Life Cycle Analysis (LCA) in the building sector

Guidelines

2007

1 Introduction

1.1 Why use this methodology

The Life Cycle Assessment (*LCA*) is a method voted to analyze and assess the environmental impact of materials, products or services throughout their *entire life cycle*, from the origin of raw materials to their disposal. The LCA can be applied to every typology of good or service defining their eco-profile. This approach allows to perform a scientific balance between the benefits and the impacts related to the product's use.

1.2 Requirements in regulations

The LCA is regulated by the international standards of series ISO 14040 (Table 1). These rules define the principles and the general framework of a LCA.

Table 1: The standards of series ISO 14040

Standard n°	Title
ISO 14040	Environmental management - Life cycle assessment - Principles and framework (1997)
ISO 14041	Environmental management - Life cycle assessment - Goal and scope definition and inventory analysis (1998)
ISO 14042	Environmental management - Life cycle assessment - Life cycle impact assessment (2000)
ISO 14043	Environmental management - Life cycle assessment - Life cycle interpretation (2000)
ISO/DIS 14044	Environmental management - Life cycle assessment - Requirements and guidelines
ISO/TR 14047	Environmental management - Life cycle impact assessment - Examples of application of ISO 14042 (2003)
ISO/TR 14048	Environnemental management - Life cycle assessment - Data documentation format (2002)
ISO/TR 14049	Environmental management - Life cycle assessment - Examples of application of ISO 14041 to goal and scope definition and inventory analysis (2000)

LCA guidelines carried out by the SETAC - Society of Environmental Toxicology and Chemistry [1] are one of the most relevant in the field.

The EU has promoted the LCA approach into many official documents as the Sixth European Environment Action Programme and the Green Paper of Integrated Product Policy. The Green Paper underlines that "*once a product is put on the market, there is relatively little than can be done to improve its environmental characteristics*". Thus, it is clear the need to integrate the analysis of environmental issues throughout the life-cycle, and in particular, during the early stages of product development.

Dealing with the building sector (see Construction Product Directive 89/106/CE adopted in 1988) several Member States have set and developed approaches aimed to integrate the environmental criteria in the design and construction of buildings. This process has led to questioning construction material producers on the environmental performance of their products. Several methods concerning the environmental performance of construction products were developed.

An effort to harmonise different tools and schemes has been developed by the European Commission in a detailed study in 2002 [2].

1.3 Structure of a LCA

According to the ISO standards, the general structure of LCA is based on the following steps (Fig. 1):

A) *Goal and scope definition*: is the first phase aiming to define the study's goals and scopes as well as the typology of the study itself, the detail of results, the stakeholders, etc.;

B) I*nventory Analysis*: is the step including the compilation and assessment of inputs and outputs, for a given product system throughout its life cycle;

C) *Impacts Assessment*: phase aimed at understanding and evaluating the magnitude and significance of the potential environmental impacts of a product system;

D) *Life Cycle Interpretation*: phase in which the results of either the inventory analysis and the impact assessment are combined according to the defined goals and scopes in order to point out significant conclusions and recommendations.

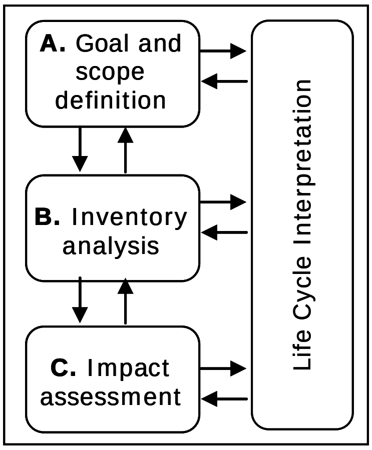

Figure 1: Structure of LCA

To perform a LCA of a product/service item it is necessary to start form the definition of the study's purposes. This choice is particularly important because, depending on the *goals* (i.e. an internal study for design purposes or a study for product certification and external communications to consumers), it could be necessary to modify the structure, the depth of the analysis and the detail of results. Particularly important is the definition of the study's object (defined "Functional Unit - FU") that represents the unit which refers the whole study.
The analyst has to carry out a detailed description of every life cycle steps. Starting from the analysis of product's component, it is necessary to trace back every process till up raw materials extraction.
The study has also to describe and, eventually to foresee, the future product's transformation during the use and maintenance phase till up the product disassembly and disposal. All the energy and mass flows occurring during each life cycle step have to be computed. The detail of this investigation depends on the declared level of precision. This data collection is called *life cycle inventory analysis* and it is based on field data and on scientific references.
Data from inventory need to be processed in order to assess energy and environmental impacts. These are generally assessed by global impacts indicators (as global warming potential, ozone depletion potential, etc.) obtaining an eco-profile of the FU.
The last part of a LCA is a backward study of every life cycle steps to state the limits of the analysis as assumptions, omissions, data sources and collection techniques, etc.

2 Current practise

Traditional environmental analyses generally focus on a restricted number of life cycle steps according to the contest of the investigation.
In the building sector, for example, an household producer generally focuses the attention on the products use stage, maybe giving to the consumer information about final energy consumption and other consumables.
A conventional energy audit is generally focused on the assessment of energy consumption of a building/HVAC system.
Environmental information regarding the manufacturing, maintenance or disposal of building materials are generally omitted or neglected.
Furthermore, those analyses generally concern direct environmental impacts, neglecting external and indirect impacts due to suppliers, retailers and consumers activities.

3 Innovative solutions

In comparison to traditional environmental analyses, a LCA allows to avoid partial or wrong assessments concerning the products environmental performances. In fact, it is not scientifically correct to limit the environmental analysis of a building only assessing the impacts due to the use phase (energy for lighting, air conditioning, sanitary water heating, etc.) but it is necessary to include other life cycle steps as manufacture of constructing materials, building construction and maintenance till up building dismantling and material's disposal.
The LCA investigated every direct and indirect impact throughout the life cycle. For example a LCA of a building has to include the life-cycle study of employed materials and energy sources.
The LCA represents also a scientific based approach to compare replaceable products or alternative design solutions. For example, with respect to a traditional Heating, Ventilation and Air Conditioning plant, the employment of high efficiency systems could imply higher energy consumptions for the plant's manufacture but successively could cause lower energy consumption during the use.

3.1 Application of the LCA to the analysis of a building

A LCA of a building should be developed according to the following scheme:

1. Qualitative and quantitative analysis of building components including the main construction materials and the main equipments;
2. Analysis of the construction phase including material origin and transport, the use of construction machineries, installation steps, environmental impacts due to the construction (as land use, soil removal, air and water emissions, wastes, noise levels), etc.;
3. Reference analysis to collect information regarding the construction materials and plant's components. When available, it is generally suggested to refer to local producers; otherwise the analyst could refer to national or international data and statistics;
4. Detailed analysis of the use phase, computing the yearly energy employed for lighting, air conditioning, sanitary water heating, food cooking, etc.;
5. Analysis of maintenance operations. For new buildings the analyst could refer to experiences of previous buildings or to local and national statistics. This step should include the qualitative and quantitative analysis of utilised materials and environmental impacts due to the maintenance (following a similar approach as performed for the building construction analysis);

6. Analysis of disposal phase. That should include the energy and the environmental impacts related to the building demolition (energy employed by machineries, air and water emissions, etc.) and the exhausted materials disposal or recovery. Being generally not possible to exactly foresee and describe the disposal phase before accomplishing it, the analysis should be based on different disposal scenarios. These scenarios have to describe different disposal assumptions and technologies (i.e. material totally moved to landfill or partially reused and recycled, energy recovery, etc.);
7. Data regarding each life cycle step have to be processed in order to obtain global environmental indexes that synthesize the environmental performances of the building;
8. Analysis of all the previous steps to locate hot spots (components of the system with the higher environmental burdens) that are further investigated in order to reach the desired level of precision and reliability of the results. Assumptions concerning hot spot have to be discussed in a sensitivity analysis.

The LCA is also a valid scientific basis to obtain environmental labels and certifications as well as to develop further detailed environmental analysis. These topics are briefly discussed in the following.

3.2 LCA-based tools

Being the LCA a global “environmental overview” of the products, it is internationally agreed to award the environmental labels on the basis of a life-cycle approach. Following the classification introduced by the standard ISO 14020, the voluntary environmental labels are subdivided in:

- Type I: identifies products as being less harmful to the environment compared to other similar products, thanks to the compliance of minimum level of environmental performances and within the context of a third party verify. The European Ecolabel Scheme belongs to this category;
- Type II: self-declared environmental statement about the environmental performance of a product by the manufacturer itself;
- Type III: environmental declaration compiled by the producer including setting minimum requirements, selecting categories of parameters, defining the involvement of third parties and the format of external communications. The Environmental Product Declaration scheme belongs to this category [3].

To accomplish to the requirements of credibility, relevance and comparability, the ISO standards of series 14020 established that Type I and III labels have to be based on LCA.

Many building products and equipments have been included in the Ecolabel and EPD schemes as: hard floor covering, paints and varnishes, lighting devices, toilets, construction materials, cement, ceramic tiles, concrete, insulation, electric plants, air conditioners, households, etc.

Although not mandatory, a LCA study is also useful for the implementation and maintenance of an Environmental Management System (i.e. to improve the initial environmental analysis, to facilitate the selection of the set of significant environmental indexes or the definition of the environmental improvement programme, etc.).

4 Advantages/disadvantages

There are many benefits for businesses activities adopting the LCA approach, including:

- Assessing, on the basis of a internationally agreed scientific procedure, the components and the life cycle steps of the good/service responsible of the most significant environmental impacts;
- Identifying the most efficient and cost effective options for increasing the environmental performance of a product or service, to create a 'greener' product that is more desirable to consumers;
- Assessing a company's operations and production processes to identify opportunities for efficiency improvements, such as avoiding waste treatment and using fewer resources, while reducing financial costs;
- Reducing greenhouse emissions and other environmental burdens in accordance with national and international laws and agreements;
- Utilising the LCA results as the basis to develop an Environmental Management System (EMS) or to obtain environmental label and product certifications;
- Comparing the performances of replaceable products in terms of environmental performances or life cycle costs (global costs valued throughout the entire life cycle).

The main problems related to a life cycle approach are related to the difficulties that the analyst has to face carrying out the study. These are summarised ad follows:

- The backward analysis of processes till up raw material can not indefinitely lead but has to be arrested at a desired level of precision;
- The complete analysis of every system’s component’s is difficult and sometimes not practicable. The system can be composed by a great variety of elements. The aim of a LCA is not to “exactly” quantify the impacts but to estimate their order of magnitude. Consequently, the analyst can choice to neglect some marginal parts[2] verifying that his assumptions do not heavily affect the reliability of the study;
- The inventory phase is generally a difficult and time consuming process;

[2] The exclusion from the analysis of some system’s part is generally called ”cut-off rule”. Generally are excluded those components whose mass is lower than a fixed percentage of the global system’s mass (i.e. lower than 1%). This percentage is fixed during the goal and scope definition and it is related to the required precision of the study. However the mass based cut-off rule is not correct for high impacting materials (as toxic or cancerogenous materials), responsible of large environmental impacts even in small quantities.

- Non linearity of process that are often mutually related, requiring and iterative analysing process;
- Data inaccuracy (due to errors and imperfections in the measurements) and mistakes (unavoidable in every step of LCA);
- It is not possible to directly collect all the necessary data and information. Consequently the analyst has to refer to references and statistic, facing problem related to data quality as:
  - Data availability (data not yet collected or not published);
  - Data reliability;
  - Data representativeness (data referring to productive system not perfectly adherent to the case study);
  - Geographical matters (as data referring to national or international economic context more than the local ones);
  - Age of data (data older than 10 years are generally considered out-of-date);
  - Data strongly aggregated

All these problems can affect the reliability of the study. For this reason the analyst, during the interpretation phase, should verify each assumption in order to locate "hot spots" to be furthermore analysed and improved.
Such step generally includes an uncertainty and sensibility analysis. The aim is to individuate possible mistakes and inaccuracies as well as to assess the incidence of initial assumptions and hypotheses on the final results.

5 Costs

5.1 Investment costs

The costs of a LCA are mainly related to data collection and process phase. As previously described, this is a time consuming procedure that requires the commitment of specialised analysts.
The time necessary for an analysis depends on the complexity of the subject and on the desired detail of the results.
Approximately, a LCA of a construction material could require an average commitment of an analyst for 1÷2 months. If the scope of the analysis is an internal company survey this time period can be sensibly reduced; otherwise, if the scope of the study is to make a public communication of the results or to obtain an environmental certification, the commitment can be the double or more.
The time length of a study grows with the complexity of the systems. A complete analysis of a mono-familiar house could require months of study. However the commitment does not grow linearly with the building scale: the analysis of large building, that differs form a small one only for the employed masses, is not sensible larger form the study of small house.

5.2 Energy and environmental benefits

It is not easy to estimate and quantify the energy and environmental benefits related to the implementation of a life-cycle approach.
In fact the LCA is a methodology that provides information regarding the effective system's environmental performances. The environmental benefits depend on the selected corrective actions. LCA is then a starting point for the further system's development and upgrading as well as an efficacious tool to support decision-maker during the design stage.
For example the choice of a thicker insulation layer implies higher impacts during the construction phase but strongly reduces the heating impacts; the choice of natural fibres and materials into constructions reduces the release of toxic compounds; reducing the variety of employed materials in the products it is easier the disassembly stage; the employment of local constructing materials reduce impacts due to transports; to avoid dangerous substances reduces impacts and costs of disposal.

5.3 Additional costs

Additional economic expenditures can be related to the cost of the analyst work and to the purchase of specialised software and data-bases for LCA. Their cost is sensible variable, from free (as some national environmental data-bases) to 15000 € for high specialised tools, with and average cost of 2000-3000 €. The purchase of LCA software is suggested to large enterprises that foresee to employ constantly the LCA approach in the product development. On the other hand, those who occasionally employ the LCA approach, as small or medium enterprises are suggested to apply to specialised companies and universities.

6 Analysis progress and evolution

6.1 LCA improving and updating

Data regarding life cycle of products can require frequently updates. Although the production process is not modified, the eco-profile of raw materials, energy sources, ancillary materials and consumables can change affecting indirectly the environmental performances of the product.
If no structural changes have occurred in the production process or in the local economy, the update process is not particularly difficult: it is suggested to revise the product's eco-profile yearly and to renew it completely every 3÷5 years[3]. Enterprises can implement a data collection and survey system that allow them to control the processes evolution, to monitor the environmental performances and to update information into LCA easily.
Being buildings strongly different each others, it is necessary a new LCA study every new construction. On the other side, the eco-profile of traditional construction materials generally does not change rapidly and it can simplify the analyst's work.
Contemporary to the updating process the analyst should carry out a continuous improving process focusing on:

- gathering of more representative data;

[3] A mandatory three years renewing period is requestes to Ecolabel and EPD certified products.

- gathering of local data;
- including previous neglected components;
- further investigation on hot spots and other critical components and life-cycle steps.

7 Best practise example

The execution of LCA-studies within the context of the building sector is faced with various sector specific peculiarities, as:

- Each building is unique and it is difficult to define sector's standardised rules;
- The time aspect, e.g. long service life compared to consumer products, which has implications on energy and maintenance scenarios;
- The long service life of buildings and constructions has as a consequence that a major part of the environmental load associated with a building or construction occurs during the usage phase;
- Disparate lifetimes for different building materials included in the same system, which has implications on service life and maintenance scenarios;
- The high potential for recycling and reuse of building materials, components and whole building frames in combination with long service life has implications on end of life scenarios and how to handle distribution of environmental loads between life cycles.

Concerning construction materials and buildings, really a lot of LCA studies have been performed. A data sample regarding the LCA of construction materials is shown in table 2. The table includes the consumed energy and the CO_2 emitted.

Table 2: Environmental data of construction materials

Material	Energy consumed [MJ/kg]	CO_2 emitted [kg_{CO2}/kg]	Reference
Aluminium	198	11.3	[4]
Cement	4.52	0.75	[5]
Copper	91	5.9	[6]
Glass	13.6	1.1	[6]
PVC	56.6	1.9	[7]
Polystyrene	87.5	2.6	[7]
Polyurethane	111.4	3.4	[7]
Steel	21.5	1.34	[8]

An interesting comparative study among different residential buildings is presented in [9]. Sixth semi-detached houses, with a living surface are from 176 m^2 to 185 m^2, have been analysed supposing an average useful life of 80 years[4].
The houses differed in their energy efficiency of the heating system as well as in building materials. The energy standard of the reference house "R" meets the legal requirements set in the Germany (applied since 1995) and corresponds to the standard actually build in Germany. It had an energy requirement for heating of 98 kWh/m^2 year. The other houses (A, B,C,D[5] and E) needed between 34 and 52 kWh/m^2 year, which characterize low energy houses. The houses only differed slightly in their sizes and layouts. Figure 2 shows a comparison of the embodied energy referring to the analysed case studies. The study shows that respect to the reference study "R" the adoption of high efficiency design solutions (with better insulations, high efficiency plants, low energy materials, etc.) sensibly decrease the global energy demands. Case study D_2 is resulted the worst one due to the use of electricity for the building heating.

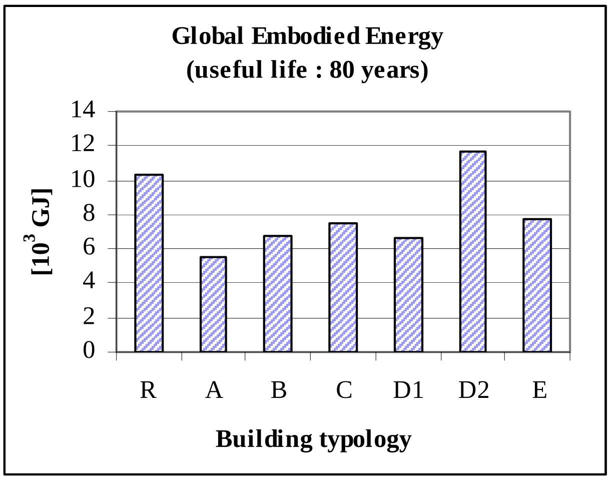

Fig. 2: Energy comparison among six buildings.

A component detail of the LCA of a building is presented by [10] as shown in Figure 3. The analysis regarded a residential building in Sweden and it includes energy for material's production (defined "initial materials"), building installation ("spillage") and maintenance and replacement ("renovation"). Figure 3 does not include the energy requirement for heating that is estimated to be 45 kWh/m^2.
The energy consumption due to embodied energy of materials could be sensible decreased by employing recycled materials. The study shows that about 37-42 % of the embodied energy can be saved through the recycling.

4 A summary of the study is available at: http://europa.eu.int/comm/environment/ipp/studiesevents.htm

5 The case study "D" as been furhter divided into D_1 (considering a gas fired boiler for heating) and D_2 (with and electrical heating).

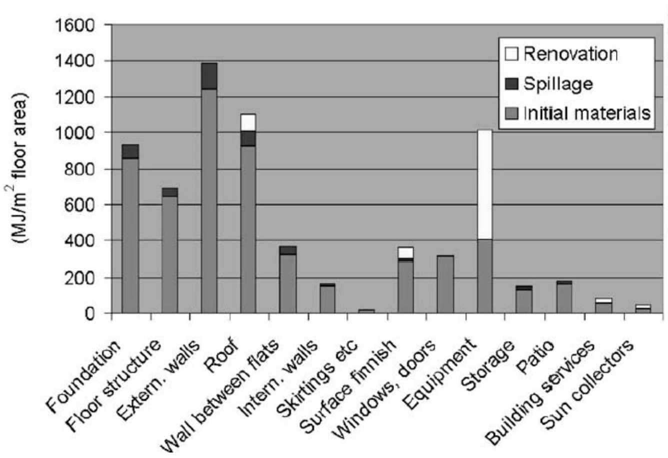

Fig. 3: Details of a building LCA

7.1 LCA to building retrofit: key issues

The LCA methodology has been applied to the analysis of the BRITA demo-buildings retrofitting actions, in order to evaluate the efficacy of such approach. Furthermore, this application allowed to focus the attention on the key issues and to identify and discuss the main encountered difficulties. In particular, it became evident that a complete LCA is a too complex and time-consuming procedure that goes beyond the same goals of the designers.

The greatest difficulties dealt with data availability during the inventory phase. Designers, in fact, have not a so detailed knowledge of materials and components utilized in their retrofitting, as it should have been necessary into a complete LCA.

In particular, data easy to acquire concerned:

- quantity and typology of construction materials (insulations, panels, bricks, plasters, concrete, etc.);
- waste produced during the retrofitting and energy consumed by building machines (generally accounted by building firms).

Concerning windows and solar plants (both photovoltaic and thermal collectors), designers have generally information only about installed surfaces and typologies of devices. Few other information can be obtained about solar panel components.

On the other hand, the mass detail of HVAC systems and other plants is almost entirely missing. Such know how belongs only to producers, and it is not possible to proceed easily on their survey and collection.

Such data gaps can be filled up with data coming from references, scientific literature or from environmental LCA databases. On this subject, we remind that, as previously discussed, the aim of a LCA is not to “exactly” quantify the impacts but to estimate their *order of magnitude* and to identify *hot spots* of the assessed action.

Therefore, a simplified LCA is fitting with the activities of designers for the evaluation of better performing solutions. The loss of precision due to the assumption of average reference data is balanced by the simplicity of such procedure. A complete and detailed LCA can be applied to some system details or can be suitable for larger academic and research purposes.

The data survey can be facilitated by providing inventory questionnaires to designers. These data sheets can guide the collection of information and focus the attention on priority components.

7.2 Case-study: LCA applied to retrofit actions

In the following the retrofit of the demo-building of the *Vilnius Gediminas Technical University* (VGTU) has been analysed. The actions involved mainly the substitution of old wall insulation with a new and a better performing envelope, and the installation of high efficiency windows with selective glasses (low-e) and low thermal transmittance. The assesses energy savings have been *220589 kWh/a* due to high-efficient windows and *236672 kWh/a* due to insulation of roofs and facades. The estimated useful life-time of the retrofit components is 35 years.

The construction phase involved the use of electricity and diesel oil for the operation of building machineries. The disposal scenario includes the transportation of wastes and their disposal to landfill.

A detail of the main inputs and outputs of the retrofit actions is shown in Table 3. The table also includes the reference for inventory life-cycle data of products. Inventory data concerning windows have been gathered by the GEMIS database and successively updated and adapted to the Lithuanian context.

Table 3: Main Inputs and Outputs of the retrofit action

Material/component	Quantity	Unit	Reference
Materials for insulation and renovation			
Roll roofing layers (bitumen)	12.6	ton	[11]
Expanded polystyrene (EPS)	8.65	ton	[7]
Expanded clay	27.7	ton	[12]
Stone wool	4.18	ton	[12]
Panel (Glued laminated timber)	5.2	m^3	[12]
Panel (Particle board, cement bonded)	3.9	m^3	[12]
Patterned daub (base plaster):	110.2	ton	[12]
Wood board	1.72	ton	[11]
Profiles (Steel)	1	ton	[8]
Windows			
PVC framed windows	1001.2	m^2	[6; 7; 12]
Aluminium framed windows	257.1	m^2	[6; 7; 11; 12]
Other			
Electricity	1547	kWh	[6]
Diesel oil for construction machines	4.5	m^3	[12]
Waste production and disposal (aluminium, wood, glass)	43.8	ton	[12]

The environmental impacts have been synthesized by the indexes of the EPD scheme [3]: GER – Global energy requirement, GWP – Global Warming Potential, ODP – Ozone Depletion Potential, Acidification and Eutrophication.

Concerning the GER, the result of the analysis shown that the greatest impacts are due to the manufacture of materials. In particular, insulation and window substitution are responsible each one of about an half of the global consumptions. Construction phase represent about 5% of the GER, in accordance to bibliographic references; the contribution to GER due to wastes disposal is almost negligible (Figure 4).

A similar trend has been observed also for the other indexes.

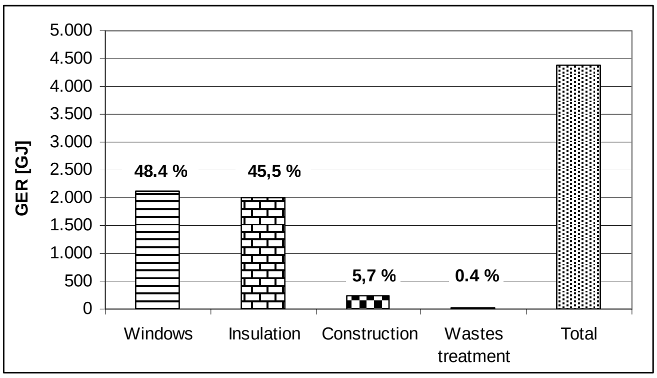

Figure 4: Contribution to GER due to various life-cycle phases

The comparison among the environmental impacts due to the building retrofit and the benefits related to the energy saving is shown in Table 4. Environmental benefits have been assessed by calculating the avoided emissions that a conventional gas heating plant should have produced. Specific emissions of heating plants refer to the Ecoinvent database [12].

Table 4: Comparison of environmental Impacts & Benefits

Index	Benefits	Impacts	Net benefits
GER [TJ]	71.46	4.36	*67.10*
GWP [ton $CO_{2-Eq.}$]	4069.92	217.32	*3852.60*
ODP [kg CFC_{11}]	0.40	0.16	*0.24*
Acidification [kg SO_2]	3206.0	1253.18	*1953.52*
Eutrophication [kg PO_4]	333.62	111.07	*222.55*

It is possible to observe that benefits largely overlook the impacts. In particular, the primary energy saving is one order of magnitude larger than the overall energy consumed during each life cycle steps of the retrofit materials. This simplified LCA approach demonstrated therefore the great energy and environmental convenience of these actions.

From the analysis of construction materials, it resulted that the largest impacts are due to the use of chemicals (EPS and Bitumen); stone wool is, instead, characterised by lower specific life-cycle energy consumptions and consequently, its use in retrofit is preferable.

Regarding the two window typologies, the PVC and the aluminium framed, a comparison of specific environmental impacts have been carried out. It resulted that the aluminium structure causes impacts 3÷4 time larger than the plastic ones (Table 5). This is mainly related to the assumption that only primary aluminium has been employed in the window manufacture. Recycled aluminium is characterised by lower environmental impacts respect to primary one (even 80÷90% lower) [4].

A significant reduction of the environmental impacts due to windows substitution could be obtained supposing to utilize partially or totally recycled aluminium for windows frames, or assuming to use only PVC based windows. In any case, these improvement solutions will decrease the impact indexes of Table 4, confirming and strengthening the positive judgement on the performed retrofit actions.

Table 5: Comparison of two window typologies

	1 m^2 of aluminium window	1 m^2 of PVC window
GER [GJ]	3.6	1.2
GWP [kg $CO_{2-Eq.}$]	204.7	48.1

Finally, a separated discussion is necessary about the wastes management. The retrofit causes the production of about 49.7 ton of wastes, whose about 88% directly ascribable to demolitions and renovations, while the remaining 12% related to the other life-cycle phases (mainly the materials manufacture). These impacts are not balanced by benefits due to the energy saving, and therefore they represent the main negative consequence of the retrofit. Anyway, impacts due to wastes could be reduced assuming to address materials life to recycling plants or to address combustible substances to treatments of incineration with energy recovery.

8 Calculation tools

Many specialised software and databases have been developed to assist analysts in developing LCA studies (a detailed comparative study regarding the performances of LCA tool has been performed by the Swedish Environmental Research Institute [13]).

The use of LCA in the building sector requires an adaptation of the LCA methodology and tools to the specific conditions of the building sector. The efforts to adapt the methodology have resulted in several national and international methodology and tool development projects and working groups. Examples are: tools for LCA at building part component level (as the BEES tool [14] and the ATHENA tool [15]), LCA design tool (as ECOit and Eco-Scan, ENVEST [16]), LCA CAD tools (ECOtec, EPCMB) Green Product guides and checklists (as the Environmental Preference Method), building assessment schemes (as GBTool), etc. Interesting are also the results of the Working Group of SETAC-EUROPE on LCA in Building and Construction [17].

9 References

9.1 Compilation

This guideline is written as a part of the project BRITA in PuBs – Bringing retrofit innovation to application in public buildings, EU 6th framework program Eco-building (TREN/04/FP6EN/S.07.31038/503135).

The authors are Fulvio Ardente, Marco Beccali and Maurizio Cellura from the University of Palermo, Italy. The professional editing was closed in November 2007.

9.2 Further reading

To approach the LCA methodology we suggest to start from the ISO standards (see table 1). Really interesting and complete are the guidelines performed by the SETAC [1], Boustead [18] and EPA [19].

Regarding the LCA of buildings and construction materials it is suggested to refers to:

- APME – Association of plastic manufacture in Europe[6];
- Global Emission Model for Integrated Systems. by Institute for Applied Ecology – GEMIS[7];
- UNEP/SETAC Life cycle Initiatives[8];
- European Commission - Analysis of LCA tools[9];
- Swedish Environmental Management Council – EPD[10];
- Environment Australia – LCA tools in the building and construction sector[11].

9.3 Literature

[1] SETAC - Society for Environmental Toxicology and Chemistry,"SETAC Guidelines for Life-Cycle Assessment: A Code of Practice", Brussels, 1993.

[2] EC (European Commission) DG Environment, Evaluation of Environmental Product Declaration Schemes, Final Report, September 2002.

[3] The international EPD® system. "General Programme Instructions for an international EPD® system for environmental product declarations Draft for International Open Stakeholder Consultation version 0.1 - dated 2007-03-02.

[4] European Aluminium Association. Environmental profile report for the European aluminium industry, report of the European Aluminium Association, April 2000.

[5] Buzzi Unicem "Environmental Product Declaration – Average cement" 1999.

[6] Öko-Institut (Institut für angewandte ökologie). Global Emission Model for Integrated Systems (GEMIS), Version 4.2, 2005, German environmental database.

[7] Boustead model, Boustead Consulting Ltd., environmental database, Ver. 4.4 2001. Black Cottage, West Sussex, UK, 2001.

[8] International Iron and Steel Institute. LCI data of steel products - Hot-dip galvanised coil and Hot rolled coil, June 2005.

[9] EC (European Commission) – Directorate General Environment, "Study on external environmental effects related to the life cycle of Products and Services – Final Report", February 2003.

[10] Thormark C., "A low energy building in a life cycle—its embodied energy, energy need for operation and recycling potential", Building and Environment 37 (2002) 429 – 435.

[11] ETH-ESU Switzerland. "Ökoinventare von Energiesystemen"Licensed database from SimaPro software 1996.

[12] Swiss Centre for Life Cycle Inventories. ECOINVENT database. 2000.

[13] Jönbrink A K, Wolf-Wats C, Erixon M, Olsson P, Wallén E, "LCA Software Survey", IVL-Swedish Environmental Research Institute Ltd, report No B 1390, Stockholm, September 2000.

[14] Lippiatt, B. (2000): "Building for environment and economical sustainability. Technical Manual and user guide (BEES 2.0)", National Institute of Standards and Technology (NIST), report NISTIR 6220, June 2000.

[15] Trusty, W.B. (1997): "Research Guidelines, ATHENATM", Sustainable Materials Institute, Merrickville, Canada, 1997.

[16] BRE (2000): "ENVEST, Environmental impact estimating design software". Building Research Establishment, Garston, Watford, 2000. www.bre.co.uk/envset.

[17] SETAC - Society for Environmental Toxicology and Chemistry, "LCA in building and construction – A state-of-the-art report of SETAC-EUROPE", Intron B.V.,Sittard, Holland, 2001.

[18] Boustead I & Hancock G F, "Handbook of Industrial Energy Analysis", Ellis Horwood, Chichester/John Wiley, New York. ISBN 0-85312-064-1. 1979.

[19] Vigon B.W., Tolle D.A., Carnaby B.W., Lathem H.C., Harrison C.L., Boguski T.L., Hunt R.G. e Sellers J.D., Life-Cycle Assessment: Inventory Guidelines and Principals, U.S. EPA Report, EPA/600/R-92/245, Cincinnati OH., 1993.

10 Disclaimer

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6 www.apme.org/lca

7 www.oeko.de/service/gemis

8 www.uneptie.org/pc/sustain/lcinitiative/home.htm

9 www.europa.eu.int/comm/enterprise/construction/index_en.htm

10 www.environdec.com

11 http://buildlca.rmit.edu.au