ENSLIC_BUILDING : Energy Saving through Promotion of Life Cycle Assessment in Buildings

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D3.1Guidelines for LCA calculations in early design phases
D3.2Recommendations on choice of LCA indicators for application to buildings
D3.3 Recommendations on specific LCA features
D3.4 Recommendations for communication of LCA results


What are the relations between buildings, energy use and environmental impact?

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1. Introduction

How does a new design affect the future energy cost and environmental impact of the building? What measures are most important to take in order to perform an energy-efficient refurbishment? Knowledge about this is possible to gain from life cycle assessment (LCA) and calculation of life cycle costs (LCC). With the ongoing development including energy certification schemes, environmental labelling, the climate change debate, etc. the interest for a life cycle perspective of buildings is increasing steadily. The demands among clients, municipalities and property developers for more sustainable buildings are also becoming stronger.

LCA/LCC is sometimes looked upon with suspicion. Barriers for implementation for instance include prejudices about the complexity and arbitrary results, accuracy, problems regarding interpretation of results and too high costs to perform it. LCA tools that are well integrated with standardised softwares used by e.g. architects are also still rare. To this date, the demand for similar assessments has been low. This demand can be expected to increase. Concerning the other barriers these guidelines aim at bridge most of them by providing a basic lesson in what LCA is, what it can be used for and how it can be performed, all adapted to the design process of buildings.

1.1 Target groups of the guidelines

These guidelines are directed to you as a practitioner who work in early design phases of building developments or refurbishment projects and want to achieve energy saving and environmental improvements with regard to the entire life time of the building. Since LCA and LCC are accounting methods some input data are necessary. Here it is implied that at least some rough quantitative data regarding building dimensions, orientation, window design and choice of basic building materials are available.

Architects and other consultants are the main target group of these guidelines since they are the ones who may perform an LCA assessment. However, clients such as property developers and urban planners are also targeted since these groups can demand better buildings and assessments to prove this.

When developing these guidelines three levels of performing an LCA was considered:

- Basic – basic calculations in excel sheets with simple input and output only covering one or a few environmental impacts. No or very little experience is demanded
- Medium – LCA calculations done with help of building tools like Ecosoft, EcoEffect, Equer, Legep, Envest, Beat etc. Some experience and exercise is required to use these tools.
- Advanced – General and comprehensive LCAtools like SimaPro, Gabi, etc. A lot of experience is needed to handle these softwares on a building level. These tools demand much training and profound understanding of LCA models. They might not even be suited for application in early design phases.

The goal for these guidelines is to support advancement on the two lower levels, i.e. get inexperienced people to start to make simple LCAs and later on try the buildings tools. Advanced LCA calculations will therefore not be discussed more.

This Guideline report starts with summarizing LCA and LCC and then outlines the system for environmental management in design where LCA/LCC can be used. To understand the possibilities for how and when to apply LCA it is important to have a clear picture of the building process. A recommended step-by-step procedure for performing an LCA is summarised in the end.

1.2 Why performing an LCA?

LCA provides better decision support when optimising environmentally benign design solutions that consider the impacts caused during the entire life-time of the building. Thus, the quality of buildings in a long-term perspective can be improved. It can for example provide better grounds for deciding on questions like:

- Which are the best combination of building materials in the facade?
- Which load bearing structure is most environmentally benign for this building?
- What energy sources should be cosen for this building?
- What thickness of the insulation would be optimal?
- How much do solar collectors reduce the environmental impact in this case?
- What does recyclability of a certain technival solution mean?
- What environmental targets would be suitable for this project?

Further, there are a number of other arguments for getting to know more about LCA and how it can be utilised:

- In a number of European countries, The Energy Performance of Buildings Directive includes environmental information in energy certificates, particularly CO_2 emissions. Life cycle assessment (LCA) can serve with this information.
- For commercial actors, LCA supports CSR (Cooperate Social Responsibility) strategies and enables reporting environmental performance which supports the value of good-will.
- There are increasing examples in the world on different types of economic incentives such as loans and subsidies connected to sustainability of buildings.
- Not only the amount of energy use is considered but also the energy embodied in building materials, transports and the advantage of recycling are evaluated.


Low energy housing, Landskrona, Sweden

1.3 What is LCA – Life Cycle Assessment?

LCA is a technique for assessing the environmental aspects and potential impacts associated with a product, by

- compiling an inventory of relevant inputs and outputs of a product system;
- evaluating the potential environmental impacts associated with those inputs and outputs;
- interpreting the results in relation to the objectives of the study.

LCA studies the environmental aspects and potential impacts throughout a product's life (i.e. cradle-to-grave) from raw material acquisition through production, use and disposal. The general categories of environmental impacts needing consideration include resource use, human health and ecological consequences (ISO 14040). By performing an LCA you get quantitative information about the buildings contribution to for instance climate change and depletion of resources, which can be compared with the same information for other buildings.

The principle of LCA calculations is simple. For each life cycle stage you investigate the amounts of materials and energy used and the emissions associated with processes. The latter are multiplied with characterisation factors proportional to their power to cause environmental impact. One specific emission is chosen as the reference and the result is presented in equivalents with regard to the impact of the reference substance (table 1).

Table 1. Calculation of environmental impacts according to LCA.

Input data						Output result
Amount	**x**	**Emissions**	**x**	**Characterisation factor**	**=**	**Equivalents**
MJ alt kg	x	g/MJ alt g/kg	x	$f_{substance}$	=	g equivalents
From Building		From database		From database		

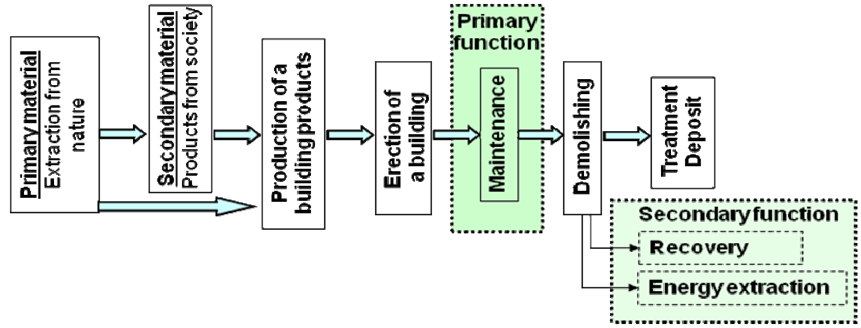
1 MJ combusted oil is associated with the following emissions and the resulting gram equivalent CO_2 which represents the contribution to global warming when CO_2 is given the Characterisation factor 1,0.

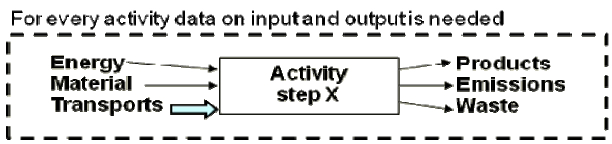
Emissions		mg/MJ		Characterisation factor		
Carbon dioxid	CO_2	90 000	x	1	=	90 000
Methane	CH_4¤	4	x	25	=	108
Laughing gas	N_2O	1	x	298	=	179
				gequivalents CO_2 per MJ		**90,3**

The number of equivalents summed up for each environmental impact (impact category) can further be normalised and weighted to arrive at an aggregated result. The marked area in Table 1 is the core of each assessment method (in this case building tool). Different tools may use different characterisation factors and different emission data if production processes and combustiuon technique differs. These tools also use different normalisation and weighting methods which naturally can cause different results.

The possibility to easily acquire building data improves steadily with modern CAD-tools and improved data bases. A simplified LCA tool may include a generic database with emission data for a limited amount of building materials and energy carriers. Preferably data are retrieved from EPDs (Environmental Product Declarations), which are Type III declarations (third party control, ISO 14025). More sophisticated LCA calculations need access to larger international databases like Ecoinvent.

Figure 1. Illustration of the life cycle stages of a building and input data for LCA





1.4 Core elements of an LCA

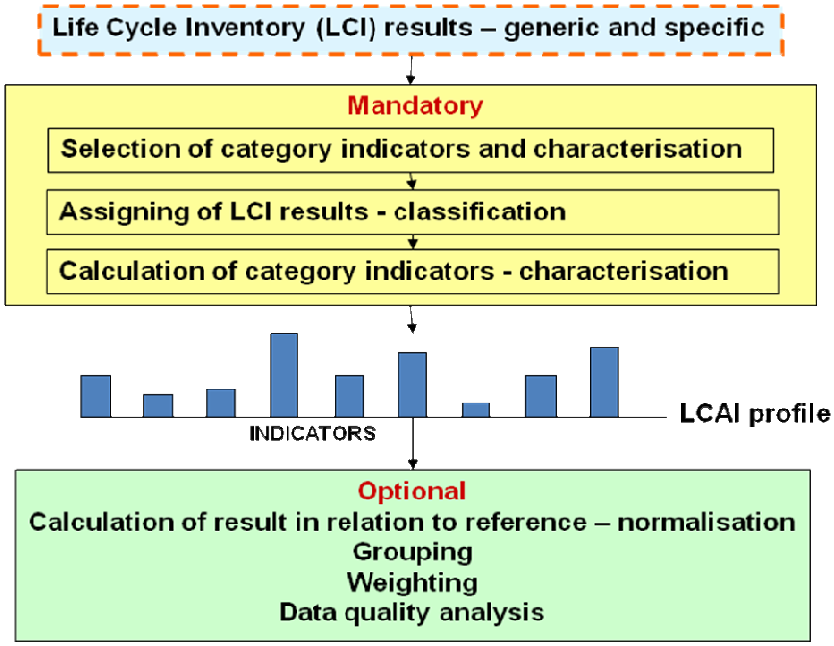
Although striving for simplifications to attract new groups of LCA users, some key elements are needed to perform an LCA which are described in the international standard EN-ISO 14040. Although stressed that there is no single method for conducting LCA studies it is expected that an LCA includes the following features:

- Goal and scope definition
- Inventory analysis
- Impact assessment
- Result interpretation

During the goal and scope definition, a functional unit (the unit to which the environmental impact is related) and system boundaries (the boundaries for what will be included in the assessment) must be defined in relation to the purpose of the study. Data quality requirements should be addressed. At least two life cycle stages must be included, for instance production of building materials and operation of the building, to justify talking about a life cycle approach.

The definition of the functional unit is particularly important when different products, or in this case, different buildings are compared. In the European standardisation process Sustainability in Construction (CEN 350), it is recommended to call it functional equivalent at building level in contrast to functional unit at the product (building material) level. For a residential building, the functional equivalent may be described as: A building designed for 90 residents at a specific location, which fulfil national regulations and requirements regarding comfort, health, safety, energy demand etc. over a presumed life time, e.g. 80 years. This definition can naturally vary but the important thing is that it is the same for the buildings that are compared.

Figure 2. Illustration of the actions performed in a life cycle assessment (ISO 14042)



Further, the inventory analysis is the process of compiling the necessary data for the assessment. In the next step, life cycle impact assessment, the calculations described in table 1 take place. The life cycle impact assessment (LCIA) has some mandatory elements according to ISO 14044:

- Selection of impact categories, category indicators and characterisation models
- Assignment of LCI results (classification)
- Calculation of category indicator results (characterisation)

These elements are in general already decided on if you use a simplified LCA tool or a building tool.

1.5 What is LCC – Life Cycle Costing

Life Cycle Costing (LCC) is a tool for assessing the total cost performance of an asset over time, including the acquisition, operation, maintenance and disposal cost. Its primary use is in evaluating different options for achieving a client's objectives, where those alternatives differ not only in their initial costs, but also in their subsequent operational cost.

LCC is central to the current international trend to achieve better value for money from the buildings and constructed assets we produce and use. The focus today has shifted to minimising both life cycle costs and the environmental impact (Davis Langdon 2007).

The inventory of building data for use in LCA can also be used in LCC but here you need complementary information on €/MJ and €/kg.

The benefit with a LCC is that you can study the pay back time for the whole life cycle of different building products and design solutions. Since the future interest rate has to be anticipated different scenarios can be examined.

1.6 Integrating LCA and LCC

Since both LCA and LCC is based on life cycle thinking assuming a certain life time for materials and the building they are suitable to combine giving simultaneously both potential life cycle costs and environmental impacts for alternative designs. This combination may for instance be used for:

- Choice of alternative technical solutions
- Identifying the technical solution that meets an environmental target to the least cost
- Recount environmental impact into costs
- Evaluate an building investment

It can be seen that LCC and LCA can either be used alongside each other in a broader evaluation process, or either process can form an input into the other (Davis Langdon 2007).

1.7 Current use of LCA/LCC in building applications

In the building sector few professionals today have deeper knowledge about LCA. Some people in most European countries have extensive experience from developing or using building specific LCA tools. The simplest and probably most common building related application up to current date is the use of LCA for comparing the environmental impacts of different building materials. Concerning LCC, the main use so far is probably for deciding on alternative installations in buildings.

1.8 Possible simplifications for LCA in practical building design

The complexity and uncertainties of LCA results is often seen as main barriers to more frequent use of LCA. It is natural that if unreliable data is used, unreliable results will be the output. However, rough estimates of the environmental impacts over the life cycle are still better than to ignore these impacts. But in early design stages it is important not to trust small differences in result. For coming up with rough estimates there are a number of possible simplifications which can be done with the aim to promote LCA to wider user groups:

- simplify the acquisition of building data by focusing on larger building elements, skip transports etc.

- simplify the inventory analysis by focusing on the most important substances that contribute to a certain impact category, skip or simplify the end-of-life of the building, only use generic emission data etc.
- simplify calculations by focusing on only a few impact categories.
- reduce the time of the building data acquisition by improved CAD softwares.

Since calculations are performed by computers, simplified calculations are of less importance than to simplifying the tool interface and usability. Data acquisition is the most prominent problem since buildings contain a huge amount of different materials and the availability of quality assured production data is restricted. When the aim is to simplify, questions like which data for which life cycle stage is more important than others are important to tackle. How to communicate clear and useful results is also a very important question since this is the key to demand for LCAs.

2. Application of LCA in building design

2.1 Introduction

LCA was mainly developed for designing products with low environmental impacts. As products, buildings are special since they:

- have a comparatively long life
- undergo changes often (especially offices and other localities)
- often have multiple functions
- contain many different components
- are locally produced
- are normally unique (seldom are many of the same kind)
- cause local impacts
- are integrated with the infrastructure, i.e. physical system boundaries are not obvious.

This implies that making a full LCA of a building is not a straight forward process like for many other consumer products.

A general problem when applying LCA in a design process is that in early design phases the options for choosing different solutions are many and subsequently data on the products, which is needed for LCA calculations, is scarce. Later in the process, when more decisions have been taken, better LCAs are possible to perform but then the possibilities to utilise the result for alternative designs are restricted, fig 2.

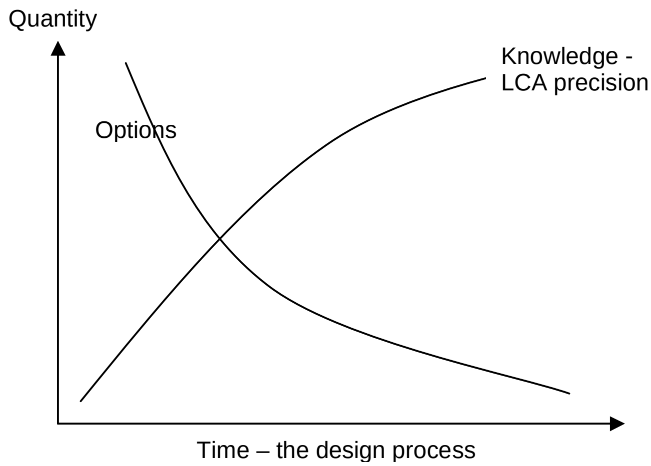


Figure 2. General illustration of the relation between choice options and product data availability during a design process.

There are different ways to overcome this problem. It concerns mainly ways to get improved information about alternative options early in the design process and to speed up calculations of rough results. A toolbox with already calculated results is one possible solution. Introducing facilities to easily create alternative options and extract data with new computer programs (BIM- Building Information Modelling), is another.

2.2 The life cycle stages of a building

If making an LCA or LCC of a building by definition it shall cover the whole life cycle of a building. This means that generic facts about the environmentally impacting activities related to each stage of the life cycle are needed already from the beginning. According to CEN 350 the building´s life cycle stages include: product stage, construction stage, use stage and end-of-life stage.

2.3 The building process

The process of developing a new building is commonly referred to as the building process. This process is in general the same everywhere but details, sub-divisions of phases and terms may differ from country to country. In general the building process can be described as in table 2. For refurbishment projects, the same phases are followed except for that many pre-conditions and boundaries are already fixed.

Table 2. The building process and examples of options for taking LCA-based decisions in different phases.

Phase	Specifications	Actors	Planning instruments
1. Project development/ planning phase	City/spatial planning authorities sets the frames for the development. ▪ Choice of site, orientation ▪ Costs ▪ Size (e.g. room allocation plans) Targets for the energy performance, environmental impact, health requirements etc. are stated.	Munici-pality	Master plan Local plan Land contract Local Agenda 21 Local environmental targets
2. Investigation phase	The developer starts the design process. Probably this phase is one of the most important phases in the building process. All project phases of a new building are based on specifications made in this phase, so here we can find the highest potential for sustainable building design. ▪ Design – construction (e.g. light weight or solid construction) ▪ if possible e.g. benchmarks for heating and cooling, renewable energy sources for the building services etc.	Deve-loper	Environ-mental program
3. Preliminary/ Conceptual design / architects' competition	Revised preliminary design, including preliminary selection of superstructure, building materials, constructions. In this phase mainly design-related issues are available such as a definition of heated/cooled areas, shape/volume ratio, area and disposition of windows, building position and orientation. It is generally still too early to decide details about the technical systems (HVAC) and choice of building materials.	Deve-loper Architect	Sketch
4. Submission planning	Final design for submission to building authority for planning permission (determination of superstructure, building materials, constructions), energy certificate following the EPBD.	Architect	Design
5. Detailed design phase / Implementation planning	Final selection of superstructure, building materials, constructions, systems for building services as the base for tendering for the construction work. In this design phase the exact definition of all components of the building and the HVAC system are addressed.	Architect Consul-tants Deve-loper	Tendering documents Environ-mental plan

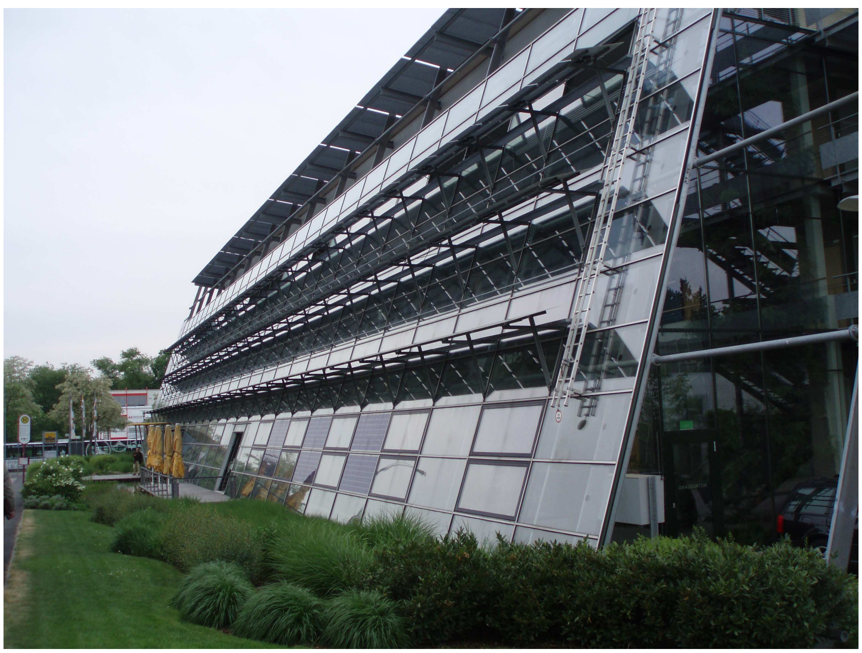
6. Construction phase	Now the construction work according to the implementation plan is carried out. This should include clear quality assurance measures for monitoring energy and ecological performance.	Contrac-tor Deve-loper	

2.4 Environmental management in building design

Making an LCA can be looked upon as a part of an environmental management process. So it could be integrated into the environmental management of a building process which is often performed in a standardised way.

To illustrate this process an example is taken from Sweden. Here a kind of practice for environmental management in the design phase has been evolved based on publications by the Swedish Eco-cycle Council and ISO 14001. Since it is voluntary it is applied a bit differently by different users and companies. The main ingredients are:

1. The client states the general and detailed preliminary targets
2. The designer analyses the consequences and an environmental program is settled
3. An environmental plan to implement the program is developed
4. The environmental program is interpreted in drawings and documents and an environmental declaration is erected
5. Targets and preconditions are transferred to the building owner.



An example of components in environmental programs that are LCA related:

General target:	Contribution to climate change shall be small
Detailed target:	Contribution to climate change should be less than 10 kg CO_2/m_2,yr
Strategies:	a) reduce energy use
	b) reduce use of non renewable energy
	c) complement with local energy
Investigate:	a) improved building envelop and equipment performance. Energy recovery on ventilation and sewage.

	b) impact of the district heating system on climate change. Bying environmentally labelled electricity and heat. c) solar collectors, photovoltaics, local wind energy, biofuels
Confirmation:	State the chosen solutions, their anticipated performance and cost. Make an environmental declaration.

3. Possible integration of LCA in the building process

In the following ideas on useful purposes for performing an LCA to improve the building design process are given.

3.1 Project development - The planning phase

Here the national and local regulations set the boundaries. The possibilities for the local authorities to set specific local environmental targets vary a lot. Some municipalities are eager to be in the forefront of sustainable development which may include environmental targets for building and planning. Especially as land owners the possibilities improve.

In Sweden the Energy Agency underline the importance of integrating energy planning and physical planning in order to successively expand the use of renewable energy (2003). In Sweden there also are master plans which however are not legally binding but where it is possible to introduce energy targets linked to physical planning and developing issues
A Swedish master plan gives possibilities to:

- State targets for renewable energy
- Show scenarios regarding replacing fossil fuels by bio fuels
- Show consequence assessments regarding scenarios
- State balances, priorities, strategies and standpoints
- Create links to business targets, social targets, environmental targets etc.

Examples of issues that the municipality can decide on are: exploitation rate, building density, heat use density (kWh/m2, year concerning district heating), transportation grid etc.

Targets for the local plan may be formulated as:

Exploitation:

- Floor space index shall not exceed xx m2/m2 city district area .
- Energy demand should not exceed xx kWh/m2
- Parking space should not extend 0,5 per dwelling
- Distance to bus or train stop < 500 m
- No emissions from combustions, or max XX kg CO2/m2,yr
- Contribution to climate change from building materials < CO2-eqv/m2
- Space use efficiency for dwellings <xx m2/person

3.2 Investigation phase

Actor: municipality, developer
Town planning and design rules generally don’t demand LCA, but this is an emerging trend with the concept of ecological urban settlement (e.g. Concerto Programme at EU level).

National, international and sector goals sometime contain quantifications. For example goals for CO_2 reduction - then these have to be broken down to an area or building level? Further demands on the buildings set by the municipality depends on to which extent implementation of national goals have been forced on them. Sometimes communities seem to be worried about putting to rigid demands may lead to that developers move to another municipality.

Typical issues dealt with:
activity description, identifying needs target setting, causes to change, initiate a program work. Targets have to be clear and easily understandable.

Activity description might include scenarios and societal trends, the enterprises relation to a sustainable development and to what extent it could be expressed in actions, buildings etc. Through the buildings an enterprise can strengthen its image towards actual and potential customers.

A general target for energy saving could be formulated as:

1. “For the municipality, the CO2 cap in relation to energy used for the built environment shall not exceed xx in year yy. For this very project, a CO2 cap is set to xx.
2. “Minimise embodied energy the need of energy for heating, hot water, cooling, ventilation and lighting”.

Possible further development

3. "The release of CO_2 for production of equipment and heating and lighting should be less than x kg CO_2 equiv/m2".
4. "The release of CO_2-equivalents for production of equipment heating and lighting should be less than x kg CO_2 equiv/m2".
5. "The contribution to climate change, acidification, generation of radioactive waste…. etc. for the production and operation stages, should be below…..xx.

In this phase also time and cost limits are formulated. These could also be described in life cycle terms as a complement.

3.3 Conceptual design

Here the functional, energy and environmental demands are stated. Costs are roughly estimated.

Targets for the building may be formulated as:

1. Heat loss parameter < W/m2,K
2. Solar heat load factor < W/m2 or solar aperture in m2 eq. South glazing / m2 heated area.
3. Energy/primary energy < kWh/m2,år
4. Emissions CO_2 emissions < xxg/m2, år
5. Fraction of renewables > x%

A possible goal at this phase is to investigate if a passive or low energy alternative is a feasible option and what it means with reference to environmental impact.

3.4 Submission planning – Building components

In this phase detailed LCA and LCC calculations are possible to perform in order to make final decisions about building materials and HVAC systems. The final results can also be used as environmental declarations directed towards tenants and local authorities.

When using LCA and LCC for choice of individual building materials as roof and fascade surfaces, flooring etc these materials contribution in relation to the buildings overall impact has to be kept in mind. Putting too much efforts into comparing options that means less than say 5% of the total environmental impact of a building throughout its life time. To get a sense of the environmental significance of different building elements a simplified LCA may make sense as a first step.

3.5 The construction phase

Is initially not covered here.

4 Procedure for LCA/LCC calculations in building design

The Enslic project recommends a step-by-step procedure for using LCA/LCC in building design. To provide extra support and simplify comparisons in a standardised way two excel files have also been developed.

The first file called the ENSLIC TEMPLATES (appendix 1) contain a number of sheets following the recommended procedure which are meant to standardise collection of data and communication of building LCA results. Here environmental targets can also be specified. The information includes an verview of the purpose of the assessment and the type of building that is assessed, the quantitative assessment results, specifications of use of energy, materials, water etc needed for impact calculations and specifications on building characteristics and building data. Such collected information improves the transparency of the LCA calculations and helps to interpret the result. These sheets synchronised with the present version of recommended LCA calculations for buildings developed by CEN working group TC 350.

The second excel file called *LCA simplified* (appendix 2) is a work sheet with possibilities to make simplified LCA calculations in a building design phase in the most basic way. Here building dimensions and cross sections are inserted and the program calculates material amounts and their related environmental impacts, estimates roughly yearly energy use and its associated environmental impact when energy sources are inserted. This file normally needs to be complemented with national data. The file can be used if one wants to perform very simplified LCA calculations.

The recommended procedure is:

1. **State the purpose of the study**
   (project development, impact comparison, classification, etc)
2. **Choose assessment tool**
   (Basic, building, advanced)**Describe the building**
   (Name, type, size, location etc)
3. **State the system boundaries for the assessment**
   (Reference time, building stage, assessed features, data requirements etc)**Define targets, references, benchmarks etc**
   (impact, depletion, energy use, Country or EU average, target,..)
4. **State scenarios for the reference time**
   (steady state, regular retrofit, cost development etc)
5. **Define targets, references, benchmarks etc**
   (impact, depletion, energy use, … Country or EU average, target,
6. **Describe the building**
   (Name, type, size, location etc)
7. **Collect data**
   a) Environmental data that is not in the tool (emissions per Joule, emissions per kg etc)
   b) Building data, for example material amounts, energy use, energy source, recycled materials, etc
8. **Perform assessment**
   (trial and error if targets should be reached
9. **Present results**
   (graphs, tables, analysis, eventually desired improvements etc)
10. **Validate**
    (check results relative to purpose, check calculations, fulfillment of requirements etc.)

A template for each step will be developed. A first attempt is shown in Appendix 1.

These guidelines and the templates address performing LCA of *a building*. However, the principles are possible to use also for assessment of another scales, such as building component level or city district level. Each step is commented below.

4.1 State the purpose of the study

Start with stating the purpose of the study. This is important since it is decisive for the interpretation of results and possibilities to compare your calculations with others. The purpose also guides important methodological choices. A number of possible purposes are exemplified in chapter 3 of this guideline and the ENSLIC case study report.

4.2 Choose assessment tool

For practical use, these guidelines recommend either that you use a simplified, basic tool for LCA assessment or one of the many existing LCA tools that are adapted for assessing buildings. For the beginner, a basic tool (e.g. excel sheet) might be preferable to start with, such as the appended excel sheet called *LCA simplified* (appendix 2).

In appendix 3, examples of adapted LCA building tools are listed. The choice of assessment tool depends on requirements such as which indicators one is interested in, purpose of the study (since some tools are more adapted to specific purposes than others), precision of the calculation and the way in which results are presented. In practice, the tool need to be easily accessible which means that it is often natural to choose a tool developed in the national context where support is easily accessible.

There are also more advanced, general LCA tools, such as SimaPro and Gabi. With these tools, the user is more free to choose certain assumptions and they contain more product data. On the other hand, they demand much higher experience and understanding of the methodology in order to use it and interpret the results. Since these guidelines target building sector practitioners, advanced tools will not be dealt with further here.

For the beginner it is recommended to:
Start by using the appended excel sheet LCA simplified for making simplified calculations of CO2-equivalents. It represents the simplest possible way to apply LCA thinking and make a calculation. It is meant to be open for use and completion and used on own risk by anyone. This tool enables estimations of contributions to climate change of both the energy use and material use during the building life time.

4.3 State the system boundaries for the assessment

In this step, assumptions made for the study as well as the boundaries for the assessed object need to be clarified. It is highly important that this information is clear and consistent if one wants to make comparisons with other studies. Important decisions include:

- Choose reference time (assumed life-span of the building) - 50 years is often used as default value since it is impossible to foresee the real life span. The relation between impacts of the use stage and the product stage is depending on this choice. The shorter reference time chosen the more important seems the impact from the product stage (material production) to be. To test different reference times when making the assessment often provides interesting information.
- What life cycle stages and activities should be included in the assessment – product stage (production of building materials), construction of building, use of building, maintenance and refurbishment, demolition, waste treatment (end-of-life stage). etc.
- Delimitation of the features of the building to be assessed - such as whether user electricity is included in the energy use or not, or which building elements that are assessed.

4.4 State scenarios for the reference time

For the given reference time (e.g. 50 years) assumptions or scenarios about what will happen with the building also need to be stated for instance:

- Assumptions with regard to maintenance, refurbishment, etc. For each building element that is included in the study the expected reference service life time should be stated and what kind of actions that will take place during and after this period.
- If the end-of-life of the building is included, assumptions are needed on how different building elements will be demounted or demolished and further treated.
- Expected occupant behaviour (normally standardised with respect to use of household electricity, etc)

- If building user transports are included, assumptions are needed on number of travellers going with different kind of vehicles, frequencies and distances. These numbers in turn are depending on destinations, access to public transports, frequency of services, age and fitness of users etc.

If LCC calculations are performed, assumptions regarding the expected development of future costs should be stated.

For the beginner it is recommended to:

- *Assume a normal behaviour*
- *Leave out the materials and energy for maintenance*
- *Leave out refurbishment of different building elements*
- *Leave out building user transports*

4.5 Define targets, references, benchmarks, etc

To be able to interpret the results later on, targets, references and/or benchmarks to compare with, are necessary. Here indicators are selected. If there already are specific environmental targets decided for the project (for instance set by a municipality or the client), these may already define what indicators need to be included in the assessment.

In the present version of CEN 350, preferable indicators may be chosen from Table 3 below. If performing an LCA according to the coming CEN standard, all these indicators need to be included. Additional indicators can be found in Work package 2, State of the art report, chapter 2, Environmental indicators.

Table 3. Environmental indicators currently suggested in the CEN 350 standard.

Indicator	Unit
Contribution to global warming	Kg CO2-eq.
Destr. of the stratosph. ozone layer	Kg CFC-11-eq.
Acidification of land and water	Kg SO2-eq.
Eutrophication	Kg PO4-eq.
Formation of ground level ozone	Kg C2H4-eq.
Radioactive waste	Kg, MJ
Use of renewable/non renewable primary energy	MJ
Use of freshwater resource	M3
Use of renewable/non renewable resource (other than primary energy)	Kg
Use of recycled/reused resource	Kg
Material for recycling/energy recovery	Kg,/MJ
Non hazardous/hazardous waste	Kg

To claim that a life cycle study is performed at least two stages and one of the indicators in table 3 must be handled. A minimum study thus may contain:

- *Energy use during operation (use stage) and building material production (product stage)*
- *Contribution to global warming*

For more in-depth reading about the choice of indicators – see ENSLIC report “Choice of indicators”.

If you want to compare a number of alternative solutions, targets are not always necessary. However, in all cases it may be interesting to compare to other studies or benchmarks. Targets for the chosen indicators can be formulated as % values of a chosen benchmark or as absolute values. Examples on targets are found in chapter 3 of this guideline. Benchmarks to use may be other similar studies, current national norm values, best practice values or targets at society level. If a building tool is used for the assessment, such benchmarks are commonly provided. The LCA study may also be used in itself to find reasonable levels of targets for a project.

4.6 Describe the building

In the next step, the building under study need to be described as detailed as possible depending on how far the building process has come. It includes information about building size, type, etc. An important issue here is to state facts regarding the *functional equivalent*, that is information about the function of the building such as type of use of the building, number of users and requirements regarding indoor air quality, thermal climate, safety, etc.. If comparing with other buildings these criteria need to be the same. The information inserted here should be the information that finally serves as framework for the calculation (something that may be changed during the study).

4.7 Collect data

There are two types of data that are necessary for making the calculations, 1) building specific data such as amounts of building materials and energy use, and 2) emissions related to the production of the building materials and energy, (which normally is included in the LCA tools). In the conceptual design phase, data on energy and material use can either be estimated or simulated by using softwares such as Sketch-up and Revit with alternative default solutions. This is also possible in some of the existing building tools, such as Equer. In other cases, estimations of u-values and material amounts are necessary from early sketches. In the Enslic template *LCA simplified*, the amount of building materials, u-values and energy use during operation is estimated automatically when building specifications are inserted. These include for example building dimensions and information on cross sections. Even though the purpose of the study is to explore environmentally benign design alternatives, it is necessary to have some data on energy and material use as a start for the calculations.

In order to calculate environmental impacts from the building, data regarding emissions related to the production, use and end-of life of different building materials and energy production is also necessary. Most LCA tools include databases with such production data, however if one wants data for a specific item or when national data is expected to be different from average EU data, this data may need to be collected separately. This is only done once and then stored for future use. With the increasing numbers of Environmental Product Declarations (EPD) for different products, such data can be gained from these EPD´s.

In the basic Enslic excel tool *LCA simplified*, a default set of such data (Swedish data) is included which can be used as a start for the beginner. It can also be exchanged for more country specific data.

Data uncertainty is a major concern when making LCA calculations. Regarding building data the main issue is to gather enough information for a trustworthy assessment. For the emission data, the main issue is data quality. ISO 14040 states data quality requirements in general terms including time-related, geographical and technological coverage, precision, completeness and representativeness. For simple life cycle approaches these requirements are hard to fulfil but data taken from large and well-known databases are secured with reference to quality. When finding data for instance for a specific building material for which an EPD is lacking (true for most materials) the most important thing is to report assumed deficiencies and the data source which makes controls possible. Such a transparency facilitates discussions about the uncertainty of data and associated results and thereby stimulates the use of better data. Databases with emission data is developing continuously. In appendix 4, a list of databases commonly used is given.

For the beginner:
Collect the data necessary for the assessed features stated for your study in section 4.4 by calculating amounts of energy and material with for example the template LCA simplified. Do not collect emission data, use the database that is included in the assessment tool you use.

4.8 Perform the assessment

Once assumptions are made, boundaries for the study delimited and data collected, the calculations are made.

If using the Enslic template *LCA simplified*, CO_2-equivalents (contributions to climate change) are calculated automatically once the data on material and energy use has been inserted in this excel file. This tool also enables testing different amounts of energy and material use and making comparisons with regard to the result in CO_2-equivalents.

The more advanced building tools also calculate impacts automatically, but enables many more options of result presentations, calculations of many more indicators, comparisons with other buildings and weighted results.

4.9 Present results

The results of the LCA can be presented in many different ways. How they shall be presented is depending on the purpose you stated for the study and the receiver of the result. In a full LCA naturally all your impacts of interest (chosen indicators) need to be presented for all the alternative solutions investigated. If you are using a building tool, this tool serves you with options regarding how to present results. The coming Case study report of the Enslic project (to be appended later) provides numerous examples of useful result presentations related to LCA studies with different purposes.

For a report meant as decision support, a central thing is to provide total transparency of the results and the calculations behind. It should be open for scrutiny. To collect the information about the study in one place, such as the Enslic Guideline template, is therefore useful as a transparent documentation.

If you have used a simplified tool for making a comparative LCA, your results will be rough. This is not suitable for comparing single building products since it only gives a general overview of the sizes of impacts from different sources. Even on this level conclusions shouldn't be drawn if differences between alternatives are less than 20%.

For the beginner:
The best way of presenting your results depends on the purpose of the study. See examples in the Enslic case study report (coming). See to that your results are backed up by transparent calculations and data so that the results can be discussed by anyone.

4.10 Validate - Control the results

Finally, the results should to be checked relative to the purpose of the LCA. In a complete LCA according to the ISO standard, the results should be examined by an external reviewer and this is particularly important if the results are to be presented to the public or used for marketing, etc. Calculations with a simplified tool are purely meant for internal considerations. Sensitivity analysis performed by successively varying different parameters gives valuable information about the robustness of a result.

The example building.

5. Example on how to use the guidelines

In this section one simplified example is described of how the step-by-step procedure in section 4 can be followed.

1. **State the purpose**
The LCA study aims at providing decision support for designing a simple single family house of 120 m^2, demanding only 50% of the operative energy use required by Swedish regulations and low CO_2 emissions from a life cycle perspective.
2. **Choose assessment tool**
The simplified excel tool *LCA Simplified* will be used since it allows making rough calculations of the indicators of interest (testing different amounts of energy and material use and making comparisons with regard to the result in CO_2-equivalents).
3. **State the system boundaries of the assessment**
The building reference time is set to 50 years. The use stage is considered regarding energy use but without including household electricity. The product stage is considered regarding production of building materials. Other life cycle stages are omitted. Building

materials considered are major materials in the basic building elements: slabs, external walls, internal walls, attic, roof and windows.

4. State scenarios for the reference time

A steady state during the reference time is anticipated. Normal maintenance is presupposed but not accounted for in the assessment and a normal user behaviour is anticipated. No end-of-life scenarios are assumed since this life cycle stage is excluded in the study. Costs are not considered and therefore no assumptions made for LCC.

5. Define targets, references and benchmarks

Targets for the example include that the maximum allowed energy use when household electricity is excluded should be 55 kWh/m^2,yr. The CO_2 target is set to less than 10 kg CO_2-equivalents/m^2,yr.

6. Describe the building

The building's interior size is 6 by 10 m. The location is Stockholm. The house should host 4 residents. The indoor temperature in winter should be 22^{o}C. The building should fulfil requirements in the Swedish building code.

7. Collect data

Building dimensions, types of building materials and their thicknesses were taken from drawings, Table 4. Emission data were captured from the Swedish Environmental Research Institute (Energy) and self declared building product declaration, less rigorous than EPDs (building materials).

Table 4 Building specific data for the example building, used in the assessment. Mauritz inserts.

8. Perform the assessment

In the example, the purpose of the study was to use LCA in order to design a single family house that would live up to targets regarding energy use and CO_2 emissions. The assessment in the example therefore implies testing different design and technical solutions with help of the simplified excel tool, to see how the targets could be reached. Table 5 summarises this procedure/assessment.

Table 5. Actions taken step by step to reach the target for energy and CO_2 emissions for a new single family house situated in Sweden and initially designed to fulfil the requirements of the Swedish building code.

	Actions to decrease energy use and CO_2 emissions	Basement	Roof	Slabs	Exterior walls	Win-dows	Ext. doors	Int. walls	Glass area/ Floor area	Ext. door area /Floor area	Vent. heat recovery	Hot water by solar	kWh/m ^{2},yr	Kg equiv CO_2/m^2,yr
0	Start	EPS 100 Concrete 100 Wood	Concrete 100 Steel sheet Min wooll 150 Gysum	Concrete 100 Wood	Brick EPS 50 Min wool 150 Gypsum	3 layer U=1,5	Wood U=2,5	Wood 100	21%	5%	0%	0%	107	23
1	Increase insulation	+ EPS 100	+Min wool 300		+Min wool 150	0,9	1,5		21%				86	18,2
2	Decrease window size								13%				83	17,7
3	Recover ventilation heat										85%		68	14,6
4	Install solar collectors											50%	**55**	10,6
5	Change brick to timber												55	9,7
6	Ch concr. slabs to timber												55	9,2
7	Ch to CO2 free prop. Electr													8,7
8	Wood stove for 20% sp heat													**7,7**

9. Present result

The simplified Excel tool currently presents the main results as in Table 6. Table 6 shows the results after all the actions taken as described in Table 5. For providing a transparent result, a results table as the one in Table 6 should be shown for each action taken.

Table 6. Summary of specific yearly energy use and CO_2 emissions for the single family house ($120m^2$) once the targets are reached.

Anticipated building life time	50

ENERGY FOR OPERATION	$kWh/m^2,yr$	%	kg equiv $CO_2/m^2,yr$	%
Household Electricity	30	35%	1,0	12%
Building Electricity	15	18%	0,0	0%
Space cooling	0	0%	0,0	0%
Total electricity	**45**	**53%**	**1,0**	**12%**
Total electricity without household electricity	**15**	**18%**	**0,0**	**0%**
Space heating	25	29%	4,2	49%
Ventilation	3	3%	0,5	6%
Hot water	13	15%	1,3	15%
Total heating	**40**	**47%**	**6,1**	**70%**
Total energy use	**85**	**100%**	**7,1**	**82%**
Total energy use without household electricity	**55**	**65%**	**6,1**	**70%**

MATERIALS	kg/m2	%	kg equiv $CO_2/m^2,yr$	%
Exterior walls including windows and doors	56	22%	0,6	7%
Attic	18	7%	0,2	2%
Basement	157	61%	0,5	6%
Slabs	15	6%	0,1	2%
Internal walls	12	5%	0,1	2%
Total material use	**258**	**100%**	**1,6**	**18%**

Total yearly impact	**8,7**	**100%**
Total yearly impact without user electricity	**7,7**	**88%**

There are naturally many ways to present life cycle calculations. In focus should be what the client is specifically interested in presented in a short and clear way. The result should be accompanied with a report where more details could be shown.

10. Validation

Preferably the result should be accompanied by a sensitivity analysis where main parameters are varied to show the robustness of the conclusions. This is not done in this example where calculations still are very rough and need to be scrutinized in further work. The purpose with this example is mainly to show the procedure.

6. References

CEN TC 350.. CEN/TC 350/WG1 N075 – Working Draft. Under development.
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ISO. (2004). *Environmental management systems - Requirements with guidance for use* (ISO 14001:2004). Geneva: ISO.
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Palm and Ranhagen. Swedish Energy Agency. (2003) avsnitt 3.2

D3.3 Recommendation on specific LCA features

D3.4 Recommendations for communication of LCA results

Will be elaborated in next version.

Appendices

1. The Enslic guidelines template (separate excel sheet)
2. The Enslic simplified LCA estimations tool (separate excel sheet)
3. LCA tools for buildings – Examples
4. LCI Databases
5. Environmental practices and regulations in different countries
6. Vocabulary

Appendix 1. The Enslic guidelines template (separate excel sheet)

Sheet 1

	Step	Template
1	**State the purpose of the study** (project development, impact comparison, classification, etc)	Assessment
2	**Choose assessment tool** (Basic, building, avanced)	Assessment
3	**State the system boundaries for the assessment** (Reference time, building stage, assessed features, data requirements etc)	Assessment
4	**State scenarios for the reference time** (steady state, regular retrofit, cost development etc)	Assessment
5	**Define targets, references, benchmarks etc** (impact, depletion, energy use, … Country or EU average, target,..)	Targets
6	**Describe the building** (Name, type, size, location etc)	Building
7	**Collect data** a) Environmental data that is not in the tool (emissions per Joule, emissions per kg etc)	Not here
	b) Building data depending on assessed stages	Data input
8	**Perform assessment** (trial and error if targets should be reached)	Assessm. res
9	**Present results** (graphs, tables, analysis, eventually desired improvements etc)	Assessm. pres
10	**Validate** (check results relative to purpose, check calculations fulfillment of requirements etc.)	Validation

Sheet 2. ASSESSMENT INFORMATION

CEN 350	1	**1. Purpose of assessment**	*Test*		
CEN 350	2	Client for assessment	*Enslic group*		
CEN 350	3	Assessor	*MG*		
CEN 350	4	**2. Assessment tool used**			
Enslic	5	Type of tool (basic, building, advanced etc)	*Enslic basic*		
CEN 350	6	Assessed life cycle stages			
CEN 350	8	Period of assessment	*081215*		
CEN 350		**3. System boundaries**			
Enslic	9	Design life or reference time, yr	*50*		
CEN 350	10	Assessed energy for operation	*district heating, electricity for building operation*		
Enslic	11	Assessed building elements	Type	Design life, yr	Maintainance
Enslic	12	Load bearing structure			
Enslic	13	Roof			
Enslic	14	External walls including windows			
Enslic	15	Interior walls			
Enslic	16	Installations			
Enslic	17	Finsihing surfaces			
Enslic	18	…….			
		4. Scenarios			
CEN 350	19	The end of life including:(demolition, deconstr.,recovery, recycling, disposal)	*Not assessed*		
CEN 350	20	Building operations that affects energy, water use, waste production & commissioning	*Normal*		
CEN 350	21	Available infrastructure	*Electricty, district heating, water, sewage, waste recycling*		
CEN 350	22	Occupants behaviour in operation stage	*Normal*		
CEN 350	23	Building's location and its influence on user transportation	*Not assed, but very good location nearby underground station*		
	24	Other scenarios assumed			
		Data sources			
Enslic	25	Building data	*Skanska, Carl Jonsson, tel*		
Enslic	26	Environmental data	*IVL & Swedish Energy Agency*		
CEN 350		**Verification**			
Enslic	27	Sensitivity analys			
Enslic	27	Expert control			
CEN 350		**Life Cycle Cost**			
Enslic	29	Construction			
Enslic	30	Maintenace			

Sheet 3. ENVIRONMENTAL TARGETS

			Stage I		Stage II				Stage III				Stage IV		Total	
Enslic		**5. Environmental targets**	Materials		Transports		Construction		Operation		Maint. materials		End-of-life			
		Impact category	Target	Ref	Target	Ref	Target	Ref	Target	Ref	Target	Ref	Target	Ref	Target	Ref
Enslic	1	Contribution to global warming, kg/m2														
Enslic	2	Destruction of the stratospheric ozone layer,														
Enslic	3	Acidification of land and water, kg/m2														
Enslic	4	Eutrophication, kg/m2														
Enslic	5	Formation of ground level ozone, kg/m2														
Enslic	6	Radioactive waste (Swed. mix 2007), MJ/m2														
Enslic	7	**Energy**														
Enslic	8	Use of energy (excluding user el.), MJ/m2														
Enslic	9	Use of energy (including user el.), MJ/m2														
Enslic	10	Bought energy, MJ/m2														
CEN350	11	Use of renewable primary energy, MJ/m2														
CEN350	12	Use of non renewable primary energy, MJ/m2														
CEN350		**Water**														
CEN350	13	Use of freshwater resource, m3/yr														
		Resources														
CEN350	14	Use of renewable resource (other than primary energy), kg/m2														
CEN350	15	Use of recycled/reused resource kg/m2														
CEN350	16	Material for recycling, kg/m2														
CEN350	17	Use of non renewable resource (other than primary energy), TMR, kg/m2														
CEN350	18	Material for energy recovery, kg/m2														
		Waste														
CEN350	19	Non hazardous waste, kg/m2														
CEN350	20	Hazardous waste, kg/m2														
		Other														
	21	Other 1														
	22	Other 2														
	32	Other 3														

Sheet 4 BUILDING INFORMATION

		BUILDING INFORMATION	
CEN 350		**6. Building description**	*Grönskär, Stockholm, Sweden*
Enslic	1	Building owner & manager	*Svenska bostäder*
Enslic	2	Architect/contractor	*Skanska*
Enslic	3	Location (address)	*South Stockholm, Sweden*
Enslic	4	Construction / refurbisment period	*Construction start: Spring 2007. Finsihed: Spring 2008*
CEN 350	5	Type/Main use	*Residential/32 apartments*
Enslic	6	Additional Space (garage, shops etc)	Garage places *14* Parking places *22*
Enslic	7	Site area, m2	-
Enslic	8	No of floors, floor height etc	*8* Storey hight *2,83* Room hight *2,5*
		FUNCTIONAL EQUIVALENT	
CEN 350	9	Floor area , m2	Gross area *2893* Net area - Heated area ***2607*** Letable a *2249*
Enslic	10	Reference area, m2	***2607***
CEN 350	11	Volume, m3	-
CEN 350	12	Design number of building occupants	94
CEN 350	13	Time period of consideration, yr	50
CEN 350	14	Occupancy (period and pattern of use)	
CEN 350	15	Regulatory requirements	*Conforming to Swdish regulations regarding space need, indoor environmental*
Enslic		**TECHNICAL INFORMATION**	
		Materials	
Enslic		Bearing structure	
Enslic		Walls	External *Concrete & EPS* Internal *Concrete resp. gypsum*
Enslic		Slabs	*Concrete*
CEN 350		Roof	*Steel*
Enslic		U-values	*Walls* *Windows* Roof *Doors*
Enslic		HVAC & hot water service system	
CEN 350		Air change rate	
Enslic		Operating schedule ventilation, heating and cooling	
Enslic		Energy supply	*District heating. A heat pump on exhaust air*
CEN 350		Lighting system	
Enslic		Operating schedule ventilation, heating and cooling	
CEN 350		Year of commissioning	
CEN 350		Year(s) of refurbishment	
CEN 350		Power and communication systems	

Sheet 5 DATA INPUT

7. Data collection
ENERGY USE

Clear energy use

Electricity use	kWh/yr	kWh/ m^2, yr	kWh/ user,yr	MJ/yr	Kind
Property electricity	18 387	7	196	66 193	Swedish Mix
Household electricity	84 096	32	895	302 746	Swedish Mix
Total electricity use	**102 483**	**39**	**1 090**	**368 939**	Swedish Mix
Solar cell production	0	0	0	0	
Other renewable electr. prodduction	0	0	0	0	
Bought electricity	**102 483**	**39**	**1 090**	**368 939**	**Swedish Mix**
Heat use					
Electricity for heat pump	45 167	17	481	162 601	Sw. Mix
Space heating from heat pump	112 918	43	1 201	406 503	Free
Space heating fr distr heating	58 166	22	619	209 398	Stockholm district heat
Space heating from fuel	0	0	0	0	
Hot water from electricity	0	0	0	0	
Hot water from district heating	79 891	31	850	287 608	Stockholm district heat
Total heat use	296 142	114	3 150	1 066 109	
Solar panels	0	0	0	0	
Bougth heat excl. electricity	**138 057**	**53**	**1 469**	**497 005**	Stockholm district heat
Bought energy	285 707	110	3 039	1 028 545	
Bought energy excl. housh electr.	201 611	77	2 145	725 800	

BUILDING MATERIALS

Building reference time 50 years

Use, Kg	Concrete	Wood	Styren	Min. wool	Polyeten	Steel	Glass	Gypsum	Sum
Foundation	123 687	1 956	10	1 369	124				**127 146**
Slabs	1 053 656	13 692	68						**1 067 416**
External walls	667 952	3 960	3 960		867				**676 739**
Windows							9 316		**9 316**
External doors				4		64	56		**124**
Roof		2 461				13 867			**16 328**
Attic	198 648			2 347					**200 995**
Internal walls	459 080			821		71 710		60 688	**592 299**
Fixed carpentry									**0**
Sum	**2 503 023**	**22 069**	**4 038**	**4 541**	**991**	**85 641**	**9 372**	**60 688**	**2 690 363**
Losses,% transp. & site	9%	13%	8%	4%	4%	12%	0%	12%	
Total	**2 728 295**	**24 938**	**4 361**	**4 723**	**1 031**	**95 918**	**9 372**	**67 971**	
Maintenance and reparation									
Est. service life, y	50	50	50	50	50	50	30	25	
During ref time	**2 728 295**	**24 938**	**4 361**	**4 723**	**1 031**	**95 918**	**15 620**	**135 941**	
Transport, km	50	100	500	500	500	100	500	500	
Carrier	Lorry	Lorry	Lorry	Lorry	Lorry	Lorry	Lorry	Lorry	

WATER USE	l/pers,day	l/m2,yr	l/yr
Potable water			

		Yearly						
COST	Erection	Maintain.	Energy	Waste	Water	Cleaning		
Specification								

Sheet 6

Types, quantities, supply chain and logistics, estimated service life (CEN 350)

ENERGY USE

Clear energy use

Electricity use	kWh/yr	kWh/ m^2, yr	kWh/ user,yr	MJ/yr	Kind
Property electricity	18 387	7	196	66 193	Swedish Mix
Household electricity	84 096	32	895	302 746	Swedish Mix
Total electricity use	**102 483**	**39**	**1 090**	**368 939**	Swedish Mix
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Other renewable el. prodduction	0	0	0	0	
Bought electricity	**102 483**	**39**	**1 090**	**368 939**	**Swedish Mix**
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BUILDING MATERIALS

Building reference time 50 years

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Slabs	1 053 656	13 692	68						**1 067 416**
External walls	667 952	3 960	3 960		867				**676 739**
Windows							9 316		**9 316**
External doors				4		64	56		**124**
Roof		2 461				13 867			**16 328**
Attic	198 648			2 347					**200 995**
Internal walls	459 080			821		71 710		60 688	**592 299**
Fixed carpentry									**0**
Sum	**2 503 023**	**22 069**	**4 038**	**4 541**	**991**	**85 641**	**9 372**	**60 688**	**2 690 363**
Losses,% transp. & site	9%	13%	8%	4%	4%	12%	0%	12%	
Total	**2 728 295**	**24 938**	**4 361**	**4 723**	**1 031**	**95 918**	**9 372**	**67 971**	
Maintenance and reparation									
Est. service life, yr	50	50	50	50	50	50	30	25	
During ref time	**2 728 295**	**24 938**	**4 361**	**4 723**	**1 031**	**95 918**	**15 620**	**135 941**	
Transport, km	50	100	500	500	500	100	500	500	
Carrier	Lorry	Lorry	Lorry	Lorry	Lorry	Lorry	Lorry	Lorry	

WATER USE	l/pers,day	l/m2,yr
Potable water		

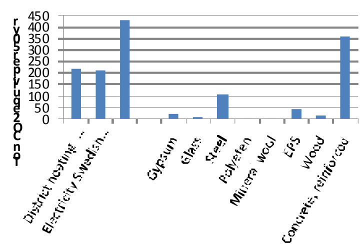
Sheet 7 ASSESSMENT RESULT

	8. Assessment	Indicator	Unit	Life time	Stage I	Stage II		Stage III		Stage IV	Total	Bench-mark	Relative Target
	ISSUES				Produc-tion	Tran-sport (Enslic)	Con-struc-tion	Normal use (Enslic)	Mainte-nance & repair	End of life			
	Impact category												
CEN350	Contribution to global warming	$CO_{2\,eq}$	kg/m2	*50*	*212*			*164*			*376*	500	
CEN350	Destr. of the stratosph. ozone layer	CFC-11 eq	kg/m2										
CEN350	Acidification of land and water	$SO_{2\,eq}$	kg/m2										
CEN350	Eutrophication	$PO_{4\,eq}$	kg/m2										
CEN350	Formation of ground level ozone	$C_2H_{2\,eq}$	kg/m2										
CEN350	Radioactive waste (Swed. mix 2007)		MJ/m2					*4590*			*4 590*		
	Energy												
Enslic	Use of energy (excluding user el.)		MJ/m2,yr					*550*			*550*		
Enslic	Use of energy (including user el.)		MJ/m2,yr					*435*			*435*		
Enslic	Bought energy		MJ/m2,yr					*395*			*395*		
CEN350	Use of renewable primary energy		MJ/m2,yr										
CEN350	Use of non renewable primary energy		MJ/m2,yr										
CEN350	**Water**												
CEN350	Use of freshwater resource		m^3										
	Resources												
CEN350	Use of renewable resource (other than primary energy)		kg/m2										
CEN350	Use of recycled/reused resource		kg/m2										
CEN350	Material for recycling		kg/m2										
CEN350	Use of non renewable resource (other than primary energy)	TMR	kg/m2										
CEN350	Material for energy recovery		MJ/m2,yr										
	Waste												
CEN350	Non hazardous waste		kg/m2										
CEN350	Hazardous waste		kg/m2										

Sheet 8 ASSESSMENT PRESENTATION (Example)

9. Result presentation

BASIC IMPACT CALCULATION



Building:	Gronskar	
Building life time, yr	50	
Impact category	**Climate change**	
Reference area	2 607	m2 heated area
Designed no of users	94	
Impact total	981 344	kg CO2 equiv
Impact relative	376	kg CO2 equiv per m2
Impact relative	10 440	kg CO2 equiv per user

SUMMARY OF CALCULATIONS

	Type	Amount MJ	Life time years	Potential Impact	Unit	Ratio
OPERATING ENERGY	District heating - Stockholm	497 005		219 228 906	g eqv CO2	22%
	Electricity Swedish mix	531 540		208 416 834	g eqv CO2	21%
			Sum	427 645 740	g eqv CO2	
BUILDING MATERIALS	Gypsum	67 971	50	20 391 300	g eqv CO2	2%
	Glass	9 372	50	5 670 060	g eqv CO2	1%
	Steel	95 918	50	103 783 276	g eqv CO2	11%
	Polyeten	1 031	50	1 993 954	g eqv CO2	0%
	Mineral wool	4 723	50	2 796 016	g eqv CO2	0%
	EPS	24 938	50	44 963 214	g eqv CO2	5%
	Wood	24 938	50	13 965 280	g eqv CO2	1%
	Concrete, reinforced	2 728 295	50	360 134 940	g eqv CO2	37%
			Sum	553 698 040	g eqv CO2	56%
		Both Energy & Materials		**981 343 780**	g eqv CO2	100%

Appendix 2. Simplified Excel tool for life cycle estimates

The tool consists of the following sheets:

1.	Instructions	Brief explanation of how to use the tool
2.	General information about the building	Owner, architect, addresses, areas, etc
3.	Construction	Materials & thicknesses in building envelop
4.	Dimensions	Measures of the envelop
5.	Energy use & CO_2 emissions	Is calculated when sources are input
6.	Materials	Amounts and associated CO^2 em. are calculated
7.	Result	Summary of specific use & emissions by source
8.	Data	U-values & materials amounts calc. (automatic)
9.	Energy emissions	Specific emissions from diff. energy sources
10.	Material emissions	Spec. emissions from diff. material production
11.	Global Warming Potential	Characterisation factors from IPCC
12.	Application	Sheet for simplif. energy & CO_2 optimisation

Appendix 3. LCA tools for buildings - examples

Name	Country	URL
ATHENA	Canada	http://www.athenaSMI.ca
BECOST	Finland	http://www.vtt.fi/rte/esitteet/ymparisto/lcahouse.html
BEES	USA	http://www.bfrl.nist.gov/oae/software/bees.html
ECOEFFECT	Sweden	http://www.ecoeffect.se
ECO-SOFT	Germany, Austria	http://www.ibo.at/de/ecosoft.htm
ECO-QUANTUM	Netherlands	http://www.ecoquantum.nl
ENVEST 2	UK	http://envestv2.bre.co.uk/
EQUER	France	http://www.izuba.fr
GREENCALC	Netherlands	http://www.greencalc.com
LEGEP	Germany	http://www.legep.de/
OGIP	Switzerland	http://www.ogip.ch/

General LCA tools

Boustead: www.boustead-consulting.co.uk
Eco-it: www.pre.nl
Ecopro : www.sinum.com
Ecoscan: www.ind.tno.nl
Euklid: www.ivv.fhg.de
KCL Eco: www.kcl.fi/eco
Gabi: www.gabi-software.com
LCAit: www.ekologik.cit.chalmers.se
Miet: www.leidenuniv.nl/cml/ssp/software
Pems: www.piranet.com/pack/lca_software.htm
SimaPro: www.pre.nl
Team: www.ecobilan.com
Wisard: www.pwcglobal.com
Umberto: www.umberto.de

To be completed!

Appendix 4. LCI databases

Name	URL
European Reference Life Cycle Database (ELCD)	http://lca.jrc.ec.europa.eu/lcainfohub/datasetArea.vm
Ecoinvent	www.ecoinvent.ch
Gemis	Gemis: www.gemis.de

Appendix 5. Environmental practices and regulations in different countries

(To be completed by respective partner)

There are different incentives and regulations that aim at making new buildings more environmentally benign in different countries. Because of this an efficient way to promoting LCA may be slightly different in different European countries.

The French and UK regulations concern primary energy consumption and CO_2 emissions for new buildings. More environmental topics are sometimes considered at a local level, e.g. radioactive waste in an urban renewal project in Lyon.

Appendix 6. Vocabulary

Word	Description
Building data	
Characterisation	
Characterisation factor	
CO2-equivalents	
Emission data	
Energy Performance of Building Directive (EPBD)	
Environmental Product Declaration (EPD)	
Functional equivalent	
Functional unit	
Impact category	
Life cycle assessment (LCA)	
Life cycle costs (LCC)	
Life cycle impact assessment (LCIA)	
Life cycle inventory (LCI)	
Normalisation	
Product system	
Reference substance	
System boundary	
Weighting	

To be completed!