	Input in mg					
Crude oil	1200000000					
Gas/condensate	2600000000					
Coal	5400000000					
Metallurgical coal	672000000					
Lignite	2300000000					
Peat	72000					
Wood	13000000000					
Biomass	23000000					
RAW MATERIALS						
Raw material	Input in mg					
unspecified	12000000					
barytes	4600					

bauxite	171000000					
sodium chloride	252000000					
calcium sulphate	5300000000					
clay	23000000000					
ferromanganese	16000					
fluorspar	2100000					
iron	2500000000					
lead	130000					
limestone	22000000000					
manganese	1200000					
nickel	<1					
sand	58000000000					
tin	21000					
zinc	12000000					
copper	831000000					
quartz	-190000					
sulphur (elemental)	15000000					
dolomite	106000000					
chromium	4000000					
oxygen	220000000					
nitrogen	24000000					
air	242000000					
bentonite	510000					
gravel	57000000000					
olivine	210					
shale	1300000000					
granite	10000					
ulexite	16000000					
talc	7000000					
potassium chloride	13000000					
sulphur (bonded)	7100000					
ilmenite	48000000					
Scrap iron/steel	2000000000					
Flyash	3700000000					
WATER USE						
Source	Use for	Use for	Totals			
	processing	cooling				
	(mg)	(mg)	(mg)			
Public supply	1E+11	-	1E+11			
River canal	27000000000	480000000	28000000 000			
Sea	10000000	2800000000	28000000 00			
Unspecified	4200000000	3100000000	73000000 00			
Well	17000000	970000	18000000			
Totals	1.4E+11	6400000000	1.4E+11			
Recirculating total	1300000000					

AIR EMISSIONS						
Emission	From	From	From	From	From	Totals
	fuel	fuel	transport	process	biomass	
	production	use	operations	operations	use	
	(mg)	(mg)	(mg)	(mg)	(mg)	(mg)
Dust	54000000	38000000	720000	12000000	-	104000000
CO	5600000	9200000	7900000	51000000	-	74000000
CO2	14000000000	14000000000	1100000000	10000000000	-8800000000	31000000000
SOX	121000000	69000000	6900000	7800000	-	205000000
NOX	52000000	111000000	11000000	1900000	-	176000000
N2O	9	2	-	<1	-	11
Hydrocarbons	3500000	3400000	3100000	7800000	-	18000000
Methane	51000000	53000000	-	8900	39000000	144000000
H2S	-	-	-	81000	-	81000
HCl	2600000	1100000	-	93000	-	3800000
Cl2	-	-	-	410	-	410
HF	140000	55000	-	15000	-	210000
Lead(Pb)	-	1400	-	630	-	2000
Metals	2900	7900	-	1600000	-	1600000
F2	-	-	-	6000	-	6000
Mercaptans	-	<1	-	5800	-	5800
Organo-Cl	-	-	-	91	-	91
Aromatic-HC	-	-	-	230000	-	230000
Other organics	-	-	-	96000	-	96000
CFC/HCFC	-	-	-	30	-	30
Aldehydes (CHO)	-	-	-	170000	-	170000
HCN	-	-	-	3	-	3
H2SO4	-	-	-	<1	-	<1
Hydrogen (H2)	-	-	-	5000	-	5000
Mercury (Hg)	-	-	-	16	-	16
Ammonia (NH3)	-	-	-	880	-	880
CS2	-	-	-	<1	-	<1
DCE	-	-	-	<1	-	<1
VCM	-	-	-	1	-	1
VOC	-	-	-	1200000	-	1200000
CO2 EQUIVALENTS						
Type	From	From	From	From	From	Totals
	fuel	fuel	transport	process	biomass	
	production	use	operations	operations	use	
	(mg)	(mg)	(mg)	(mg)	(mg)	(mg)
20 year equiv	17000000000	17000000000	1100000000	10000000000	-6600000000	39000000000
100 year equiv	15000000000	16000000000	1100000000	10000000000	-7900000000	34000000000
500 year equiv	15000000000	15000000000	1100000000	10000000000	-85000000	32000000000

					00	
SOLID WASTE						
Type	From	From	From	Totals		
	fuel	fuel	process			
	production	use	operations			
	(mg)	(mg)	(mg)	(mg)		
Mineral	1500000000	-	20000000 000	22000000000		
Mixed industrial	4500000	-	114000000	118000000		
Slags/ash	554000000	15000000	79000000 0	1400000000		
Inert chemical	14	-	17000000	17000000		
Regulated chemical	1900	-	20000000	20000000		
Unspecified	120	-	20000	20000		
Construction	-	-	9400	9400		
Metals	-	-	-27000000	-27000000		
To incinerator	-	-	78000	78000		
To recycling	-	-	131000000	131000000		
Paper & board	-	-	27600000 0	276000000		
Plastics	-	-	290000	290000		
Putrescibles	-	-	28000000 00	2800000000		
Wood waste	-	-	90	90		
WATER EMISSIONS						
Emission	From	From	From	From	Totals	
	fuel	fuel	transport	process		
	production	use	operations	operations		
	(mg)	(mg)	(mg)	(mg)	(mg)	
COD	47000	-	-	4200000	4200000	
BOD	45000	-	-	420000	470000	
Acid (H+)	360	-	-	27000	28000	
Dissolved solids	5500	-	-	32000000	32000000	
Hydrocarbons	45000	50	-	10000	56000	
NH4	320	-	-	83000	84000	
Suspended solids	1900000	-	-	1200000000	120000000 0	
Phenol	45000	-	-	62	45000	
Al+++	-	-	-	2600	2600	
Ca++	-	-	-	21000000	21000000	
Cu+/Cu++	-	-	-	5	5	
Fe++/Fe+++	-	-	-	34000	34000	
Hg	-	-	-	5	5	
Pb	-	-	-	1100	1100	
Mg++	-	-	-	49	49	
Na+	-	-	-	9600000	9600000	
K+	-	-	-	3	3	
Ni++	-	-	-	4	4	
Zn++	-	-	-	9	9	

Other metals	87	-	-	81000	81000	
NO_3^-	-	-	-	14000	14000	
Other nitrogen	9	-	-	84000	84000	
BrO_3^-	-	-	-	<1	<1	
CrO_3	-	-	-	<1	<1	
Cl^-	-	-	-	50000000	50000000	
ClO_3^-	-	-	-	1	1	
CN^-	-	-	-	440	440	
F^-	-	-	-	63000	63000	
SO_4^{--}	-	-	-	370000	370000	
CO_3^{--}	-	-	-	4600	4600	
Phosphate as P_2O_5	-	-	-	37000	37000	
AOX	-	-	-	<1	<1	
TOC	-	-	-	8700	8700	
Arsenic	-	-	-	<1	<1	
DCE	-	-	-	<1	<1	
Detergent/oil	-	-	-	58000	58000	
Dissolved Cl_2	-	-	-	<1	<1	
Organo-chlorine	-	-	-	170	170	
Dissolved organics	-	-	-	160000	160000	
Other organics	-	-	-	88	88	
Sulphur/sulphide	-	-	-	2700	2700	

Summarised Energy Results (GJ)

	Fuel production and delivery	Energy used in processes	Transport energy	Feedstock	Total (GJ)
Electricity	91	38	1	0	130
Oil fuels	6	21	13	10	52
Other fuels	9	207	1	33	251
Total (GJ)	**107**	**267**	**16**	**44**	**433**

APPENDIX 2 - CANADA

Domestic building
Analysis tool: OPTIMIZE
By: Sebastian Moffatt, Sheltair Scientific, Vancouver, Canada
Date: July 14, 1998

Introduction

OPTIMIZE was developed by Sheltair Scientific Ltd. for the Canadian Mortgage and Housing Corporation. It is a Canadian data base and spread sheet application for estimating the life cycle energy, material flow, environmental impact and cost of residential buildings and assemblies. It is intended to assist researchers and designers in optimizing house performance by considering environmental externalities at the same time as other factors related to house design. It is probably one of the first applications in which interior environmental quality is included.

Use of Tools in Optimisation Process

The OPTIMIZE program was used in conjunction with the operating energy program. Because operating energy was more significant, reductions in that component of the lifecycle energy were targeted first. Changes to the embodied energy as the result of reducing the operating energy were then modelled using OPTIMIZE.

Who is using the tool

Hot 2000 is a design and research tool being used by a wide range of designers, engineers and retrofit contractors in Canada and Northern United States. OPTIMIZE is still a research tool that is being used within academic institutions and research consultants in Canada.

What are the experiences of the tool

Limited market research of OPTIMIZE has been conducted by the Canada Mortgage and Housing Corporation. Market research has focused on university researchers and overall response has been good. There is no recorded information from designers using the tool.

Step 1: Environmental impact of case study building

What is the input of the method?

The input method included using the OPTIMIZE program in conjunction with the spreadsheets provided on the domestic building. There were some difficulties in importing the information presented in the spreadsheets into OPTIMIZE, mainly due to differences in terminology and information gaps on the case study building.

Most of the time and effort required to input a building description occurs in the Input Quantity Take-off Materials sub-menu. This menu is organized according to the Master-format system of classification developed by Construction Specifications

Canada (CSC). From this menu, the user inputs material quantities according to the classifications:

- o Site Work;
- o Concrete;
- o Masonry;
- o Metals;
- o Carpentry;
- o Insulation and Moisture Protection;
- o Doors, Windows and Finishing Hardware;
- o Finishes;
- o Specialities;
- o Cabinets and Appliances;
- o Mechanical; and,
- o Electrical.

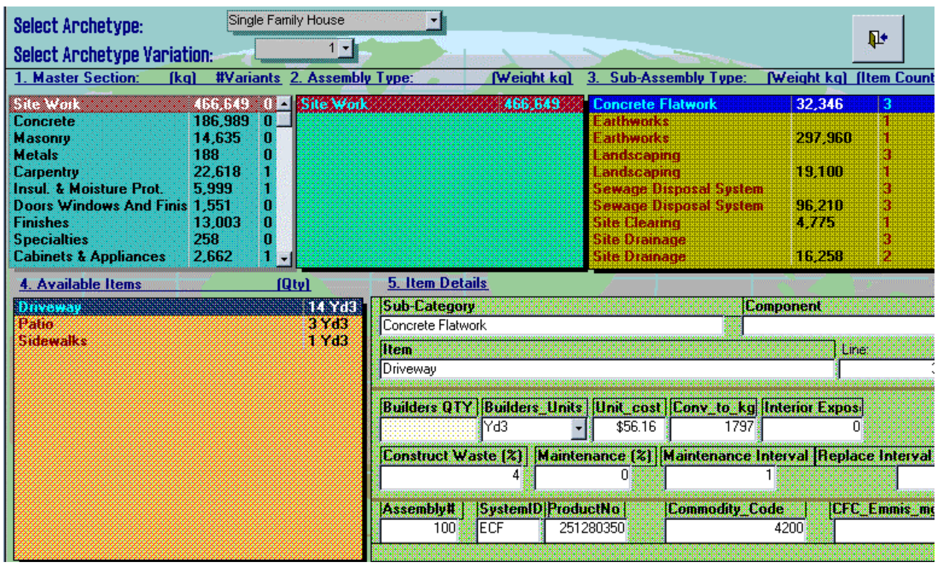


Figure 2.1: Input Quantity Takeoff Screen

What is the Output from OPTIMIZE?

Specific information available from OPTIMIZE includes:

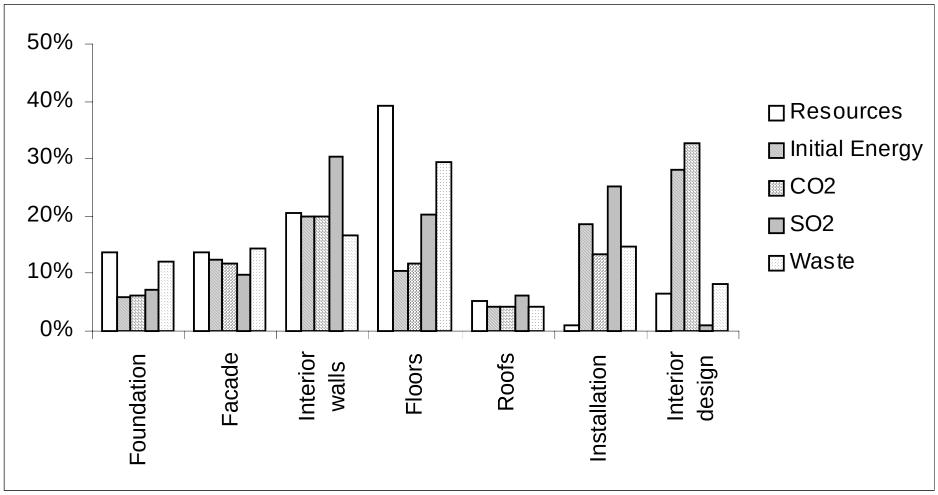
- o weight of building by commodity;
- o breakdown of indoor air pollutant emission rates;
- o life-cycle (operating and embodied) energy of the building;
- o energy related emission and externality costs, and
- o the building costs.

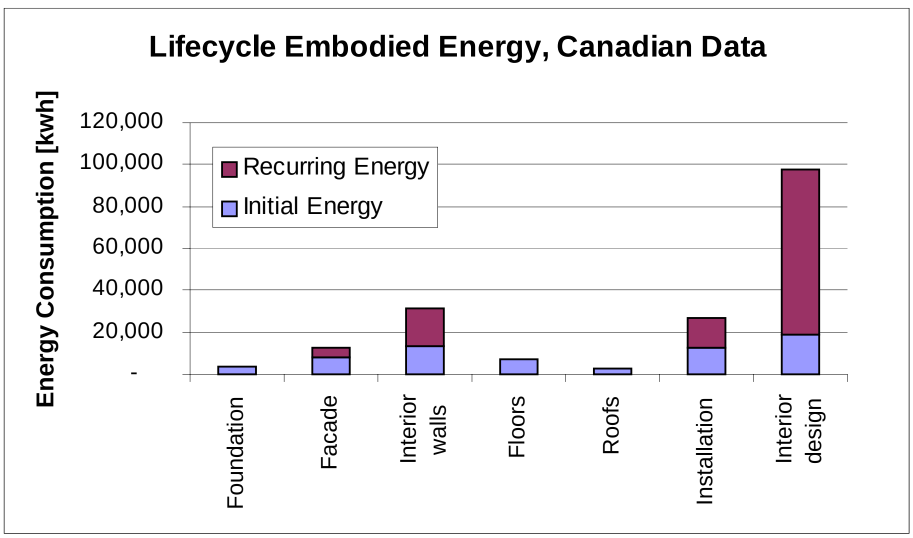
What Calculations are performed

The results of the calculations are summarized below.

1. The Operating Energy for the building was estimated at 0.56 GJ/sq m
2. The initial embodied energy is 243 GJ
3. The initial CO_2 is 13,458 kg
4. The initial SO_2 is 17,810 grams

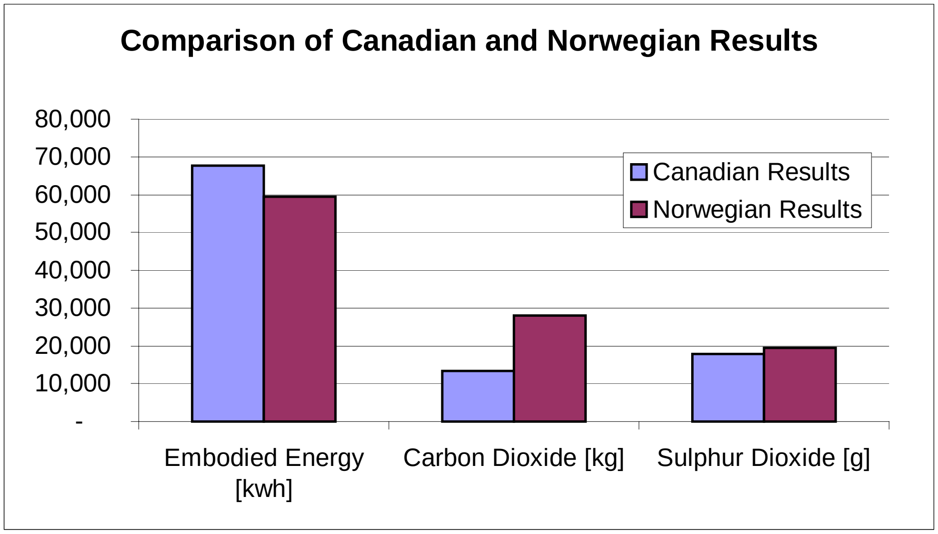
5. The lifecycle-embodied energy (assuming a 40 year building life) is 600 GJ. Normalising for building life and floor area, this corresponds to 0.183 GJ/ sq m/yr.
6. The lifecycle energy, (assuming a floor area of 82.1 sq m) is estimated at 2430GJ. Normalising for building life and floor area, this corresponds to 0.74 GJ/sq m/yr.
7. The operating energy accounts for more than 75% of the lifecycle energy.





What conclusions can be drawn from evaluating the results

The most interesting results emerge as the building is compared to similar buildings from other jurisdictions, or from different building types in the same jurisdiction. For instance, the figure below compares embodied energy carbon dioxide emissions and sulphur dioxide emissions for the case study building for Canadian and Norwegian building materials. Note that while the initial embodied energy of the Canadian building is higher, the Carbon dioxide and sulphur emissions are lower. This is due, in large part to the predominance of hydro-electricity in the production of Canadian goods and services.



Step 2: Environmental Impact of building after adapting to local climate and construction technologies.

What is the input method

The method of data input was to use the OPTIMIZE program for embodied energy and HOT 2000 to estimate operating energy.

What are the changes made to the building

The house modelled in this section underwent considerable alterations from the base building examined in Step 1. For instance, wall construction changed from brick envelope with concrete structure to stucco siding with stick frame structure. There was some uncertainty about the wall and floor areas of the case study building.

Therefore, in the current analysis, information was normalised according to the building's floor area.

What are the outputs of the model

The energy analysis performed for the Standard House predicts the following results:

- The as-built embodied energy is 2.4 GJ/sq.m.
- The life cycle embodied energy is 0.10 GJ/sq.m.yr.
- The total life cycle energy for the standard house is 0.64 GJ/sq.m.yr.
- The operating energy for the building is 0.525 GJ/sq.m.yr.
- The life cycle embodied energy is approximately 16% of the total life-cycle energy.

What conclusions can be drawn

Based on the calculations, lifecycle embodied energy and the lifecycle of the building modified to Canadian construction is lower, as summarized in the table below:

	Concrete structure	Wood Structure
Initial embodied energy	2.96 GJ/sq m	2.4 GJ/sq m
Lifecycle embodied energy	0.18 GJ/sq m/yr	0.1 GJ/sq m/yr
Annual operating energy	0.56 GJ/sq m/yr	0.53 GJ/sq m/yr
Lifecycle energy	0.74 GJ/sq m/yr	0.63 GJ/sq m/yr

Step 3: Improving the Building

Input method

The operating energy was analysed using the HOT 2000 program. Changes to the embodied energy were modelled using OPTIMIZE.

Changes made to optimise the building

The wood frame building in step 2 was optimised by reducing the operating energy to an R2000 standard. This implied additional insulation to the walls, improved glazing systems and a more airtight design that included a heat recovery ventilator. While this implied modifications to the materials used to construct the house, changes to the embodied energy were small in comparison to changes in the operating energy. In the analysis, it is assumed that energy and in particular operating energy has the largest environmental impact.

Model Outputs

Model output is the output form from the HOT 2000 program.

Evaluation of results

By improving the performance of the building envelope, the operating energy was reduced to 0.40 GJ/sq m. The most important conclusion to be drawn from the analysis is that it is possible to reduce the operating energy of the building significantly without significant increases in the embodied energy of the building. A second important conclusion is that lifecycle embodied energy is likely more significant than initial embodied energy. However, without sufficient data regarding the life of components, the significance of recurring embodied energy is difficult to estimate with a high level of confidence.

Concluding Remarks

Optimize is an improvement model. It is intended to assist researchers and designers in optimizing house performance by considering environmental externalities at the same time as other factors related to house design. As such the three steps of the application are performed. Terminology and input appeared to differ largely. In step 2 there are a lot of changes in comparison to step 1.

OPTIMIZE is a research tool that is being used within academic institutions and research consultants in Canada. The energy performance is done by Hot 2000, a design and research tool being used by a wide range of designers, engineers and retrofit contractors in Canada and Northern United States.

APPENDIX 3 - DENMARK

Domestic building
Analysis tool: SBI´S LCA Database and Inventory Tool
By: Ebbe H. Petersen, Danish Building Research Institute, Denmark
Date: May 29, 1998

Introduction

SBI's LCA Database and Inventory Tools is as the name states an LCA-based tool, developed by the Danish Building Research Institute. Researchers use it in their daily work at SBI and it more or less constitutes the basis for any LCA calculations at SBI: it is the only LCA tool they use. SBI-tool is very easy to use. Also other researchers in Denmark (DTU) and Sweden (KTH, CTH, LTH) use it. A few consulting engineers in Denmark also use it, but not on a regular basis (yet). SBI keeps developing it, and will continue to make new versions of both the user interface and the database (available for free on SBI-homepage (**www.sbi.dk**)).

Who and when

SBI-tool can be used both very early by an architect to try and identify the type of building (geometry, materials) which is most environmentally benign, or alternativly: which should be avoided. It can also be used by a consulting engineer to optimize the individual building elements later in the design.

SBI-tool can be used for any product, building element and building for all or part of their life cycle. One may therefore compare (and thereby optimize) buildings with e.g. different geometry, materials or energy supply.

Output

The outcome of the tool is either input/output tables or normalized and weighted environmental profiles. It is then up to the user to interpret them.

Step 1

Extraction of raw materials, production of materials, production of energy and transport are already defined in the database. Therefore only the different building elements used in the building have to be defined in the database by the input (materials and energy used to produce them on the building site) and output (associated emissions and solid waste) per meter or square meter of building element.

Afterwards the building itself is defined by specifying the amounts of building elements used. Then a calculation for the building can be performed. The output of the method consists of three parts:

a. Tables containing the total input/output associated with the extraction of raw materials, production of materials, construction of the building and, finally, demolition and disposal (figure 1). The energy use during use of the building can also be specified (it is, however, calculated by use of a separate tool: BV95).

b. Detailed calculations of the normalised environmental scores on the environmental themes according to LCA practice combined with a method used in Denmark for normalising and weighting effects (figure 2). Here it is possible to identify which emissions contribute the most to the individual effects.

c. Profiles showing the normalised environmental effects (figure 3), and how they are distributed on the individual building elements (effects not related to building elements, such as energy use during use are displayed separately)

Figure 3 shows that the building elements primarily responsible for the environmental effects are: floor and floor finish, roof & roof finish and external walls (in that order). They seem to be responsible for 60-70% of the environmental loadings. The largest potential for improvements therefore probably could be achieved by substituting these with more environmentally benign building elements.

Step 2

Here energy use for heating during use is added to the building, and the calculation repeated as described above.

Step 3

By substituting elements and/or energy sources, calculations for alternative solutions can quickly be performed and compared. As a simple example environmental profiles for alternative heating systems are shown (natural gas). In the same way alternative building elements could easily have been tested, and in this way the building's environmental performance could have been improved further.

Total energy use, ressource use and emissions for 1 stk IEA, building

Estimated lifetime (years): 40

Consumption of primary raw materials/fuels	Unit	Total	Pr. year	Std deviation
Dolomit	kg	2.142,05	53,55	0,00
Gips, anhydrit	kg	1.490,61	37,27	0,00
Granit	t	446,82	11,17	0,00
Jernmalm	kg	28.431,31	710,78	0,00
Kalksten	kg	1.883,27	47,08	0,00
Kaolin	g	16.066,51	401,66	0,00
Kridt	t	183,32	4,58	0,00
Kul, brunkul	kg	385,74	9,64	0,00
Kul, stenkul	kg	30.366,98	759,17	0,00
Kvartssand	kg	8.881,09	222,03	0,00
Ler	m3	26,91	0,67	0,00
Naturgas	Nm3	14.608,51	365,21	0,00
Råolie	kg	31.758,27	793,96	0,00
Sand	t	515,84	12,90	0,00
Sten	t	134,33	3,36	0,00
Zinkmalm som Zn	g	6.660,00	166,50	0,00

Consumption of secondary raw materials/fuels	Unit	Total	Pr. year	Std deviation
Brændbart, naturgas	Nm3	0,38	0,01	0,00
Brændbart, olie	g	-259,49	-6,49	0,00
Brændbart, træ, 0% vand	kg	178,12	4,45	0,00
Flyveaske	t	64,99	1,62	0,00
Gips, industrigips	kg	1.475,50	36,89	0,00
Kisaske	kg	3.956,20	98,90	0,00
Mikrosilika	kg	1.230,00	30,75	0,00
Skrot, stål	kg	2.753,31	68,83	0,00
Træ, savværk	m3	1,81	0,05	0,00

Consumption of energy	Unit	Total	Pr. year	Std deviation
Biobrændsel	GJ	3,54	0,09	0,00
El, atomkraft	GJ	226,19	5,65	0,00
El, vandkraft	GJ	19,71	0,49	0,00
Kul, brunkul	GJ	3,86	0,10	0,00
Kul, stenkul	GJ	921,50	23,04	0,00
Naturgas	GJ	333,92	8,35	0,00
Naturgas, restprodukt	GJ	32,35	0,81	0,00
Olie, fuelolie	GJ	215,13	5,38	0,00
Olie, gasolie	GJ	776,96	19,42	0,00
Olie, petcoke	GJ	134,89	3,37	0,00
Olie, restprodukt	GJ	35,90	0,90	0,00
Uspecificeret	GJ	7,62	0,19	0,00
Total		2.711,57	67,79	0,00
Precombustion		150,81	3,77	0,00

Atmospheric emissions	Unit	Total	Pr. year	Std deviation
Ammoniak (NH3)	mg	39450,93	986,27	0,00
Arsen (As)	mg	3755,78	93,89	0,00
Bly (Pb)	g	133,44	3,34	0,00
Cadmium (Cd)	mg	3888,30	97,21	0,00

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Chlor (Cl2)	mg	3749,00	93,72	0,00
Chlororganiske forb.	g	1370,50	34,26	0,00
Fluorid (F)	g	9058,50	226,46	0,00
Hydrogenchlorid (HCl)	g	622,75	15,57	0,00
Kuldioxid (CO2)	t	281,31	7,03	0,00
Kulmonoxid (CO)	kg	431,35	10,78	0,00
Kviksølv (Hg)	mg	2333,27	58,33	0,00
Lattergas (N2O)	g	394,53	9,86	0,00
Metan (CH4)	g	788,98	19,72	0,00
Nikkel (Ni)	g	52,00	1,30	0,00
Nitrogenoxider (NOx)	kg	1015,11	25,38	0,00
Partikler	g	14985,26	374,63	0,00
Støv, cement	g	1324,29	33,11	0,00
Svovldioxid (SO2)	kg	528,62	13,22	0,00
VOC, bil (diesel)	g	27637,86	690,95	0,00
VOC, kraftværk	g	767,15	19,18	0,00
VOC, plast	kg	378,78	9,47	0,00
Zink (Zn)	g	125,50	3,14	0,00

Solid wastes	Unit	Total	Pr. year	Std deviation
Farligt affald, uspec.	g	34008,38	850,21	0,00
Radioaktivt affald	kg	1581,20	39,53	0,00
Slagge & flyveaske	kg	1594,03	39,85	0,00
Volumen affald, beton	kg	6590,00	164,75	0,00
Volumen affald, mørtel	kg	2480,00	62,00	0,00
Volumen affald, teglsten	kg	1054,00	26,35	0,00
Volumen affald, uspec.	kg	31387,00	784,67	0,00

Figure 3.1: Input/Output calculated for the building excluding energy use during use

Normalized environmental effects for 1 stk IEA, building

Estimated lifetime (years): 40

Drivhuseffekt (GWP)

	Unit	Emission (total)	Emission (pr. year)	Equivalents Factors	Equivalents (pr. year)	Normalisation (1/PE)	Normalisation (µPE)
Kuldioxid (CO2)	t	2,81E+02	7,03E+00	1,00E+00	7,03E+00		
Kulmonoxid (CO)	t	4,31E-01	1,08E-02	2,00E+00	2,16E-02		
Lattergas (N2O)	t	3,95E-04	9,86E-06	3,20E+02	3,16E-03		
Metan (CH4)	t	7,89E-04	1,97E-05	2,50E+01	4,93E-04		
					7,06E+00	8,70E+00	11.265,23

Forsuring (AP)

	Unit	Emission (total)	Emission (pr. year)	Equivalents Factors	Equivalents (pr. year)	Normalisation (pr. PE pr. yr)	Normalisation (µPE)
Ammoniak (NH3)	t	3,95E-05	9,86E-07	1,88E+00	1,85E-06		
Nitrogenoxider (NOx)	t	1,02E+00	2,54E-02	7,00E-01	1,78E-02		
Svovldioxid (SO2)	t	5,29E-01	1,32E-02	1,00E+00	1,32E-02		
					3,10E-02	1,24E-01	49.852,22

Fotokemisk ozondannelse (POCP)

	Unit	Emission (total)	Emission (pr. year)	Equivalents Factors	Equivalents (pr. year)	Normalisation (pr. PE pr. yr)	Normalisation (µPE)
Kulmonoxid (CO)	t	4,31E-01	1,08E-02	4,00E-02	4,31E-04		
Metan (CH4)	t	7,89E-04	1,97E-05	7,00E-03	1,38E-07		
VOC, bil (diesel)	t	2,76E-02	6,91E-04	5,00E-01	3,45E-04		
VOC, kraftværk	t	7,67E-04	1,92E-05	4,00E-01	7,67E-06		
					7,85E-04	2,00E-02	39.231,53

Humantoksicitet (HT)

	Unit	Emission (total)	Emission (pr. year)	Equivalents Factors	Equivalents (pr. year)	Normalisation (pr. PE pr. yr)	Normalisation (µPE)
Arsen (As)	t	3,76E-06	9,39E-08	5,00E+08	4,69E+01		
Bly (Pb)	t	1,33E-04	3,34E-06	1,00E+07	3,34E+01		
Cadmium (Cd)	t	3,89E-06	9,72E-08	2,86E+07	2,78E+00		
Kulmonoxid (CO)	t	4,31E-01	1,08E-02	1,00E+02	1,08E+00		
Kviksølv (Hg)	t	2,33E-06	5,83E-08	6,67E+07	3,89E+00		
Lattergas (N2O)	t	3,95E-04	9,86E-06	1,11E+07	1,09E+02		
Nikkel (Ni)	t	5,20E-05	1,30E-06	6,67E+05	8,67E-01		
Nitrogenoxider (NOx)	t	1,02E+00	2,54E-02	8,00E+04	2,03E+03		
Svovldioxid (SO2)	t	5,29E-01	1,32E-02	2,50E+04	3,30E+02		
					2,56E+03	2,90E+04	88.241,66

Næringssaltbelastning (NP)

	Unit	Emission (total)	Emission (pr. year)	Equivalents Factors	Equivalents (pr. year)	Normalisation (pr. PE pr. yr)	Normalisation (µPE)
Ammoniak (NH3)	t	3,95E-05	9,86E-07	3,64E+00	3,59E-06		
Lattergas (N2O)	t	3,95E-04	9,86E-06	2,82E+00	2,78E-05		
Nitrogenoxider (NOx)	t	1,02E+00	2,54E-02	1,35E+00	3,43E-02		
					3,43E-02	2,98E-01	15.071,69

Persistent toksicitet (PT)

	Unit	Emission (total)	Emission (pr. year)	Equivalents Factors	Equivalents (pr. year)	Normalisation (pr. PE pr. yr)	Normalisation (µPE)

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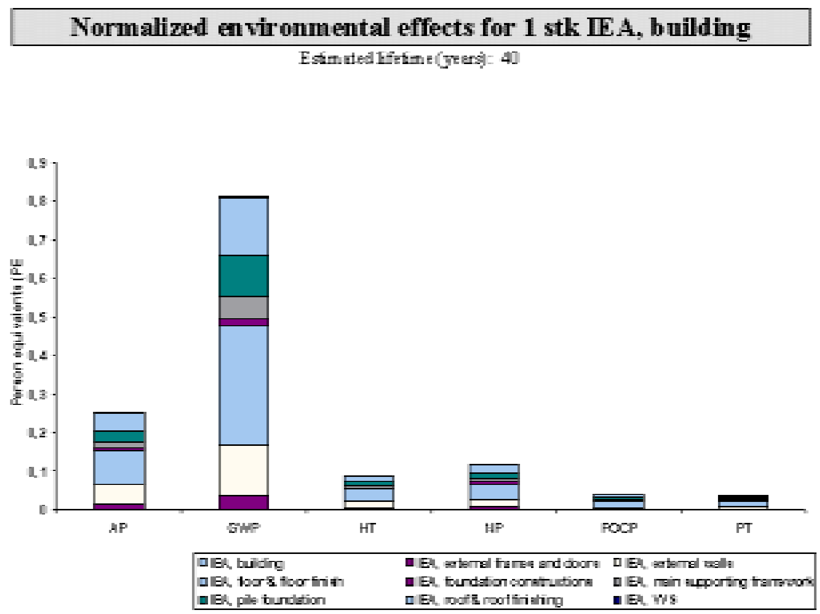
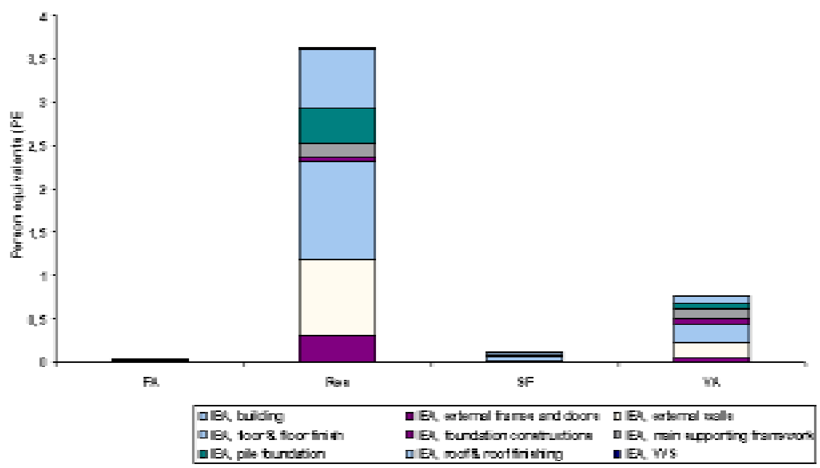
Figure 3.2: Normalised environmental effects for building excluding energy use during use (page 1 of 3)





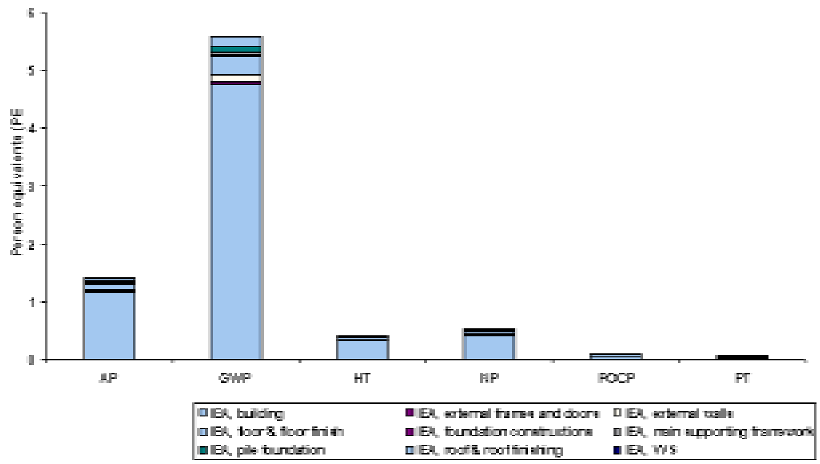
Signatures:

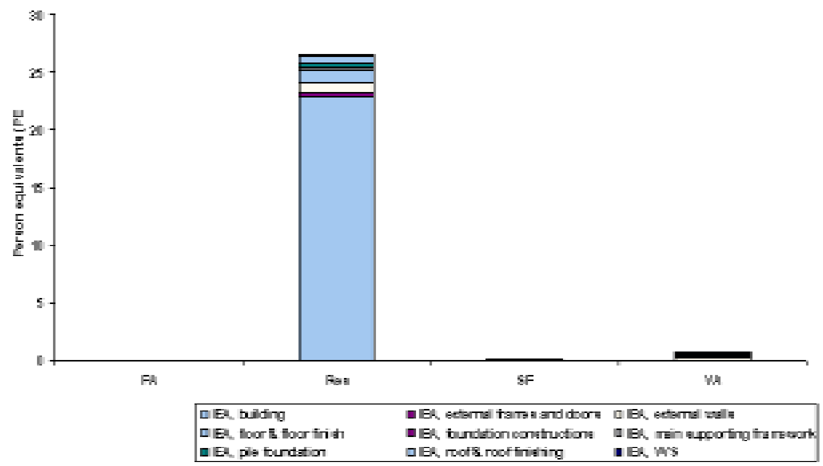
GWP	:	Drivhuseffekt	FA	:	Farligt affald
AP	:	Forsuring	Res	:	Ressourceforbrug
POCP	:	Fotokemisk ozondannelse	SF	:	Slagge & flyveaske
HT	:	Humantoksicitet	VA	:	Volumen affald
NP	:	Næringssaltbelastning			
PT	:	Persistent toksicitet			

Figure 3.3: Normalised environmental profiles for the building excluding energy use during use

Normalized environmental effects for 1 stk IEA, building

Estimated lifetime (years): 40

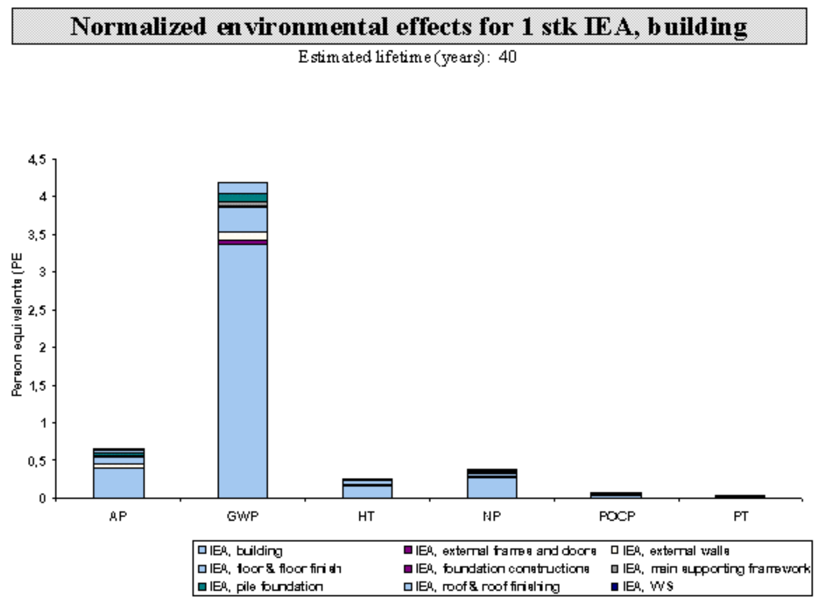


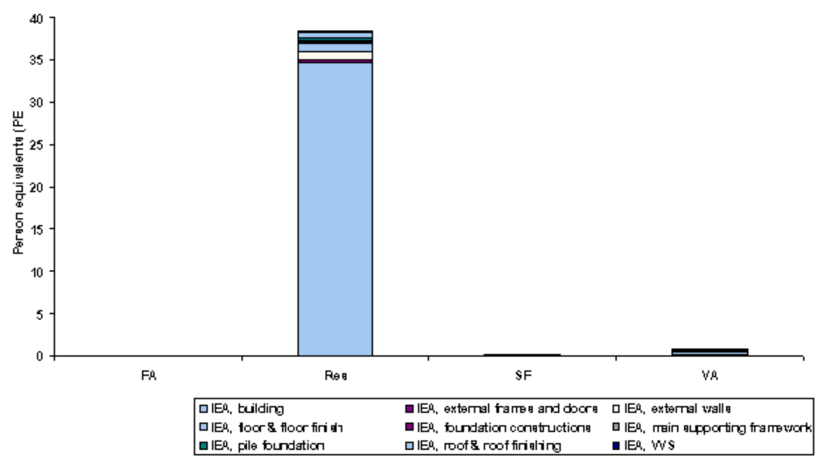


Signatures:

GWP	:	Drivhuseffekt	FA	:	Farligt affald
AP	:	Forsuring	Res	:	Ressourceforbrug
POCP	:	Fotokemisk ozondannelse	SF	:	Slagge & flyveaske
HT	:	Humantoksicitet	VA	:	Volumenaffald
NP	:	Næringssaltbelastning			
PT	:	Persistent toksicitet			

Figure 3.4: Normalised environmental profiles for the building including energy use (oil) during use.





Signatures:

GWP	:	Drivhuseffekt	FA	:	Farligt affald
AP	:	Forsuring	Res	:	Ressourceforbrug
POCP	:	Fotokemisk ozondannelse	SF	:	Slagge & flyveaske
HT	:	Humantoksicitet	VA	:	Volumen affald
NP	:	Næringssaltbelastning			
PT	:	Persistent toksicitet			

Figure 3.5: As per figure 3.4 with energy for heating added

Concluding Remarks

The researchers use the SBI tool in their daily work at SBI and it more or less constitute the basis for any LCA calculations at SBI: it is the only LCA tool they use. SBI-tool is very easy to use. At this moment SBI-tool is not used by architects or engineers. The results are expressed in tables and graphics which contain a lot of information. To interpret the results expertise is necessary.

SBI-tool provides insight into the largest components of environmental impact: the figures in step 2 and 3 show that of a fairly typical building, approximately 10% of the energy use is related to extraction of raw materials, production of materials, construction and demolition of the building, while the remaining 90% are used for heating etc. It can also be seen that by using natural gas instead of oil, most environmental effects are reduced by 25-50%, with the exception of resource use (since natural gas is a more scarce resource than oil).

APPENDIX 4 - FINLAND

Office building
Analysis tool: BEE 1.0 (Building Energy, Environment)
By: Ilari Aho, VTT Building Technology, Finland
Date: June 5, 1998

Introduction

BEE is a tool for calculating the life cycle environmental impacts and annualized life cycle costs of buildings. In this exercise only the environmental impact calculations for initial embodied energy and energy in use are taken into account. Environmental impacts of recurring production and life cycle costs are not considered.
The BEE tool has, in practice, only been used to assess entries to the Viikki ecological housing area architectural competition.

BEE is a step towards a real design tool. There are plans of starting the development of a design tool integrating building energy analysis and LCA data for building materials.

At which moment in the process is the tool used?

BEE is used when at least preliminary documentation is available for all details of the design, in other words at a point in time when accurate estimates of material amounts can be specified.

For which improvements is the tool most sensitive, in other words which improvements have the highest environmental impact?

As for all tools also incorporating impacts from energy-in-use, the range of outcome could be characterised as being from 10...20 % for extremely low energy solar buildings up to 150-200 % for 1950's/1960's construction (100 % representing today's practice).

How accurate is the tool on a zero to ten scale (10 is very accurate)?

The tool is based on summing up material amounts and specific impacts per kg of material. Thus it should be noticed that accuracy does not depend on the tool but rather on the data that it is built upon.

Step 1

Input to the tool consists of three tables, one for initial construction, one for recurring repairs over the lifetime of the building (assumed to be 50 years) and one for energy consumption in use. The following information has to be input separately for initial and recurring production:

- Amount of different materials used, expressed either in area (m2) and layer thickness (mm) or alternatively directly in volume (m3).
- Estimated percentage of material waste during initial construction (%; default values are provided in the tool for each material).

- For energy during use estimates on annual consumption values for heating (district heat) and electricity are input in MWh/a (Note: these are not calculated in the tool, but a separate calculation program needs to be used.)
- An example of the input table for initial production is presented in the figure on the following page. The input table for recurring production is exactly similar.

The output of the method consists of one table presenting the following items for materials used in initial construction, materials used in recurring production, 50 years of operating energy consumption and life cycle totals:

- Amount of construction waste (kg);
- Consumption of primary energy (GJ);
- Global Warming Potential (kg of CO_2 equivalent);
- Acidifying Potential (g of SO_2 equivalent); and
- Photochemical Ozone Creation Potential (g of NOx equivalent).
- The tool does not produce graphical output (even though it runs on Excel).

Example of the output table for the office building with original Dutch specifications:

	jäte kg	GJ	GWP kg	AP kg	COD,POCP kg
Rakennusmateriaa	207538	1448	206064	1012	834
Uusittavat	0	0	0	0	0
50 v. energian		0	0	0	0
YHTEENS	207538	1448	206064	1012	834

jäte = constr. waste

Initial construction
Recurring prod.
Energy in use (50 a)
Totals

Input table for the office building with original Dutch specifications (unfortunately only in Finnish).

Columns from left: 1. available materials; 2. Area (input); 3. Layer thickness (input); 4. Alternatively input material volume directly; 5. Calculated material volume; 6. Material density; 7. Estimated wastage during construction; 8. Calculated material waste in kg; 9. Specific primary embodied energy data in GJ per kg of material; 10. Calculated total primary embodied energy by material; 11-13. Specific GWP, AP and POCP data in emissions per kg of material; 14-16. Calculated gross environmental impacts by material.

Materiaali		Pinta-ala m²	Paksuus mm	Tilavuus m³	Tilavuus m³	Tiheys kg/m³	Hukka-prosentti	Hukka-massa kg	PEF MJ/kg	PEF GJ	GWP g/kg	AP g/kg	COD POCP g/kg	GWP kg	AP kg	COD POCP kg
Yhteensä										**1448**				**206064**	**1012**	**834**
Alumiini					0	2700	21 %	0	58	0	1900	13	3	0.000	0.000	0.000
Valurauta					0	7200		0	13	0	771	6	5	0.000	0.000	0.000
Teräs				2.3	2.3	8000	21 %	3864	6	134	250	2	1	5566.000	44.528	22.264
	galvanoitu				0	7500	21 %	0	12	0	1000	4	1	0.000	0.000	0.000
	ruostumaton			0.0089	0.0089	7800	21 %	15	12	1	1000	4	1	83.998	0.336	0.084
Lyijy					0	11300	21 %	0	22	0	1137	10	63	0.000	0.000	0.000
Kupari				0.0089	0.0089	8930	16 %	13	127	12	1200	5	6	110.632	0.461	0.553
					0			0		0				0.000	0.000	0.000
					0			0		0				0.000	0.000	0.000
Betoni	rakennus			516.8	516.8	2400	16 %	198451	0.6	863	120	0.5	0.4	########	719.386	575.508
	kattokivi				0	2200	4 %	0	2	0	131	1	1	0.000	0.000	0.000
	kuitubetoni				0	1200	20 %	0	7	0	434	2	3	0.000	0.000	0.000
	maakostea				0	1900	10 %	0	1	0	180	0.5	0.6	0.000	0.000	0.000
Kevytbetoni					0	500	5 %	0	4	0	280	2	30	0.000	0.000	0.000
Kevytsorabetoni					0	750	6 %	0	2	0	230	1	0.4	0.000	0.000	0.000
Kalkkihiekkakivi					0	1600	11 %	0	1	0	68	0.6	0.4	0.000	0.000	0.000
Kalsiumsilikaattilevy					0	875	20 %	0	2	0	130	1	1	0.000	0.000	0.000
Kipsilevy					0	900	25 %	0	5	0	330	5	5	0.000	0.000	0.000
Perliitti	ei bitumia				0	80	1 %	0	8	0	871	2	1	0.000	0.000	0.000
	bitumia				0	85	1 %	0	8	0	871	2	1	0.000	0.000	0.000
	silikonia				0	80	1 %	0	8	0	871	2	1	0.000	0.000	0.000
Lasi				4.788	4.788	2400	3 %	345	7	83	600	4	4	7101.562	47.344	47.344
	tinaoksidilla				0	2400	3 %	0	7	0	600	4	4	0.000	0.000	0.000
Mineraalivilla	kivivilla				0	30	6 %	0	11	0	770	3	2	0.000	0.000	0.000
	lasivilla				0	20	6 %	0	20	0	880	8	9	0.000	0.000	0.000
Kivi	rakennus				0	2700		0	0.1	0	8	0	0	0.000	0.000	0.000
	levyt				0	2700	6 %	0	0.1	0	8			0.000	0.000	0.000
Maa					0	2000	1 %	0	0.1	0	8			0.000	0.000	0.000
Tiili	rakennus			25.52	25.52	1800	10 %	4594	2	101	160	2	3	8084.736	101.059	151.589
	katto				0	1800	3 %	0	3	0	160	2	3	0.000	0.000	0.000
Keraamiset laatat					0	2000	18 %	0	8	0	571	4	51	0.000	0.000	0.000
Kevytklinkkeri					0	450	1 %	0	2	0	120	0.2		0.000	0.000	0.000
Polyeteeni	PE				0	940	11 %	0	67	0	751	9	0.1	0.000	0.000	0.000
Polypropyleeni	PP				0		11 %	0	71	0	900	7	0.1	0.000	0.000	0.000
Polystyreeni	EPS				0	23	11 %	0	75	0	2000	14		0.000	0.000	0.000
Polystyreeni	XPS				0	23	11 %	0	72	0	2200	15		0.000	0.000	0.000
Polyuretaani	PUR			66.84	66.84	35	11 %	257	98	254	4800	38	14	12464.323	98.676	36.354
Polyvinyylikloridi	PVC				0	1380	11 %	0	56	0	700	13		0.000	0.000	0.000
Puu	kyllästämätön				0	550	20 %	0	3	0	40	0.6	0.8	0.000	0.000	0.000
	painekyllästetty				0	550	20 %	0	3	0	40	0.6	0.8	0.000	0.000	0.000
	liimapuu				0	550		0	4	0	50			0.000	0.000	0.000
Puukuitulevyt	huokoinen ilman bitumia				0	300		0	16	0	120	2	1	0.000	0.000	0.000
	huokoinen bitumilla				0	350		0	18	0	120	2	1	0.000	0.000	0.000
	kova ilman bitumia				0	700	20 %	0	4	0	766	3	8	0.000	0.000	0.000
	kova bitumilla				0	900	20 %	0	4	0	766	3	8	0.000	0.000	0.000
Tuulensuojalevy					0	230	21 %	0	20	0	980	4	11	0.000	0.000	0.000
Lastulevy					0	750	20 %	0	2	0	20	0.3	1	0.000	0.000	0.000
Selluvilla					0	60	1 %	0	19	0	140	2	2	0.000	0.000	0.000
Kartonkilevyt	PE-laminointi				0	750	20 %	0		0				0.000	0.000	0.000
	lateksilaminointi				0	720	20 %	0		0				0.000	0.000	0.000
Pellavakuitu					0	150	1 %	0		0				0.000	0.000	0.000
Linoleumi					0	1200	11 %	0	7	0	1000	4	4	0.000	0.000	0.000
Kookoskuitu					0	100		0		0				0.000	0.000	0.000
Juuttikuitu					0	100				0				0.000	0.000	0.000

The tool performs the following calculations:

- Based on the material volumes supplied by the user the tool calculates the masses of materials used and amounts of materials wasted during construction. These are calculated using material densities and estimated wastage percentages which are provided as constants in the tool.

- On the basis of calculated material amounts the environmental indicators mentioned above (primary energy, GWP, AP, POCP) are calculated using Danish LCA data for building materials (Bygningsmaterialer for en baerekraftig utvikling = Building materials for sustainable development; NKB report 1995:07), which includes specific emission and embodied energy data in units per kg of material.

- Based on energy-in-use values input by the user the tool calculates primary energy consumption and emissions for the 50 year operation phase using data (efficiency, specific emissions) for the electricity and district heat production mix of Helsinki Energy (the Helsinki municipal energy utility).

The main conclusions that can be drawn from the output table are:

a) Whether the design as a whole meets specific targets related to the environmental indicators calculated; and
b) The relative share of initial construction, recurring production and operation within the total environmental impact.

However, as the environmental indicator values are also shown in the input table for each individual material the relative importance of materials within initial construction and recurring production can be traced.

In the case of the office building with Dutch specifications the most important factors regarding initial production are as follows (NOTE: These figures exclude sand cement in floor screeds and bitumen in roof coverings, because these are unknown to the tool):

- The total amount of embodied energy is 1448 GJ. Of this amount almost two thirds is accounted for by concrete used in foundation and supporting frame. An additional 17 % comes from polyurethane used for thermal insulation of external walls and roof 9 % of steel in concrete elements.

- Concrete plays a similarly important role also in terms of GWP, AP and POCP. Especially in GWP concrete's contibution is approximately 85 %. The contribution of glazing to all of the emission indicators is also large.

Step 2

The following modifications were done in order for the building to reflect Finnish construction practice.

External walls:
Concrete facade element 85 mm
Rockwool 140 mm
Reinforced concrete 100 mm
Finishing 5 mm
U-value 0.25 W/m^{2}K

Roof:
Bitumen 3 mm
Rockwool 20+140 mm
Bitumen 1 mm
Cement plaster 20 mm
Hollow core concrete element 240 mm
Finishing 10 mm
U-value 0.21 W/m^{2}K

Ground floor:
Polystyrene 100 mm
Reinforced concrete 80 mm
Finishing 10+2.5 mm

Windows:
Triple glazing
U-value 1.8 W/m^{2}K
U-value 0.28 W/m^{2}K

An estimate for the annual energy consumption of the office building with the modified structures is as follows:

Space and water heating: 168 MWh/a 112 kWh/m^2/a District heat
Electricity: 114 MWh/a 76 kWh/m^2/a

The input table with the appropriate modifications is shown on the following page.

The output including 50 years of operating energy is as follows:

	jäte kg	GJ	GWP kg	AP kg	COD,POCP kg
Rakennusmateriaalit	210578	1355	202630	904	698
Uusittavat materiaalit	0	0	0	0	0
50 v. energian käyttö		50760	5358000	12690	11280
YHTEENSÄ	210578	52115	5560630	13594	11978

jäte = constr. waste

Initial construction
Recurring prod.
Energy in use (50 a)
Totals

As can be seen the operating energy consumption is responsible for 90 - 99 % of the respective environmental impacts of the building. Initial embodied energy is slightly lower than in the original case with Dutch values that is mainly explained by changing the insulation material from polyurethane to rock wool.

Input table for the office building with modified Finnish specifications for envelope parts.

Columns from left:

1. Available materials;
2. Area (input);
3. Layer thickness (input);
4. Alternatively input material volume directly;
5. Calculated material volume;
6. Material density;
7. Estimated wastage during construction;
8. Calculated material waste in kg;
9. Specific primary embodied energy data in GJ per kg of material;
10. Calculated total primary embodied energy by material;

11-13. Specific GWP, AP and POCP data in emissions per kg of material;
14-16. Calculated gross environmental impacts by material.

Materiaali		Pinta-ala m²	Paksuus mm	Tilavuus m³	Tilavuus m³	Tiheys kg/m³	Hukka-prosentti	Hukka-massa kg	PEF MJ/kg	PEF GJ	GWP g/kg	AP g/kg	COD POCP g/kg	GWP kg	AP kg	COD POCP kg
Yhteensä										**1355**				**202630**	**904**	**698**
Alumiini					0	2700	21 %	0	58	0	1900	13	3	0.000	0.000	0.000
Valurauta					0	7200		0	13	0	771	6	5	0.000	0.000	0.000
Teräs				2.4	2.4	8000	21 %	4032	6	139	250	2	1	5808.000	46.464	23.232
	galvanoitu				0	7500	21 %	0	12	0	1000	4	1	0.000	0.000	0.000
	ruostumaton			0.00895	0.00895	7800	21 %	15	12	1	1000	4	1	84.470	0.338	0.084
Lyijy					0	11300	21 %	0	22	0	1137	10	63	0.000	0.000	0.000
Kupari				0.0089	0.0089	8930	16 %	13	127	12	1200	5	6	110.632	0.461	0.553
					0			0		0				0.000	0.000	0.000
					0			0		0				0.000	0.000	0.000
Betoni	rakennus			535.4	535.4	2400	16 %	205594	0.6	894	120	0.5	0.4	########	745.277	596.221
	kattokivi				0	2200	4 %	0	2	0	131	1	1	0.000	0.000	0.000
	kuitubetoni				0	1200	20 %	0	7	0	434	2	3	0.000	0.000	0.000
	maakostea				0	1900	10 %	0	1	0	180	0.5	0.6	0.000	0.000	0.000
Kevytbetoni					0	500	5 %	0	4	0	280	2	30	0.000	0.000	0.000
Kevytsorabetoni					0	750	6 %	0	2	0	230	1	0.4	0.000	0.000	0.000
Kalkkihiekkakivi					0	1600	11 %	0	1	0	68	0.6	0.4	0.000	0.000	0.000
Kalsiumsilikaattilevy					0	875	20 %	0	2	0	130	1	1	0.000	0.000	0.000
Kipsilevy					0	900	25 %	0	5	0	330	5	5	0.000	0.000	0.000
Perliitti	ei bitumia				0	80	1 %	0	8	0	871	2	1	0.000	0.000	0.000
	bitumia				0	85	1 %	0	8	0	871	2	1	0.000	0.000	0.000
	silikonia				0	80	1 %	0	8	0	871	2	1	0.000	0.000	0.000
Lasi				7.128	7.128	2400	3 %	513	7	123	600	4	4	10572.250	70.482	70.482
	tinaoksidilla				0	2400	3 %	0	7	0	600	4	4	0.000	0.000	0.000
Mineraalivilla	kivivilla			117.6	117.6	30	6 %	212	11	41	770	3	2	2879.554	11.219	7.479
	lasivilla				0	20	6 %	0	20	0	880	8	9	0.000	0.000	0.000
Kivi	rakennus				0	2700		0	0.1	0	8	0	0	0.000	0.000	0.000
	levyt				0	2700	6 %	0	0.1	0	8			0.000	0.000	0.000
Maa					0	2000	1 %	0	0.1	0	8			0.000	0.000	0.000
Tiili	rakennus				0	1800	10 %	0	2	0	160	2	3	0.000	0.000	0.000
	katto				0	1800	3 %	0	3	0	160	2	3	0.000	0.000	0.000
Keraamiset laatat					0	2000	18 %	0	8	0	571	4	51	0.000	0.000	0.000
Kevytklinkkeri					0	450	1 %	0	2	0	120	0.2		0.000	0.000	0.000
Polyeteeni	PE				0	940	11 %	0	67	0	751	9	0.1	0.000	0.000	0.000
Polypropyleeni	PP				0		11 %	0	71	0	900	7	0.1	0.000	0.000	0.000
Polystyreeni	EPS				0	23	11 %	0	75	0	2000	14		0.000	0.000	0.000
Polystyreeni	XPS			75.6	75.6	23	11 %	191	72	139	2200	15		4246.150	28.951	0.000
Polyuretaani	PUR				0	35	11 %	0	98	0	4800	38	14	0.000	0.000	0.000
Polyvinyylikloridi	PVC			0.058	0.058	1380	11 %	9	56	5	700	13		62.191	1.155	0.000
Puu	kyllästämätön				0	550	20 %	0	3	0	40	0.6	0.8	0.000	0.000	0.000
	painekyllästetty				0	550	20 %	0	3	0	40	0.6	0.8	0.000	0.000	0.000
	liimapuu				0	550		0	4	0	50			0.000	0.000	0.000
Puukuitulevyt	huokoinen ilman bitumia				0	300		0	16	0	120	2	1	0.000	0.000	0.000
	huokoinen bitumilla				0	350		0	18	0	120	2	1	0.000	0.000	0.000
	kova ilman bitumia				0	700	20 %	0	4	0	766	3	8	0.000	0.000	0.000
	kova bitumilla				0	900	20 %	0	4	0	766	3	8	0.000	0.000	0.000
Tuulensuojalevy					0	230	21 %	0	20	0	980	4	11	0.000	0.000	0.000
Lastulevy					0	750	20 %	0	2	0	20	0.3	1	0.000	0.000	0.000
Selluvilla					0	60	1 %	0	19	0	140	2	2	0.000	0.000	0.000
Kartonkilevyt	PE-laminointi				0	750	20 %	0		0				0.000	0.000	0.000
	lateksilaminointi				0	720	20 %	0		0				0.000	0.000	0.000
Pellavakuitu					0	150	1 %	0		0				0.000	0.000	0.000
Linoleumi					0	1200	11 %	0	7	0	1000	4	4	0.000	0.000	0.000
Kookoskuitu					0	100		0		0				0.000	0.000	0.000
Juuttikuitu					0	100				0				0.000	0.000	0.000

Step 3: Improvement

As the BEE-tool is intended primarily for analysing/assessing ready designs against specified targets there are no particular means of optimizing designs included. For this reason the optimization exercise is excluded from the case study.

Concluding Remarks

BEE is a tool for calculating the life cycle environmental impacts and annualized life cycle costs of buildings. In this exercise only the environmental impact calculations for initial embodied energy and energy in use are taken into account. Environmental impacts of recurring production and life cycle costs are not considered.
BEE is a step towards a real design tool. There are plans of starting the development of a design tool integrating building energy analysis and LCA data for building materials.

APPENDIX 5 - FRANCE

Domestic building
Analysis tool: EQUER
By: Bruno Peuportier, Ecole des Mines de Paris
Date: October 1998

Introduction

Presentation of the method

Life cycle assessment (LCA) is applied to buildings by simulating the different phases, from construction to demolition. The CML indicators are used. Data collected in the European REGENER project, or from the Oekoinventare data base (Federal polytechnic school of Zürich, Switzerland) has been used concerning the inventories corresponding to most processes (energy, transportation, manufacturing of building materials).

The simulation tool EQUER is based upon a building model structured on objects, this structure being compatible with the thermal simulation tool COMFIE. The functional unit considered is the whole building over a certain duration. Impacts due to the activities of occupants (e.g. home-work transportation, domestic waste production, water consumption) may be taken into account according to the purpose of the study: this possibility is useful e.g. when comparing various building sites with different home-work distances, waste collection system, water network efficiency etc. Coupling LCA and energy calculations simplifies the use of the tool, which makes the comparison of design alternatives easier. The object structure is presented in the following figure 1, according to a formalism taken from the STEP approach (standard for computer data exchange).

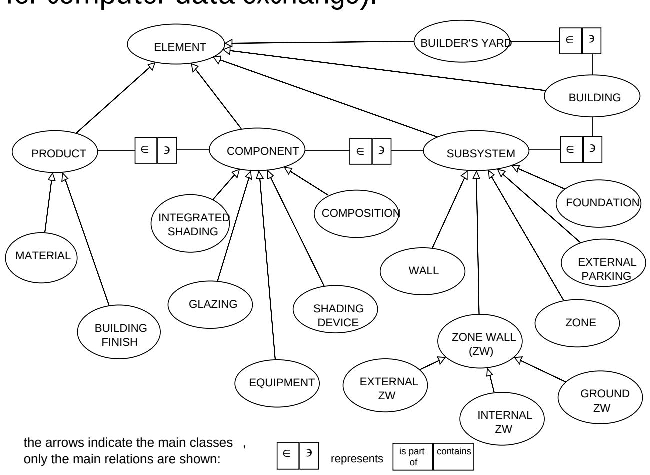


Figure 5.1: Technical building objects according to the NIAM formalism

The main classes are the products (building materials or finishes), the components (manufactured set of products like windows, shading devices,...), the subsystems (on-site built set of products and components like walls or zones), the whole building and the building site. A zone is here meant as a thermal zone, i.e. a part of the building with a homogeneous thermal behaviour. It can include several rooms with the same occupancy schedule, orientation and internal heat gains. A day lighting module has been added to the thermal simulation tool. In order to simplify this presentation, we do not consider here comfort issues and we restrict the topic of this exercise to life cycle assessment. The different phases of a building life cycle are considered (figure 2).

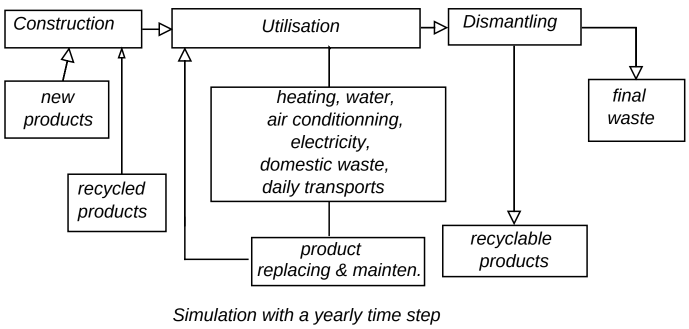


Figure 5. 2: Principle for calculating the inventory for the whole building

The output of the software is an ecoprofile including the different CML indicators (global warming, acidification, eutrophication potentials, smog, etc.), plus some agregated values like primary energy and water consumption, and generation of radioactive and other waste. These indicators are given either for the different phases or for different alternatives or projects.

Application in the IEA Annex 31 case study (domestic building)

The input uses an "architectural description" of the building, i.e. plans, facades and information about the materials and components (e.g. wall composition, type of glazing,...). Thus we did not start from the table including all quantities of materials, which is not in general available in practice (in France). But as the plans were not vey clear (e.g. the area of windows given in the table does not correspond to the scheme of facades), we modified the description so that is it approximately corresponds to the table. It is important for us that our tool is adapted to the building practice, this is why we preferred to use a description which makes comparison of alternatives easier, e.g. if we modify the area of a window (cf step 3), the area of the opaque wall in which this window is included is automatically modified accordingly.

Another characteristic of EQUER is the link between LCA and the energy simulation tool COMFIE. This allows evaluation of heating, lighting (possibly cooling) loads and thermal (possibly visual) comfort. The modification of the envelope often has consequences on theses aspects, and such a link is useful in practice. The consequence on the description of buildings is the definition of thermal zones, i.e. part of the building that are considered to be at a homogeneous temperature. In the case study proposed for the domestic building, we defined three zones : the ground floor, the first floor and the attic (considered unheated). The whole description of the building is given in annex 1. This input table has the same structure for the other steps, and is not given again for steps 2 and 3 : only the modifications are indicated.

General questions: professional use and references

EQUER may be used at various steps of a project by various actors:
- by clients when choosing a building site

In this case, a default building is considered and processes possibly differing in the various sites are accounted for: homework and home-shops transport, treatment of domestic waste, management of water:

- by clients when selecting projects in an architectural competition,
- by clients when comparing retrofitting and new construction,
- by architects and engineers during the design of new buildings or retrofitting,
- by owners when improving the management of existing buildings,
- by manufacturers wishing to design environmentally friendly products for building applications.

Concerning the design, the tool concerns all envelope components, and accounts for the link with energy aspects during use (heating, possibly cooling, lighting). Previous experience shows that components influencing energy consumption have a high contribution in the global environmental impact of buildings, concerning most environmental themes. Though, some indicators (particularly solid waste, smog, toxicity) may be more sensitive to non-energy related aspects.

The accuracy of the tool depends mainly on the accuracy of the databases of materials. A first comparison of several databases (Oekoinventare, Sima-pro, Buwal) show large discrepancies and it is difficult to provide an overall indication on accuracy. Sensitivity studies have been performed using the tool in order to check the sensitivity to the most influencing processes (gas or electricity production and use, waste and water management, transport,...). Also, an accuracy indicator is relative, and would be different whether “ qualitative ” tools are also considered or not.

EQUER has been used:

- to compare different building sites for a social housing project (by the tool developer and a property developer),
- to assist design teams working on green highschools (by an architecture agency and an engineering consultant),
- to compare various retrofitting possibilities in a collective dwelling building (by the tool developer with a general contractor),
- to evaluate the environmental performance of the EcoLogis house built for an exhibition at the science museum in Paris, organized by Committee 21 (by the developer in relation with building components manufacturers),
- to study the performance and compare alternatives concerning a social housing project, this study being compared with the results of other methods in France, in the frame of a workshop organized by the ministry of dwelling (ATEQUE),
- to compare various building materials in another working group of the same workshop (by the tool developer in relation with the industry).

EQUER complements the existing energy analysis tool COMFIE by balancing:

- energy aspects with other aspects (mostly transport, waste and water management),
- use related impacts with other phases (construction and material production, renovation, demolition).

The experience gained shows the importance of the use phase, but the other phases should not be neglected, particularly:

- o the construction phase (toxicity, smog),
- o the renovation phase (solid waste, toxicity, smog, odours),
- o the demolition phase (solid waste).

The future expectations concern the improvement of the tool (particularly concerning the accuracy of the data bases, the actualisation of environmental indicators) and the link with CAD and other technical assessment tools (STEP or IFCs approaches). A reflexion should also be made concerning the integration of LCA in professional practice, with a particular attention on environmental management (e.g. links with ISO 14001 standard). An experimental users club may be constituted, such as has been done for the energy simulation tool COMFIE. EQUER is presently an operational prototype that can be used in demonstration or innovative projects and thus contribute to improve the environmental quality of buildings.

APPENDIX 6 - GERMANY

Office building
Analysis tool: EcoPro
By: Markus Koch, IFIB, Karlsruhe
Date: September 1998

Introduction

Ecopro is an LCA-based tool, which is used early in the design process. It is meant to be used by planners and architects.

A design can be improved by the insight which can be obtained of environmental impact of materials (and by that the impact of elements and the building) during the whole planning process. There is a free choice of construction and criteria, supported with figures and schedules.

At this moment only a prototype of Ecopro exists and it is not used in practice yet. Only members of IFIB use Ecopro. At this moment a user interface is developed. For the future the intention is to link Ecopro with CAD.

Steps 1 and 2: Environmental impact of the given building, with embodied energy with(out) energy in use and optimization

Input

The input of step 1 and 2 is the same; energy in use cannot be excluded.
The following is the input:

- General description of the building user and the site
- Data of using the building, distances of transports
- General areas of the building and the elements
- Description of elements
- Energy in use (heating water and heating system) and an estimate of electrical energy

Output

Various diagrams which describe the different types of buildings, the share of the different phases of LC and the categories of elements referring to the whole building:

- Results of each element and criteria during the LC of buildings
- Description of the results in shedules/figures
- Determination of energy in use (heating system, heating water)
- Determination of electrical energy (estimation)

Figure 6.1 shows the output in figures, figure 2 the graphical output (if available).

Calculations

The calculations performed are:

- Mass calculation (DIN 277, Standard of Germany)
- Cost calculation (DIN 276, Standard of Germany)
- Environmental impacts. The calculation is based on “Ecoinvent” data base and the “Baustoffdaten-Ökoinventare”, Germany/Switzerland, SIA 380/1 Standards of Switzerland
- End energy consumption in use (direct/indirect) with energy in use values of UCPTE-Energy-mix

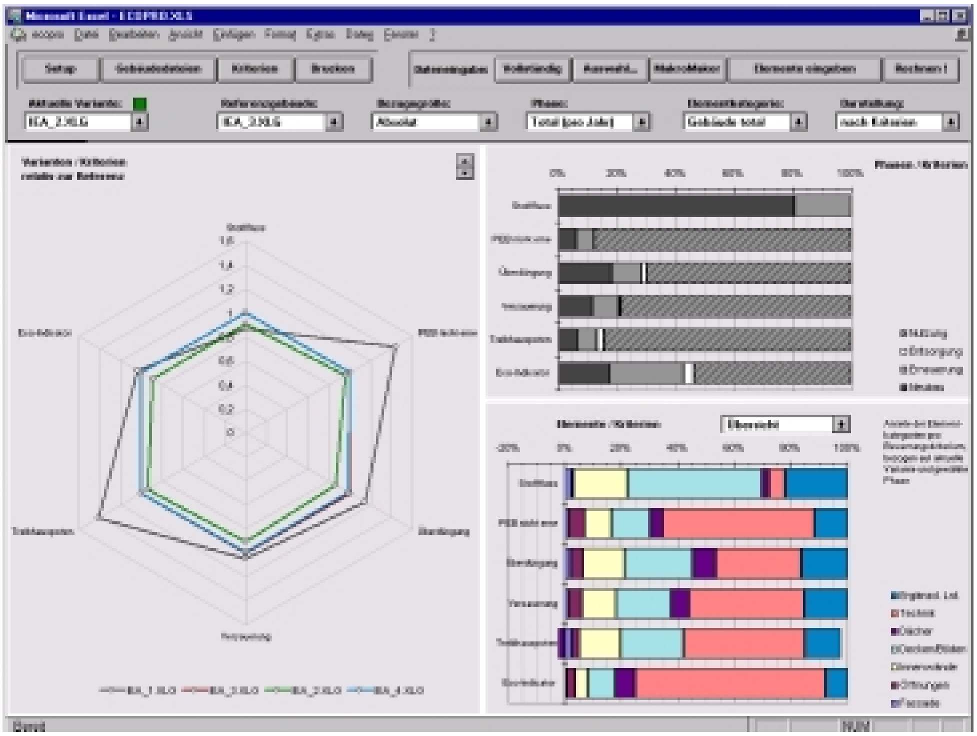
Conclusions

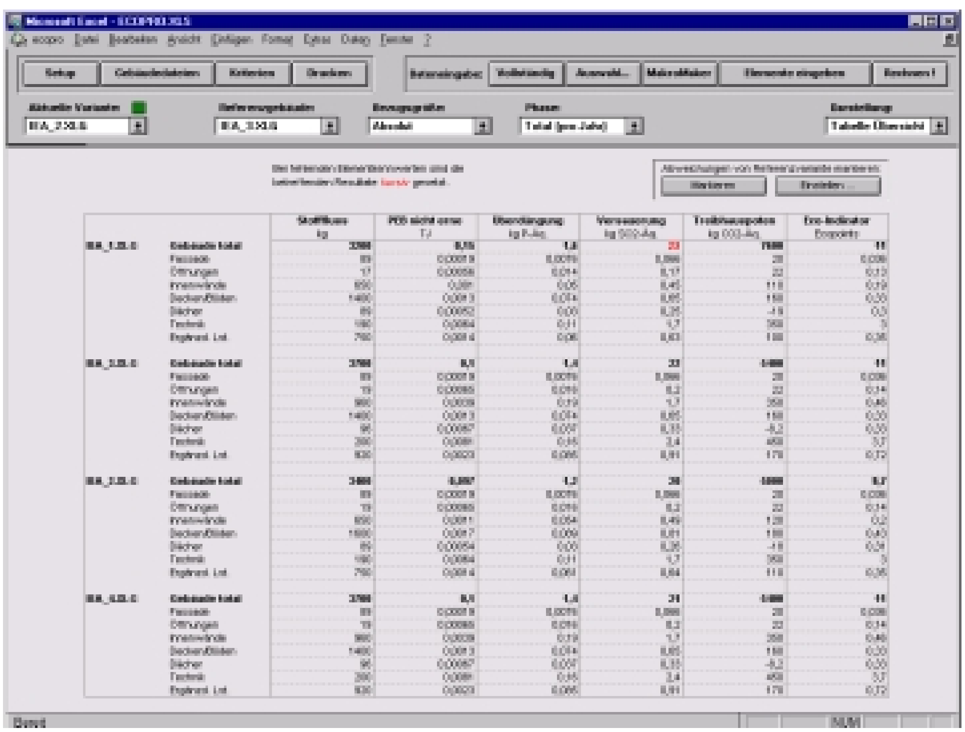
The operating energy consumption is responsible for 85 -88% of the environmental impacts during the whole LC. A higher insulation reduces the energy in use.

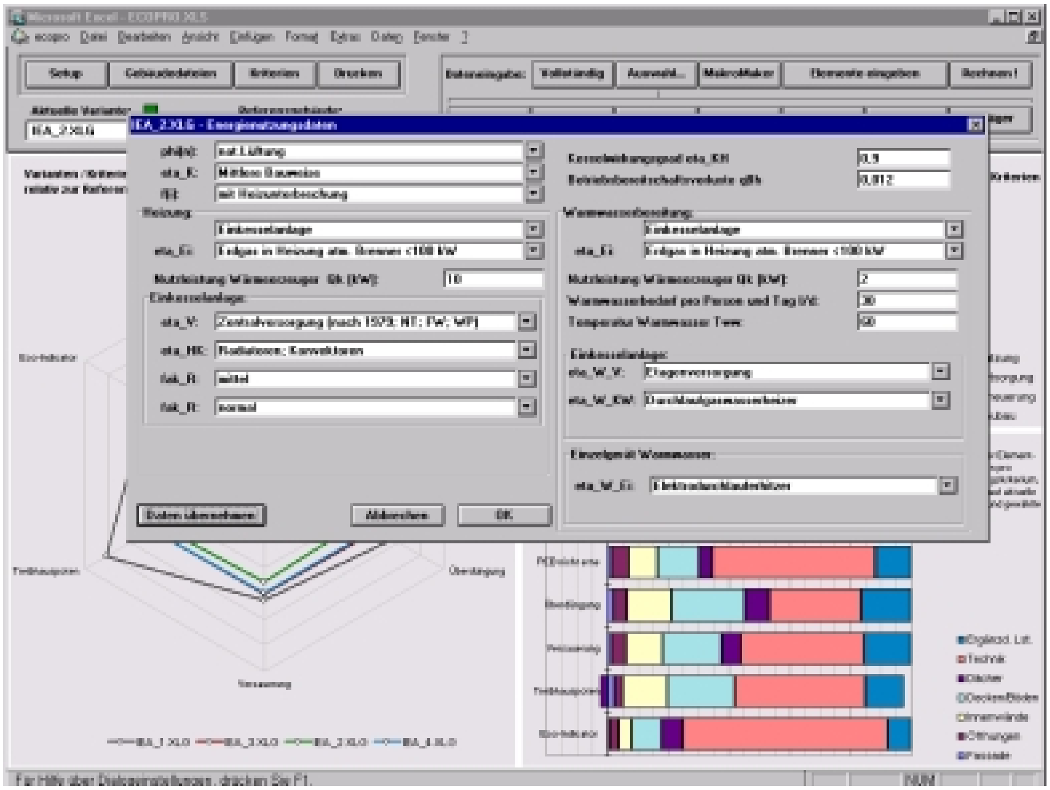
Step 3: Environmental impact of the building, demonstrating how the tool assists in improving the design

With a description of the final results it is possible for the user to make a conclusion between several types of buildings and the building constructions. The result is an optimization between the effects, which is chosen by the planners. You can chose six criteria out of a pool of 20 criteria.

The planner can create his own elements, based on information of different raw materials (separate tool). You can aggregate the materials in the elements with its special background information.







Concluding Remarks

Ecopro is an LCA-based tool, which is used early in the design process. It is meant to be used by planners and architects.

A design can be improved by the insight that can be obtained of environmental impact of materials (and by that the impact of elements and the building) during the whole planning process. There is a free choice of constructions and criteria, supported with figures and schedules.

The output is presented in a spider graphic and tables. At this moment Ecopro is an Excel spreadsheet. A user interface is built around, so it will become an easy to use tool for architects.

APPENDIX 7 – JAPAN DOMESTIC BUIDLING

Domestic building
Analysis tool: BRI-LCA
By: Noriyoshi Yokoo, Utsunomiya University, Utsunomiya, Japan
Date: August 21, 1998

Introduction

The program BRI-LCA is composed of several main routines, and the effect of the types of the building, the locations of the buildings, the types of the materials and components being used, the life style of the dwellers of the houses, the characteristics of the buildings, the construction and demolition method and the transportation method can be evaluated.

Compiling database for the inventory is an important task that compared to the task of making an interactive calculation program itself. Data on consumption of energy were collected through enormous surveys. Not only using the input/output tables but also investigating the direct energy input. The categories of the inventory are as follows:

1. Materials and components.
2. Assembling system on construction site
3. Building service.
4. Renewal and renovation
5. Demolition

As the energy consumption and CO_2 emission due to the renewal and renovation of the finishing of the buildings is automatically calculated by the data of the service life of the finishing materials and components, there is no input menu for the renewal renovation. Also the energy consumed and CO_2 emitted by both on site construction and transportation to the site is automatically calculated.

Step 1

There are input items for types of the building, locations of the building, scale of the building, materials and components being used, (temporary work, foundation work, earth work, formwork, concrete work, reinforcing bar work, prefabricated concrete, carpentry, the facilities, the roof, exterior wall, the opening part, the interior finishing). The database of energy consumption and CO_2 emission are already in the program. When the amount of materials in use is evaluated, environmental load at construction, in other words, energy consumption and CO_2 emission are calculated. Table 1 shows input data of domestic building, table 2 shows energy consumption and CO_2 emission of materials and construction. Energy consumption is 6.94 GJ/year and CO_2 emission is 251 Kg-CO_2/year.

Case	Domestic Building
building use	residence
structure	reinforced concrete wall construction
floor area	140m2
construction site	Tokyo
assembling system	No
lifetime building	50years

Table 7.1: Domestic Building for Step 1

Item	INPUT DATA (quantities)		Energy Intensity		CO2 Intensity	
Concrete	49.54	m3	1315.72	MJ/m3	67.30	kg-c/m3
Rainforcement	2485.41	kg	14.65	MJ/kg	0.28	kg-c/kg
Mortar	8565.97	kg	1.07	MJ/kg	0.12	kg-c/kg
Bitumen	8.00	m2	230.53	MJ/m2	8.77	kg-c/m2
Brick	6816.00	piece	8.29	MJ/piece	0.14	kg-c/piece
Lumber(pinewood,meranti)	3.37	m3	1484.13	MJ/m3	19.35	kg-c/m3
MineralWool	259.18	m2	34.23	MJ/kg	0.68	kg-c/kg
Sand	4847.04	kg	5.87	MJ/kg	0.12	kg-c/kg
Sand lime brick	2.32	m3	2672.47	MJ/m3	88.13	kg-c/m3
Ceramics Tile	14.73	m2	41.91	MJ/m3	1.86	kg-c/m3
Gypsum WallBoard	4847.77	kg	0.75	MJ/kg	0.14	kg-c/kg
Single Glazing	2.70	m2	80.62	MJ/m2	5.92	kg-c/m2
Double Glazing	8.40	m2	562.77	MJ/m2	41.31	kg-c/m2
WallPaper	170.00	m2	36.75	MJ/m2	2.77	kg-c/m2
InternalDoor	11.77	m2	881.62	MJ/m2	69.19	kg-c/m2
Chipboard	1212.27	kg	0.85	MJ/kg	0.18	kg-c/kg
Copper	25.80	kg	7.07	MJ/kg	0.59	kg-c/kg
Steel	268.84	kg	9.37	MJ/kg	0.91	kg-c/kg
Gravel	74.25	kg	5.87	MJ/kg	0.12	kg-c/kg
PVC(Pipes etc.)	58.99	kg	28.13	MJ/kg	0.55	kg-c/kg
Sink	2.00	piece	67.87	MJ/piece	1.11	kg-c/piece
WC Suites	1.00	piece	67.87	MJ/piece	1.11	kg-c/piece
Ventilation	1.00	piece	31.98	MJ/piece	0.66	kg-c/piece
Boiler	1.00	piece	207.21	MJ/piece	2.64	kg-c/piece

Table 7.1: Domestic Building data for Step 1

	E(GJ/year)	CO2(Kg-C/year
materials	4.99	200.33
construction	1.95	50.70
heating load for house	-	-
cooling load for house	-	-
cooking load for house	-	-
hot-water supply load for house	-	-
lighting load for house	-	-
solar energy load for house	-	-
electric power load for office building	-	-
gas load for office building	-	-
kerosene load for office building	-	-
new materials used at repair work	-	-
re-cycled materials used at repair wo	-	-
total of materials	4.99	200.33
total of construction	1.95	50.70
total of building service	-	-
total of renewal and renovation	-	-
total of demolition	-	-
total	6.94	251.03

Table 7.2: Output data of Domestic Building for Step 1

Step 2

In step 2, structure was changed according to Japanese building codes. Definitely, quantity of concrete and reinforcing rod increased substantially.

As a result, the quantity of energy consumption in construction increased 70%, quantity of CO_2 emission increased 55% in comparison with the step1 building. Table 3 shows input data of domestic building for step 2. In step 2 calculations about the environment load at operation is also done. In BRI-LCA, when inputting the location, scale of the building, thermal insulating materials of roof, opening and wall, annual cooling/ heating load is set up. As also the other input data, there is the dwellers way of living and by inputting other conditions needed, energy consumption and CO_2 emission are automatically calculated. As table 4 shows, way of living was set up as ordinary home in Japan.

Figure 1 shows energy consumption of domestic building, figure 2 shows CO_2 emission of domestic building.

Case	Domestic Building
building use	residence
structure	reinforced concrete wall construction
floor area	140m2
construction site	Tokyo
assembling system	no
lifetime building	50years

Item	INPUT DATA (quantities)	Energy Intensity	CO2 Intensity
Concrete	102.76 m3	1315.72 MJ/m3	67.30 kg-c/m3
Rainforcement	14000.00 kg	14.65 MJ/kg	0.28 kg-c/kg
Mortar	8565.97 kg	1.07 MJ/kg	0.12 kg-c/kg
Bitumen	8.00 m2	230.53 MJ/m2	8.77 kg-c/m2
Brick	6816.00 piece	8.29 MJ/piece	0.14 kg-c/piece
Lumber(pinewood,meranti)	3.37 m3	1484.13 MJ/m3	19.35 kg-c/m3
Mineral Wool	259.18 m2	34.23 MJ/kg	0.68 kg-c/kg
Sand	4847.04 kg	5.87 MJ/kg	0.12 kg-c/kg
Sand lime brick	2.32 m3	2672.47 MJ/m3	88.13 kg-c/m3
Ceramics Tile	14.73 m2	41.91 MJ/m3	1.86 kg-c/m3
Gypsum Wall Board	4847.77 kg	0.75 MJ/kg	0.14 kg-c/kg
Single Glazing	2.70 m2	80.62 MJ/m2	5.92 kg-c/m2
Double Glazing	8.40 m2	562.77 MJ/m2	41.31 kg-c/m2
Wall Paper	170.00 m2	36.75 MJ/m2	2.77 kg-c/m2
Internal Door	11.77 m2	881.62 MJ/m2	69.19 kg-c/m2
Chipboard	1212.27 kg	0.85 MJ/kg	0.18 kg-c/kg
Copper	25.80 kg	7.07 MJ/kg	0.59 kg-c/kg
Steel	268.84 kg	9.37 MJ/kg	0.91 kg-c/kg
Gravel	74.25 kg	5.87 MJ/kg	0.12 kg-c/kg
PVC (Pipes etc.)	58.99 kg	28.13 MJ/kg	0.55 kg-c/kg
Sink	2.00 piece	67.87 MJ/piece	1.11 kg-c/piece
WC Suites	1.00 piece	67.87 MJ/piece	1.11 kg-c/piece
Ventilation	1.00 piece	31.98 MJ/piece	0.66 kg-c/piece
Heatpump	2.00 piece	2442.56 MJ/piece	33.10 kg-c/piece
Boiler	1.00 piece	207.21 MJ/piece	2.64 kg-c/piece

Table 7.3: Domestic Building for Step 2

	E(GJ/year)	CO2(Kg-C/year j
materials	9.87	338.46
construction	1.95	50.70
heating load for house	1.70	44.39
cooling load for house	0.41	10.61
cooking load for house	3.13	81.60
hot-water supply load for house	21.79	567.92
lighting load for house	26.98	703.11
solar energy load for house	0.00	0.00
electric power load for office building	-	-
gas load for office building	-	-
kerosene load for office building	-	-
new materials used at repair work	2.10	44.22
re-cycled materials used at repair work	0.00	0.00
total of materials	9.87	338.46
total of construction	1.95	50.70
total of building service	54.01	1407.63
total of renewal and renovation	2.10	44.22
total of demolition	0.31	8.03
total	68.24	1849.04

Table 4 Way of Living

Item	Input Data	Unit
way of dwelling	1	house
number of person who's age is over 10	3	person
number of person who's age is over 10	1	person
annual incom	7.5	million yen
breakfast(take or not)	take	
employment of house wife	no	
frequency of taking bath	5	times
frequency of taking shower	5	times
consciousness of energy conservation	average	
solar heating panel	0	m2
type of central heating	yes	
number of rooms using central heating	5	room
number of rooms using central ventilation	5	room
number of gas stopcock	0	

Table 7.5

Figure 7. 1: Domestic Building for step 2

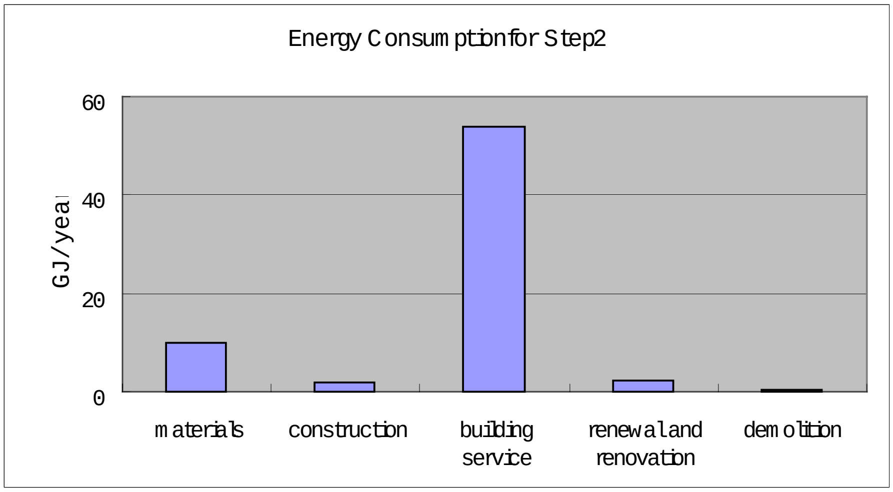
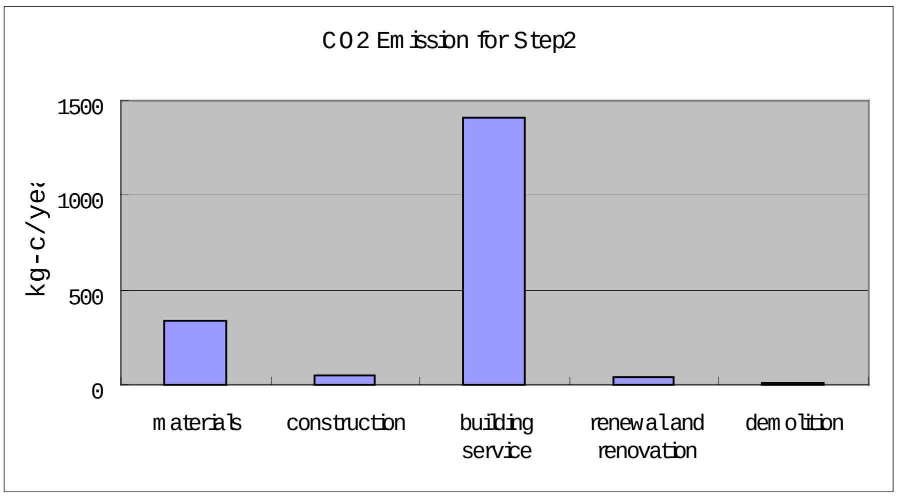


Figure 7.2: Domestic Building for step 2



Step 3

In step 3, the industrialization method of construction was adopted, and steel (electric furnace) that the environment load used is small. For reduction of environmental load at operation, solar water heater was used and alteration of dwellers' consciousness to saving energy was done.

Table 6 shows input data of domestic building for step 3. Table 7 shows input data of domestic building's type of lifestyle for step 3. Table 8 shows output data of domestic building.

In comparison with step 1, energy consumption increased 40%, CO_2 emission increased 35% at materials and construction. In comparison with step 2, energy consumption decreased 17.67%, CO_2 emission decreased 12.69% at materials and construction. Energy consumption decreased 40%, CO_2 emission decreased 40% at the time of building service. This is because hot-water supply is provided by solar energy entirely. Figure 3 shows energy consumption of domestic building, and figure 4 shows CO_2

emission of domestic building. BRI-LCA can calculate the environmental loads of renewal and demolition if necessary conditions are given. In this case study because the default value are used, the result of renewal and demolition at step 2 and step 3 are equal.

Table 7.6: Domestic Building for Step 3

Case	Domestic Building
building use	residence
structure	reinforced concrete wall construction
floor area	140m2
construction site	Tokyo
assembling system	yes
lifetime building	50years

Item	INPUT DATA (quantities)	Energy Intensity	CO2 Intensity
Concrete	102.76 m3	1315.72 MJ/m3	67.30 kg-c/m3
Rainforcement	14000.00 kg	9.30 MJ/kg	0.16 kg-c/kg
Mortar	8565.97 kg	1.07 MJ/kg	0.12 kg-c/kg
Bitumen	8.00 m2	230.53 MJ/m2	8.77 kg-c/m2
Brick	6816.00 piece	8.29 MJ/piece	0.14 kg-c/piece
Lumber(pinewood, meranti)	3.37 m3	1484.13 MJ/m3	19.35 kg-c/m3
Mineral Wool	259.18 m2	34.23 MJ/kg	0.68 kg-c/kg
Sand	4847.04 kg	5.87 MJ/kg	0.12 kg-c/kg
Sand lime brick	2.32 m3	2672.47 MJ/m3	88.13 kg-c/m3
Ceramics Tile	14.73 m2	41.91 MJ/m3	1.86 kg-c/m3
Gypsum Wall Board	4847.77 kg	0.75 MJ/kg	0.14 kg-c/kg
Single Glazing	2.70 m2	80.62 MJ/m2	5.92 kg-c/m2
Double Glazing	8.40 m2	562.77 MJ/m2	41.31 kg-c/m2
Wall Paper	170.00 m2	36.75 MJ/m2	2.77 kg-c/m2
Internal Door	11.77 m2	881.62 MJ/m2	69.19 kg-c/m2
Chipboard	1212.27 kg	0.85 MJ/kg	0.18 kg-c/kg
Copper	25.80 kg	7.07 MJ/kg	0.59 kg-c/kg
Steel	268.84 kg	9.37 MJ/kg	0.91 kg-c/kg
Gravel	74.25 kg	5.87 MJ/kg	0.12 kg-c/kg
PVC (Pipes etc.)	58.99 kg	28.13 MJ/kg	0.55 kg-c/kg
Sink	2.00 piece	67.87 MJ/piece	1.11 kg-c/piece
WC Suites	1.00 piece	67.87 MJ/piece	1.11 kg-c/piece
Ventilation	1.00 piece	31.98 MJ/piece	0.66 kg-c/piece
Heatpump	2.00 piece	2442.56 MJ/piece	33.10 kg-c/piece
Boiler	1.00 piece	207.21 MJ/piece	2.64 kg-c/piece

Table 7.7 of Domestic Building for Step 3

Item	Input Data	Unit
way of dwelling	1	house
number of person who's age is over 10	3	person
number of person who's age is over 10	1	person
annual incom	7.5	million yen
breakfast(take or not)	take	
employment of house wife	no	
frequency of taking bath	5	times
frequency of taking shower	5	times
consciousness of energy conservation	high	
solar heating panel	9	m2
type of central heating	yes	
number of rooms using central heating	5	room
number of rooms using central ventilation	5	room
number of gas stopcock	0	

Table 7.8: Out of Domestic Building for Step 3

	E(GJ/year)	CO2(Kg-C/year
materials	13.58	406.05
construction	1.36	35.49
heating load for house	1.70	44.39
cooling load for house	0.41	10.61
cooking load for house	3.13	81.60
hot-water supply load for house	0.00	0.00
lighting load for house	26.98	703.11
solar energy load for house	25.49	0.00
electric power load for office building	-	-
gas load for office building	-	-
kerosene load for office building	-	-
new materials used at repair work	2.10	44.22
re-cycled materials used at repair wo	0.00	0.00
total of materials	8.37	304.30
total of construction	1.36	35.49
total of building service	32.22	839.71
total of renewal and renovation	2.10	44.22
total of demolition	0.31	8.03
total	44.36	1231.75

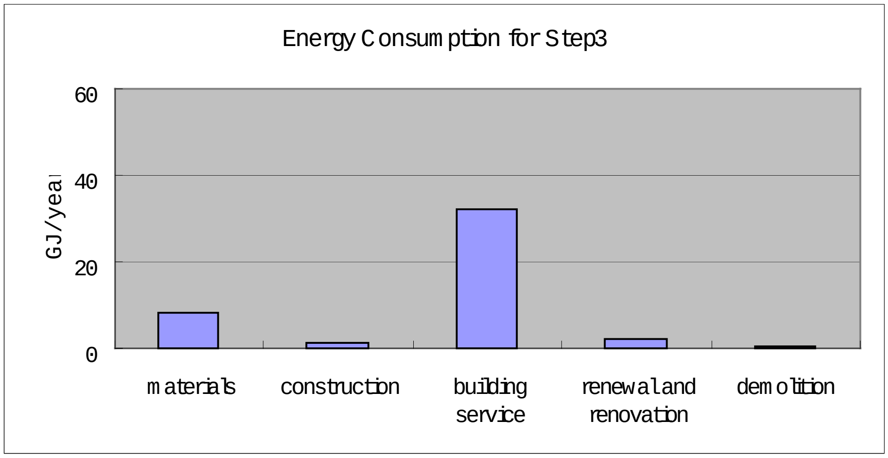


Figure 7.3: Energy Consumtion of Domestic Building

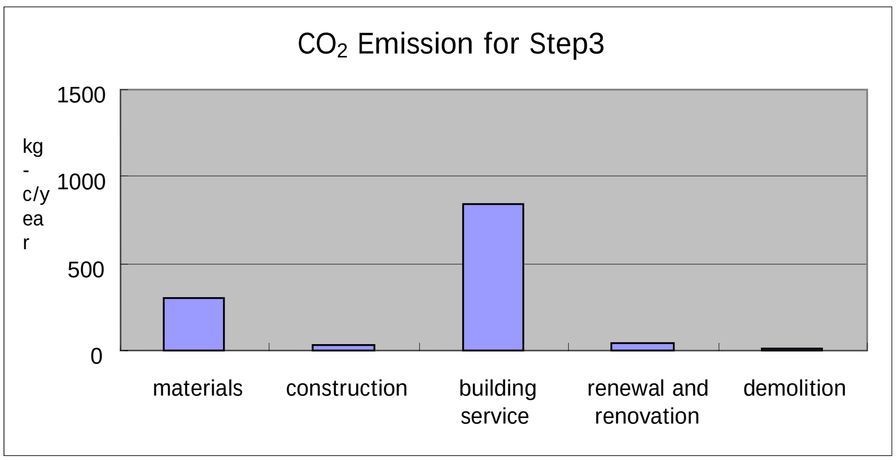


Figure 7.4: CO_2 Emission of Domestic Building

Concluding Remarks

The main purpose of BRI-LCA is to estimate and evaluate energy consumption concerning building through its life cycle. It includes not only energy consumption during building operation, but also during construction, repair work, demolition and removal.

When an energy conservation technique is considered, it is examined to see whether the amount of energy saved compensates for the amount of energy used to implement the new technique. It is evaluated to determine the amount of energy saved caused by the adaptive energy conservation technique and to account for what total amount of energy is conserved.

The tool can be used at the first stage of building design: it is then possible to reduce the energy consumption and CO_2 emissions. It is possible to decrease energy consumption and CO_2 emission at the first stage of building design. Materials and energy conservation techniques can be changed and compared with energy consumption and CO_2 emissions at each stage of construction, operation, repair work and demolition.

The tool is to be used by engineers at working level. At this moment the tool is not yet used and there are no experiences with the tool.

For the future

As for materials, energy consumption at production of materials, and at building operation, it is necessary that more accurate data are to be made for more accurate evaluation. The evaluation of load for each energy conservation technique must be possible. Choice of energy conservation techniques is not varied enough.

APPENDIX 8 – JAPAN OFFICE BUILDING

Office building
Analysis tool: BRI-LCA
By: Noriyoshi Yokoo, Utsunomiya University, Utsunomiya, Japan
Date: August 1998

Introduction

The program is composed of several main routines, and the effect of the types of the building, the locations of the buildings, the types of the materials and components being used, the life style of the dwellers of the houses, the characteristics of the office buildings, the construction and demolition method and the transportation method can be evaluated.

Data base compilation for the inventory is an important task that compared to the task of making an interactive calculation program. Data on consumption of energy were collected through enormous surveys. Not only using the input/output tables but also investigating the direct energy input. The categories of the inventory are as follows;

- Materials and components.
- Assembling system on construction site
- Building service.
- Renewal and renovation
- Demolition

As the energy consumption and CO_2 emission due to the renewal and renovation of the finishing of the buildings is automatically calculated by the data of the service life pf the finishing materials and components, there is no input menu for the renewal renovation. Also the energy consumed and CO_2 emit by the labors both on site and on the way to the site is automatically calculated.

Step 1

There are input item of types of the building, locations of the building, scale of the building, materials and components being used, (temporary work, foundation work, earth work, formwork, concrete work, reinforcing bar work, prefabricated concrete, carpentry, the facilities, the roof, exterior wall, the opening part, the interior finishing) The data base of energy consumption and CO_2 emission are already in the program. When the amount of materials in use is evaluated, environmental load at construction, in other words, energy consumption and CO_2 emission are calculated. Table 1 shows input data of office building, table 2 shows energy consumption and CO_2 emission at construction. Energy consumption is 102GJ/year and CO_2 emission is 3651.89Kg-c/year.

Table 1 of Office Building for Step 1

Case	office
building use	office
structure	reinforced concrete frame
floor area	1500m2
construction site	Tokyo
assembling system	no
lifetime building	40years

Item	INPUT DATA (quantities)		Energy Intensity		CO2 Intensity	
Concrete(Columns,Girder,etc.)	605.70	m3	1315.72	MJ/m3	67.300	kg-c/m3
Reinforcement	53266.50	kg	14.63	MJ/kg	0.283	kg-c/kg
RC Pile	199680.00	kg	1.95	MJ/kg	0.063	kg-c/kg
Concreat Block(Wall)	55.44	m3	2672.55	MJ/m3	88.125	kg-c/m3
Brick	18420	piece	8.29	MJ/piece	0.143	kg-c/piece
Polyuretaan(Roofs)	52.92	m2	774.96	MJ/m3	64.560	kg-c/m3
Polyuretaan(Walls)	13.92	m2	1335.27	MJ/m3	108.870	kg-c/m3
Glazing(double)	399.00	m2	562.77	MJ/m2	41.310	kg-c/m2
PVC(Window frame)	393.00	m2	346.60	MJ/m2	27.140	kg-c/m2
Glass	1.67	m2	80.60	MJ/m2	5.920	kg-c/m2
Sand Cement(Floor Finishing)	576.00	m2	39.47	MJ/m2	2.019	kg-c/m2
Asphalt Roofing Felt	756.00	m2	230.53	MJ/m2	8.773	kg-c/m2
Steel	2836.70	kg	19.51	MJ/kg	0.393	kg-c/kg
Steel(pipe)	190.00	m	625.94	MJ/m	10.370	kg-c/m
Boiler	2	piece	207.21	MJ/piece	2.640	kg-c/piece
Ventilation	1	piece	31.98	MJ/piece	0.657	kg-c/piece

Table 8.1 of Office Building for Step 1

	E(GJ/year)	CO2(Kg-C/year
materials	76.49	2972.86
constraction	26.06	679.03
heating load for house	-	-
cooling load for house	-	-
cooking load for house	-	-
hot-water supply load for house	-	-
lighting load for house	-	-
solar energy load for house	-	-
electric power load for office building	-	-
gas load for office building	-	-
kerosene load for office building	-	-
new materials used at repair work	-	-
re-cycled materials used at repair wor	-	-
total of materials	76.49	2972.86
total of constraction	26.06	679.03
total of building service	-	-
total of renewal and renovation	-	-
total of demolition	-	-
total	102.55	3651.89

Table 8.2: Output Data of Office Building for Step 1

Step 2

In step 2, the structure was changed according to Japanese building codes. Quantities of concrete and reinforcing rod definitely increased substantially. As a result the quantity of energy consumption in construction increased 54%, quantity of CO_2 emission increased 39% in comparison with the standard building.

Table 3 shows input data of the office building for step 2. Step 2 calculation about the environment load at operation is also done. In BRI-LCA, when inputting the location, the annual cooling/heating load is set up. As also the other input data, there is a building service and facility outline, and by inputting other conditions needed, energy consumption and CO2 emission are automatically calculated.

As table 4 shows building service and facility outline were set up as general 1500m^2 scale office building in Japan. Energy consumption at operation is 1902GJ/year and CO_2 emission is 26047Kg-C/year. The quantity of electricity, gas, the energy consumption by kerosene, and the CO_2 emission are shown as table 5.

Figure 1 shows energy consumption of the office building, figure 2 shows CO_2 emission of the office building.

Case	office
building use	office
structure	reinforced concrete frame
floor area	1500m2
construction site	Tokyo
lifetime building	40years

Item	INPUT DATA (quantities)		Energy Intensity		CO2 Intensity	
Concrete(Columns,Girder,etc.)	1158.00	m3	1315.72	MJ/m3	67.300	kg-c/m3
Reinforcement	154500.00	kg	14.63	MJ/kg	0.283	kg-c/kg
RC Pile	199680.00	kg	1.95	MJ/kg	0.063	kg-c/kg
Concreat Block(Wall)	55.44	m3	2672.55	MJ/m3	88.125	kg-c/m3
Brick	18420	piece	8.29	MJ/piece	0.143	kg-c/piece
Polyuretaan(Roofs)	52.92	m2	774.96	MJ/m3	64.560	kg-c/m3
Polyuretaan(Walls)	13.92	m2	1335.27	MJ/m3	108.870	kg-c/m3
Glazing(double)	399.00	m2	562.77	MJ/m2	41.310	kg-c/m2
PVC(Window frame)	393.00	m2	346.60	MJ/m2	27.140	kg-c/m2
Glass	1.67	m2	80.60	MJ/m2	5.920	kg-c/m2
Sand Cement(Floor Finishing)	576.00	m2	39.47	MJ/m2	2.019	kg-c/m2
Asphalt Roofing Felt	756.00	m2	230.53	MJ/m2	8.773	kg-c/m2
Steel	2836.70	kg	19.51	MJ/kg	0.393	kg-c/kg
Steel(pipe)	190.00	m	625.94	MJ/m	10.370	kg-c/m
Boiler	2	piece	207.21	MJ/piece	2.640	kg-c/piece
Ventilation	1	piece	31.98	MJ/piece	0.657	kg-c/piece
Heatpump	3	piece	2442.56	MJ/piece	33.100	kg-c/piece

Table 8.3 of Office Building for Step 2

Item	Unit	Value
Year of construction	year	98
Gross floor Area	~,P000 ,0	15
Number of Floor		2
Ratio of shop floor area	%	0
Business hour	hour	9
Electric Equipment Capacity of Lighting	W/m2(gross floor area)	25
Electric Equipment Capacity of Cooling	W/m2(gross floor area)	30
Electric Equipment Capacity of Heating	W/m2(gross floor area)	5
Electric Equipment Capacity of Fan	W/m2(gross floor area)	10
Electric Equipment Capacity of Plumbin	W/m2(gross floor area)	5
Electric Equipment Capacity of Another	W/m2(gross floor area)	10
Capacity of Boiler Equipment	kcal/m2(gross floor area)	80
Capacity of Refrigerating Equipment	kcal/m2(gross floor area)	80
Air Conditioning System with Packaged	Yes/No	Y
Water-to-Air System	Yes/No	Y
Another System	Yes/No	N
Combined System of Contrifugal and ab	Yes/No	N
Absorption Hot and Chilled Water Gener	Yes/No	N
Bilding Management on Commission	Yes/No	N
Using of Total Heat Exchanger	Yes/No	N
Thermal Storage Tank	Yes/No	N
Capacity of Single-Phase Transformer	W/m2(gross floor area)	30
Capacity of Three-Phase Transformer	W/m2(gross floor area)	50
Contract Demand	W/m2(gross floor area)	80
Capacity of Transformer	W/m2(gross floor area)	80
Number of user	W/m2(gross floor area)	0.05
Single-Duct System	Yes/No	N
Dual-Duct System	Yes/No	N
Fan coil Unit System	Yes/No	Y
Water-Cooled Packaged Air Conditioner	Yes/No	N
Heat Pump Packaged Air Conditioner	Yes/No	Y
Heavy Oil Boiler	Yes/No	N
Perimeter Annual Load factor		72.3
Coeffieient of energy Consumption of Airconditioning		1.5
Coeffieient of energy Consumption of Mechanical Ventilation		1.2
Coeffieient of energy Consumption of Lighting		1
Coeffieient of energy Consumption of Elevator		1

Table 8.4 of Office Building for Step 2 (Type of Facilities)

Table 8.5: Out of Office Building for Step 2

	E(GJ/year)	CO2(Kg-C/year
materials	131.87	4620.82
construction	26.06	679.03
heating load for house	-	-
cooling load for house	-	-
cooking load for house	-	-
hot-water supply load for house	-	-
lighting load for house	-	-
solar energy load for house	-	-
electric power load for office building	1133.93	14447.09
gas load for office building	671.97	10273.72
kerosene load for office building	96.69	1686.87
new materials used at repair work	22.39	559.64
re-cycled materials used at repair wor	0.00	0.00
total of materials	131.87	4620.82
total of construction	26.06	475.32
total of building service	1902.59	26407.68
total of renewal and renovation	22.39	238.03
total of demolition	56.82	106.29
total	2139.73	31848.14

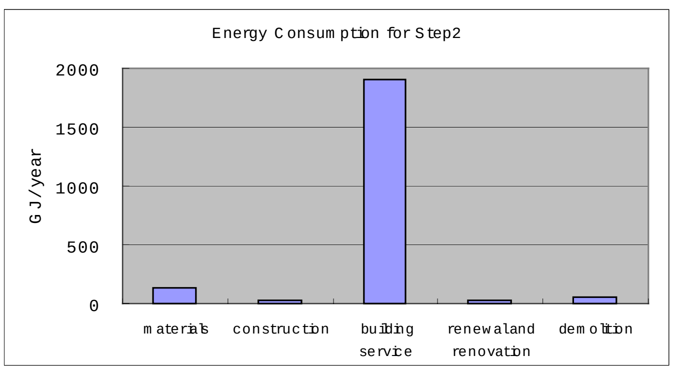


Figure 8.1: Energy Consumption of Office Building

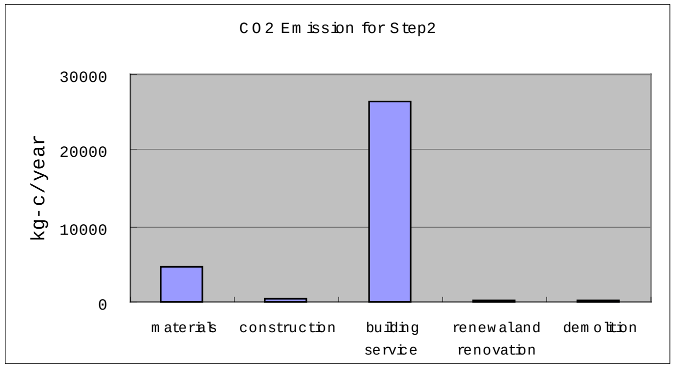


Figure 8.2: CO_2 Emission of Office Building

Step 3

In step 3, the adoption of the industrialization method of construction, the use of steel (electric furnace) that the environment load is small, introduction of total heat exchanger for air conditioning, and made opening part only on north and south side of surface.

Table 6 shows input data of office building for table 6. Table 7 shows input data of office building's type of facilities for step 3. Table 8 shows output data of office building.

In comparison with step 1, energy consumption increased 26%, CO_2 emission increased 26% at the time of construction. In comparison with step 2, energy consumption decreased 17%, CO_2 emission decreased 9% at the time of construction. Energy consumption decreased 10%, CO_2 emission decreased 11% at the time of building service.

Figure 3 shows energy consumption of office building, and figure 4 shows CO_2 emission of office building.

3

Case	office
building use	office
structure	reinforced concrete frame
floor area	1500m2
construction site	Tokyo
lifetime building	40years

Item	INPUT DATA (quantities)		Energy Intensity		CO2 Intensity	
Concrete(Columns,Girder,etc.)	1158.00	m3	1315.72	MJ/m3	67.300	kg-c/m3
Reinforcement	154500.00	kg	9.30	MJ/kg	0.161	kg-c/kg
R.C.Pile	199680.00	kg	1.95	MJ/kg	0.063	kg-c/kg
Concreat Block(Wall)	55.44	m3	2672.55	MJ/m3	88.125	kg-c/m3
Brick	18420	piece	8.29	MJ/piece	0.143	kg-c/piece
Polyuretaan(Roofs)	52.92	m2	774.96	MJ/m3	64.560	kg-c/m3
Polyuretaan(Walls)	13.92	m2	1335.27	MJ/m3	108.870	kg-c/m3
Glazing(double)	399.00	m2	562.77	MJ/m2	41.310	kg-c/m2
PVC(Window frame)	393.00	m2	346.60	MJ/m2	27.140	kg-c/m2
Glass	1.67	m2	80.60	MJ/m2	5.920	kg-c/m2
Sand Cement(Floor Finishing)	576.00	m2	39.47	MJ/m2	2.019	kg-c/m2
Asphalt Roofing Felt	756.00	m2	230.53	MJ/m2	8.773	kg-c/m2
Steel	2836.70	kg	19.51	MJ/kg	0.393	kg-c/kg
Steel(pipe)	190.00	m	625.94	MJ/m	10.370	kg-c/m
Boiler	2	piece	207.21	MJ/piece	2.640	kg-c/piece
Ventilation	1	piece	31.98	MJ/piece	0.657	kg-c/piece
Heatpump	3	piece	2442.56	MJ/piece	33.100	kg-c/piece

Table 8.6: Input data Office Building for Step 3

Item	Unit	Value
Year of construction	year	98
Gross floor Area	~P,000 ,0	1.5
Number of Floor		2
Ratio of shop floor area	%	0
Business hour	hour	9
Electric Equipment Capacity of Lighting	W/m2(gross floor area)	25
Electric Equipment Capacity of Cooling	W/m2(gross floor area)	30
Electric Equipment Capacity of Heating	W/m2(gross floor area)	5
Electric Equipment Capacity of Fan	W/m2(gross floor area)	10
Electric Equipment Capacity of Plumbin	W/m2(gross floor area)	5
Electric Equipment Capacity of Another	W/m2(gross floor area)	10
Capacity of Boiler Equipment	kcal/m2(gross floor area	80
Capacity of Refrigerating Equipment	kcal/m2(gross floor area	80
Air Conditioning System with Packaged	Yes/No	Y
Water-to-Air System	Yes/No	Y
Another System	Yes/No	N
Combined System of Contrifugal and ab	Yes/No	N
Absorption Hot and Chilled Water Gener	Yes/No	N
Bilding Management on Commission	Yes/No	Y
Using of Total Heat Exchanger	Yes/No	Y
Thermal Storage Tank	Yes/No	N
Capacity of Single-Phase Transformer	W/m2(gross floor area)	30
Capacity of Three-Phase Transformer	W/m2(gross floor area)	50
Contract Demand	W/m2(gross floor area)	80
Capacity of Transformer	W/m2(gross floor area)	80
Number of user	W/m2(gross floor area)	0.05
Single-Duct System	Yes/No	N
Dual-Duct System	Yes/No	N
Fan coil Unit System	Yes/No	Y
Water-Cooled Packaged Air Conditioner	Yes/No	N
Heat Pump Packaged Air Conditioner	Yes/No	Y
Heavy Oil Boiler	Yes/No	N
Perimeter Annual Load factor		67.3
Coeffieient of energy Consumption of Airconditioning		1.5
Coeffieient of energy Consumption of Mechanical Ventilation		1.2
Coeffieient of energy Consumption of Lighting		1
Coeffieient of energy Consumption of Elevator		1

Table 8.7: Office Building facilities for Step 3 (Type of Facilities)

Table 8.8: Output data for Office Building

	E(GJ/year)	CO_2(Kg-C/year
materials	111.28	4149.59
construction	18.24	475.32
heating load for house	-	-
cooling load for house	-	-
cooking load for house	-	-
hot-water supply load for house	-	-
lighting load for house	-	-
solar energy load for house	-	-
electric power load for office building	1133.93	14447.09
gas load for office building	466.36	7130.09
kerosene load for office building	96.69	1686.87
new materials used at repair work	22.39	559.64
re-cycled materials used at repair wor	0.00	0.00
total of materials	111.28	4149.59
total of construction	18.24	475.32
total of building service	1696.97	23264.05
total of renewal and renovation	22.39	559.64
total of demolition	56.82	1480.77
total	1905.70	29929.37

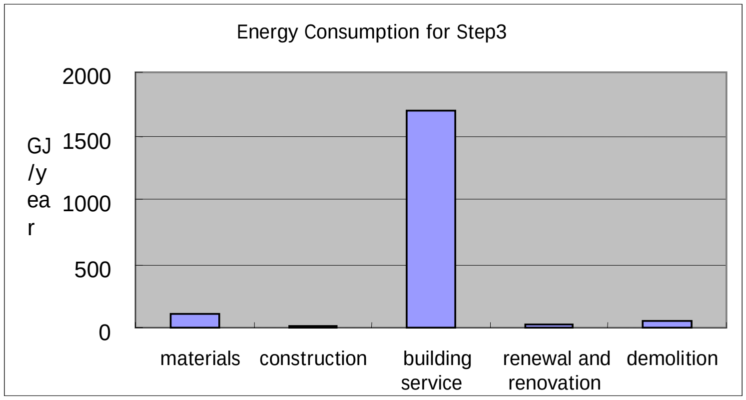


Figure 8.3: Energy Consumption of Office Building

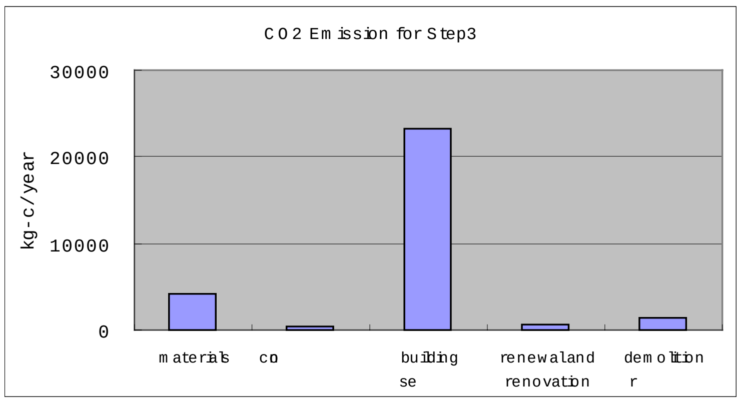


Figure 8.4: CO_2 Emission of Office Building

Concluding Remarks

The main purpose of BRI-LCA is to estimate and evaluate energy consumption concerning building through its life cycle. It includes not only energy consumption at building operation, but also at construction, repair work, demolition and removal. If an energy conservation technique was adapted, it is examined as to whether the amount of energy saved compensates for the amount of energy used to implement the new technique. The amount of energy saved resulting from the adaptation of energy conservation technique is compared with the whole amount of energy conserved.

The tool can be used at the first stage of building design: it is then possible to reduce the energy consumption and CO_2 emissions. It is possible to decrease energy consumption and CO_2 emission at the first stage of building design. Materials and energy conservation techniques can be changed and compared on energy consumption and CO_2 emissions at each stage of construction, operation, repair work and demolition.

The tool is to be used by engineers at working level. At this moment the tool is not yet used and there are no experiences with the tool.

For the future

As for materials, energy consumption at production of materials, and at building operation, it is necessary that more accurate data be made for more accurate evaluation. The evaluation of load for each energy conservation technique must be possible. Choice of energy conservation techniques is not varied enough.

APPENDIX 9 - THE NETHERLANDS

Domestic building and Office building
Analysis tool: Eco-Quantum Domestic and Eco-Quantum Research
By: Marjo Knappen and/or Chiel Boonstra
Date:

Introduction

Eco-Quantum Domestic and Eco-Quantum Research are the two tools in the Netherlands that are developed on the basis of the calculation model Eco-Quantum. They enable architects and project developers to measure the environmental performance of complete buildings on the basis of LCA. With Eco-Quantum Domestic architects are able to quickly identify environmental consequences of material choices and water and energy consumption in their designs of domestic buildings. Eco-Quantum-Research is the tool for in depth analysis of the environmental performance of buildings and developing innovative designs for sustainable houses and offices. Eco-Quantum Research is used in this annex for the assessment of the office building.

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

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

General lay out of Eco-Quantum

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

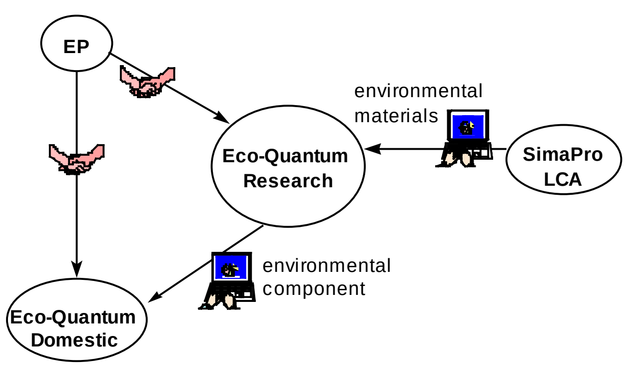
In figure 9.1 the general layout of Eco-Quantum is presented. Eco-Quantum Domestic and Eco-Quantum Research are provided with information from a stand-alone version of the Dutch LCA programme SimaPro 4 [4] and the Dutch Environmental Performance Standard (EP). SimaPro calculates split environmental profiles per kilogram building materials and for processes related to the production of energy and water, transportation and waste processing. These environmental profiles are the input to the database Environmental profiles in Eco-Quantum Research. The Dutch Energy Performance standard is applied to determine the energy consumption during the use of the building.

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

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

Various outputs can be presented: environmental indicators, environmental profiles and material flows.

Figure 9.1: Subsystems Eco-Quantum



Eco-Quantum

EQ domestic

Performing LCA of a complete building is normally a complex and time consuming task. Environmental requirements are added to an enormous amount of design requirements which architects have to consider for designing a building. If an instrument does not consider this complex task and the time constraints of architects, it won’t be used in a design process.

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

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

The user performs the following steps in EQ domestic:

- **Enter information about the building project**

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

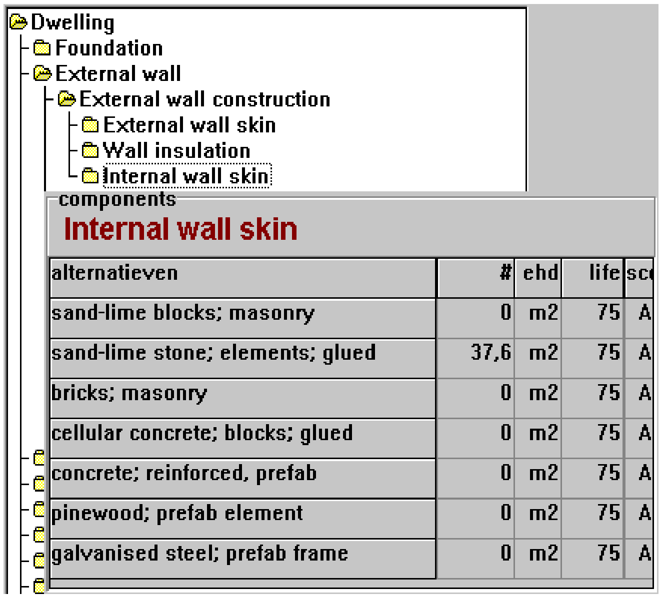
- **Enter the design data of the project**

In Eco-Quantum Domestic the input of a design is as limited as possible. In figure 9.2 an input screen is presented. In the upper part of the figure a small part of the tree is shown following the four levels:

1. building
2. 8 building parts, e.g. external wall
3. buildings elements: only one building element is opened up: e.g. external wall construction
4. buildings components: only one component is folded out: e.g. internal wall skin

The architect opens one element (in this case external wall construction) and selects one component (in this case the inner side of the cavity wall, the internal wall skin). In the lower part of the screen the architect enters the necessary design information in the form of the amount of walls (37,6 m^2). Furthermore the architect can change the life span (here 75 years) and choose between demolition scenario A (current situation) and B (optimised situation). After finishing the input for this component Eco-Quantum Domestic automatically goes to the following component. Besides this information both the information about energy consumption and water consumption of the specific design is entered in the programme.

Figure 9.2: Input screen and part of the tree



o Calculate the environmental profile of the building

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

o Presentation of results

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

1. an overview of materials streams
2. 11 effect scores, according to the life cycle analysis of Heijungs.
3. 4 environmental indicators, according to the “Environmental ratings in the constructions industry” (exhaustion of resources, emissions, energy and waste)

If an architect wants to detect the causes of the environmental burden of the design it is possible to give a division of the environmental impacts over the stages of the life cycle of the parts, elements and components of the building.

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

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

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

The range of optimizing depends strongly on the first design. An environmentally sound building can be hard to optimize. Reduction of energy during use has a large impact on the environmental impact. When a building contains materials with a large environmental impact, like lead, the impact can be reduced largely by optimizing (replacing lead by plastics for example).

The accuracy of Eco-Quantum depends on the accuracy of the database, life span and waste scenarios. However if recent data are used, this is not possible for all materials. One of the results of Eco-Quantum is that manufacturers are willing to provide recent data. Another development in the Netherlands is the development of Environmental Related product information, a project in which LCA data of products are collected and verified by an independent committee. In this way accurate data are obtained. These are to be part of Eco-Quantum's Life-span data obtained from empirical research conducted by the Dutch Building Research Institute. Waste scenarios are according to best current practice and are accurate. If the user uses the 'future' waste scenario, more uncertainties are part of the calculation.

- **Compare the environmental performance of various designs**

The user can also compare the environmental performance of different projects and designs. Different designs can be put in and compared for example with the environmental performance per m^2 /yr or per m^3 /yr or, per m^2 during the life span of the building.

Sensitivity analysis

Because of the large impacts of life span and waste scenario on the results the sensitivity analysis can be performed for these parameters. Sensitivity analysis can simply be performed in Eco-Quantum by pressing one button. Different default life spans and waste scenarios are calculated for the building.

- All components having a life span which is 20% less: more components have to be replaced which leads to a higher environmental impact
- All components having a life span which is 20% longer: less components have to be replaced which reduces the environmental impact
- All components having waste scenario A (current practice)
- All components having waste scenario B (expected future practice)

Eco-Quantum Research

Eco-Quantum Research is the instrument for in depth research of the environmental impacts for all types of buildings by researchers, consultants and large design offices. An important difference is that in Eco-Quantum Research users can enter new building components whereas Eco-Quantum Domestic works with fixed standardised building components. This makes Eco-Quantum Research a tool that is suited for all building types. The environmental impact of any building type can be calculated with it, like schools, hospitals and other health buildings, offices and other industry buildings.

This can on the other hand make EQ Research a more time consuming instrument. A user can, but is not obliged to, add self-made building components. If the user wants to add components, he or she has to enter the design data himself, for example material consumption per square meter, building waste, life span and waste scenario.

Use of Eco-Quantum

The tool was launched at the market in the summer of 1999. In 1998 Eco-Quantum was tested by architects. They used it to optimise their designs on environmental impact. This lead to some adaptations of the tool. In the beginning of 1999 Eco-Quantum was tested by about 12 local communities, which used Eco-Quantum to set targets. After this second testing phase it was released to the market and used by local communities, architects and consultants. Architects and local communities welcome Eco-Quantum as an easy to use tool, which enable them to improve the environmental quality quickly. Their only comment was that not all material alternatives are yet part of the tool. A lot of labour is being applied to improve that part of Eco-Quantum and add alternatives, but this will be of course a continuous point of attention.

Eco-Quantum Research is at this moment used by the developers of Eco-Quantum to calculate the environmental impact of non-domestic buildings or building parts.

Step 1

Input of Eco-Quantum

The input of the design is quantities of the material alternatives of the building components of the design. The input is as is given in the input table of the domestic building.

Outputs of Eco-Quantum

Various outputs can be presented:

- Environmental indicators as set by the Dutch Building Council: Resources depletion, Emissions, Energy and Waste, and in the future Hindrance: see figure 9.3
- Environmental profiles (see figure 9.4)
- Material flows.

Each output can be presented in the following forms:

- For the whole building (with the distinction of the environmental impact because of energy in use (see step 2) and because of materials);

- For the elements of the building: foundation, facade, interior walls, floors, roofs, transport, installations and interior;
- Each of these elements can be explored more in detail up to the material alternatives.

Other variations of the output are possible:

- Per m^2 user surface per year, for the total user surface for the whole life span, per m3 nett building per year. In this case the results are expressed per m^2 user surface per year.
- Different weighting factors (MET weighting factors or an own made set of weighting factors) or different normalisation factors (Dutch or West European) can be used. In this case the MET weighting factors and the Dutch normalisation factors are used.

Calculations that are performed

Eco-Quantum translates the materials and quantities in kilogram materials. For this, Eco-Quantum comprises an extensive component database that consists of building material components, with information about life span, materials needs, maintenance and waste scenarios.

In order to calculate the environmental performance of a building the environmental information from the database environmental profiles is connected to the material, water and energy flows of the building. By doing this environmental interventions related to the total life cycle of the building are accumulated. Furthermore the environmental interventions are converted on the basis of characterisation factors of the LCA methodology of Heijungs *et al.* [1992] into 11 environmental effect scores such as raw material depletion, ecotoxicity and greenhouse effect. In a following step these 11 effects-cores are converted into four environmental indicators: raw material depletion (resources), emissions, energy consumption and waste according to the Dutch project “Environmental Ratings in the construction industry” set up by the Dutch Council for the Construction Industry.

Conclusions

The relative contribution of each part of the building to the environmental indicators is shown in figure 9.3. The facade and the installations contribute in large measure to the exhaustion of resources. The installations contribute for a large part to emissions, this is because of the large quantity of copper that is used: this contributes to the ecotoxicity, see also figure 9.4

Eco-Quantum is an improvement tool; it shows improvement options. An example is shown in figure 9.5 (in Dutch). Six alternatives for the window frames are shown: aluminium (with two kinds of treatment), PVC (recycled and not recycled), wood (not durable, with painting) and wood (durable, with painting, without FSC mark). The four graphics present the environmental indicators of the alternatives. In this case the worst is the first one: galvanized aluminium.

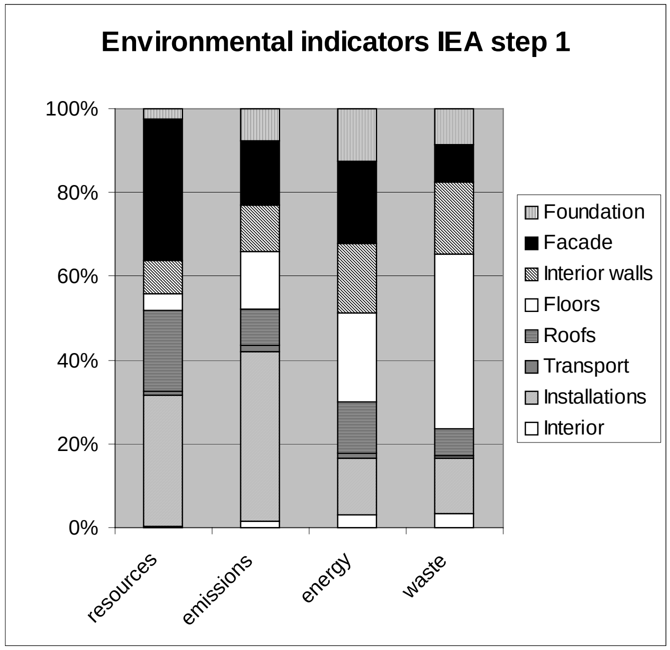


Figure 9.3: Environmental indicators of dwelling step 1 IEA case study.

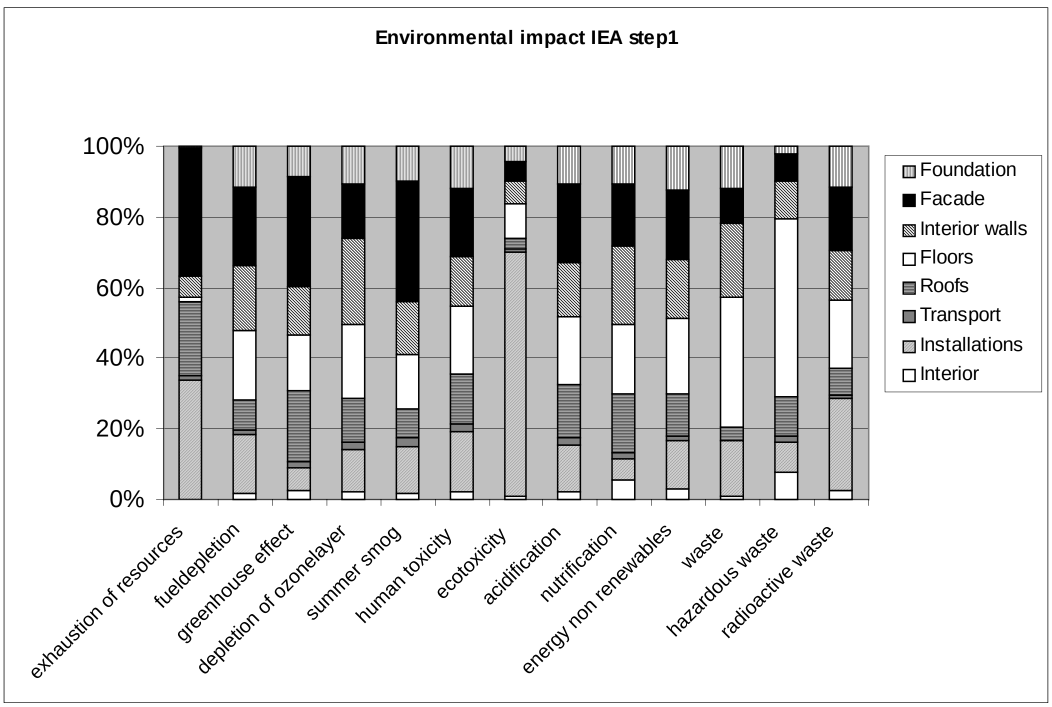


Figure 9.4: Environmental profile of dwelling IEA case study step 1.

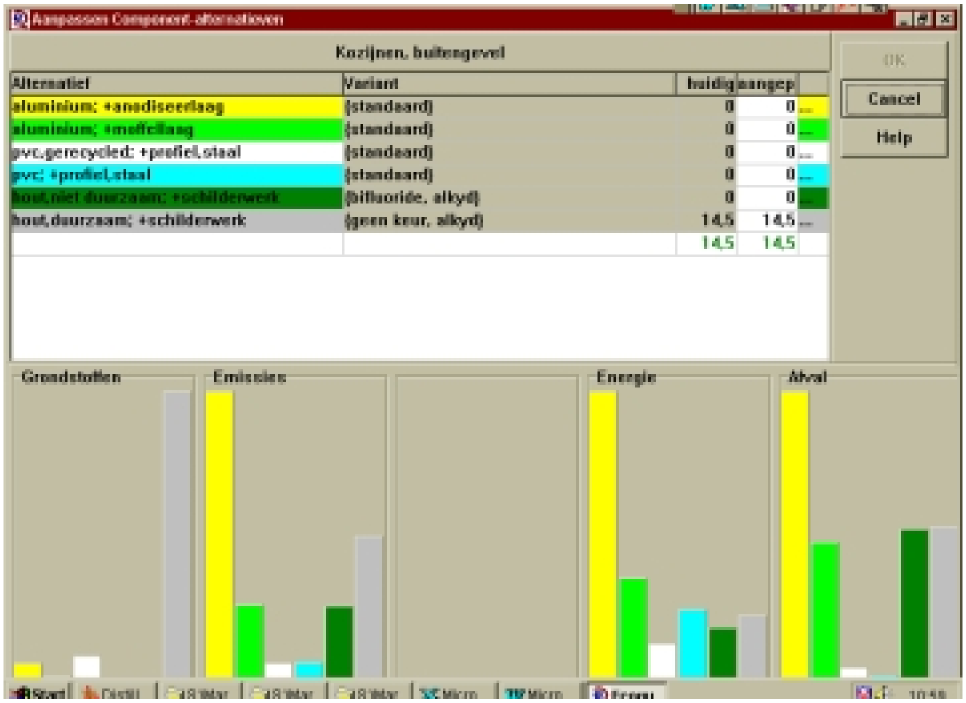


Figure 9.5: Improvement options of window frames within Eco-Quantum

Step 2

In step 2 the building should be adapted to local situations. However, a Dutch building is used, so adaptations on that part is not necessary. The building is adapted to current 'green' building practice. Changes are made to make the building like a common domestic Dutch building built in 1999.

Changes, step 2 in comparison to step 1:

- Energy in use is added: the energy performance of the building is according to the Dutch building regulation. The life span of the building is 50 years.
- Concrete contains 20% regranulate as a replacement of gravel (concrete in step 1 contained no regranulate)
- U values of roof, facade and floor insulation are improved: from 0.4 W/m2K to 0.33 W/m2K
- Wood which is used has been approved by FSC (Forest Stewardship Council)
- Interior door frames are made of wood (instead of steel)
- Painting contains less VOCs (volatile organic compounds) in most cases: high solids or acrylate.

The environmental indicators are shown in figure 9.6. The results of the (first) improvements (bar in the middle) and the adding of energy in use (right bar, the middle bar is part of the black bar) are shown separately.

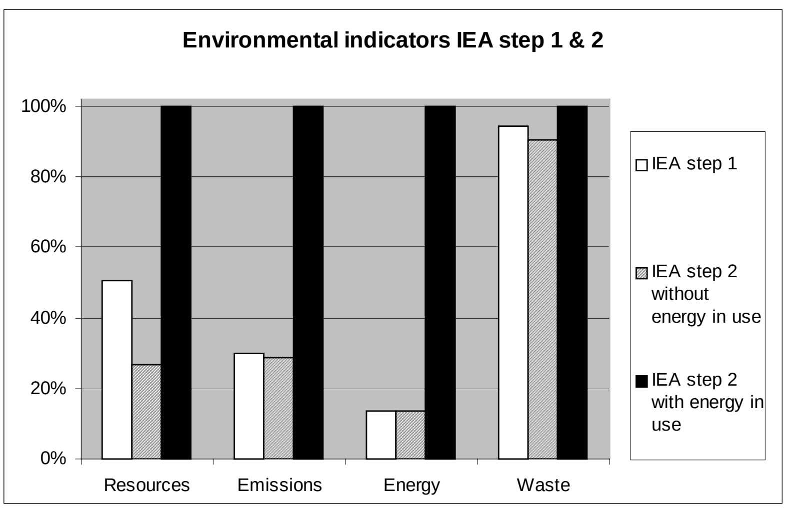


Figure 9.6: Environmental indicators step 1 & 2 IEA dwelling.

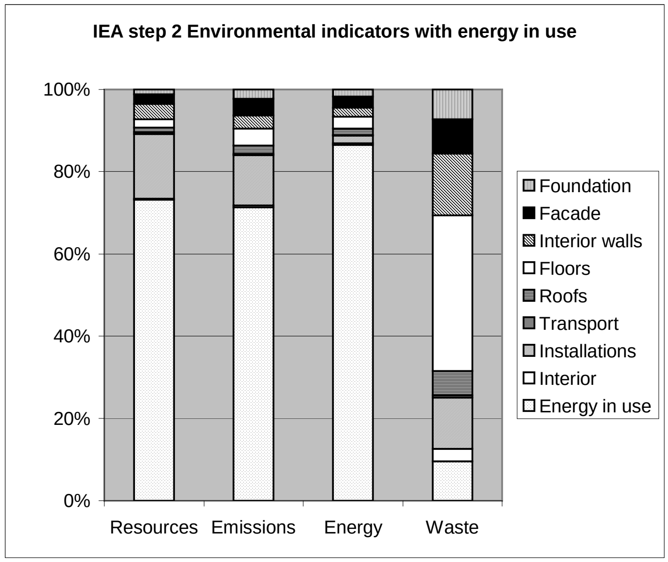


Figure 9.7 Environmental indicators step 2 IEA dwelling.

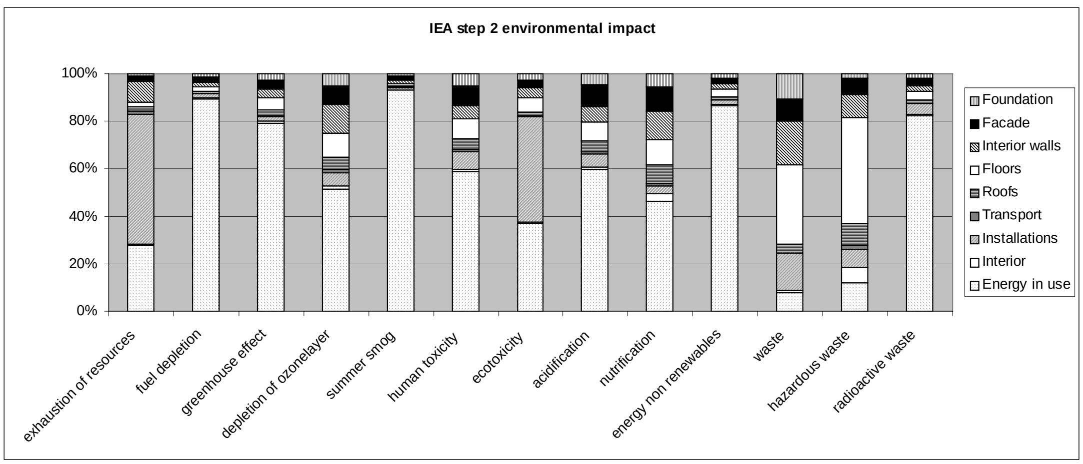


Figure 9.8

Conclusions

The energy in use is responsible for a large part of the environmental impact of three of the four environmental indicators: Resources (73% by energy in use), Emissions (71% by energy in use) and Energy (86% energy in use).

The environmental impact of the materials is reduced by some relatively simple changes of materials, which are becoming more and more common in the Netherlands (like use of wood with FSC approval, concrete with regranulate and paints with less VOC's (reduced for 50% or more).

Step 3

The goal of Eco-Quantum is to reduce the environmental impact of buildings by offering insight into the environmental impact of material alternatives. It is a material improvement tool. In step one is shown the way to improve the environmental impact. For each building component the material alternative with the less environmental impact can be chosen. This is done for the case study building. The energy performance is not improved, although with reducing energy in use the largest reduction of the environmental burden can be achieved. The energy performance used now is according to the Dutch building regulation. The Energy Performance is not yet part of Eco-Quantum. The results or the EP calculation are filled in EQ. The idea for the future is to link the EP program to EQ, so the effects of reduced EP are shown immediately in EQ.

Improvements of the building in comparison to step 2:

- Internal wall skin: clay lime stone instead of gypsum
- Windowsill: vessel cement instead of chipboard with melamine
- Internal wall, non-carrying: clay lime stone instead of gypsum
- Internal wall carrying: wood instead of concrete
- Construction of flat roof: concrete with canals instead of massive concrete
- Roof covering of EPDM instead of bitumen
- Water supply of polybutene instead of copper
- Heath distribution of polybutene instead of copper
- Internal waste system of polyethene instead of PVC
- Rain water drainage: polyethene instead of PVC

Figure 9.8 shows the environmental indicators of the three steps. The environmental impact of the building is reduced by 5 to about 20%, dependent of the indicator. Emissions are largely reduced by not using copper but plastics for water pipes (amongst others).

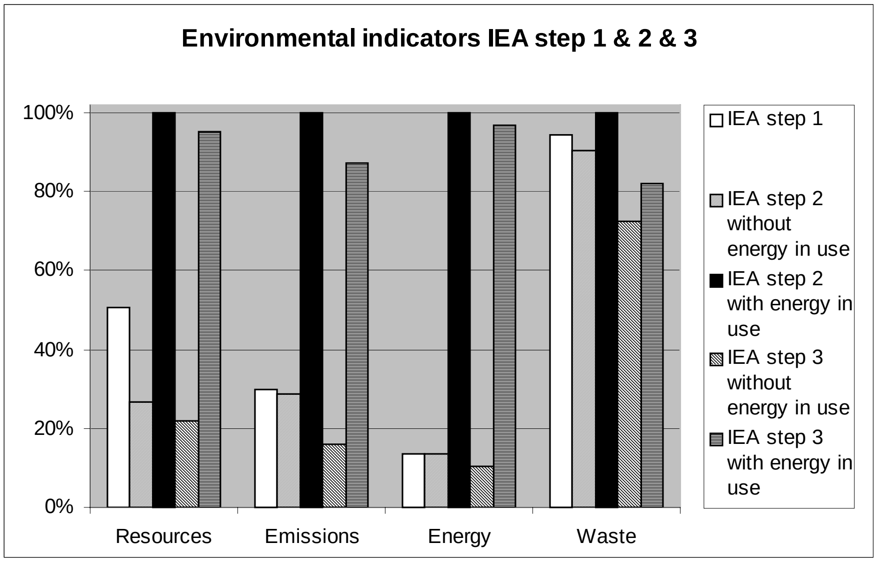


Figure 9.8 Environmental indicators for the building of step 2 and 3, with and without energy in use.

Conclusions

The figures 9.8 and 9.9 show the results of the improvements. From step 1 to 2 a reduction in environmental impact is reached. This is reduced even further by the changes made in step 3. Changing the copper to plastics influence the Emissions considerably. Further reduction of the environmental impact has to be reached in other ways: by changing life span of materials and by changing waste scenarios: large reductions can be reached by reusing material. Materials have to be used then in a way that they can easily be reused (or recycled). Reducing the energy in use contributes also largely to reduction of the environmental impact. The results of the sensitivity analysis are shown in figure 9.10. The influence of 20% shorter or 20% longer life span of material alternatives and the influence of waste scenario A (current practice) or B (expected future practice) are shown:

I. Original results step 3
II. 20% shorter life span of material alternatives
III. 20% longer life span of material alternatives
IV. Waste scenario A (current practice), the same as the orgininal
V. Waste scenario B: more reuse and recycling of materials

The figure shows the range of interpretation of the results. Figure 9.11 shows the result for the materials only, without energy in use. The range of the results is shown this way.

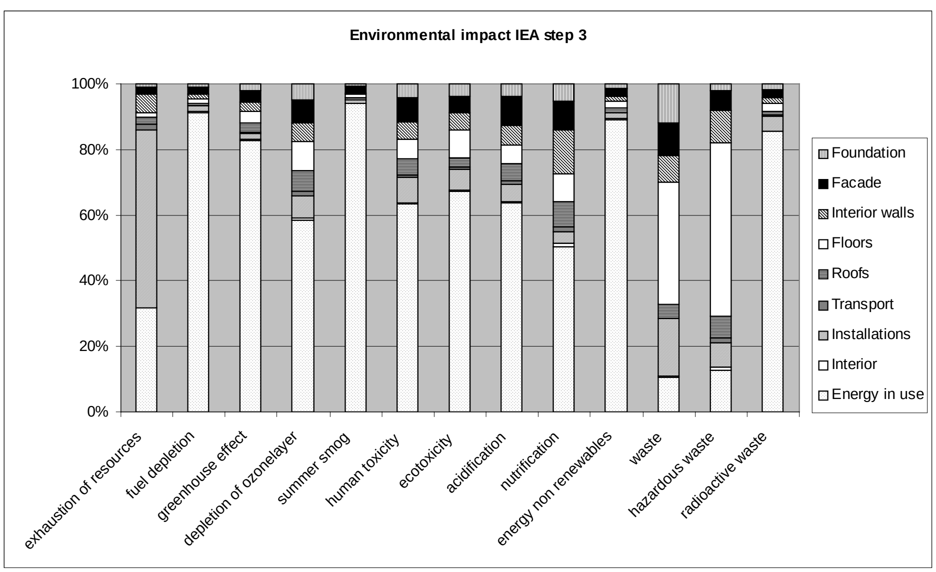


Figure 9.9: Environmental impact of step 3 building.

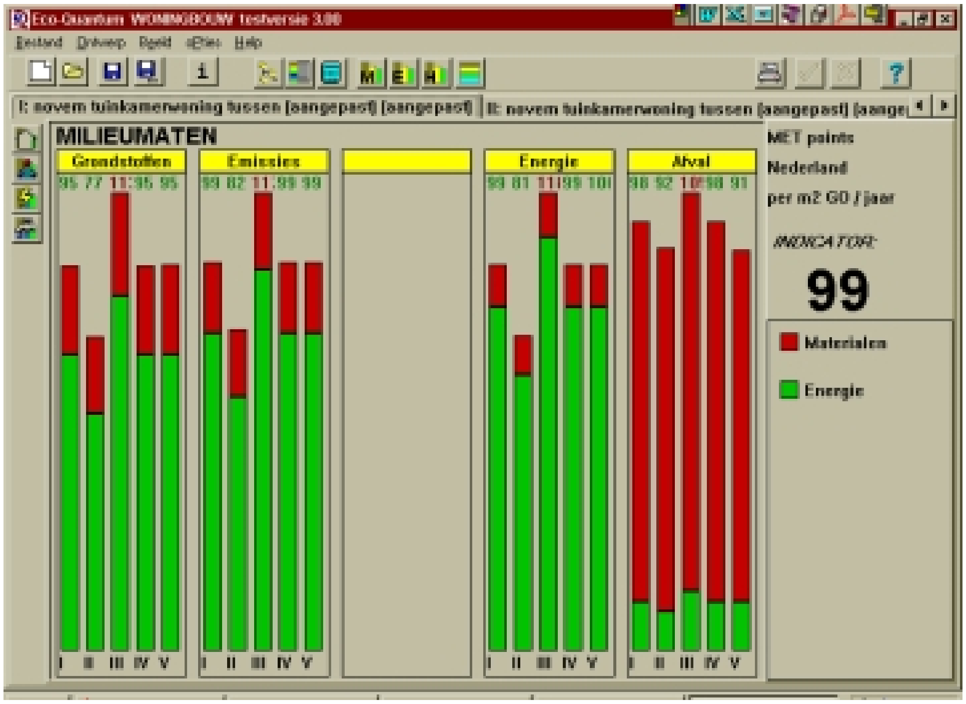
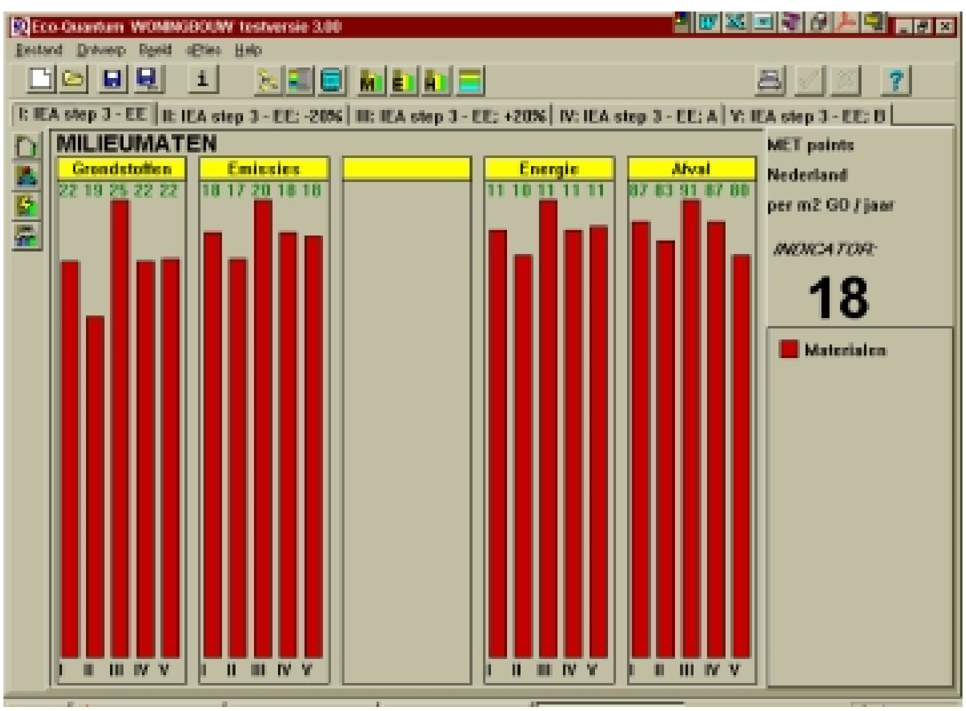


Figure 9.10: Results of the sensitivity analysis with Eco-Quantum on the step 3 building. I is the original building; II is with 20% less life span of materials; III is with 20% longer life span; IV is with waste scenario A and V with waste scenario B. Energy in use and materials (darker/upper part).

Figure 9.11: Results of the sensitivity analysis with Eco-Quantum on the step 3 building. I is the original building; II is with 20% less life span of materials; III is with 20% longer life span; IV is with waste scenario A and V with waste scenario B. Only environmental impact of materials is shown.



APPENDIX 10 - NORWAY

Domestic building
Analysis tool: LCA
By: Trine Dyrstad Pettersen, Norwegian Building Research Institute, Norway
Date: June 30, 1998

Introduction

The domestic building is assessed with an LCA-method. The output is based on environmental values from the Norwegian project Energy- and environmental account for buildings from 1995. Some values may also be older than this. Some values are also fairly uncertain because some transport information may missing. The electrical energy is based on non-pollutive hydropower.

Step 1: Environmental impact of domestic building

The output table is found by using input from the Norwegian project Energy- and environmental account for buildings, together with actual information about the different building elements used in the building. The calculations are made in spreadsheets.

	Resources kg		Tot. energy kWh		CO_2 kg		SO_2 g		Waste kg	
Foundation	19299	13%	5560	9%	2536	9%	1691	9%	676	11%
Façade	21114	14%	9504	16%	3200	11%	3029	16%	879	15%
Interior walls	31145	21%	10988	18%	4761	17%	5331	28%	1007	17%
Floors	59800	40%	11305	19%	7176	26%	2990	15%	1794	30%
Roofs	7775	5%	3422	6%	949	3%	651	3%	265	4%
Installation	1347	1%	5051	8%	1176	4%	2865	15%	898	15%
Interior Design	10052	7%	13621	23%	8277	29%	2806	14%	503	8%
	150533		59450		28075		19363		6022	

Table 10.1: The output without energy in use given in figures.

The same results are presented graphical.

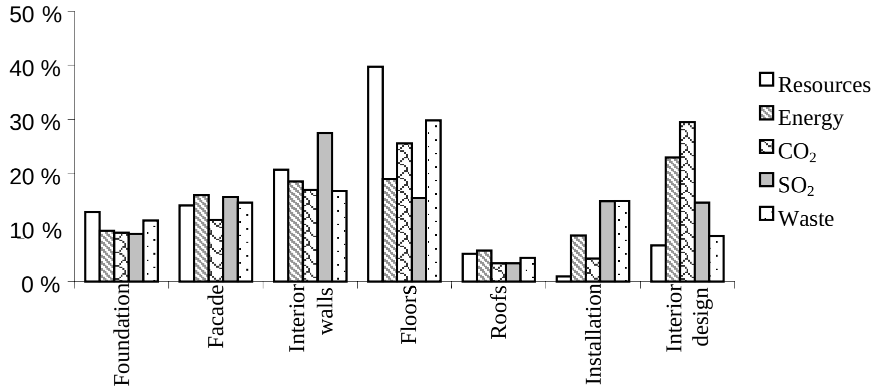


Figure 10.1: The output without energy in use.

All buildings are assumed to have a lifetime of 50 years, while all installations are replaced every 20 years. No maintenance of the constructions is assumed. For all the building materials it is assumed 5 % waste with the exception of concrete which is assumed the have 3 % production waste.

The environmental output of installations made of steel (heating element and ventilation installations and so on) are based on the approximate steel weight these installations have.

The floor constructions dominate the resources due to the massive concrete floor. The energy consumption for this group is however not dominating, but because most of the energy used for concrete production is based on oil the emissions are also high.

The high environmental impacts due to the installations are mainly caused by the replacements made every 20 years. To improve the lifetime of the materials and constructions will reduce these impacts.

Step 2: Environmental impact of the building, after adaptation to local climate conditions and construction technologies.

Environmental impact and energy consumption is carried out for both the solutions described by Knapen and according to the Norwegian building code. These two solutions are then compared.

The energy for heating is calculated on an average monthly basis with Oslo climate. The heating energy is electricity, which is the most typical energy in new Norwegian houses.

1. Insulation due to Dutch insulation solution

Heat loss	kWh/year	Heat gain	kWh/year
Transmission	14163	Sun	2494
Infiltration	1655	Cooking [1]	531
Ventilation	8276	Hot water [2]	538
		Electrical [3]	2438
Heat loss	24094	Heat gain	6001

Table 10.2: The domestic building with Dutch insulation thickness

The delivered energy for domestic purposes may be reduced when the heat demand is calculated. The percentages that are assumed as heat gain are as below:

- o 80% of delivered energy is assumed as heat gain.
- o 10% of delivered energy is assumed as heat gain.
- o 90% of delivered energy is assumed as heat gain.

Calculated heating demand is 18,270 kWh/year while the total energy demand in use is 27,030 kWh/year. As shown in table 3, the energy in use dominates the total energy consumption during the lifetime of the building.

	kWh/50 year	
Materials	59450	5 %
Energy in use, 50 years	1351450	95 %
Total	1148450	

Table 10.3: Total energy during the whole lifetime

2. Insulation due to the Norwegian Building code

The external constructions are assumed in this case to be insulated according to the Norwegian building code. The heat gain is according to the Norwegian Standard. As shown in Table 4

Heat loss	kWh/year	**Heat gain**	kWh/year
Transmission	6604	Sun	2014
Infiltration	1655	Electrical	7000
Ventilation	8276	Hot water [1]	
		Persons	1680
Heat loss	16535	Heat gain	10694

Table 10.4: The domestic building with Norwegian insulation level and heat gain

Heat gain from the water is included in the electrical heat gain. When the total energy consumption is calculated it is assumed 4,500 kWh/year for hot water while the energy consumption for electrical appliances is increased by 20%.

Calculated heating demand is 8,974 kWh/year while the total energy demand is 19,670 kWh/year. The heating energy and energy for lights and appliances dominate also in this case the total energy consumption for the building.

	kWh/50 years	
Materials	62130	6 %
Tot. energy in use, 50 years	983400	94 %
Total energy	1045500	

Table 10.5: Total energy consumption during the whole lifetime

The heating demand is reduced significantly by increasing the insulation thickness while the energy and corresponding environmental impacts for producing the additional insulation is insignificant.

Step 3: Environmental impact of the building, demonstration how the tool assists in improving the design

Instead of concrete and masonry facade construction a framework with insulation and wooden claddings assumed. The external cladding is painted and is repainted every 8 years (the cladding has to be painted due to the wet and cold climate). The concrete floors are also replaced with a floor with pinewood beams, some insulation and both plasterboard and parquet.

I have already in step 2 oriented the building to optimise the solar heat gain. The same insulation thickness is also used because the Norwegian regulations due to U-values are fairly high. An increase due to this level is not likely to be carried out because of the high costs. The energy consumption due to heating is consequently the same as in step 2.

The optimising concerns therefore only the energy consumption for producing and maintaining materials.

	Resources		Energy, kWh		CO_2, kg		SO_2, g		Waste, kg	
	step 2	step 3	step 2	step 3	step 2	step 3	step 2	step 3	step 2	step 3
	21265	3020	10320	7101	3332	1893	3225	2355	887	132
	31145	29667	10979	8709	4761	4163	5331	3756	1007	881
	59968	4629	12204	7484	7323	1430	3208	1638	1802	52
	112378	37316	33503	23294	15415	7486	11764	7749	3696	1065

Table 10.6: The output without energy in use for step 2 and 3 given in figures.

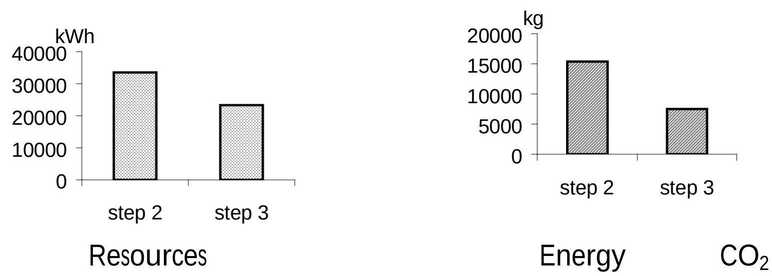


Figure 10.2: Comparison of resources, energy and CO_2 for step 2 and step 3.

Changing the masonry and concrete facade and floor into constructions with wood will reduce the environmental impacts.

This conclusion must be taken with some important reservations. The function of the constructions, as fire resistance or sound insulation for instance, may change when the primary constructions were changed into new ones. This means that the new constructions might not be permitted due to the building regulation.

The other reservation is the input values that are uncertain to some extent because of some lacking transport information.

Concluding Remarks

The conclusions from step 1 are:

- The environmental output of installations made of steel (heating element and ventilation installations and so on) are based on the approximately steel weight these installations have.
- The floor constructions dominate the resources due to the massive concrete floor. The energy consumption for this group is however not dominating, but because most of the energy used for concrete production is based on oil are the emissions also high.
- The high environmental impacts due to the installations are mainly caused by the replacements made every 20 years. To improve the lifetime of the materials and constructions will reduce these impacts.

In step 2 the Oslo climate and Norwegian building regulation are added, this means that the insulation thickness has largely increased. The heating energy and energy for lights and appliances dominate also in this case the total energy consumption for the building.

In step 3 instead of concrete and masonry facade construction a framework with insulation and wooden claddings is assumed. The external cladding is painted and repainted every 8 years (the cladding has to be painted due to the wet and cold climate). The concrete floors are also changed into a floor with pinewood beams, some insulation and both plasterboard and parquet. Changing the masonry and concrete facade and floor into constructions with wood will reduce the environmental impacts, but not for the resources and waste.

This conclusion must be taken with some important reservations. The function of the constructions, as fire resistance or sound insulation for instance, may change when the primary constructions were changed into new ones. This means that the new constructions might not be permitted due to the building regulation.

The other reservation is that the input values are uncertain to some extent because of some transport information which is lacking.

APPENDIX 11 - SWEDEN

Domestic building
Analysis tool: EcoEffect
By: Mauritz Glaumann, KTH
Date: October 1998

Introduction

The method gives assessments in four areas: energy, materials, indoor environment and outdoor environment. Energy and materials are assessed in the same way based on the LCA-methodolgy. Below only results from energy and material use are discussed. The software programme is transparent and default values for example for emissions are easily changed. So far the system is programmed in Microsoft Access. The principles of the methodology are ready but several specific parts are not finished yet.

Input

The amounts of materials and components in kg and energy by source in kWh used throughout the life cycle are input data. Transportation may be added. From these values total emissions, environmental effects and depletion of raw materials are calculated. The environmental load is reduced for recycled materials according to the probability of future recycling based on certain criteria.

Output

The output is presented on different information levels. Level 1 shows environmental effects and depletion expressed in equivalents per person and year. They are GWP, acidification, eutrofication, ODP, POCP, human toxicity, eco toxicity and natural resource depletion. Where we lack data on relative toxicity and depletion we so far just note the amounts. Level 2 is a normalisation of effects and depletion based on the average contribution to the different impacts per person. This means that the environmental profile shows the contribution to different environmental impacts by a user of the property (building) compared to the average contribution by a person in the region or on the globe depending on the scale of the impact. The unit is stated as a percentage. Level 3 is optional. It gives the client a possibility to interpret the environmental profiles into a single value based on suggested default weights. It is easy to change weights according to ones specific knowledge, focus or opinion.

No final judgement is given as bad, good, better and best. The intention is rather to compare buildings and technical solution between different buildings than giving a mark. This is however possible to do for example within a city or a stock of buildings belonging to a large building owner company by picking a specific building as a reference.

Calculations

Calculations performed are additions of the converted emissions to equivalents for the different effect categories derived from use of materials, energy etc. The result is environmental loading values for the different effect categories. These values are then normalised per person and expressed as relative environmental loadings. The relative environmental categories may be weighted to one figure. An environmental assessment is done by comparing the weighted figures from material, energy, indoor environment, and outdoor environment to a reference building.

Conclusions

You can make conclusions on all levels if you know the normal environmental loadings from buildings. A future version will include full assessments for a couple of buildings that are typical for period, kind or construction. With these examples conclusions about environmental loadings can be drawn at all levels.
Important questions:

The developers believe that an assessment tool and a design tool shouldn't be exactly the same. In the first and recent stage the assessment tool is developed. Based on this a design tool that is more adapted to the work stages and questions raised during the design process will be developed later. However the recent tool may also be used for optimisation through a trial and error process. The components that contribute at most to the overall environmental impact are easily found. But it is not a tool for common use.

The tool is primarily developed for existing buildings and the users are the building owners.

The standard results are presented as an environmental profile. This profile is not possible to "optimise" unless you have put weights on the different effect categories. The recent suggested weights are not final and these should not be called the "right" ones against which one should optimise ones building. They give a possible interpretation of the profile but could also be debated.

The development of the tool is supported by a lot of large building owners and organisations and the expectations for the future are great.

Step 1

As many components as possible thus far were used in the assessment of the described building.

Step 2

Q2.1) Input data is <u>underlined</u> in question 2. The input data for energy is the calculated energy use for heating and electricity, the source of energy, e.g., district heating (which is different in different parts of Sweden), gas, and solar panels. The environmental loadings from electricity will be the same per kWh in all Sweden, so called green electricity is not positively assessed since it is not depending of the properties of the building. If solar panels or a wind mill are located on the site they will be positively assessed since they are not accounted for in any environmental load for the user phase.

Q2.2) Adaptations made: It is mainly the materials in the building construction that has been changed from being concrete to consist of wood and mineral insulation. See further in the input information below.

Q2.3) Input: See Q1.2
Q2.4) Output: See Q1.3
Q2.5) Calculations: See Q1.4

Q2.6) Conclusions: Since materials and energy are separated in the method it is difficult to interpret the importance of energy included in the assessment. The building in step 2 has furthermore been substantially changed from the original building. Overall, when common building materials and construction techniques in Sweden where assessed, a lower environmental loading of GWP was found. The other effect categories showed similar loadings (except for ODP that was not assessed because most of the substances affecting the ODP is not yet imported in our database).

Step 3

Q 3.1) The same input table as for step 1 and 2. So far there is no specific tool to optimise the environmental performance, but it is easy to find the large impacts and exchange technical solutions to reduce them.

Q 3.2) Adaptations made:
An increased use of wood based materials was used. The energy consumption is supposed to be the same as for step 2 but the energy source for district heating is different, see below.

Q 3.3) See Q1.2
Q 3.4) See Q1.3
Q 3.5) See Q1.4
Q 3.6)

Conclusions

When the buildings in step 2 and 3 are compared, the effect categories, GWP, AP and POCB are fairly similar but the eutrofication is 5 times higher for step 3 which is presumed to be the environmentally optimised building with a lot of wood based materials. Recycling and renewability are, however, not considered, which they will be at a later stage. The amount of hazardous waste is about 5 times greater for the building in step 2 but the amount of nuclear waste is practically the same.

All three buildings were compared after weighting the effect categories to total environmental loading of material and energy respectively (here equal weights were put on each effect category). It was found that the building from step 3 had the greatest environmental load for the materials (3,2 % when step 1 and 2 had 2,8% and 2% respectively).

Input information

Building components and materials included in all three steps:

Foundation constructions:
Foundation beam (3.66 m3)
Aboveground masonry (2,1 m2)
Internal doors: Plywood (11,74 m3)
Joinery: Wood (0,027 m3 + 0,048 m3)
Tiles; supposed density of 3000 kg/m3

Building components and materials NOT included in any step:

Internal stairs
Balustrades and railings
CV-boiler
Drainage
Copper
Heating elements
Ventilation installation
Cooking
Kitchen blade
Sanitary fittings
Pavement
Windowpanes

Step 1

According to the described building as far as possible.

Step 2

Building area: 88,4 m2
Net usable area: 150m^2
External walls: Panel, plywood skeleton, 13 mm plaster board, 250 mm mineral insulation
Panel: 1,5 x 214,2 m^2 x 0,015 m = 4,8195 m^3.
Plywood skeleton: cc 600 mm, beam 60 mm; 2 x 33 x 0,06 x 5,4 x 0,35= 7,4844 m^3
Plaster board: 214,2 m^2
Plastic film: 214,2 m^2
Mineral insulation, glass wool: 0,90 x 214,2 m^2 x 0,15 m = 28,917m^3

Roof: Tiles, roofing felt, plywood skeleton, panel, 200 mm mineral insulation;
Area: 2 x 5,8 x 10,5 = 60,9 m^2
Roofing felt: 2 x 60,9 = 121,8 m^2
Plywood skeleton: 2 x 18 x 0,06 x 5,8 x 0,6 m^3 = 7,5168 m^3
Panel: 2 x 60,9 x 0,015 m3 = 1,827 m3
Mineral insulation, glass wool: 0,90 x 2 x 60,9 x 0.2 m^3 = 21,912 m^3

Base joist: 16 mm chipboard, plywood skeleton, 16 mm chipboard, tiles, 20 mm mineral insulation;

Chipboard: 88,4 m^2.
Plywood: 18 x 0.06 x 8,5 x 0,5 = 4,59 m3.
Tiles: 2,6 x 2,4 x 0,001 = 0,00624 m^3; => 18,75kg
Mineral insulation, glass wool: 0,90 x 88,4 m^2 x 0,2 m = 15,912 m^3

Two joists: 13 mm plaster board, plywood skeleton, floor boards, tiles (second floor bathroom), 150 mm mineral insulation.
Plaster board 13 mm: 2 x 88,4 m2 = 176,8 m2
Plywood: 2 x18 x 0,06 x 8,5 x 0,15 m3 = 2,754 m3
Floor boards (wood): 88,4 m2
Tiles: 3,6 x 2,4 = 8,64 m2 x 0,001m = 0,00864 m^3 supposed density of 3000 kg/m3 => 25,92 kg
Mineral insulation, glass wool: 2 x 0,90 x 88,4 x 0,15 = 23,868 m3;

Internal walls: 16 mm chipboard, wood skeleton, mineralwool, wall paper; 80 m^2. (Default in Danish software programme)
Tiles: 2 x 3,6 + 2 x 2,4 + 2x2,6 + 2 x 2,4 =22 m2 x 0,0001m 0,022m3 =>66 kg

Windows: Double glazing, area 24 m^2.
(Not assessed in the Danish software programme)

External doors: Double, U-value 0,65 W/m^2K.

Energy: The energy consumption is calculated with hourly simulations.
Heat exchange ventilation air, 60 % efficiency, mechanical ventilation.
Energy consumption for hot water and heating: 8 748 kWh/year
Energy source: 100 % natural gas
Energy consumption for electricity: 6502 kWh/year
Energy source: 50 % nuclear power
50 % water power
Average U-value: 0,13 W/m^2K.

Step 3

Building area: 88,4 m2
Net usable area: 150m^2.

External walls: Panel, plywood skeleton, 16 mm chipboard, 350 mm cellulose insulation; U-value 0,15 W/m^2K; area 214,2 m^2.
Panel: 1,5 x 214,2 m^2 x 0,015 m = 4,8195 m^3.
Plywood skeleton: cc 600 mm, beam 60 mm; 2 x 33 x 0,06 x 5,4 x 0,35= 7,4844 m^3
Chipboard: 214,2 m^2
Cellulose insulation, cutter shavings (120 kg/m^3) : 0,90 x 214,2 m^2 x 0,35 m = 67,473 m^3; 8096,76 kg.

***Roof*:** Roofing felt, plywood skeleton, panel, 600 mm cellulose insulation; U-value 0,10 W/m^2K.
Area: 2 x 5,8 x 10,5 = 60,9 m^2
Roofing felt: 2 x 60,9 = 121,8 m^2
Plywood skeleton: 2 x 18 x 0,06 x 5,8 x 0,6 m^3 = 7,5168 m^3
Panel: 2 x 60,9 x 0,015 m3 = 1,827 m3

Cellulose insulation, cutter shavings (120 kg/m^3): 0,90 x 2 x 60,9 x 0.6 m^3 = 65,772 m3; 7892,64 kg.

***Base joist*:** 16 mm chipboard, plywood skeleton, floor boards, tiles (ground floor bathroom), 500 mm cellulose insulation; U-value 0,12 W/m^2K.
Chipboard: 88,4 m^2.
Plywood: 18 x 0.06 x 8,5 x 0,5 = 4,59 m3.
Floor board (wood): 88,4 m2
Tiles: 2,6 x 2,4 x 0,001 = 0,00624 m^3; => 18,75kg
Cellulose insulation, cutter shavings (120 kg/m^3): 0,90 x 88,4 m^2 x 0,5 m = 39,78 m^3; 4773,6 kg.

Two joists: 16 mm chipboard, plywood skeleton, floor boards, tiles (second floor bathroom), 150 mm cellulose insulation.
Chipboard: 2 x 88,4 m2 = 176,8 m2
Plywood: 2 x18 x 0,06 x 8,5 x 0,15 m3 = 2,754 m3
Floor boards (wood): 88,4 m2
Tiles: 3,6 x 2,4 = 8,64 m2 x 0,001m = 0,00864 m^3 supposed density of 3000 kg/m3 => 25,92 kg
Cellulose insulation, cutter shavings (120 kg/m^3): 2 x 0,90 x 88,4 x 0,15 = 23,868 m3; 2864,16 kg

Internal walls: 16 mm chipboard, plywood skeleton, tiles (bathroom) 60 mm cellulose insulation, wallpaper.
Area: 80 m2
Chipboard: 2 x 80 m^2
Tiles: 2 x 3,6 + 2 x 2,4 + 2x2,6 + 2 x 2,4 =22 m2 x 0,0001m 0,022m3 =>66 kg
Plywood skeleton: (12+8+10+10+16+8) x 0,06 x 0,06 x 2,4 = 0,55296 m3
Cellulose insulation, cutter shavings (120 kg/m3): 0,90 x 80 x 0,06 m3 = 4,32 m3; 518,4kg
Wallpaper: 2 x 80 m^2

Windows: Triple glazing, low-emission, argon; U-value 1,00 W/m^2K: area 24 m^2.

External doors: Double, U-value 0,65 W/m^2K.

Energy: The energy consumption is calculated with hourly simulations.
Heat exchange ventilation air, 60 % efficiency, mechanical ventilation.
Energy consumption for hot water and heating: 8 748 kWh/year
Energy source: 100 % biomass fuel
Energy consumption for electricity: 6502 kWh/year
Energy source: 50 % nuclear power
50 % water power
Average U-value: 0,13 W/m^2K.

Output table for the material use in step 1 per m2 and year.

Product use

Deviation	Name	Amount	Unit	Complete
0	Annex 31, step 1, material	0,02	m2	no
0	Reinforced concrete, cellular floor unit	0,0024	ton	yes
0	Concrete, wall unit	0,013143	ton	yes
0	Concrete, wall unit, 2300 kg/m3	0,00401	m3	yes
0	Cement, basis	0,001450013	ton	no
0	Cement, white	0,000039429	ton	no
0	Cement, fast	0,000420576	ton	no
0	Plaster, 9 mm, 7.2 kg/m2	0,00684	m2	yes
0	Plaster, 13 mm, 14 kg/m2	0,00818	m2	no
0	Extracted, boric acid, Na2B4O7, 10H2O	1,17096E-06	ton	no
0	Extracted, dolomite, CaMg(CO3)2	0,000001071	ton	no
0	Extracted, gypsum, CaSO4·2H2O	4,16972E-05	ton	no
0	Extracted, gravel, land	0	ton	yes
0	Extracted, limestone, CaCO3	2,6418E-07	ton	no
0	Extracted, carbon dioxide, CO2	0	ton	no
0	Extracted, quartz sand, SiO2	4,5696E-06	ton	no
0	Extracted, clay	0,00232128	ton	yes
0	Extracted, natural gas	0	Nm3	yes
0	Extracted, nephrite	1,88496E-06	ton	no
0	Extracted, oxygen, O2	6,01949E-06	ton	yes
0	Extracted, sand, land	0,000292392	ton	no
0	Extracted, sand, lake	0,006034914	ton	yes
0	Extracted, granite, crushed	0,005942796	ton	yes
0	Insulation, glass wool - EU	0,00001428	ton	yes
0	Insulation, glass wool, 14 kg/m3	0,00102	m3	yes
0	Lime, slaked lime	9,59439E-06	ton	yes
0	Chemistry, ammoniak, NH3	0	ton	no
0	Chemistry, benzene, C6H6	0	ton	yes
0	Chemistry, formaldehyde, HCHO	0	ton	no
0	Chemistry, methanol, CH3OH	0	ton	no
0	Chemistry, natrium carbonate (soda), Na2CO3	0,000001785	ton	no
0	Chemistry, natrium hydroxide (caustic soda), NaOH	0	ton	no
0	Chemistry, phenol, C6H5OH	0	ton	yes
0	Chemistry, propylen, CH3(CH)CH2	0	ton	yes
0	Chemistry, sulphuric acid, H2SO4	0	ton	no
0	Chemistry, urea, NH2CONH2	0	ton	no
0	Oil, refined	0	ton	yes
0	Paper, cardboard	0,000006759	ton	no
0	Steel, reinforcing bar of scrap	0,00026286	ton	yes
0	Steel, galvanized sheet metal	0	ton	yes
0	Steel, iron ore	7,3589E-05	ton	no
0	Brick, red	0,002232	ton	yes
0	Brick, red, 1800 kg/m3	0,00124	m3	yes

0	Tiles, iron	2,06189E-05	ton	no
0	Tiles, rigid	4,3262E-07	ton	no
0	Wood, raw wood	0,0071988	m3	yes
0	Wood, plywood	0,00168	m3	no
0	Wood, board	0,00229	m3	yes
0	Wood, chipboard, 675 kg/m3	0,000004	m3	yes
0	Zinc, thermal process	0	ton	yes

Consumption of energy

Deviation	Name	Amount	Unit Name	Complete
0	Electricity, biomass fuel	12,14305099	MJ	yes
0	Electricity, nuclear power	4,292894805	MJ	no
0	Electricity, water power	0,362847428	MJ	yes
0	Coal, brown coal	0,081945197	MJ	no
0	Coal, stone coal	4,803505088	MJ	yes
0	Natural gas	6,521088843	MJ	yes
0	Natural gas, rest product	0	MJ	yes
0	Oil, fuel oil	1,357239359	MJ	yes
0	Oil, gasoline	11,40987181	MJ	yes
0	Oil, rest product	0	MJ	yes
0	Oil, waste oil	0,20978	MJ	yes
0	Unspecified	0,037162435	MJ	yes

Raw material use

Deviation	Name	Amount	Unit
0	Combustable, natural gas	0	Nm3
0	Combustable, oil	0	µg
0	Combustable, wood, 0% water	-425,0795183	g
0	Dolomit	1,071	g
0	Fly ash	324,8712	g
0	Gypsum, industrial	99,4292	g
0	Gypsum, natural	41,6972	g
0	Glasspliners	4,4268	g
0	Granite	5,942796	kg
0	Iron ore	147,17796	g
0	Limestone	20,412399	g
0	Coal, brown coal	8,194519748	g
0	Coal, stone coal	159,7852797	g
0	Quartz sand	4,5696	g
0	Clay	0,001657394	m3
0	Natural gas	0,183860221	Nm3
0	Recycled paper	6,759	g
0	Raw oil	295,5183362	g
0	Sand	6,327306	kg
0	Scrap, steel	229,73964	g
0	Wood, 50% water	0,0071988	m3
0	Wood, sawdust	0,0001116	m3
0	Zinc ore as Zn	0	µg

Atmospheric emissions

Deviation	Name	Amount	Unit Name
0	Ammoniak (NH3)	47,65556711	mg
0	Arsenic (As)	56,84687746	µg
0	Lead (Pb)	1,452780641	mg

0	Cadmium (Cd)	43,63527878	µg
0	Fluoride (F)	558	mg
0	Formaldehyde	4,80176	mg
0	Carbon dioxide (CO2)	1,954246704	kg
0	Carbon monoxide (CO)	7,023665513	g
0	Mercury (Hg)	36,30148411	µg
0	Nitrogen dioxide (N2O)	3,174018094	mg
0	Methane (CH4)	6,346474799	mg
0	Nickel (Ni)	555,1696258	µg
0	Nitrogen oxides (NOx)	7,427276507	g
0	Particles	1,532394402	g
0	Phenol	4,22688	mg
0	Sulphur dioxide (SO2)	7,463746195	g
0	VOC, car (diesel)	227,8011762	mg
0	VOC, power station	956,1189127	mg
0	VOC, unspecified	0	µg
0	Zinc (Zn)	4,675568359	mg

Solid wastes

Deviation	Name	Amount	Unit Name
0	Hazardous waste, unspecified	3,691225112	mg
0	Nuclear waste	33,59014852	g
0	Slag & fly ash	28,77468457	g
0	Waste volume, unspec.	736,9129414	g

Output table for the material use in step 2 per m2 and year

Product use

Deviation	Name	Amount	Unit	Complete
0	Annex 31, step 2, materials	0,02	m2	no
0	Reinforced concrete, cellular floor unit	0,0012026	ton	yes
0	Cement, basis	0,0001503	ton	no
0	Plaster, 13 mm, 14 kg/m2	0,02856	m2	no
0	Parition wall, chipboard/wood skeleton/mineral wool (16/95/95)	0,0114286	m2	yes
0	Extracted, boric acid, Na2B4O7, 10H2O	1,387E-05	ton	no
0	Extracted, diabase	0	ton	no
0	Extracted, dolomite, CaMg(CO3)2	1,269E-05	ton	no
0	Extracted, gypsum, CaSO4·2H2O	0,0001142	ton	no
0	Extracted, limestone, CaCO3	3,129E-06	ton	no
0	Extracted, Carbon dioxide, CO2	0	ton	no
0	Extracted, quartz sand, SiO2	5,413E-05	ton	no
0	Extracted, clay	0,0005616	ton	yes
0	Extracted, natural gas	0,0032644	Nm3	yes
0	Extracted, nephrite	2,233E-05	ton	no
0	Extracted, sand, land	7,074E-05	ton	no
0	Extracted, sand, lake	0,0004029	ton	yes
0	Extracted, granite, crushed	0,0005279	ton	yes
0	Insulation, glass wool - EU	0,0001692	ton	yes
0	Insulation, glass wool, 14 kg/m3	0,0120828	m3	yes
0	Insulation, stone wool - EU	3,429E-05	ton	yes
0	Insulation, stone wool, 30 kg/m3	0,0011429	m3	yes
0	Chemistry, ammoniak, NH3	0	ton	no
0	Chemistry, benzene, C6H6	0	ton	yes
0	Chemistry, formaldehyde, HCHO	0	ton	no
0	Chemistry, methanol, CH3OH	0	ton	no
0	Chemistry, natrium carbonate (soda), Na2CO3	2,114E-05	ton	no
0	Chemistry, natrium hydroxide (caustic soda), NaOH	0	ton	no
0	Chemistry, phenol, C6H5OH	0	ton	yes
0	Chemistry, propylen, CH3 (CH)CH2	0	ton	yes
0	Chemistry, sulphuric acid, H2SO4	0	ton	no
0	Chemistry, urea, NH2CONH2	0	ton	no
0	Oil, refined	3,38E-06	ton	yes
0	Paper, Cardboard	1,285E-05	ton	no
0	Plastic film, LDPE, 0,15 mm	0,02856	m2	no
0	Plastic, granulate LDPE	4,284E-06	ton	no
0	Steel, iron ore	1,804E-05	ton	no
0	Brick, yellow	0,00054	ton	yes
0	Brick, yellow, 1800 kg/m3	0,0003	m3	yes
0	Tiles, iron	1,528E-05	ton	no
0	Tiles, stivelse	1,228E-06	ton	no
0	Wood, raw wood	0,0123922	m3	yes

0	Wood, plywood	0,0029804	m3	no
0	Wood, board	0,0028243	m3	yes
0	Wood, chipboard, 675 kg/m3	0,0009498	m3	yes
0	Wood, chipboard, 675 kg/m3, 16 mm	0,0593601	m2	yes

Consumption of energy

Deviation	Name	Amount	Unit Name	Complete
0	Electricity, biomass fuel	22,949804	MJ	yes
0	Electricity, nuclear power	3,1083906	MJ	no
0	Electricity, water power	0,2644385	MJ	yes
0	Coal, brown coal	0,0591981	MJ	no
0	Coal, stone coal	2,970975	MJ	yes
0	Natural gas	4,8295091	MJ	yes
0	Natural gas, rest product	0,0405266	MJ	yes
0	Oil, fuel oil	1,0766951	MJ	yes
0	Oil, gasoline	3,4391637	MJ	yes
0	Oil, rest product	0,0415548	MJ	yes
0	Unspecified	0,0100091	MJ	yes

Raw material use

Deviation	Name	Amount	Unit
0	Combustable, natural gas	1,114E-07	Nm3
0	Combustable, oil	-599,76	µg
0	Combustable, wood, 0% water	-544,14516	g
0	Diabase	0	µg
0	Dolomit	12,68694	g
0	Fly ash	41,608991	g
0	Gypsum, industrial	274,176	g
0	Gypsum, natural	114,24	g
0	Glassplinter	52,439352	g
0	Granite	527,92911	g
0	Iron ore	36,07716	g
0	Limestone	3,1294452	g
0	Coal, brown coal	5,9198149	g
0	Coal, stone coal	98,647203	g
0	Quartz sand	54,130944	g
0	Clay	0,000401	m3
0	Natural gas	0,1313367	Nm3
0	Recycled paper	12,852	g
0	Raw oil	108,57217	g
0	Sand	473,60162	g
0	Wood, 50% water	0,0123922	m3
0	Wood, sågspån	0,000027	m3

Atmospheric emissions

Deviation	Name	Amount	UnitName
0	Ammoniak (NH3)	560,98893	mg
0	Arsenic (As)	40,753692	µg
0	Lead (Pb)	165,15016	µg
0	Cadmium (Cd)	5,9797587	µg
0	Fluoride (F)	135	mg
0	Formaldehyde	70,597221	mg

0	Hydrochloride (HCl)	299,88	µg
0	Hydrofluoride (HF)	21,42	µg
0	Carbon dioxide (CO2)	1,0414743	kg
0	Carbon monoxide (CO)	8,8126784	g
0	Mercury (Hg)	7,3578874	µg
0	Nitrogen dioxide (N2O)	2,2618314	mg
0	Methane (CH4)	4,5236629	mg
0	Nickel (Ni)	401,22459	µg
0	Nitrogen oxides (NOx)	5,9429632	g
0	Particles	2,764712	g
0	Phenol	50,071123	mg
0	Sulphur dioxide (SO2)	5,407433	g
0	VOC, car (diesel)	168,32192	mg
0	VOC, power station	1,7965087	g
0	VOC, plastic	89,964	mg
0	VOC, unspecified	0	µg
0	Zinc (Zn)	16,8535	µg

Solid wastes

Deviation	Name	Amount	Unit Name
0	Hazardous waste, unspecified	18,088983	mg
0	Nuclear waste	24,265908	g
0	Slag & fly ash	22,124543	g
0	Waste volume, mineral wool	1,71429	g
0	Waste volume, unspec.	144,36368	g

Output table for the energy use in step 2 per m2 and year

Consumption of energy

Deviation	Name	Amount	Unit Name	Complete
0	Electricity, nuclear power	78,012	MJ	no
0	Electricity, water power	78,012	MJ	yes
0	Natural gas	209,952	MJ	yes

Raw material use

Deviation	Name	Amount	Unit
0	Coal, stone coal	42,4103	g
0	Natural gas	5,139625	Nm3
0	Raw oil	10,4976	g

Atmospheric emissions

Deviation	Name	Amount	Unit Name
0	Cadmium (Cd)	7,852205	µg
0	Carbon dioxide (CO_2)	11,46128	kg
0	Carbon monoxide(CO)	5,887054	g
0	Nitrogen dioxide (N_2O)	23,15771	g
0	Sulphur dioxide (SO_2)	2,561414	g

Solid wastes

Deviation	Name	Amount	Unit Name
0	Slag & fly ash	2,309472	g
0	Waste volume, unspec.	39,26102	g

:Output table for the material use in step 3 per m2 and year

Product use

Deviation	Name	Amount	Unit	Complete
0	Annex 31, step 3, materials	0,02	m2	yes
0	Reinforced concrete, cellular floor units	0,001202572	ton	yes
0	Cement	0,000150322	ton	no
0	Extracted, carbon dioxide, CO_2	0	ton	no
0	Extracted, clay	0,0005616	ton	yes
0	Extracted, natural gas	0	Nm3	yes
0	Extracted, sand, land	0,00007074	ton	no
0	Extracted, sand, lake	0,000402862	ton	yes
0	Extracted, granite, crushed	0,000527929	ton	yes
0	Insulation, cellulose wool	0,003219408	ton	yes
0	Chemistry, aluminium hydroxide, $Al_2O_3{\cdot}3H_2O$	0,000321941	ton	no
0	Chemistry, ammoniak, NH_3	0	ton	no
0	Chemistry, borax, $Na_2B_4O_7$, $10H_2O$	8,04852E-05	ton	no
0	Chemistry, boric acid, H_3BO_3	8,04852E-05	ton	no
0	Chemistry, formaldehyde, HCHO	0	ton	no
0	Chemistry, methanol, CH_3OH	0	ton	no
0	Chemistry, urea, NH_2CONH_2	0	ton	no
0	Steel, iron ore	1,80386E-05	ton	no
0	Brick, yellow	0,00054	ton	yes
0	Brick, yellow, 1800 kg/m3	0,0003	m3	yes
0	Tiles, iron	0,00001528	ton	no
0	Wood, raw wood	0,012995116	m3	yes
0	Wood, plywood	0,003053981	m3	no
0	Wood, board	0,00266428	m3	yes
0	Wood, chipboard, 675 kg/m3	0,001364064	m3	yes
0	Wood, chipboard, 675 kg/m3, 16 mm	0,085254	m2	yes

Energy consumption

Deviation	Name	Amount	Unit Name	Complete
0	Electricity, biomass fuel	24,51741223	MJ	yes
0	Electricity, nuclear power	3,082805224	MJ	no
0	Electricity, water power	0,260567286	MJ	yes
0	Coal, brown coal	0,058846325	MJ	no
0	Coal, stone coal	2,668706798	MJ	yes
0	Natural gas	3,324553474	MJ	yes
0	Oil, fuel oil	0,899353828	MJ	yes
0	Oil, gasoline	3,958422625	MJ	yes
0	Unspecified	0,009109483	MJ	yes

Raw material use

Deviation	Name	Amount	Unit
0	Combustable, wood, 0% water	-495,2159503	g

0	Fly ash	41,6089912	g
0	Granite	527,929108	g
0	Iron ore	36,07716	g
0	Coal, brown coal	5,884632499	g
0	Coal, stone coal	88,45934267	g
0	Clay	0,000400982	m3
0	Natural gas	0,091150118	Nm3
0	Recycled paper	2,7364968	kg
0	Raw oil	112,1546374	g
0	Sand	473,60162	g
0	Wood, 50% water	0,012995116	m3
0	Wood, sawdust	0,000027	m3

Atmospheric emissions

Deviation	Name	Amount	Unit Name
0	Ammoniak (NH3)	338,9948534	µg
0	Arsenic (As)	38,64501276	µg
0	Lead (Pb)	162,7948878	µg
0	Cadmium (Cd)	5,710071951	µg
0	Fluoride (F)	135	mg
0	Formaldehyde	20,7337728	mg
0	Carbon dioxide (CO2)	939,9530872	g
0	Carbon monoxide (CO)	9,381801644	g
0	Mercury (Hg)	6,946436127	µg
0	Nitrogen dioxide (N2O)	3,389948534	mg
0	Methane (CH4)	6,779897068	mg
0	Nickel (Ni)	392,585306	µg
0	Nitrogen oxides (NOx)	6,083692582	g
0	Particles	2,9910285	g
0	Sulphur dioxide (SO2)	5,070372428	g
0	VOC, car (diesel)	237,2963974	mg
0	VOC, power station	1,918715867	g
0	Zinc (Zn)	7,280334256	µg

Solid wastes

Deviation	Name	Amount	Unit Name
0	Farligt affald, uspec.	2,65073536	mg
0	Radioaktivt affald	24,12169178	g
0	Slagge & flyveaske	21,13317156	g
0	Volumen affald, uspec.	137,6968908	g

Output table for the energy use in step 3 per m2 and year

Energy consumption

Deviation	Name	Amount	Unit Name	Complete
0	Electricity, biomass fuel	287,964	MJ	yes
0	Electricity, nuclear power	39,024	MJ	no
0	Electricity, water power	39,024	MJ	yes

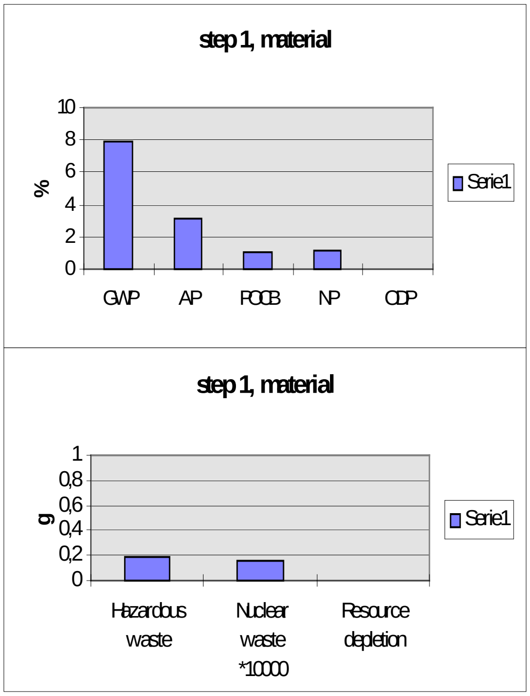
Raw material use

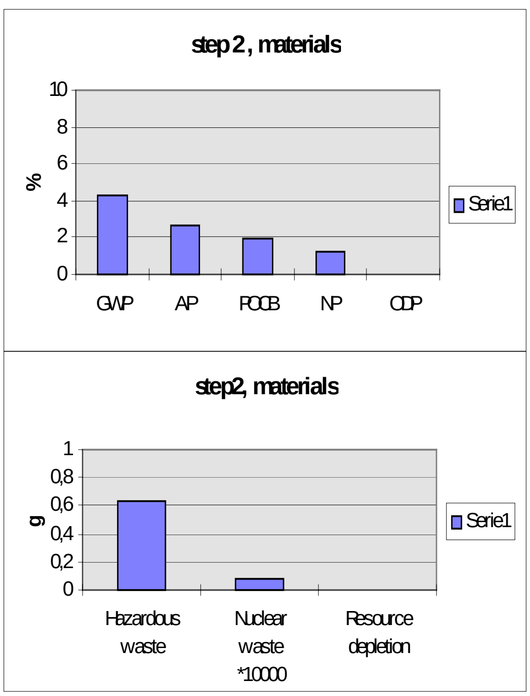
Deviation	Name	Amount	Unit
0	Combustable, wood, 0% water	14,470191	kg

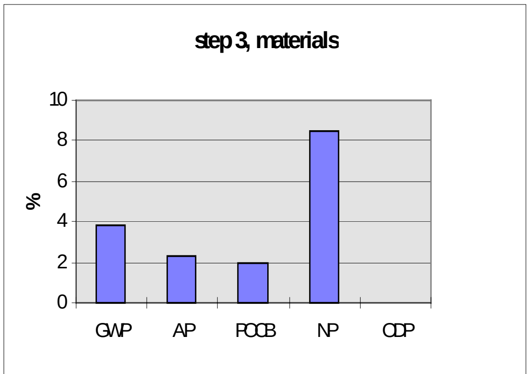
Atmospheric emissions

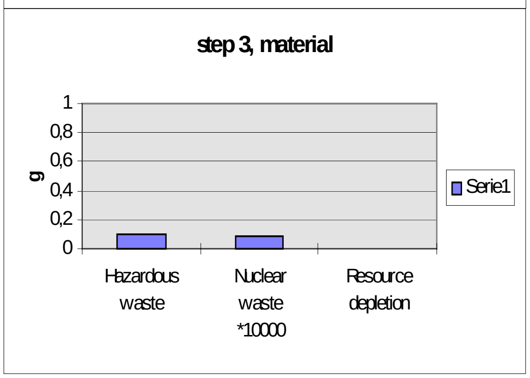
Deviation	Name	Amount	Unit Name
0	Carbon dioxide (CO2)	0	µg
0	Carbon monoxide (CO)	95,316084	g
0	Nitrogen dioxide (N2O)	25,340832	g
0	Particles	33,691788	g
0	Sulphur dioxide (SO2)	1,6701912	g
0	VOC, power station	22,461192	g

Graphical output for materials





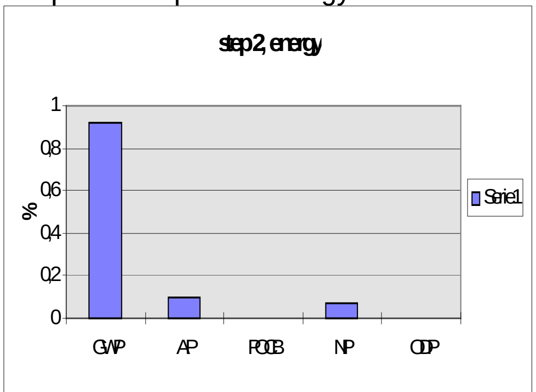


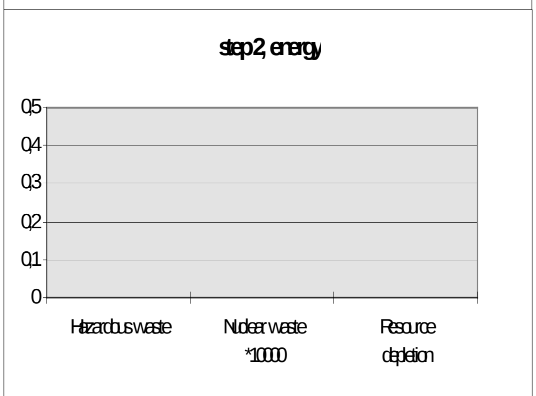


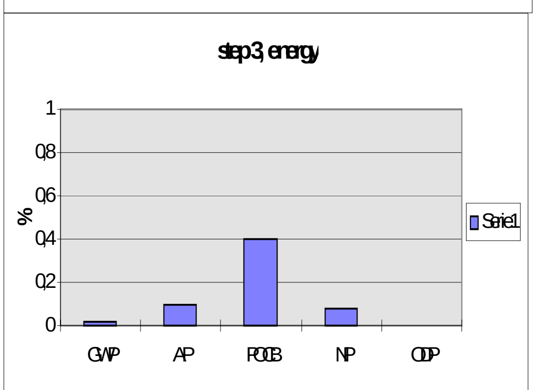
% = contribution to the environmental load per year by a user of the property compared to the average corresponding contribution of a person on a local or global scale.

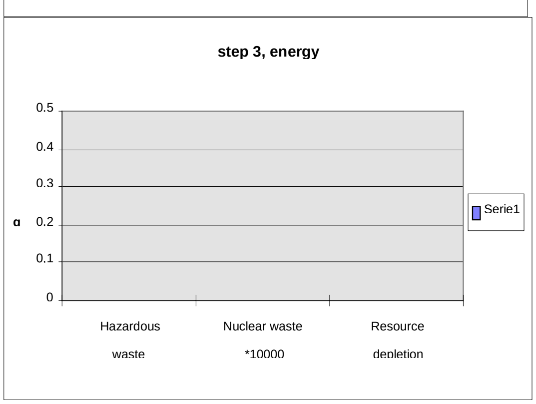
g = per person and year

Graphical output for energy









% = contribution to the environmental load per year by a user of the property compared to the average corresponding contribution of a person on a local or global scale.

g = per person and year

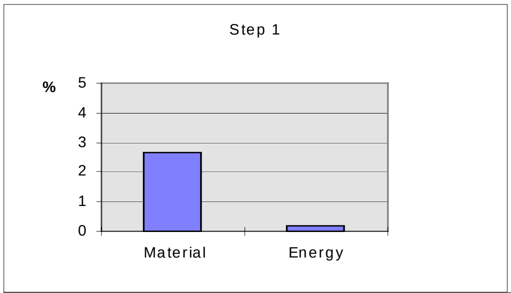
The assessment of resource depletion is not yet ready and no values are thus available.

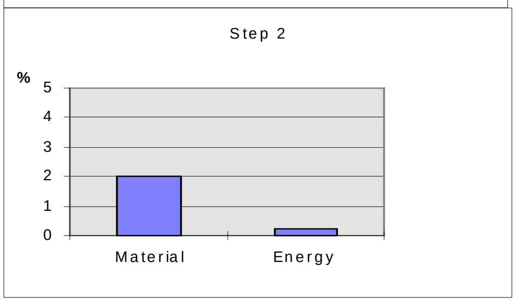
Weighting of effect categories

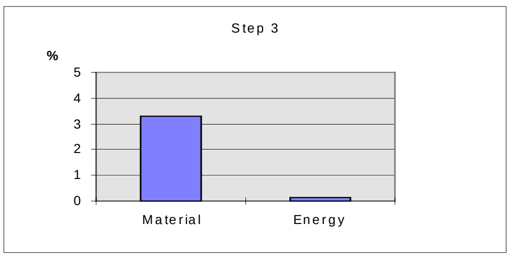
Materials	Weights	Step 1		Step 2		Step 3	
GWP	0,2	7,926725	1,585345	4,266497	0,853299	3,865974	0,773195
AP	0,2	3,190918	0,638184	2,65554	0,531108	2,332389	0,466478
POCB	0,2	1,076226	0,215245	1,893753	0,378751	1,950411	0,390082
NP	0,2	1,19906	0,239812	1,182882	0,236576	8,47814	1,695628
ODP	0,2	0	0	0	0	0	0
		%	2,678586	%	1,999734	%	3,325383

Energy	Weights	Step 1		Step 2		Step 3	
GWP	0,2	0,001825	0,000365	0,923017	0,184603	0,015339	0,003068
AP	0,2	0,69596	0,139192	0,09386	0,018772	0,09704	0,019408
POCB	0,2	0,006038	0,001208	6,18E-06	1,24E-06	0,403059	0,080612
NP	0,2	0,196167	0,039233	0,073444	0,014689	0,080357	0,016071
ODP	0,2	0	0	0	0	0	0
		%	0,179998	%	0,218065	%	0,119159

Step 1		Step 2		Step 3	
Material	2,678586	Material	1,999734	Material	3,325383
Energy	0,179998	Energy	0,218065	Energy	0,119159







% = Contribution to the environmental load per year by a user of the property compared to the average corresponding contribution of a person on a local or global scale.

Concluding Remarks

The method gives assessments in four areas: energy, materials, indoor environment and outdoor environment. Energy and materials are assessed in the same way based on the LCA-methodology. Only results from energy and material use are discussed. The software programme is transparent and default values for example for emissions are easily changed. So far the system is programmed in Microsoft Access. The principles of the methodology are ready but several specific parts are not finished yet.

With EcoEffect you can draw conclusions on all levels if you know the normal environmental loadings from buildings. A future version will include full assessments for a couple of buildings that are typical for period, kind or construction. With these examples conclusions about environmental loadings can be drawn at all levels.

APPENDIX 12 - SWITZERLAND

Domestic building
Analysis tool: E2000 Öko-Bau-Standard
By: Annick Lalive d'Epinay & Anita Müller, ETH, Zürich
Date: August 1998

Introduction

E2000 is a questionnaire that aims to get a rough ecologic characterisation of a building and to then detect the most efficient way to improve it. It has been developed for domestic buildings and can be used for new construction as well as for renovations. It is not a scientific method but a tool that supports architects, planners and building owners to quickly find out how they could optimize their project ecologically.

The tool is based on quantitative and qualitative evaluations. Where possible the method uses data that is necessary anyway to obtain planning permission from the public authority (heating energy consumption). For calculation methods and databases the authors refer to documentations of SIA, the Swiss Society of Engineers and Architects and of the federal office of energy.

For doing the assessment, one has to fill in the assessment-formula. Corresponding to the characteristics of the building, points are given. The rating is very simple. The points just have to be added. Depending on the number of points reached, the building is categorized as "eco-construction in partial areas"; "eco-construction" or "very good eco-construction" (see next paragraph).

The six criterias of the Assessment formula E2000 Öko-Bau-Standard

The assessment formula E2000 Öko-Bau-Standard assesses a building according to 6 criterias. As a maximum, one hundred points can be reached. They are distributed as follow:

	Criterias	**reachable points** min	max
1.	Low energy consumption	10*)	30
2.	Building technology: calculable with efficient ventilation and renewable energy		20
3.	Ecologic materials		10
4.	Efficient use of water		10
5.	Integrated mobility		10
6.	Cheap construction		10
	Total		**100**

*) This means, that every building has to reach at least ten points at the criterium "low energy consumption".

In the following these six criteria are explained:

Low energy consumption
The assessment of this criteria is based on the thermic protection by the building envelope. The heating energy consumption (Qh) gets compared with the corresponding limit value (Hg). For Qh being less than 50 % of Hg, 30 points can be reached, the minimum of ten points can be reached with Qh between 70 and 75 % of Hg.

This section is the first priority-criteria: one third of all points (30 out of 100 points) can be reached in this section. The reason is, that a good thermal insulated building envelope decreases the energy consumption of a building in the longterm and at the same time increases the comfort for the tenants.

Building Technology
The efficiency of the ventilation and the share of energy consumption in use that is taken from renewable resources is measured. Additional points can be received by the installation of household appliances that are distinguished with the energy-label Energie2000.

Ecologic Materials
This criteria can be divided into two parts: First is asked if the materials are chosen corresponding to defined ecologic criteria, second the amount of total non-renewable primary energy of the construction material is assessed.

Efficient water consumption
Points can be received by the installation of water-saving sanitory systems and by a surrounding (or a roof) that permits rain seepage.

Induced mobility
These criteria assess the possibility to fullfill the general needs of the tenants while maintaining low energy consumption. For example points are given if the infrastructure is good, food-stores can easily be reached by walking or close access to public traffic is given.

Economic construction
The idea of these criteria is that ecologic low-energy houses shall not be more expensive than conventional houses. The assessment takes the basis-price per squaremeter (= Grundpreis minus Parkierungskosten minus lagebedingte Mehrkosten dividiert durch Anzahl Quadratmeter Nettowohnfläche). The points are given in the range of 2'600 swiss francs per squaremeteres (10 points) to 3'500 swiss francs per squaremeters (2 points).

Ratings
For the rating, the points of the different sections have to be added and compared with the following classification:

25 - 49 points Eco-construction **in partial areas**
50 - 74 points **Eco-construction**

75 - 100 points**very good** eco-construction

Assistance of the tool in optimizing the design:

- o The tool is used during the planning phase.
- o Applicants of the tools should be architects, planners or owners that wish to optimize their project.
- o The tool concentrates mostly on an optimization of the energy consumption of the building itself and of its use.
- o The highest level of improvement enabled by the tool is an ecologic low-energy house. The lowest level of improvement is no improvement.
- o The tool is most sensitive for improvements concerning the consumption of heating energy.
- o Hard to tell.
- o The tool is at the moment accessed (Probephase) and being examined by interested architects.
- o The probation has not finished yet.
- o The future expectations of the tool are, that it will be established on the market soon and will support a gradual introduction of sustainable construction.

Step 1

Actually it does not make much sense to calculate the method ignoring the energy in use, as this is the category that is valued as the most important of all the six categories (see above).

Input:

Ecologic performance of the materials during the building process (qualitative)
non-renewable primary energy consumption of the used materials
Induced mobility (qualitative)
Economic construction: Basisprice

Output:

Assessment as “Very good eco-construction”“, “Eco-construction” or “Eco-construction in parts”, see classification given above.

Calculations:

Only additions.

Conclusions:

By going through the form of evaluation one can see what kind of points could not be reached, or otherwise: where the potential of optimization lies.

Without looking at energy-consumption in use, no conclusions can be made (concerns two of the major assessment-criterias).

Step 2

No adaptations performed.

Input *(just in addition to step 1 as here energy in use also gets considered):*

- o Consumption of heating energy

- Limit value for consumption of heating energy
- Efficiency of ventilation (mix of qualitative and quantitative)
- Ecological performance of the heating system (qualitative)
- Share of the renewable energy used for the warm-water production
- Does a proof exist for the optimization of the installed heating system? (qualitative)
- Own electricity-production, if available (qualitative)
- Type of installation of household appliance (with or without energy-label) (qualitative)
- Type of water installation (with or without water-saving systems) (qualitative)
- Treatment of raining water (leading into draining system or seeping in the surrounding and/or on the roof)

Step 3

Compare with 1.1 and 2.1.
Optimization probably would be done by:

- Decreasing the consumption of heating-energy by improving the thermal protection of the building cover
- Install a heating system that works with wood, sun-energy, heat-pump, long distance heating (where at least 80 % of the resource consist of renewable energy)
- Covering the energy for the warm-water consumption to more than 60 % out of renewable energy
- Guarantee an optimal working of the heating system
- Covering the power consumption with own production
- Installing only household appliance that are distinguished with an energy-label
- Use of construction material that fulfill ecologic criterias.
- Use of construction material that require the least non-renewable primary energy as possible.
- Install sanitary systems that support a low water consumption
- Provide seeping possibilities for the rain water around the house
- Install if possible a flat roof with retention of rain water (Grün-Dach, Aufstauung)
- Build the house in a location that provides a good infrastructure.
- Consider not only ecologic aspects but also the costs of the measures during planning.

Explanations

The former steps show how the method works. Calculations could not be done because the case study does not specify all the inputs very well for this method.

Actually there are a lot of different inputs needed. Some are quantitative, some are qualitative. A lot of the inputs an architect or a planner has to calculate anyway, as the government requests these data for giving building permission. For some of the calculations, simple computer programs are available.

To be able, to assess a building with the method, the information described below is necessary. The inputs are bold and italic. It is important to remember that the assessment points are weighted differently (compare with 1.1 The six criterias of the Assessment formula E2000 Öko-Bau-Standard“ of qualitative Bewertung).

1. **Low energy consumption (quantitative)**
   Here they ask for the ***heating energy consumption*** of the building.
   Calculation method: guidelines from the Swiss government and computer programs are available. In most of the areas of Switzerland this data is requested for the building permission**.**
   Assessment: The method compares the heating energy consumption of the building (calculated in accordance with the above mentioned guidelines) with the – from the government directed – limit of the heating energy consumption.

2. **Building (construction) technology**
   a) **Efficient ventilation (half quantitative)**
   Does the ventilation contain ***heat recovery***? If yes, you get five points and if in addition the heat recovery is seven times higher than the power consumption, you get ten points.
   b) **Heating system (qualitative)**
   What ***kind of heating system*** is used? You get points if you have got one or a combination of the following systems: heating with wood or sun, heat pump (without usage of outside air), Fernwärme (more than 80 percent from renewable energy).
   c) **Warm water (half quantitative)**
   You get points, if some of the warm water is heated ***with renewable energy*** or if you have got a heating pump.
   d) **Optimization of the processes (qualitative)**
   Points are given, if you have got a guarantee (certificate) that the ***processes*** (heating, ventilation, warm water production) are ***running at optimum***.
   e) **Own power production and efficient household appliance (qualitative)**
   You get points, if you have got an ***own power production system*** based on photovoltaic/solarcells, on a "Blockheizkraftwerk", on water or on wind. Further points are given, if all household appliances are certificated with a low energy-consumption label (i.e. Energy label EnergyE2000 from Switzerland).
3. **Ecological Materials**
   a) **Material ecology during the construction process (qualitative)**
   Did you make the choice of ***materials*** dependent on ***ecological aspects***? For example, did you include guidelines concerning the ecologic performance in the planning process?
   b) **The content of non-renewable energy of the construction material (quantitative)**
   Calculation method: Sum of ***the content of non-renewable energy*** of all the material used for the construction. For the data, the authors recommend the database of SIA D0123, "Hochbaukonstruktionen nach ökologischen Gesichtspunkten".

4. **Efficiency of the water consumption**
   a) **Reduction of the water consumption (qualitative)**
   You get points, if your sanitary facilities are specially designed to ***reduce the***

water consumption (i.e. WC with two choices of the quantity of flashing water).

b) Possibility for seeping (qualitative)
Has the ***rain*** the ***possibility to seep*** on the surrounding and/or the roof of your building? Points are given for possibility of direct seeping of the rainwater, for a roof with retention and for a “Retentionsbecken”.

5. Integrated mobility (all qualitative)

a) Distance to important infrastructure
You get points, if you can fulfill your general needs with low ***energy consumption***, i.e. if you can do your everyday shopping by walking.

b) Quality of the net of public transportation
How easy is it for the inhabitant of your building, to ***get around by public transportation***? The answer is based on guidelines of the government.

c) Accessibility of the property
Is there a direct footpath from the front door to important destinations? Are there at minimum two covered parking areas for bicycles? Are there more parking lots (car) as specified by the government (negative point)?

d) “Kostenwahrheit” and flexibility
Concerns the costs of the parking lots and the possibility, to use them for something else.

6. Economic construction (quantitative)
Here they ask for the ***basis-price per square meter.***
Calculation: “Grundpreis minus Parkierungskosten minus lagebedingte Mehrkosten dividiert durch Anzahl Quadratmeter Nettowohnfläche.”

Concluding Remarks

E2000 is a questionnaire that follows the aim to get a rough ecologic characterisation of a domestic building project and to detect the most efficient way to improve it. It is used in the very early phase of building design. The questionnaire itself is based on a simple checklist and point system. It consists of six different parts looking at six different aspects and using six different methodological backgrounds:

1. For energy in use related questions the total amount of estimated consumption is weighted. The calculation of this predicted energy consumption is based on a well-known national standard method (SIA 380/1 and 380/4).
2. In the building control sector labels are indicators for ecological decisions and the use of renewable energy sources.
3. The weighting of the different materials is based on biological studies and on the embodied energy aspect. It also includes waste related aspects.
4. The assessment of water consumption is more qualitative: water-saving sanitary systems and a rain seeping system are judged ecologically useful.
5. A rather special issue is the transport criteria: also on a qualitative basis the potential for using public transport systems or bicycles (e.g. the distance to and the frequency of public transport systems) are used for the assessment.

The behaviour of later inhabitants cannot be considered in this early planning phase.

6. Economic aspects are also considered, above all because banks use the questionnaire to give better condition for financing the construction project.

The checklist is not based on LCA-methodology, even if different life cycle stages (use phase, construction and demolition) are considered.

The case study shows which information can be used as an input for the method, but also shows which information is missing. One of the outputs of the method is the improvement options. They are formulated in common terms, the interpretation is up to the architect or planner or consultant.

APPENDIX 13 - UK

Office building
Analysis tool: BREEAM 98 for Offices
By: Matthew Janssen, Environmental and Energy Services
Date: May 1998

Introduction

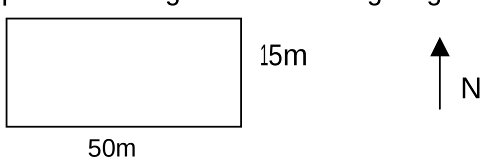
BREEAM'98 for offices is a kind of questionnaire with which credits can be earned. It is a tool which is used at the early design stage and then throughout the elaboration of the design. It is used by a BREEAM assessor for labelling the overall attribute of a building design. BREEAM assessors are expected to be regular members of the design team.

The scheme in this form was launched September 1998 in the UK. Earlier versions of BREEAM have been market assessed, with very favourable responses. The current revision takes account of the findings of a Deloitte and Touche market survey. The tool is expected to achieve rapid penetration of the office sector of the UK and to be taken up over a longer term.

Step 1: Environmental impact of the given building (embodied energy only)

The assumptions which had to be made to perform the BREEAM 98 assessment were:

1. Speculative city building in the Thames Valley.
2. Design Temperatures : Winter External = -1; Winter Internal = 19.5^{o}C; summer Internal = 22^{o}C. Not severely exposed.
3. Floors- all carpeted
4. Ceilings- no suspended ceiling. Floor to ceiling height of 2.4m.
5. Orientation-



6. U.Value for wall- 0.45
7. No glazing on roof.
8. Occupancy- 5 days/week; 8 hrs/day, beginning at 8.00.
9. Lighting- suspended, 300 Lux; 10w/m^2 load; no uplighters; normal usage.
10. Small power- default.
11. Heating:
    - o naturally ventilated, with radiators.
    - o gas fired condensing boiler.
    - o condensing rtn of 45^{o}C- 50^{o}C.

- o on/off control with pilot flame.
- o controls through room thermostat, fixed start time.

12. Hot water- central storage.
13. No frost protection.
14. No catering.

What is the input of the method?

Answer: Selection of the closest specification to the design for the main building elements:

i.e.	Upper floor slabs	Insitu (selection slab and screed)
	External walls	Brick, insulation, denser block, plaster
	Windows	Aluminium framed, double glazing 6x6 mm glass
	Roofs	In either RC slab, insulation, asphalt chippings

What is the output of the method?

The output consists of an eco profile and survey rating of the selected specification compared to a wide range of alternative specifications that could have been selected as alternatives. The results are presented as a simple rating based mainly on LCI data estimated over a 60 year period taking account of maintenance and replacement, but not taking account of operational implications (eg heat transmission): Each assembly

For this building:	Summary Rating	Cost range £1m^2	Maintenance frequency (yrs)
Upper floor slabs	C	45-55	-
External walls	C	40-60	10
Windows	C	310-400	-
Roofs	C	60-65	7

Of which the energy related implications of the profile are:

	Primary energy	CO_2 emissions	VOC emissions	NO_x emissions	SO_s emissions	Resources
Upper floor slabs	C	C	C	C	C	C
External walls	C	C	C	C	A	B
Windows	C	C	C	C	C	C
Roofs	B	C	C	B	B	C

The output for the different elements cannot be accumulated by this method because the energy difference between the A to B or B to C ratings varies depending on the range of results achieved for the range of specification variants. BRE are developing a tool which compiles the LCI data for whole buildings, and this is not used in BREEAM 98.

What calculations are performed (in short)?

No calculations are performed. The user simply selects the most representative specification.

What conclusions can be drawn from evaluating the results?

There is ample opportunity for selecting alternative specifications with a reduced environmental impact. The Roofs specification comes closest to achieving a B rating compared to the others.

Step 2

The method is only applicable to UK climatic conditions in its standard form. If suitable data exists it can be readily adapted to other climates and construction technologies.

What is the input of the method?

The input required is fairly detailed data on the building elements, service elements and occupation. The list below illustrates the information required.

ENERGY CONSUMPTION PREDICTION

BUILDING DETAILS

Title:	Annex 31
Type:	Office
Location:	Thames Valley
Number Of Floors:	2
Gross Floor Area:	1500.0m²
% Of Glazing:	0%

ELEMENT	ORIENTATION	AREA m²	U-VALUE W/m² K
ROOF (inc GLZ)	Horizontal	750.0	1.90
FLOOR		750.0	.39
WALL	North	240.0	.45
WALL	East	72.0	.45
WALL	South	240.0	.45
WALL	West	72.0	.45

Building Class (A to F):	C
Building Definition:	Medium Heavy
Response Factor (fr):	4.67

OCCUPANCY

Starting Time: 08:00 hrs
Hours / Days: 8.0
Days / Week: 5.0

LIGHTING

Type: Suspended
Load: 10.0 W/m²
Usage: Normal

HOT WATER SERVICE

System Number: 1
System Type: Central Storage, Compact Distribution
Heat Source: Central Gas Fired Boilers
Type Of Taps: Bib
% Of Building Served: 100.0

SPACE HEATING SYSTEM

System Type: Radiators
System Control: Room Thermostat or Thermostatic Radiator Valves

HEAT GENERATION

Start Control: Fixed Start Time Switch
Heat Source: Gas Boiler Or Heater
Boiler Type: Multiple, Condensing With Ret. Temp < 50 C (No Isolation)

DESIGN CONDITIONS

Winter Internal Design Temperature:	19.5 °C
Winter External Temperature: -	1.0 °C
Summer Internal Design Temperature:	22.0 °C
Summer External Conditions:	28.0 °C Dry Bulb
	21.0 °C Wet Bulb.

Unless stated otherwise all ratings, loads and energies, are based on the gross area of the building.

VENTILATION (OCCUPIED PERIOD)

	AC/HOUR	HEAT LOSS W/m²
Natural ventilation to 100.00 % of the building above ground	1.20	19.48

Total Ventilation Heat Loss: 19.48

VENTILATION (UNOCCUPIED PERIOD)

	AC/HOUR	HEAT LOSS W/m²
Infiltration to 100.00 % of the building above ground	.25	4.06

DESIGN HEAT LOSSES (APPROXIMATE)

Fabric Heat Loss:	27.3W/m²
Ventilation Heat Loss:	19.5W/m²
Total Design Heat Loss:	46.8W/m²

Total Building Design Heat Loss: 70.2kW (19.5 W/m³)

Energy consumptions for an average preheat rate of 43.3 W/m²
(1.38 times the fabric plus infiltration heat loss at -1.0 °C)

ANNUAL HEATING BUILDING REQUIREMENTS kWh/m²
Gross Annual Building Heat Energy: 86.7

FINAL SUMMARY TABLES

MONTHLY ENERGY: ELECTRICITY

MONTH	ENERGY kWh/m²		Maximum Demand W/m²	
	DAY	NIGHT	DAY	NIGHT
OCT	3.67	.31	23.97	10.57
NOV	3.61	.30	23.97	10.57
DEC	3.67	.31	23.97	10.57
JAN	3.67	.31	23.97	10.57
FEB	3.46	.28	23.97	10.57
MAR	3.67	.31	23.97	10.57
APR	3.59	.30	23.97	10.57
MAY	3.61	.30	23.80	10.40
JUN	3.56	.29	23.80	10.40
JUL	3.61	.30	23.80	10.40
AUG	3.61	.30	23.80	10.40
SEP	3.56	.29	23.80	10.40
TOTAL / MD	**43.30**	**3.61**	**23.97**	**10.57**

Building Maximum Demand: 23.97 W/m² (35.96 kW)

ANNUAL ENERGY: ELECTRICITY

SERVICE	ENERGY kWh/m² DAY	NIGHT	TOTAL	Maximum Demand W/m² DAY	NIGHT
Space Heating:	.00	.00	.00	.00	.00
Frig. Air Rec:	.00	.00	.00	.00	.00
HWS:	.00	.00	.00	.00	00
Fans & Pumps:	.24	.04	.28	.17	.17
Lighting:	23.29	2.75	26.04	10.60	8.00
Lifts:	.00	.00	.00	.00	00
Small Power:	19.77	.82	20.59	13.20	2.40
Main Frame Computer:	.00	.00	.00	.00	.00
Catering Equip:	.00	.00	.00	.00	.00
Catering HWS:	.00	.00	.00	.00	.00

Totals 43.30 3.61 46.91 23.97 10.57

% Night Heating: .00 %
% Total Building Night Energy: 7.69 %

ANNUAL ENERGY: OTHER FUELS

SERVICE	Heat Source	ENERGY kWh/m²
Space Heating:	GAS	89.40
HWS (1):	GAS	8.58

Total 97.98

Average Seasonal Heating Boiler Efficiency = 77.68 %

CO_2 Emissions

Within BREEAM 98 there are a series of credits available depending on the amount of CO_2 emissions generated per unit of floor area. For the building being considered CO_2 emissions from the building would be 46 kg/m^2 which equates to 9 credits.

These cannot be answered without also adopting STEP 3 simultaneously. See Step 3.

Step 3

The elemental specifications can be changed to ones with a B or even and A rated specification:
Eg.

	Use
Upper floor slabs	Suspended timber joists, plywood.
External Walls	Natural stone, insulation, dense, black plaster.
Windows	Hardwood framed, double-glazing.
Roofs	Mill finished, stainless steel profiled decking, insulation.

Output of the method

	Summary Rating	Cost Range	Maintenance Frequency (years)
Upper Floor Slabs	A	18-28	10
External Walls	A	60-120	10
Windows	A	290-400	5
Roofs	A	20-30	-

In addition, use of ESICHECK to determine the operational energy performance gives the following results:

MONTHLY ENERGY: ELECTRICITY

MONTH	ENERGY kWh/m²		Maximum Demand W/m²	
	DAY	NIGHT	DAY	NIGHT
OCT	3.66	.31	23.91	10.51
NOV	3.60	.30	23.91	10.51
DEC	3.66	.31	23.91	10.51
JAN	3.66	.31	23.91	10.51
FEB	3.45	.28	23.91	10.51
MAR	3.66	.31	23.91	10.51
APR	3.58	.30	23.91	10.51
MAY	3.61	.30	23.80	10.40
JUN	3.56	.29	23.80	10.40
JUL	3.61	.30	23.80	10.40
AUG	3.61	.30	23.80	10.40
SEP	3.56	.29	23.80	10.40
TOTAL / MD	**43.21**	**3.59**	**23.91**	**10.51**

Building Maximum Demand: 23.91 W/m² (35.87 kW)

ANNUAL ENERGY: ELECTRICITY

SERVICE	ENERGY kWh/m²			Maximum Demand W/m²	
	DAY	NIGHT	TOTAL	DAY	NIGHT
Space Heating:	.00	.00	.00	.00	.00
Frig. Air Rec:	.00	.00	.00	.00	.00
HWS: .00	.00	.00	.00	.00	
Fans & Pumps:	.15	.02	.17	.11	.11
Lighting:	23.29	2.75	26.04	10.60	8.00
Lifts:	.00	.00	.00	.00	.00
Small Power:	19.77	.82	20.59	13.20	2.40
Main Frame Computer:	.00	.00	.00	.00	.00
Catering Equip:	.00	.00	.00	.00	.00
Catering HWS:	.00	.00	.00	.00	.00
Totals	**43.21**	**3.59**	**46.80**	**23.91**	**10.51**

% Night Heating: .00 %
% Total Building Night Energy: 7.68 %

ANNUAL ENERGY: OTHER FUELS

SERVICE	Heat Source	ENERGY kWh/m²
Space Heating:	GAS	35.43
HWS (1):	GAS	8.72

Total 44.14

Average Seasonal Heating Boiler Efficiency = 76.44 %

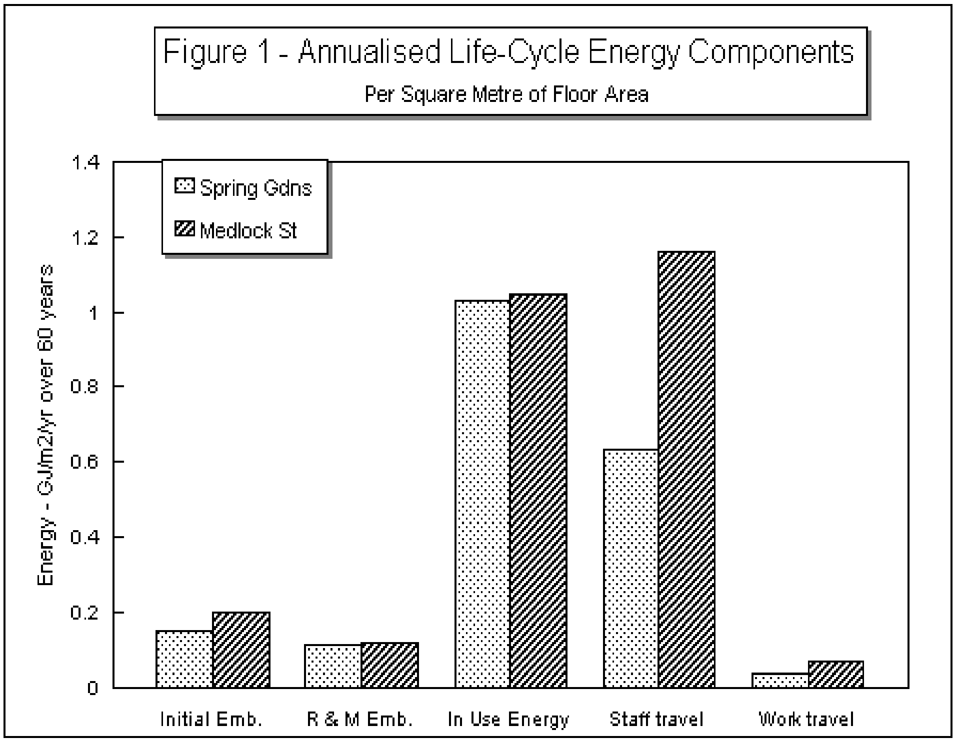
CO_2 Emissions

Within BREEAM 98 there are a series of credits available depending on the amount of CO_2 emissions generated per unit of floor area. For the building being considered CO_2 emissions from the building would be 35 kg/m^2 which equates to 10 credits.

ESICHECK can also be used to determine the CO_2 for different thickness of insulation and hence the credits achieved under BREEAM 98. The Green Guide can also optimise the selection of type of insulation form a range of alternatives.

TRANSPORT

Finally, the transport assessment checklist can demonstrate the benefits of location, proximity to public transport and levels of car park provision. These are also expressed in forms of CO_2 emissions and hence the CO_2 results. The graph below shows how the different energy components of a building over its life compare. As can be seen energy in use and the transport implications are approximately the same, where as the embodied energy components are much lower. For this reason BREEAM 98 is now rewarding buildings with lower transport implications in the same manner as for in use energy.



Concluding Remarks

BREEAM'98 for offices permits a large degree of optimisation in the selection of element specifications, adjustments of fabric insulation, ventilation measures and building services design to reduce the environmental implications for building services. About 75% reductions of the embodied energy and up to 90% reductions in operational energy could be addressed although typical improvements will be less than this.

Operational energy

Operational energy is the most significant energy related environmental impact parameter. This is in turn most sensitive to ventilation rates, insulation levels, many aspects of location and orientation for solar access etc. Building services systems can also be highly significant especially the use of ventilation or AC systems to naturally ventilated buildings.

For the less significant embodied energy implications, upper floors for medium to high rise buildings are most significant. Walls are not significant for cubic buildings and roofs and ground floors most significant for single storey buildings.

Accuracy

Esicheck had proved itself to be accurate within about 10% for most buildings. The Green Guide has proved to compare well with the environmental preference method. The Green guide has 10 issues contributing to the summary rating with a resolution of 33%. We might expect the collective summary rating to be in error by far less than 33%.

APPENDIX 14 - USA

Domestic building
Analysis tool: Energy 10 and BEES
By: Donald Fournier, Aide Uzgiris, USA Construction Engineering Research Labs
Date: December 19, 1998

Introduction

The domestic building was analyzed using two different tools in succession: Energy 10 and BEES. Energy 10 was used to optimize the buildings energy consumption and BEES was used to select the most environmentally benign materials to be used in that optimized design.

Energy 10

When starting a new file in the Energy 10 program, a set of dialog windows opens up requesting information on building location, HVAC system, square footage, number of stories, and electrical rates. Subsequent dialog windows request more specific information on building components. Later, the user may go back and change the actual composition of standard building components, or choose new materials to make up a particular component, and enter user-calculated insulation values.
Output is in the form of tables and graphs shown on subsequent pages. Values are given in U.S. units. The program performs calculations on insulation values, heating and cooling performance, and all calculations are shown on the summary page. It also calculates a low-energy case using alternative materials and methods.
Looking at the results, the designer can make decisions for changes in the building to make it more energy efficient, choosing which components to change and which to leave the same. Then the designer can input the new hybrid and see similar calculations and a further energy efficient case. This process can be repeated until the designer hones in on a satisfactory case.
The Energy 10 tool is used at any stage of a project. It may be used as a design aid for a new building, or to renovate an existing building. It will give concrete values for energy savings given specific building components and maintenance methods.
Applying Energy 10 can provide up to 50% energy and economic savings for a building. The tool is most sensitive to changes in insulating values of materials, because it was designed specifically for calculating energy use data. It is very accurate in this aspect. On a scale of 1 to 10, it would be 9. Since energy and heating values always involve estimation, it does pretty well to estimate realistically.
Energy 10 has been updated with new data and more user-friendly features. Further updates are expected in the future. All updates can be downloaded off the web page.

BEES 1.0

The input of the method is as follows. First, to select parameters for evaluation: percentage environmental vs. economic, and weighting methods. Then, the user selects from tables of materials for each building component. Two materials must be selected in order to receive output.

Output is in the form of a comparative points system. It is displayed in various types of graphs and charts. Environmental (and economic, if desired) scores are calculated as comparative percentages or points. These points are calculated as penalty points, so the higher the score, the *more* of an environmental impact the material has.
We chose all building components described by BEES which applied to our building. There were eight of these. They are shown in tabulated form on pages 8 through 11. Some building components described for the domestic building were not available in the BEES database. So output was limited. In the future, BEES will be expanded to incorporate more materials.

BEES measures environmental performance using an LCA approach, following the guidance in the International Standards Organization 14040 series of draft standards for LCA. Economic performance is separately measured using the American Society for Testing and Materials (ASTM) standard life-cycle cost (LCC) approach. These two performance measures are then synthesized into an overall performance measure using the ASTM standard for Multi-attribute Decision Analysis. The results shown here are solely in terms of environmental performance. For the entire BEES analysis, building products are defined and classified based on UNIFORMAT II, the ASTM standard classification for building elements.

There is little scientific consensus about the relative contributions of pollutants to indoor air performance. In the absence of equivalency factors, a product's total volatile organic compound (VOC) emissions are often used as a measure of indoor air performance. Indoor air quality should be considered for the following building elements currently covered in BEES: floor coverings, wall and roof sheathing, and wall and ceiling insulation. Other BEES building elements are primarily exterior elements for which indoor air quality is not an issue. Nutrients considered in BEES for nutrification include: phosphates, nitrogen oxides, ammonia, nitrates, and phosphorous. Substances considered in acidification are: nitrogen oxides, hydrogen chloride, ammonia, hydrogen fluoride, and sulfur oxides. Substances considered in global warming potential are: carbon dioxide, methane, and nitrous oxide.

The tool may be used after the design is complete, or more practically, at any stage before that. The designer, owner, or contractor may use the tool. More efficient material selections may be found through this method of comparative evaluation, and thus improvements can be made to the design. Embodied energy can be saved by 1 to 15%, depending on how many building components are changed. Transportation to site has a high impact on assessment. It is evaluated for each material. The tool is sensitive to use of local materials. On a scale of 1 to 10, BEES gets 9 points of accuracy. Designers, builders, and consumers use it. 93 percent of U.S. consumers worry about their home's environmental impact. BEES can help them understand the environmental impact of their homes beyond just the heating and electricity bill.

BEES development started in 1994. In 1997, the Environmental Protection Agency's (EPA) Environmentally Preferable Purchasing (EPP) Program began supporting the development of BEES. Over the next several years, BEES will further be developed as a tool to assist the Federal procurement community in carrying out the mandate of Executive Order 12873.

Energy 10 and BEES working together

The following project was refined using Energy 10 software to get through two cycles of energy efficient improvements, concentrating on insulation values. Then the final materials chosen in the Energy 10 Low-Energy Case were put into BEES. BEES then calculated embodied energy for the materials, as well as a 50 year use projection. BEES questioned some material selection from Energy 10 on this basis. The final design decisions can now be made using the wisdom gained from both programs.

Following is a set of data produced by Energy 10 software. The first part is a comparison of the European version of the domestic building, alongside an energy efficient, improved building designed by Energy 10. The second part is data for a U.S. version of a similar domestic building, utilizing materials and systems more common in our construction industry, and alongside it is Energy 10's energy efficient version.

Energy-10 Summary Page **Weather file: sterling.et1**

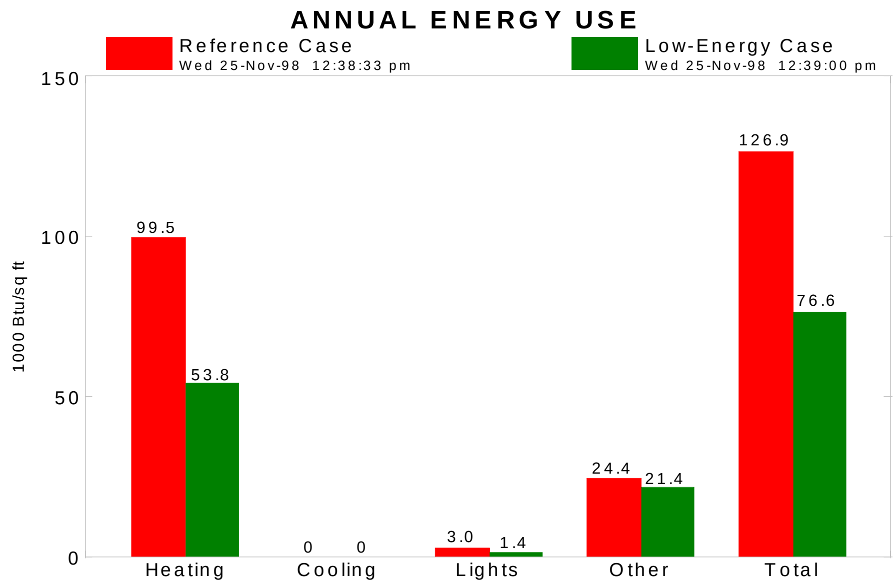
Variant: AutoBuild Shoebox Saved as C:\ENERGY10\DOMESTIC, Var. 1
European-style building

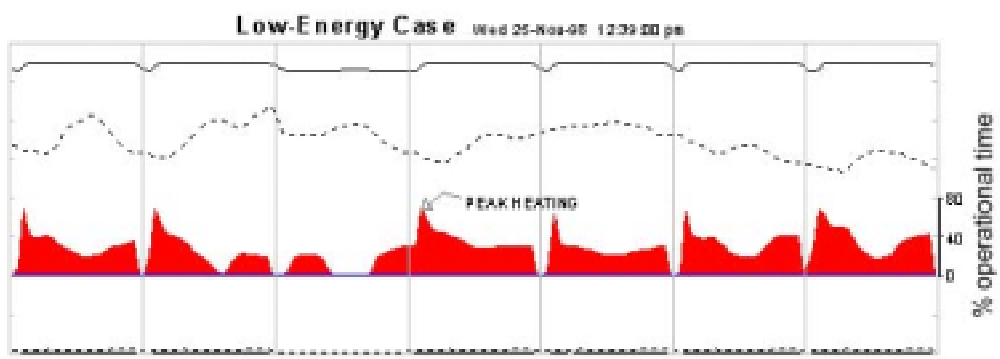
Description:	Reference Case	Low-Energy Case
Floor Area	1500	1500
Surface Area	3660	3660
Volume	13500	13500
Surface Area Ratio	1.08	1.08
Total UA	568.4	342.0
Average U-value	0.155	0.093
Wall Construction	concrete wall, R=14.2	steelstud 6 poly, R=16.6
Roof Construction	flat concrete, R=14.2	flat r-38, R=38.0
Floor type, insulation	Slab on Grade, Reff=6.9	Slab on Grade, Reff=6.9
Window Construction	3040 double, alum, U=0.78	4060 low-e al/b, U=0.31
Window Shading	None	40 deg latitude
Wall total gross area, sf	2160	2160
Roof total gross area, sf	750	750
Ground floor gross area, sf	750	750
Window gross area, sf	360	336
Windows (N/E/S/W:Roof)	9/6/9/6:0	2/3/7/2:0
Glazing name	double, U=0.49	double low-e, U=0.26

Operating parameters for zone 1		
HVAC system	Heat and Vent w/Gas Boiler	same
Heating thermostat	70 F, no setback	70 F, setback to 65 F
Cooling thermostat	78 F, no setup	78 F, setup to 83 F
Heat/cool performance	eff=80,EER=1.0	eff=90,EER=13.0
Economizer?/type	no/NA	yes/fixed dry bulb, 60 F
Duct leakages, total %	21	3
Peak Gains, W/sf	0.20/0.04/0.66/0.36	0.15/0.03/0.66/0.36
Added mass?	none	750 sf, 8in cmu
Daylighting?	no	yes, continuous dimming

Results: (Energy cost: $0.40/therm, $0.05/kWh, $2.47/kW)

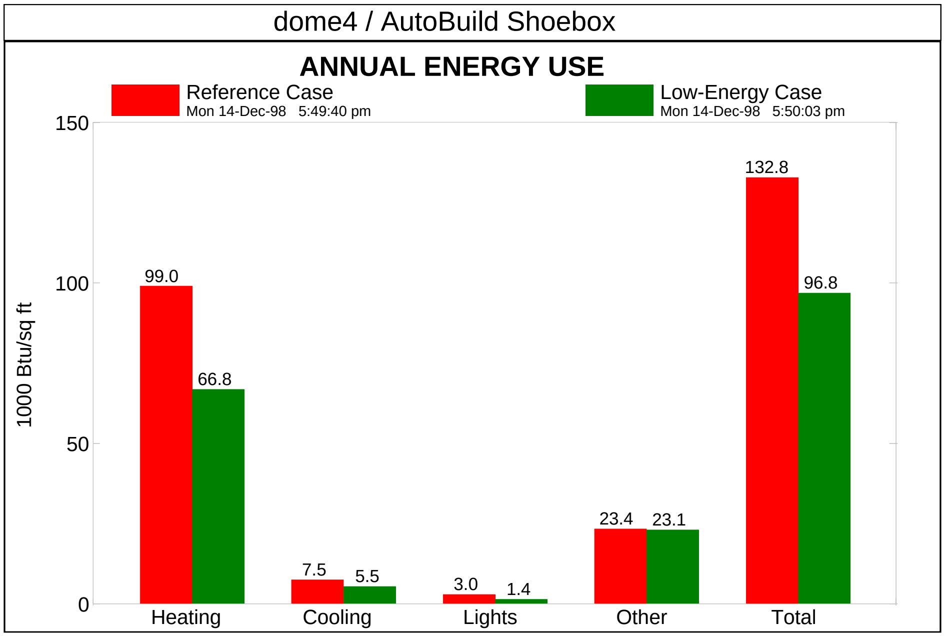
Simulation dates	01-Jan to 31-Dec	01-Jan to 31-Dec
Simulation status	valid/NA	valid/valid
Energy use, kBtu	190300	114924
Energy cost, $	1081	699
Saved by daylighting, kWh	NA	415
Internal/External lights, kWh	1179/129	529/96
Hot water/Other, kWh	4300/3573	4300/3573
Heating/Cooling/Fan, kWh	0/0/2664	0/0/1411
Total Electric, kWh	7740	5721
Peak electric, kW	1	1
Fuel, million Btu	164	95

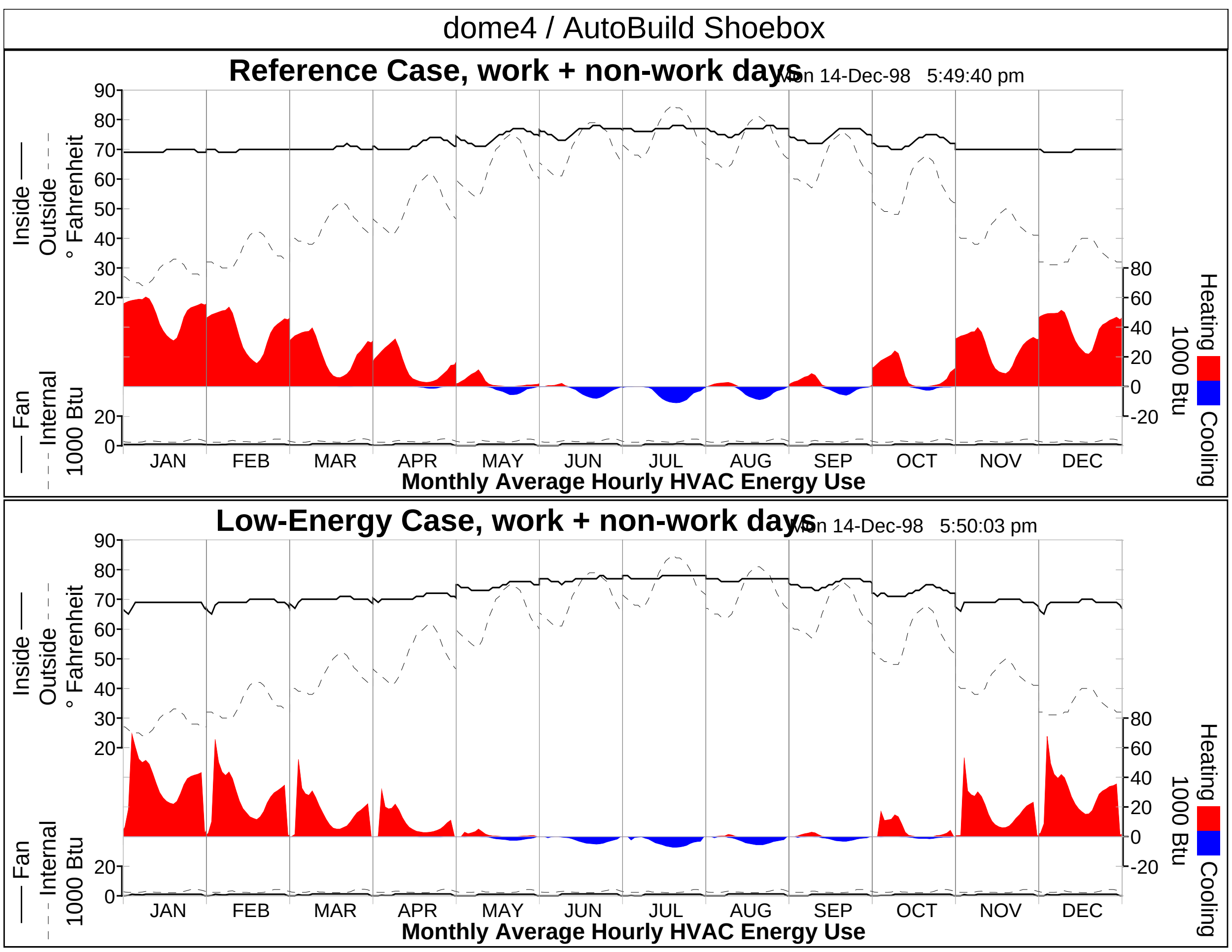




Actual Hourly HVAC Energy Use

domestic	Dec 14, 1998	
Energy-10 Summary Page	Weather file: sterling.et1	
Variant: AutoBuild Shoebox	Saved as C:\ENERGY10\DOME, Var. 1	
U.S.-style building		
Description:	Reference Case	Low-Energy Case
Floor Area	1500	1500
Surface Area	3660	3660
Volume	13500	13500
Surface Area Ratio	1.08	1.08
Total UA	490.2	342.0
Average U-value	0.134	0.093
Wall Construction	2 x 4 frame2, R=16.6	steelstud 6 poly, R=16.6
Roof Construction	attic, r-30, R=29.4	flat r-38, R=38.0
Floor type, insulation	Crawl Space, Reff=9.9	Slab on Grade, Reff=6.9
Window Construction	3040 double, alum, U=0.78	4060 low-e al/b, U=0.31
Window Shading	None	40 deg latitude
Wall total gross area, sf	2160	2160
Roof total gross area, sf	750	750
Ground floor gross area, sf	750	750
Window gross area, sf	360	336
Windows (N/E/S/W:Roof)	9/6/9/6:0	2/3/7/2:0
Glazing name	double, U=0.49	double low-e, U=0.26
Operating parameters for zone 1		
HVAC system	DX Cooling w/Gas Furnace	DX Cooling w/Gas Furnace
Heating thermostat	70 F, no setback	70 F, setback to 65 F
Cooling thermostat	78 F, no setup	78 F, setup to 83 F
Heat/cool performance	eff=80,EER=8.9	eff=80,EER=8.9
Economizer?/type	no/NA	no/NA
Duct leakages, total %	21	21
Peak Gains, W/sf	0.20/0.04/0.66/0.36	0.15/0.03/0.66/0.36
Added mass?	none	750 sf, 8in cmu
Daylighting?	no	yes, continuous dimming
Results:	(Energy cost: $0.40/therm, $0.05/kWh, $2.47/kW)	
Simulation dates	01-Jan to 31-Dec	01-Jan to 31-Dec
Simulation status	valid/NA	valid/valid
Energy use, kBtu	199250	145228
Energy cost, $	1292	991
Saved by daylighting, kWh	NA	415
Internal/External lights, kWh	1179/129	529/96
Hot water/Other, kWh	4300/3573	4300/3573
Heating/Cooling/Fan, kWh	0/3292/2410	0/2403/2293
Total Electric, kWh	10582	8894
Peak electric, kW	6	6
Fuel, million Btu	163	115


dome4 / AutoBuild Shoebox
ANNUAL ENERGY USE
Reference Case
Mon 14-Dec-98 5:49:40 pm
Low-Energy Case
Mon 14-Dec-98 5:50:03 pm
1000 Btu/sq ft
150
100
50
0
99.0
66.8
7.5
5.5
3.0
1.4
23.4
23.1
132.8
96.8
Heating
Cooling
Lights
Other
Total


dome4 / AutoBuild Shoebox
Reference Case, work + non-work days
Mon 14-Dec-98 5:49:40 pm
Inside
Outside
° Fahrenheit
Fan
Internal
1000 Btu
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
Monthly Average Hourly HVAC Energy Use
Heating
1000 Btu
Cooling
Low-Energy Case, work + non-work days
Mon 14-Dec-98 5:50:03 pm
Monthly Average Hourly HVAC Energy Use

Following is a set of data produced by BEES.

Environmental indicators (points system)

building component	foundation concrete slab		exterior wall finish		wall insulation	
two material choices and their relative environmental scores:	0% fly ash concrete	20% fly ash concrete	brick	stucco	R12 mineral wool	R15 fiberglass
environmental performance:	65	55	75	30	75	15
IAQ (16%)	0	0	0	0	0	0
Resource Depletion (17%)	17	13	15	5	15	0
Nutrification (17%)	17	13	15	5	15	0
Acidification (17%)	17	13	15	5	15	0
Global Warming (17%)	17	13	10	15	15	0
Solid Waste (16%)	0	0	0	0	5	15
by life cycle stage:						
Environmental	65	55	75	30	75	15
End Life	n/a	n/a	10	15	5	15
Use	n/a	n/a	2	0	70	0
Transport	5	5	10	5	0	0
Manufacturing	60	50	25	0	0	0
Raw Materials	n/a	n/a	25	15	0	0
embodied energy:			22	6	550	2
fuel (MJ/.08 m3) [MJ/cyd]	1100	1200	22	6	550	2
feedstock			2	0	0	0

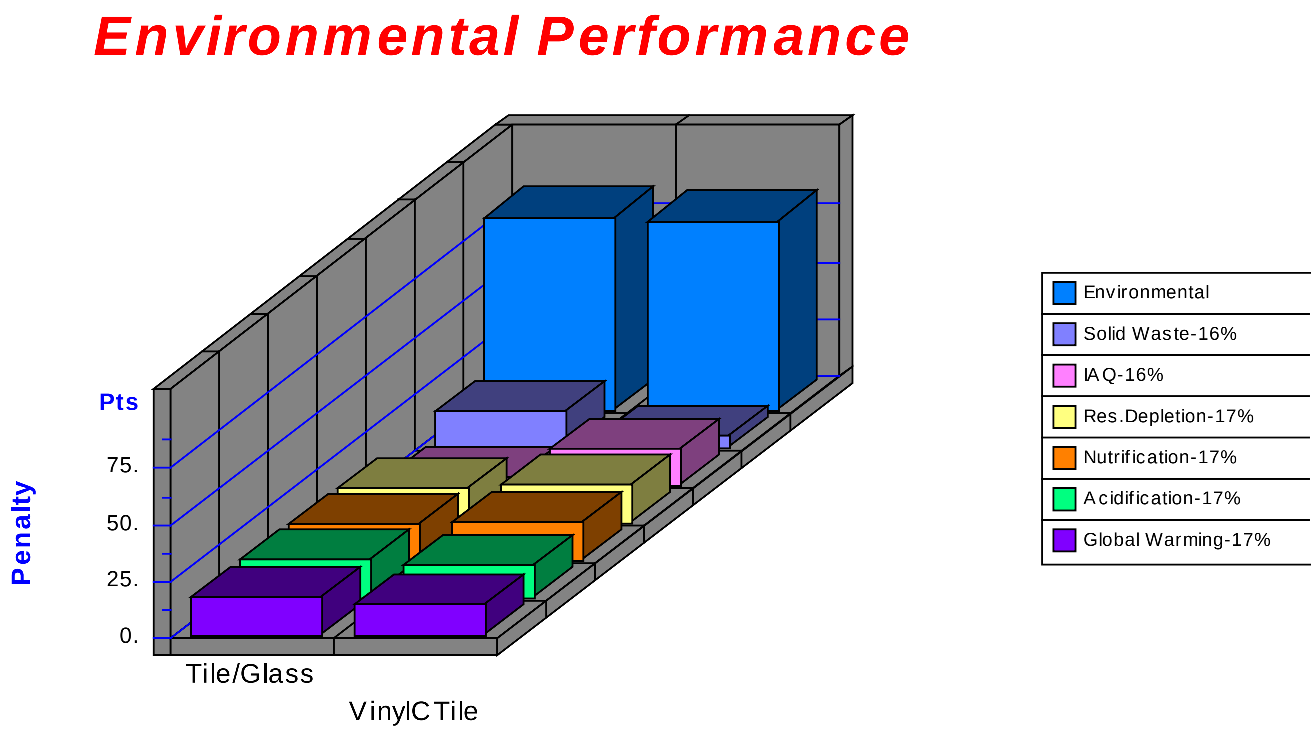
building component	roof insulation			roof finishing		roof sheathing	
two material choices and their relative environmental scores:	R30 mineral wool	R30 cellulose	R30 fiberglass	clay tile	fiber cement shingles	oriented strand board	plywood
environmental performance:	60	70	45	75	55	76	15
IAQ (16%)	0	0	15	0	0	0	0
Resource Depletion (17%)	15	10	0	15	2	15	5
Nutrification (17%)	5	15	10	15	15	15	4
Acidification (17%)	15	10	5	15	10	15	3
Global Warming (17%)	5	15	10	10	15	15	3
Solid Waste (16%)	15	10	5	15	5	15	0

by life cycle stage:							
Environmental	60	70	40	75	55	76	15
End Life	15	10	15	5	0	0	0
Use	2	5	0	3	5	15	0
Transport	0	0	0	3	2	3	2
Manufacturing	35	2	25	50	10	10	5
Raw Materials	5	45	0	2	25	48	5
embodied energy:	32	25	10	45	35	27	11
fuel (MJ/.08 m3) [MJ/cyd]	30	15	5	38	27	14	3
feedstock	2	10	5	7	8	13	8

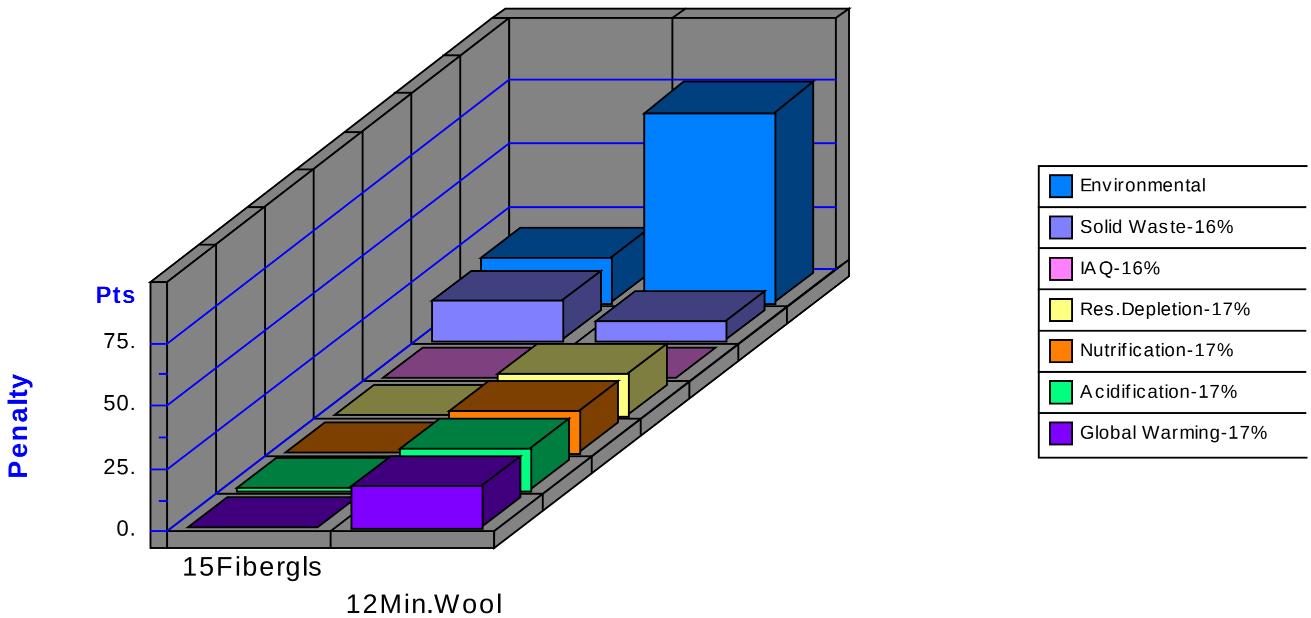
building component	interior floor coverings		exterior walkways, drive	
two material choices and their relative environmental scores:	ceramic tile w/glass	vinyl composition tile	0% fly ash concrete	20% fly ash concrete
environmental performance:	75	75	65	55
IAQ (16%)	0	15	0	0
Resource Depletion (17%)	15	15	15	13
Nutrification (17%)	15	15	15	13
Acidification (17%)	15	15	15	13
Global Warming (17%)	15	10	15	13
Solid Waste (16%)	15	5	0	0
by life cycle stage:				
Environmental	75	75	62	55
End Life	15	0	n/a	n/a
Use	5	25	n/a	n/a
Transport	10	5	0	5
Manufacturing	35	15	60	40
Raw Materials	15	25	n/a	n/a
embodied energy:	27	38	1250	1000
fuel (MJ/.08 m3) [MJ/cyd]	25	20	1250	1000
feedstock	2	18	0	0

Note:Points are calculated as penalties for poor environmental performance, the higher the point value, the less desirable the material.

Ceramic tile w/glass vs. vinyl composition tile



Environmental Performance



Concluding Remarks

Following is a set of conclusions from the building analysis using Energy 10 and BEES. Energy 10 low-energy cases greatly improved the energy efficiency of the building through better insulation, HVAC and lighting controls, and window configuration. The results of the U.S. version are slightly less effective because we chose a cooling system for the low-energy case, thus reducing its energy efficiency. The results of the BEES analysis show great improvements in the environmental effects of materials. A domestic building using the materials chosen through BEES, combined with the insulating values, HVAC controls, lighting, and window configuration chosen by Energy 10 would be 35% to 40% more environmentally friendly than an average building.

Energy 10 results

Building type	energy use (kBtu)	difference saved by low-energy case	% saved
European	190300		
European low-energy	114924	75376	40%
U.S.	199250		
U.S. low-energy	145228	54022	27%

BEES results

building component	most environmentally efficient material	environmental impact penalty reduced over other material choice	% reduced
foundation concrete slab	20% fly ash concrete	10	15%
exterior wall finish	stucco	45	60%
wall insulation	R15 fiberglass	60	80%
roof insulation	R30 fiberglass	35	50%
roof finishing	fiber cement shingles	20	27%
roof sheathing	plywood	61	80%
interior floor coverings	both show same performance		
exterior walkways, drive	20% fly ash concrete	10	15%
		average % reduced	**41%**