Using LCA in selecting technologies

Our society is increasingly concerned with safeguarding the environment. By assessing the impact that the manufacture of a product or the delivery of a service can have on the environment, Life-Cycle Assessment (LCA) can be used to identify key sources of pollution and possible ways of mitigating against it. The ways in which this tool can be used are demonstrated here by various projects which help define innovative energy production systems.

Anthropogenic activities and the way they affect the environment

There is growing debate about the impact that anthropogenic activities are having on the environment. The notion that we can continue to grow indefinitely while depleting the planet's finite resources is increasingly being challenged. The depletion of the planet's natural resources and questions about the environment's ability to withstand the effects of anthropogenic activity are now conditioning the extent to which our societies are able to develop.

These environmental impacts can be seen as a consequence of three major variables interacting:

- population;
- consumption per capita;
- environmental impact per consumption unit.

Life-Cycle Assessment (LCA) is a tool which focuses on the third of these variables. It can be used to prioritise what needs to be done in order to reduce the environmental impact associated with meeting a unit requirement (product unit of service).

Definition of LCA

LCA is a standardised method (ISO 14040 and 14044, 2006) for assessing a system (a product, as well as a service, for example). The definition given by the standard is as follows:

"LCA is a tool for assessing the environmental impact of a system, including all activities associated with this system, from the extraction of raw materials through to its disposal and the treatment of its waste."

All of the potential impacts on the environment are quantified — from the extraction of raw materials through to the treatment of waste ("from cradle to grave"). It is therefore a holistic approach. It is a multi-stage approach (the whole life-cycle associated with the product or service in question is looked at), meaning that any pollution transfer between the various stages can be identified. In the example in figure 1, the process that has the greatest impact in the overall scenario (1) is the manufacturing process. Attempting to reduce the impact that it has on the overall process (2) leads to part of the impact being transferred from the "manufacturing" process to the "extraction of raw materials" and "recycling" processes. But it does not necessarily lead to a reduction in the overall impact.

It is also a multi-criteria approach, insofar as several categories of impact on the environment are assessed. Comparing two different technologies that serve the same purpose (as seen in figure 2) is therefore a way of identifying and possibly avoiding transfers of pollution between different categories of impact.

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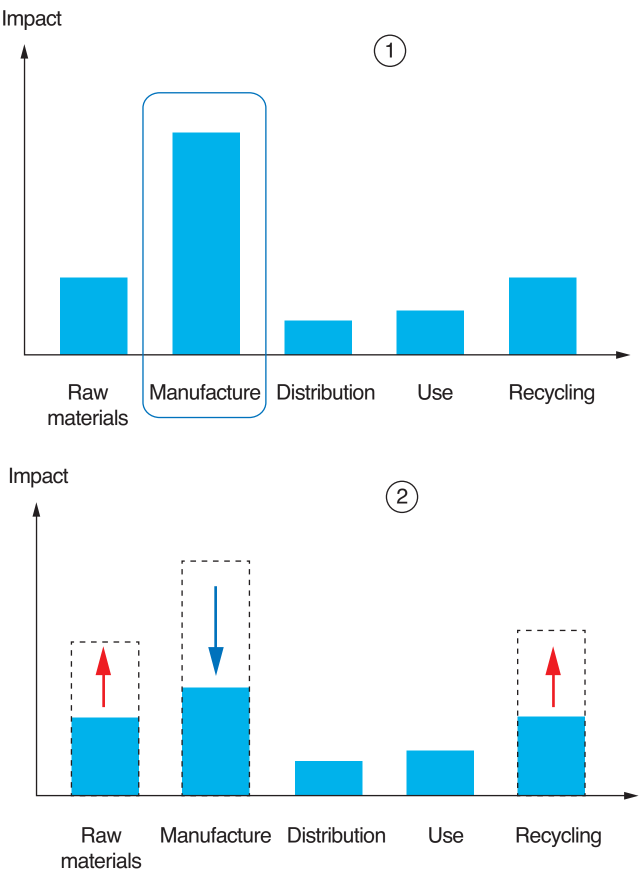
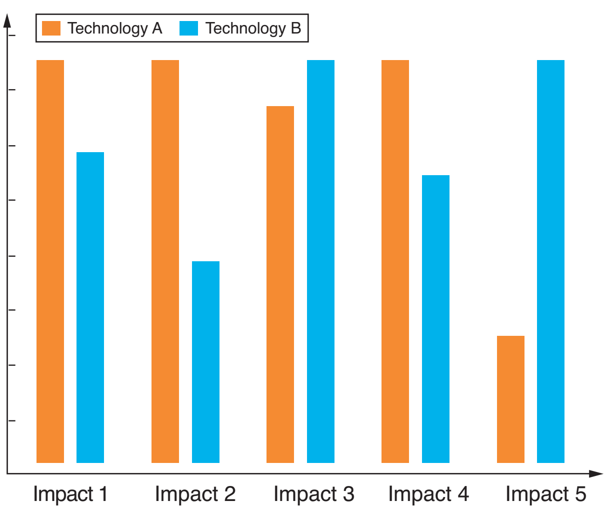
Fig. 1 – Pollution transfer between different processes



Source: ADEME, 2005

Fig. 2 – Pollution transfer between different impacts



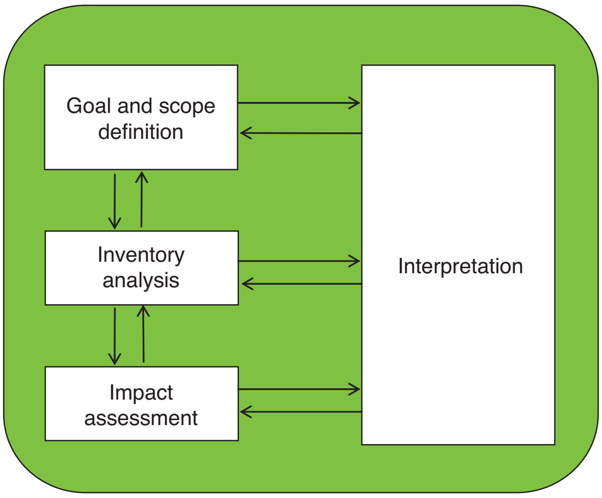
Source: INRA

The main areas in which LCA is currently used are the following:

- quantifying the environmental impact that one of a company's corporate decisions has;
- comparing the environmental burdens that different products, processes or systems have either in themselves or as part of the various stages in the life-cycle of a single product;
- improving a system's environmental performance.

An LCA is carried out in accordance with the four phases described in figure 3.

Fig. 3 – LCA's methodological framework



Source: ISO 14040

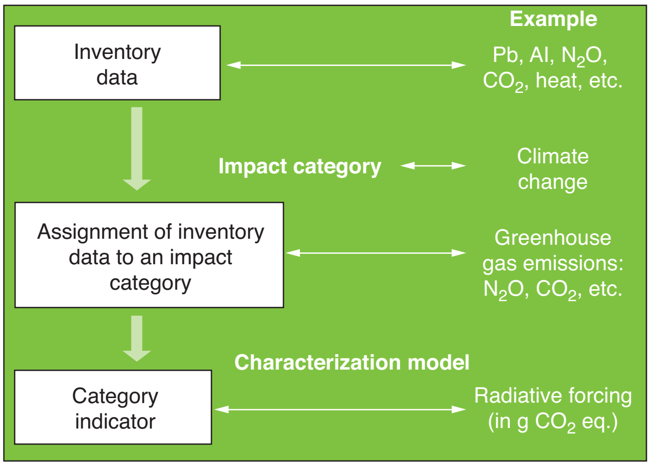
The first phase involves defining the goals and scope of the study. First of all, this means clearly and precisely formulating the question(s) that the study is intended to answer. This is essential — to a great extent, the choices and assumptions that are subsequently made depend on the type of goal. The system's boundaries are then established, specifying all of the flows that are taken into account in the system, together with the impacts that are looked at in the study. The functional unit is also defined: this is a reference value that is appropriate for the function served by the product being assessed, and to which all the flows and results (environmental impacts) can be related. In fact, more often than not, it is useful to assess the product's function rather than the product itself. This way, when different systems are being compared, it is possible to guarantee that the various alternatives under consideration do indeed perform the same service. For example, instead of comparing a car with a train, the LCA will set out to compare "transporting a person over a distance of 100 km", using either a car or a train.

An inventory of all the inputs and outputs for the system is then carried out. This involves quantifying all of the elementary flows which enter or exit the system under consideration, meaning:

- resources (materials and energy) taken from the environment without anthropogenic transformation beforehand;
- pollutant emissions and final waste discharged into the environment (air, water, ground) without subsequent anthropogenic transformation.

The third phase involves assessing the potential impacts that the previously inventoried inputs and outputs have on the environment. All the environmental flows are then converted into a limited number of indicators (or impacts) using characterization models (Fig. 4).

Fig. 4 – Procedure for assessing impacts



Source: ISO 14044

The main impact indicators used in LCA refer to environmental or toxicological-type impacts:

- global impacts, such as climate change, the depletion of non-renewable resources, or the destruction of the ozone layer, for example;
- and more local impacts, such as aquatic eutrophication, acidification or the toxicity and eco-toxicity of receiving environments (ground, water);
- but there are others that are not always easy to characterize: biodiversity, social impacts, etc.

The impact assessment results are then interpreted. Conclusions can then be drawn and the awaited recommendations formulated, making the boundaries of the study clear.

The approach also sets out to be cyclical and iterative, with many opportunities for feedback at each of the stages so that the various assumptions can be honed on the basis of the influence that they have on the study results.

The LCA technique was developed back in the 1980s and is now in increasingly widespread use all around the world. Its increase in popularity has been even more significant over the last ten years, particularly as a result of the willingness of state authorities to use LCA to support the introduction of new standards or regulations (environmental labelling of products, certifying the sustainability of biofuel sectors, etc.). This boom, together with new requirements and applications for LCA having been identified, have led to many developments in the methodologies used. The overall framework and the general principles of LCA remain unchanged (iterative four-stage process defined in the ISO 14040-44 standards). But these principles can be applied in a number of different ways and the potential for specific regional or sectorial features to be taken into account, for example, is currently being looked into (assessment of biomass production sectors, etc.). The development of methodologies based on LCA is being driven by both international public bodies (the United Nations, for example) and European and country-level bodies — as well as by the scientific community and manufacturers. In fact, many public-private partnership structures, all dedicated to further developing LCA, have been set up.

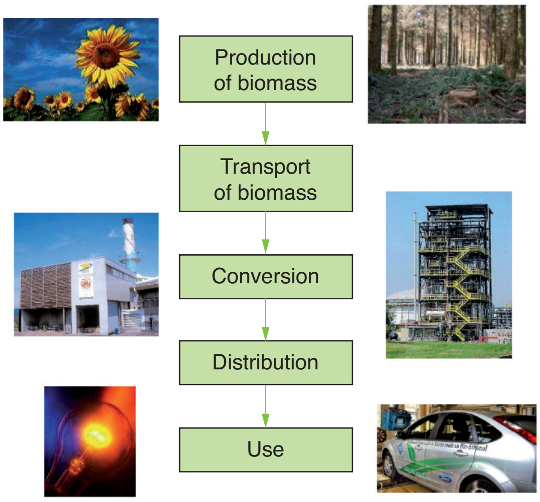
IFP Energies nouvelles, a long-standing involvement in developing LCA for energy

Since the 1990s, IFP Energies nouvelles (IFPEN) has been applying and developing LCA methodologies for assessing the performance of sectors and systems (the energy and transport sectors mainly), particularly those developed as part of its own research projects. This work is also carried out within the framework of theses and collaborative projects.

The French National Research Agency (ANR) was set up in 2005 in order to finance public and partnership research in France. Within the framework of the first national research programme into bioenergies in 2005, IFPEN coordinated the ANABIO project, which set out to carry out environmental and socio-technical-economic ANAlyses of BIOmass energy production sectors — recommendations for assessing bioenergies. In partnership with the various parties involved in the project, a methodological guide incorporating LCA was drawn up so that a multi-criteria assessment could be carried out (taking technical, economic, environmental and social factors, as well as industrial risks into account) and a comparison made of the various bioenergy sectors — from biomass production through to end use (Fig. 5).

Following on from the ANABIO project, IFPEN coordinated the BIOMAP project, which sets out to implement the methodology recommended in ANABIO by testing it on seven bioenergy production sectors. This project resulted in a knowledge base being set up, detailing the bioenergy sectors assessed in the case studies (associated impacts, description of technologies and list of bibliographical references used in assessing them).

Fig. 5 – Overview of the chain for assessing impacts in the ANR ANABIO project



Source: IFPEN

The partnerships that were set up with public bodies and technical centres for these projects (CEA, INERIS, FCBA, etc.), as well as with manufacturers (PSA Peugeot Citroën, Renault, Suez-SITA France, EDF, etc.) have all helped to develop and structure the LCA community in France for use with bioenergies. Furthermore, the results gleaned from these two projects — both in terms of producing data and creating coherent methodological frameworks — have increased our knowledge of how LCA can be applied to the various bioenergy sectors looked at.

LCA, an environmental assessment tool in R&D carried out into future technologies

IFPEN is involved in a number of research projects designed to share expertise in carrying out environmental assessments in the fields of alternative energies and green chemistry. As temperatures rise and the planet's fossil fuels become increasingly scarce, our societies are increasingly interested in diversifying energy sources and producing chemical intermediaries.

As far as producing energy sources for use in transport is concerned, IFPEN is heavily involved in two projects to produce second-generation biofuels, i.e. biofuels derived from lignocellulosic biomass (wood, straw, forestry waste, etc.): Futurol (ethanol production from lignocellulosic biomass) and BioTfueL (biodistillate production, i.e. biodiesel and biokerosene, from lignocellulosic biomass). In both these projects, IFPEN and its partners use LCA to assess the impact that each process variant under consideration has on the environment. LCA is used in the projects for identifying areas in which environmental performance can be improved. This way, R&D can be guided towards the use of technologies that have a lower impact on the environment. This work is being carried out in collaboration with the project partners — both internally, with the process development or engine technology development teams (performance, clogging, lubricant behaviour, etc.), and externally with, for example, the INRA (French public Research Institute for scientific studies into Agriculture) or the ONF (French Forestry Commission) for when supplies of biomass are required.

Because of the links that IFPEN has with the car manufacturing sector, a proportion of its environmental assessment work is geared towards vehicle electrification. The European WideMob project, for example, on which it is working with the Centro Ricerche Fiat, is involved in developing the elementary technological building bricks for multi-use urban electric vehicles. The aim is to reduce energy consumption and CO_2 and NOx emissions during use, as well as during manufacture and at end of life; here too, iteratively using LCA is a way of identifying the main areas in which improvements can be made.

IFPEN has also become involved in ocean energies, focusing its research on offshore floating wind turbines. The aim of the VertiWind project is to design, manufacture, install and test a pre-industrial prototype of a vertical-axis offshore floating wind turbine. LCA will be used in this project to help the people involved to select the right materials and identify how this innovative way of generating electricity impacts the environment.

And within the framework of the "Investments for the futur program", two of the Excellence institutes in the field of low-carbon energies in which IFPEN is also involved are attaching a great deal of importance to LCA — it will enable them to assess the extent to which their various initiatives are impacting positively on the environment. IDEEL[1] sets out to establish itself as an international leader in developing eco-efficient processes for the factories of tomorrow, particularly in relation to energy, chemistry and recycling. PIVERT[2] carries out research, into oilseed biomass-based plant chemistry (rapeseed, sunflower, etc.), drawing on local farming and forestry resources in France's Picardy region to produce biofuels, biomaterials and chemicals. Both these projects are involved in setting up biorefineries — proper industrial facilities for transforming biomass into fuel, power, heat and added-value chemicals (Fig. 6).

(1) www.ideel-factory.fr/
(2) www.institut-pivert.com/

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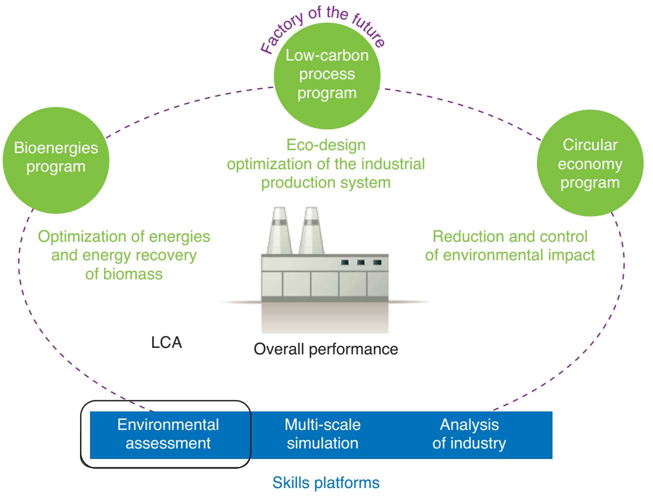
Fig. 6 – Positioning of LCA in IDEEL and how it fits in with research and development



Source: IFPEN

These varied R&D projects serve as a means of identifying any methodological gaps in the practices currently in use in LCA. These basic questions are also areas of research for IFPEN and the subject of scientific and academic studies which help bring about improvements in the methodology currently used in LCA. Having to manage the large number of different products that come out of a biorefinery, creating the problem of dividing up the impact on the environment between these products (impact allocation) is a good illustration of this.

Methodological research into LCA in France

A number of bodies are involved in carrying out methodological research into LCA, in ways that are more or less specialised, depending on their areas of expertise. For example, the LCA research carried out by the INRA is more focused on the production and use of biomass, whereas the research carried out by the IRSTEA mainly involves water management and waste treatment. Through the many projects in which it is involved, the ADEME provides R&D support to the various users of LCA in France across a wide range of fields, both in terms of methodological development and the practice and distribution of this methodology. The ADEME's work which, among other things, involves the production of first-generation biofuels or biosourced products, has enabled knowledge and expertise from a number of different bodies (state authorities, manufacturers and NGOs) to be unified.

More recently, in order to meet the requirements for methodological developments and structure this research, two new associations were set up:

- the SCORELCA[3] association, created at the initiative of a number of major French companies (EDF, GDF Suez, Renault, Saint-Gobain, Total and Veolia) with the support of the ADEME and the RECORD association. It was set up to promote and manage collaboration between manufacturers, institutions and the scientific community in order to bring about a positive, shared and recognised evolution in LCA methods and the way in which they are implemented;
- the EcoSD[4] association, jointly set up by a number of companies and academics with the support of the ADEME. Its main objective is to encourage collaboration between academic and industrial researchers in a broader field: eco-design systems for sustainable development. It is mainly involved in research into LCA methods and techniques — research that is carried out collaboratively. It has also designed a number of training programmes (doctoral courses). These serve as a means of disseminating knowledge and contributing to the development of French researchers' expertise.

The improvements that various research projects currently under way aim to bring about involve different phases of LCA: defining goals, carrying out inventories, selecting indicator categories and interpreting results.

Currently, during the goal and scope definition phase, the vast majority of existing LCA studies use the traditional so-called attributional LCA (A-LCA) approach. This approach seeks to assess the potential environmental impact associated with a given product: this means that the analysis is limited to the processes/stages that are physically linked within the sector under consideration. This approach does not take causal relationships influenced by changes on the market (such as indirect changes in land use) into account. Consequently, in some scenarios, such as when assessing impacts resulting from making a decision or investigating any possible rebound effects, this methodology has significant limitations. There is another approach, in addition to traditional LCA, which is becoming more and more popular: consequential LCA (C-LCA). This approach is one of the main areas of research being looked into by the SCORELCA and EcoSD associations. Consequential LCAs can be used to consider the impacts associated with the effects of economic interactions ("processes affected" by a particular decision), as well as the impacts associated with the physical flows which directly connect up the various stages involved in a particular sector. These effects can be either direct or indirect, and lead to a systemic view, which is very different to the view which defines attributional LCAs (view restricted to a particular sector). This approach appears in

(3) www.scorelca.org/
(4) www.ecosd.fr/

particular to be well-suited to dealing with issues with strategic implications which require a systemic view (Fig. 7).

Fig. 7 – Scope of C-LCA

Broadening of scope

	Environmental aspects
Micro scale (product-orientated)	A-LCA Input/Output analysis hybrid LCA
Meso scale (territorial and regional assessment)	Input/Output analysis territorial LCA C-LCA
Macro scale (interaction and high level of competition between sectors and uses)	C-LCA

Source: from Guinée et al., 2011

With this in mind, the ERA-NET+ SCelecTRA project, co-ordinated by IFPEN in a bid to look towards 2030-2050 and assess the impact that the proliferation of low-carbon emitting vehicles in Europe will have via several road transport electrification strategies, is testing two LCA approaches:

- attributional LCA for comparing the impacts of different vehicle types (various electric vehicles compared with internal combustion engine vehicles);
- consequential LCA assessing the consequences of various public policies on the proliferation of electro-mobility in Europe, using a predictive energy model in partial equilibrium.

A high level of collaboration between the world of economics and the world of environmental assessment is therefore essential for a consequential LCA to be properly carried out. This project will involve economists working together with environmental assessment specialists on broadening the C-LCA methodology.

Another area of methodological research that is fast-growing involves the coupling of process engineering tools (flow-sheeting, for example, which can be used to show all operations in use at a facility level) with environmental assessment tools.

Energy efficiency is an essential lever in reducing greenhouse gas emissions. In France, industry is the third largest consumer of energy and accounts for 25% of all CO_2 emissions (it is also subject to the CO_2 quota mechanisms introduced within the framework of the European Emissions Trading Scheme directive).

The aim, therefore, is to develop eco-design tools for directly integrating environmental constraints into the design process. The ANR CERES 2 project (Energy pathways for Energy Recovery in industrial Systems) is an illustration of this. It involves recovering and making use of heat sources in a bid to improve energy efficiency and reduce greenhouse gases in industry. More generally, the Plate-form(E)3 is a project to develop a digital platform for calculating and optimising energy and environmental efficiency at various levels for industry (component/process/factory/region). It helps optimise energy and environmental efficiency in industry and in various regions by taking both thermal and material issues into consideration, and by integrating the dynamics of the systems.

Much has already been written about the local approach (process/factory scale), but there is still little in the literature about the regional approach or optimising efficiency in industry. Currently, there are no tools available for optimising energy and environmental efficiency and generating substantial savings on a multi-scale level: the Plate-form(E)3 project sets out to provide one, putting forward a methodology and an associated computer application. IDEEL is also part of this initiative, and seeks to generate strong synergies between the various skills platforms represented by industry analysis, multi-scale simulation and environmental assessment.

Conclusions and outlook

LCA has become an essential tool for assessing the impact that new energy systems have: but a great deal of work is still to be done, both in terms of manufacturers producing inventory or impact data, and in terms of more academic research being carried out. It is therefore vital that direct collaborative partnerships with other areas of expertise that complement LCA be entered in to — with process engineering and economic modelling in particular. Being able to group together different skills is very useful for developing tools and methodologies so that bridges can be built between different disciplines and the scope of the conventional LCA approach broadened. Creating networks within France designed to tie together all the strands of the work being done by all the parties involved (research centres, universities and manufacturers) — such as SCORELCA or EcoSD — is a good example of this pooling of expertise.

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