Methodological improvements in life cycle analysis of buildings: results from the COIMBA project

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Summary

Fast development of sustainable construction requires more precise and relevant tools for low impact buildings design and decision-making assistance. Methods already exist but they need to be adapted to new demands, aiming either at acquiring a better understanding of low energy buildings environmental profile or at allowing a daily use of environmental evaluation tools in the design process.

COIMBA is a collaborative project initiated by a team of 5 partners in 2008 with the goal to improve buildings LCA tools available in France: EQUER and ELODIE.

After a detailed analysis of existing tools (in Europe, North America, Australia...) work has been dedicated to improve methodological approaches:

- Water. Introducing fine analysis of water consumption and management in assessment tools: calculation modules allowing the evaluation of water consumption into buildings and rainwater management on building sites were developed and integrated in LCA tools
- Energy. Performing better integration of energy issues into LCA tools: compulsory information to be delivered about thermal performance of products to be used in a LCA analysis; to include daily and seasonally variations of the electricity production mix into the calculations and thus allowing more precise climate change indicators calculation.
- Indicators. Analysing the use of end-points indicators like “land use” and “eco-toxicity” in buildings LCA
- Data. Defining the way to use both *Ecoinvent* data and French EPDs (FDES) in LCA tools, and the possibility to simplify life cycle inventories
- Perimeter. Analysis of end of life and transports treatment in buildings LCA
- Ergonomics. Practical recommendations for tools editors on data transparency and results reporting.

Finally, improved version of LCA tools EQUER and ELODIE have been evaluated through comparative analysis performed on low impact buildings.

Keywords: sustainable construction, LCA tools, LCA methodology

1. Introduction

Life Cycle Analysis (LCA) is a scientific tool to measure the environmental impacts associated with the lifecycle of a product or a service. It is a multi-criteria and multi-stage method and can be used for ecodesign.

In a LCA, the entire lifecycle of the product is analysed, from the extraction of raw materials to the end of life (waste or recycling), through the manufacture of materials, assembly, product use and maintenance.

The procedure for conducting an LCA is defined by the standards of ISO 14040 "Environmental management - Life Cycle Analysis".

For several years the construction sector has been the subject of a growing awareness of environmental issues. Indeed, the real estate residential and commercial uses count for a 44 percent of energy use in France and it is the third source of CO2 emissions (23 percent). Taking into account the environmental dimension is now at the heart of the construction industry agenda.

In France, as elsewhere in Europe, several approaches have been implemented to address this problem: High Environmental Quality (HQE ®), thermal regulation (RT 2005, RT 2012), Low Consumption Building (BBC Effinergie ® label)...

LCA methods are however difficult to apply directly in the construction industry since the buildings are quite special "products". On one hand, their complexity requires analysis of many different elements for which data are often not available. On the other hand, several environmental aspects cannot be taken into account in this analysis because of the difficulty to quantify them and the lack of adequate indicators. This is the case today for the impact on the implantation site, the impact on the quality of indoor air, or the impact related to user satisfaction.

Compared to existing systems for the environmental evaluation of buildings, rather centred on qualitative approaches, some specific tools that have been developed for the building sector offer the advantage of quantitative analysis, so the results are objective and allow for comparison. However, they are limited by the approximations imposed on multiple calculation steps: this being the case for the quality of data, the types of available data, the environmental aspects taken into account, the translation of results in environmental impacts (inventory), and possibly additional steps, such as standardization.

Sixteen tools were examined for the state of the art phase of COIMBA project. The available tools are either free of charge, have a license fee, or follow differentiated access and use schemes.

Among the existing tools, there are different levels and different types of chaining: linkings can be established between juxtaposed modules (including the module "Building Products" for example), or even between different tools (eg EQUER which is linked to the COMFIE PLEIADES tool). The description of a building can be done at different scales and with different approaches. A building can be described as a sum of materials, a sum of manufactured products or a sum of assembled components.

The tools work with either internal databases, external ones chained to the interface, or no database at all. Some tools, which have only one construction products module, just deliver an impact factor of the building: the contribution of materials and construction products impacts on the scale of the site.

Some other tools are more advanced and include modules to calculate the impacts during the life period of the building (in use).

On the other hand, few of them seem to fully address end of life of buildings. Among the tools reviewed, it appears that all the trends, from the "black box" to the most transparent tool, are represented.

The tools deliver results based on standard methodologies: it is the case for example of ELODIE which is based on indicators from French standards (see Table 1). The choice of calculated indicators often comes from consensus, whether from industrial standards or scientific work (e.g. climate change). Other indicators show, however, a more anecdotal presence (e.g. air quality). Indicators are often the result of aggregating data from the LCI (Life Cycle Inventory). Some tools provide yet a higher level of aggregation of indicators, sometimes into a single indicator (with the aim of providing the user with results that are more manageable but with the risk of an information loss).

The results are generally expressed in tables of results or graphs, they can be given for the full life cycle of a building or for each stage of the life cycle for the entire building, or even for different sections of the same building. They can be expressed with different units.

Echelle	France	Europe	International
Cadre méthodologique et principes généraux		**NF EN 15643-1** (2011) Evaluation de la contribution au développement durable des bâtiments **NF EN 15643-2, 3 et 4** pour évaluer les performances env., sociales, et économiques.	**ISO 15392** (2008) Principes généraux du développement durable dans la construction **ISO TS 21929-1** (2006) Indicateurs
Normes à l'échelle produit (Déclaration environnementale des produits de construction)	**NF P01-010** (2004) Qualité env. des produits de construction	**Pr EN 15804** (2011) Déclaration environnementale des produits de construction et règles communes d'élaboration	**ISO 21930** (2007) Déclaration environnementale des produits de construction
Normes à l'échelle de l'ouvrage (évaluation de la performance du bâtiment)	**NF P01-020-1** (2005) Qualité env. des bâtiments **XP P01-020-3** (2009) Qualité env. des produits de construction et des bâtiments	**WI 00350011** (2010) Sustainability of construction works – Assessment of environmental performance of buildings – Calculation methods **FprEN 15978**	**ISO 21931-1** (2010) Cadre méthodologique de l'évaluation de la performance environnementale des ouvrages de construction - Partie 1: Bâtiments

Table 1: Standards for analysis of the life cycle of building materials and buildings

Among the sixteen tools studied in project COIMBA's state of the art, targeted users are different (architects, technical consultancy agencies, local authorities) and don't meet the same needs neither show the same methodological transparency.
For a majority of the tools observed, complete and detailed documentation is merely not available. The tools offer in common the aggregation of environmental data (materials, products, assemblies) to obtain data on the scale of the whole site. They differ in format and method of acquisition of environmental data: automatic or manual acquisition; data concerning materials, products, or assemblies; data "from cradle to gate" or "cradle to grave"; adaptability of data). They also differ on the expression of the results, both in substance (indicators shown) as in form (graphical presentation).
In terms of methodology, the tools appear to be classified according to two alternatives:

- The tool is based on LCA data of the complete product ("from cradle to grave ") and the user can modify the data for customization.
- The tool is based on partial LCA data ("from cradle to gate") and the user provides the necessary complement to his/her case study. (E.g.: a tool like EQUER)

Alongside with the development of the LCA tools, their corresponding databases, whether national or European, have also become more consistent.
LCA databases (Ecoinvent, Idemat, Buwal ..), often corresponding to the European context, are regularly updated and expanded, now there is data available on a wide range of materials and commodities, including construction. However these data generally do not allow integration into the tools specifically dedicated to the building sector and do not feature French products.
In the French context, the INIES database includes a set of Environmental and Health Declaration Fiches (FDES in French) that deliver accurate and complete information about the products they concern. These fiches are produced according to standard NF P01-010 which specifies the framework for evaluating these data and their mode of representation. The complexity of the results thereby declared (LCA inventory) actually hinders their use, and the integration of these data in ergonomic tools (like ELODIE) can be particularly beneficial to end-users.
At the European level, environmental fiches also do exist in most other countries, and works towards harmonizing all these data are under way.

In this context, the COIMBA project aimed at developing tools for the quantitative assessment of the environmental quality of buildings, to be used in an HQE type approach.
The main innovation comes from the intellectual work carried around a tool based on a consensual pooling of current scientific knowledge and powered by reliable, verified and approved data. This led to an overall methodology capable of promoting the French approach to the environmental

quality of buildings.

2. Methodological developments

The COIMBA project has improved two LCA of buildings tools available in France, ELODIE and EQUER, including working on methodological approaches.

2.1. Taking into account water related issues

The work aimed at developing a model to estimate household water consumption and a model of stormwater management. Indeed, these aspects have been neglected or poorly regarded in available tools.

2.1.1. Drinking water

A model for estimating the water consumption of buildings has been developed for the residential sector and is in particular based on data available from different French agencies responsible for water management and/or research.
The development model has been implemented in several stages:

- Detailed identification of water requirements of a building.
- Identification of equipment consumption characteristics.
- Identification and definition of the frequency of use by equipment type and duration of use , according to statistics on usage and water consumption in France.
- Identification of all the other parameters that impact on water consumption of a building (number of occupants, the interior surface, the surface of green spaces, etc.).
- Definition of formulas for calculating water consumption, taking into account specific factors like water flow reduction equipment. Distinctions between hot (DHW) or cold water consumption have been made.
- Validation of the model by simulation and comparison with measured values from the technical literature. An "average" consumption rate of approximately 44 m^3 per person per year has been obtained by simulation using the model, which roughly corresponds to the average consumption in France, according to CIEAU (French Water Information Centre) data.

In the end, the calculation results are expressed as water consumption in m^3 per year per person; m^3 per year per building; m^3 per person throughout the life of the building; m^3 per building throughout its entire life cycle.

2.2.2 Storm water

The key issues of storm water management on the parcel are : preventing the oversize of sanitation infrastructures, the recharge of groundwater (which determines the future preservation of water resources), and limiting flooding and pollution associated with water runoff .The aim here is to promote devices that prevent or limit the impermeable surfaces to provide a direct infiltration to the place where the rain meets the floor, that collect rain water from impermeable surfaces for use or returning it to the cycle, that hold water and slowly evacuate it.
However, the overall impact of these issues is difficult to demonstrate by a single indicator.
The leakage rate at the outlet of the plot is a useful indicator of the quantitative management of storm water within the plot. A module was developed to calculate such indicator. It contributes to reduce oversizing of the network and other installations, however the indicator does not include the problems of infiltration and pollution.

The recovery of rainwater is also a technique that should be included in the analysis. It has been considered in the development of the module "domestic water consumption”, based on the following input data:

- Local rainfall, mm / year,

- Collecting area, m²
- Type of collecting surface for rainwater harvesting.

The input data allow to see the following information:

Month	day	Rainfall (mm)	Generated Volume (m^3)	Green space need (m^3/m^2)	Other needs (m^3)	Global needs (m^3)

Intermediate values of output are then as follows:

G-N Generated Volume / Needs (m^3)	Losses (m^3)	Tank level	Inputs to network (m^3)	Recovered rain water consumption (m^3)

The main resulting indicators are:

- The inputs to the network (m^3 per year).
- Rain water consumption (m^3 per year).

2.2. Improving Energy aspects

The consideration of energy issues is at the heart of environmental approaches of construction. At the life cycle scale, this results however in important simplifications. The COIMBA project worked to introduce new precise factors in this consideration.

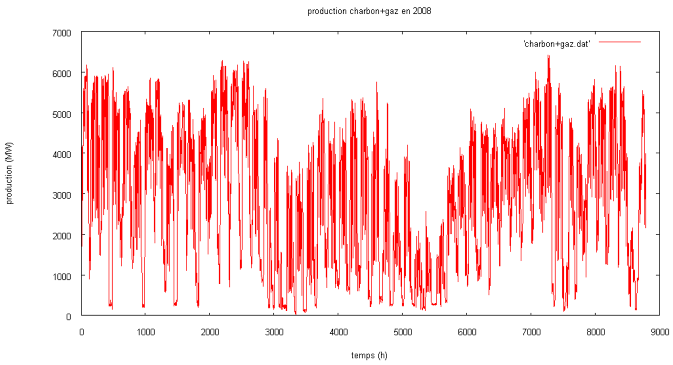
The first works concerns the homogenisation between LCA tools and dynamic thermal simulations. To enable the evaluation of the thermal performance of a building, it is necessary to clarify the physical properties of materials (density, thermal conductivity, specific heat ...). Materials and products used in the LCA must have the same physical properties.

For modelling the operation of specific equipment, such as a heat pump, it is important to know their operating characteristics. It will be useful, during the integration of such devices in a building, to introduce the appropriate operating curves (capacity based on outdoor temperature, Performance coefficient based on the charge rate), which can be obtained by correlation from different operating points where the various quantities are known, to the LCA analysis.

The PEP (Product Environmental Profiles) will, on the scale of the whole site, allow this estimation of the part of embodied energy (grey energy) related to energy equipments.

Another approach undertaken during the project is that of dynamic LCA.

Dynamic LCA refers to an LCA taking into account both the changes in certain parameters over time, and their consequential effects. This may be applied particularly to the energy mix used in the calculations. In France RTE provides data since 2007, on hours of electricity production per year, according to different modes of production (nuclear, hydro, coal + gas + oil + peak).



Graph 1: Electricity generation by coal and gas in France in 2008

Coping with peak demands for electricity, for example related to the use of electric heating, requires the use of advanced production methods, especially thermal power plants producing high emissions of CO2. The electricity production mix depends on the season (especially temperature), day of the week, and time.

The objective here was to develop a model using data available for 2008, and then use 2009 data for validation. This approach was applied to each mode of production, as well as total output, to determine trends in the energy mix. Taking into account the seasonal mix may allow a more precise calculation of indicators of climate change.

Three specific trends were identified:
An annual trend characterized by the existence of a global minimum during the warm period of the year, against which, during that same period, appear a local maximum and an overall increase in output, which corresponds to air conditioning use.
There is also a weekly trend, where electricity production is highest during the first five days (with local maxima value remaining almost constant), and a production whose importance is diminished during the weekend. This trend can be seen as illustrating the influence of professional uses of electricity, which overlap with domestic uses which almost only appear for the last two days of the week.
Finally, we observed a daily trend, which highlights two peaks of production, one during the daylight period at around 1 PM, the other at 9 PM. These peaks probably correspond to a household electricity consumption, and should therefore be treated as such.
These observations refer to future work on determining functions describing the different types of power generation, then the mathematical formalization of the relationship between use and production methods, which can provide the basis for impact assessment for each type of use of electricity involved in the building sector.

2.3. Indicators

An analysis was conducted on the use of "end-points" indicators such as land use or ecotoxicity, in LCA of buildings.

2.3.1. Land use

This kind of indicator is still rarely used today in construction products and building LCA, due to its complexity, its dependence on local conditions and numerous calculation assumptions. Nevertheless an experimental approach with this type of indicator can be interesting in order to observe the relative importance of both the impact of the plot and that of the materials. Indeed, the transformation and occupation effects on a territory (the plot) which are often solely attributed to the building on it, should be enhanced with the consideration of the materials of the building, which are also a source of transformation and land occupation.
The land use indicator was originally developed by the Ministry of Transport, Public Works and Water Management of the Netherlands in 1998. This method has been integrated for LCA in the “Eco-Indicator” indicator. It is also embedded in particular versions of indicators Impact 2002 + and CML 2001. Ecoinvent integrates the notion of transformation and land use in all its inventories.
We modelled two types of buildings with, for each one of them, three building processes: concrete structure, steel structure and timber structure. Both buildings meet the same specifications, but have different shapes that give them a different occupation of the plot: one is vertical with a small footprint and six levels, the other is horizontal with a bigger footprint on two levels. These structural differences also imply differences in the quantities of materials used for each type of construction system.
The results show surprisingly that the impact on land use is highly dependent on materials. These are the source of over 50 percent of the impacts, exception made of the case of horizontal concrete structure building.
The differences of materials in building systems have very important consequences. Concrete has little impact whereas timber has in contrast a big impact. This is explained by the large areas of forests occupied for long periods of time for forestry. The preferred choice of verticality is still relevant in all three cases.

The impact of materials has a strong influence on the overall impact generated by the transformation and the use of the plot: this indicator shows that it is therefore important to integrate materials and products in an impact analysis on biodiversity, and not just on the plot. However it seems particularly disadvantageous for timber: it would be appropriate on this point to perform additional analysis of uncertainties and to incorporate additional differentiation factors following the management conditions of the forest that is at the origin of the wood.

2.3.2. Human health / Ecotoxicity

The indicators characterising the health impacts and those related to eco-toxicity indicators are relatively well developed indicators, whose calculation depends on a lot of data, assumptions and models.

Particular attention should be given to all these factors of uncertainty and to a rigorous use of available methods. Several studies and critical analysis of existing methodologies have already been undertaken, particularly in the ILCD project (International Life Cycle Database), for which certain recommendations were made. Data collection is a fairly large factor of uncertainty. Transparency and representativeness of these should be as high as possible.

The purpose of an indicator on human health is to quantify the changes in mortality and morbidity generated by emissions of substances involved in the life cycle of a product or process.

DALY indicator, derived from the Eco-Indicator 99 method, allows this kind of evaluation. It is a damage-oriented indicator, based on modelling the evolution and effects of substances released into the environment.

The ILCD project workgroup recommends using the DALY indicator, which combines qualitative and quantitative information on health, when the damage is caused by several stressors related to the environment, aggregated into a single indicator impact. The calculation of DALYs should preferably be conducted without weighting of age or updates.

Even if the state of current health services is taken into account in evaluating a specific disease DALYs, it is important to consider the possible rebound effects and to specify the methodology used in the LCA. Also, the starting point of the analysis for human health, the intrinsic value of human life, can be subject to debate.

It is further recommended to perform some sensitivity analysis of the DALY indicator to determine the influence of various parameters:

- Set the values for YLL and YLD separately will allow to evaluate the influence of the weighting of different pathologies in the calculation of DALYs
- The optional application of an age-weighting and updating according to a standard rate of 3 percent will provide information on the importance of these parameters.

Eco-toxicity concerns natural ecosystems, their function and structure. Any changes occurring in an uncontrolled way in the ecosystem are regarded as damage, due to the implementation of the system (as in the case of a sewage treatment plant, positive impacts on the environment of the structure involved in inventory phase and not in the assessment of damages), following exposure to chemical or physical transformation.

Among several methods, only an approach seeking to determine the effects on diversity in terms of population seems sufficiently developed to be applied to the LCA of a building. The PDF method seems best suited to this type of analysis.

This method, characterising the disappearance or the stress experienced by a species, reversibly or irreversibly, over a certain area and during a given period, provides a good consistency with the conditions and the boundaries of a LCA, which may involve a small functional unit, with little information on conditions of stress experienced by the ecosystem in question arising from the effects of another system. However this aspect can be a weakness of the method, and factors used to obtain other indicators require further study.

To overcome these difficulties and gaps, one solution might be the coupling of the LCA approach with the approaches of health risk assessment (HRA) and approaches to ecological risk assessment (EDR or ERA).

So future developments of LCA may include a simplified approach using environmental indicators called "midpoint" and coupling LCA with evaluations of health risks and environmental systems to properly assess the aspects of health and ecotoxicity.

Another option is to use localized flows (depending on population density of emission site), which would permit to compare a project on the basis of common indicators, inducing more local emissions to an alternative inducing emissions elsewhere.

2.4. Data and simplification of inventories

2.4.1. Data

There are several types of LCA databases: inventory databases and ecoprofiles databases (EPD, FDES...).
Ultimately to make the LCA of a building or a building product, the use of different data sources is widespread. These databases either storing inventories or ecoprofiles, at best they all use as a reference only the ISO14040 standard, which is insufficient to ensure their consistency.
These databases have different origins:

- Work of data production by research institutes or centres specialised in LCA,
- Declarations of industrials or industrial clusters
- LCA compilation performed in a dispersed manner.

Among all the identified databases, we selected 13 that provide relevant and timely data for the construction sector: INIES, Ecoinvent, DEAM, IVAM, GEMIS, IBU ELCD, Athena, U.S. LCI Database, IBO, GaBi, CPM LCI Database, and EIME. These databases provide information on nearly 650 types of products or materials and 250 data on active systems available. Although we should not mix these data for a same analysis, this large amount of data demonstrates the growing potential for producing Building LCA today.
Two approaches are confronted: material and process data (e.g. Ecoinvent), or data on construction products (e.g. INIES database).
The first category is more suitable for early phases of design (architectural sketch, construction site selection, urban design), because the construction products are not yet defined precisely so the use of generic data is relevant. For detailed design, the second category of data allows to select products on a more accurate basis.
The second category of data is based on systems of Environmental Product Declaration (ISO 14025 at the international scale, prEN15804 at the European scale), as the FDES in France (NFP01-010 standard). The data correspond to specific products available on the market and the declarations are most often carried out on a standard and clearly defined framework (and referring to standard LCA of ISO 14040) from a Product Category Rules (PCR) defining the methodological rules of these EPD. However the still limited availability of data, compared to the multitude of products on the market, and accuracy demanding fields of application lead to risky extrapolations in studies of LCAs of buildings.

2.4.2. Inventory simplification

Currently, the most complete databases (often generic databases) consider several thousands of elementary flows in their nomenclature. On the opposite, the most synthetic databases (often corresponding to data specific to a product category) reduce the number of inventory flows to a few dozen. These different formats and inventory models often lead to the spread of these heterogeneities up to the impact characterization phase. However, these heterogeneities may cause errors on a larger scale in particular for the comparison of alternative constructive systems and buildings.
During the COIMBA project, we considered three Life Cycle Inventory (LCI) models as respectively used by the Ecoinvent, DEAMs and INIES database.
Figure 2 shows the steps in the simplification of elementary flows between each of the three ICV models. These steps are illustrated by taking a few elementary flows of air emissions. In the concern of alleviating the figure, only the "styrene " flow is shown for the Ecoinvent part.

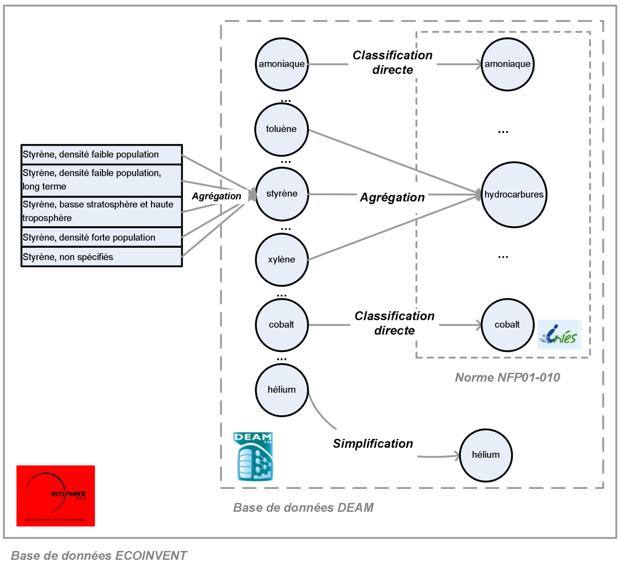


Figure 2: Example of the approach of the inventory simplification on some flows

Finally, this process of simplification of the NFP01-010 standard allows to no longer considering either 4 000 inventory flows (Ecoinvent) or 600 - 1000 flows (DEAMs) but "only" 171 flows.
A comparative analysis of Ecoinvent and NFP01-010 inventories was conducted. This work has been limited to toxicity indicators. Indeed, this type of indicator is generally sensitive to the number and types of inventory flow selected. For this, we calculated the indicators for "damage to health (DALY)" and "air pollution (PA)", for two types of flooring (wood and PVC) by constructing a new inventory from Ecoinvent data, aggregated using the FDES methodology.
We were thus able to highlight one of the limits of the simplified inventory as presented in the NF P01 010 standard. Indeed, the categorization of substances does not allow to calculate the DALY indicator in a relevant and consistent way, since some substances, that present a specially high toxicological nature, here the dioxins, are classified in a category that does not include this feature. This classification method will necessarily lead to an underestimation of the toxic nature of these substances, or even to the overstatement of the health impact of the entire class considered, depending on the method for estimating the characterization factor of the category. In order to integrate aspects of health impact assessment of a system, it might be wiser to better integrate health aspects while simplifying inventories, establishing categories on the basis of toxicological characteristics of substances.

2.5. Perimeter

An analysis was conducted on defining the study perimeter to be used for a building LCA. Here we present observations on the treatment of end of life.
The recycling modelling today appeals to numerous heterogeneous methods both on their philosophy and on the results to which they lead. Depending on the purpose of the LCA tool, namely to promote recycling and / or evaluate an effective recycling, the results will not be identical.
Existing methods can be ranked against a set of criteria for recycling modelling. Eleven criteria were defined as part of this work:

- C1: Definition of system boundaries (what are the allocating rules at the level of recycling)
- C2: Choices selected for the environmental assessment (attributional, consequential or differential)
- C3: Form of "recycling" evaluated (effective recycling and / or recyclability)
- C4: Type of recycling taken into account (open loop and / or closed)
- C5: Sharing of environmental responsibility between two products (allocation)

- C6: Status of waste recovered at the end of life of the building system
- C7: Completeness of the life cycle and self-supporting of the recycling model (dependency at the level of upstream and downstream life cycles?)
- C8: Management of uncertainty associated with end of life processes (scenarios of prudence or probabilistic scenario)
- C9: Involvement of the recycling evaluation in the inventory life cycle
- C10: Involvement of the recycling evaluation in impact indicators
- C11: Involvement in the process of decision support

Existing approaches on Recycling can be grouped into three conceptually distinct families:

- A1, the approaches by temporal cuts rules, called "cut-off", that consider only an average production mix with a certain degree of incorporation,
- A2, the avoided impact approaches, "avoided burden", that consider the recycling loop between the end of life and production of a material as a bonus which is then necessary to assign,
- A3, approaches by stocks, “stock flow”, which is based on the principle of the existence of secondary raw materials stocks (MPS).

Today, the EQUER tool is based on a method taking into account the recycling of the A2 family, while ELODIE, which uses FDES to take recycling into account, is based on an approach of A3 family.

Given the complexity and uncertainty associated with the end of life, a contemporary scenario approach seems well suited although probably conservative. Based on current statistics of building products and materials end of life, rates can be defined and implemented. It may also be useful in this work to adapt the end of life scenarios, not considering the type of material, but the type of use instead.

It is also interesting to study, beside conventional scenarios, probabilistic scenarios. This by assuming that when the building will reach the end of life, the end of life treatment technologies and processes will be improved especially with regard to recycling. The test of these probabilistic scenarios may for example be done as part of a sensitivity study of results to test their robustness.

2.6. Pilot case evaluation

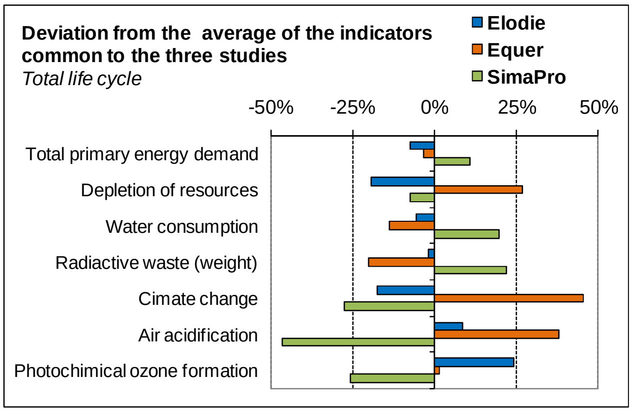
Some methodological elements previously mentioned or proposed have led to changes of the two French LCA software: EQUER (Izuba Energies - Armines) and ELODIE (CSTB).

These two tools, alongside the software SimaPro, were then tested and compared by studying a practical case: the construction of a new individual home (in the “Hauts de Feuilly” district, St Priest (Fr)) with a performance level equivalent to German PassivHaus standard. With a living area of 149 m², this house was built in timber frame. Its roof accommodates 6 m² of solar thermal panels and 12 m² of solar photovoltaic panels.

The objective of this analysis was to observe the real conditions use of these solutions of building LCA, with all factors of complexity and uncertainty inherent in the reality of practices: three tools used by three LCA practitioners.

The "materials" data set was provided by an engineering office (Enertech), which helped to establish a common basis. These data came from the description of the project at construction phase. Concerning energy consumption during the life out, CSTB used on ELODIE a calculation made by Enertech, Nobatek did the same on SimaPro, and Armines conducted a Comfie-Pleiade simulation (taking into account glass surfaces and thermal bridges).

Figures 3 and 4 show some of the main results obtained from this analysis.



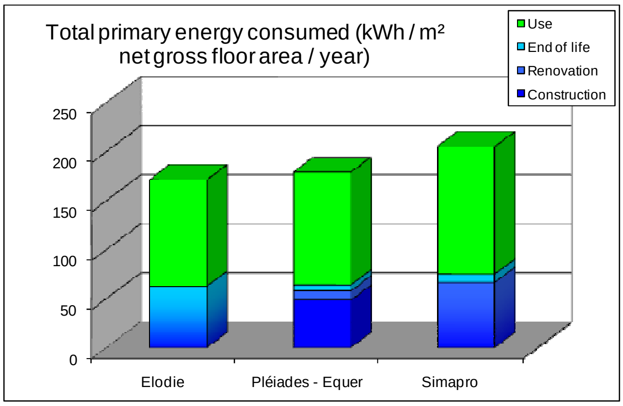


Fig. 3 and 4: Comparative results of a building LCA realized by three tools/three practitioners

The different gaps observed on results between tools may be linked to several sources of uncertainty (which can accumulate):

- 1st uncertainty layer induced by the inventories (simplifications, accuracy ...)
- 2nd uncertainty layer caused by the software (calculation, indicators)
- 3rd uncertainty layer induced by the practice / user (the bill of quantities preparation, assumptions about the life cycle, databases used ...)

Moreover many of the differences between the models are probably related to electricity generation mix considered: average annual mix for Elodie and SimaPro and specific heating mix for Equer.

Eventually, comparing the results of software tools such as SimaPro, ELODIE or EQUER on a real building is complex because of the diversity of materials taken into account, modelling assumptions at all levels and the still existing black box effect.

3. Conclusion

LCA use is continuously and fastly growing in the construction sector, particularly in France with specific tools such as EQUER and ELODIE that recently allow taking into account the full life cycle of a building. This is also supported by new standards, regulations and frameworks including the LCA of buildings. Moreover, the databases of construction products such as INIES, offer an ever widening and growing range of products.

The COIMBA project has highlighted many methodological points to harmonize for a consensus approach usable by any user. These proposals have partly been integrated into the ELODIE and EQUER tools, offering henceforth the possibility of using LCA to more accurately and easily assess the impacts of buildings in the design phase.

However the comparison of several tools in a complex context, still representative of actual practices, reveals many discrepancies between results. At the heart of the problem lies the quality of data used, but the practical aspects (level of proficiency of LCA, initial source of data, real control of the study perimeters, etc..) also generate significant discrepancies, despite the diffusion of standards framing these practices.

It seems therefore essential to define a framework for the realization of inventories, and continue to work on the transparency of the databases. Making comparisons between buildings on the basis of different tools must also be avoided. Finally, these conclusions call for new research focused on the practice of LCA to identify, in the context of detailed LCA analysis on real cases, the levers of management of uncertainties, whether they are at the scale of databases, tools, and especially working practice.

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