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► **To cite this version:**

Mylène Pongérard, Flavien San Augustin, Manuel Paredes. Comparison of Tools for Simplified Life Cycle Assessment in Mechanical Engineering. *Advances in Design Engineering II*, Springer International Publishing, pp.71-80, 2022, *Lecture Notes in Mechanical Engineering*, 10.1007/978-3-030-92426-3\_9 . hal-03744456

**HAL Id: hal-03744456**

**<https://hal.science/hal-03744456>**

Submitted on 2 Aug 2022

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# Comparison of tools for simplified Life Cycle Assessment in Mechanical Engineering

[https://doi.org/10.1007/978-3-030-92426-3\\_9](https://doi.org/10.1007/978-3-030-92426-3_9)

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## Abstract

Current trends indicate that Life Cycle Assessment (LCA) tools are going to be extremely important for companies in the forthcoming years. New laws and standards are increasingly taking environmental aspects into account but, for non-experts in LCA, it can be difficult to find software suited to their studies. This paper aims to analyze the ability of simplified LCA software to combine a simple and convenient interface with relevant and exploitable results. This work tries to show which LCA tools are usable in preliminary analysis performed by non-experts like students in mechanical engineering or designers. Various assessments were studied with different tools: ArtoACV, Ecodesign Studio, Bilan Produit, and Umberto LCA+. An evaluation grid was drawn up to compare the tools according to objective and non-objective criteria. The case studies were carried out separately in order to remain as objective as possible. In this paper, the studies were made by two students in the first year of a Master's degree in mechanical engineering at INSA Toulouse. This paper shows that the four software packages enable a preliminary LCA to be finalized and propose graphs and tables for a better understanding of results. Even though tools generally allow the users to reach the same conclusions, some parameters persist that can strongly influence the result. Designers should keep in mind that results may not be consistent for their projects and may depend strongly on the hypothesis of the study.

**Keywords:** Life Cycle Assessment (LCA), Tools, Mechanical Engineering, Simplified LCA, Comparison

## 1 Introduction

The Life Cycle Analysis method has emerged in a global context of awareness of pollution, environmental degradation, and resource management issues. This awareness began in the 1970s and 1980s because of environmental damage that appeared progressively. A major responsibility has been found to be linked to consumer products [1, 2, 3]. Considering the entire life cycle of a product has become crucial, and the LCA method can achieve this.

### 1.1 *Literature review*

LCA means both the eco-design methodology and the tools associated with it. Ecodesign considers environmental aspects in the design of the product without excluding the other essential parameters (cost, quality, etc.) [1].

Some studies thus propose to link LCA and LCC (Life Cycle Cost) on mechanical case studies like those concerning diesel engines [4] or Steyr engines [5].

The LCA method assesses the potential environmental impact of a product, a service, or a system for all steps of its life cycle: "extraction of raw materials - production - distribution - consumption - recovery - elimination" [6]. It relies on a database that can provide an inventory of information related to the life cycle of a product.

Life cycle assessment is standardized by ISO 14040 and ISO 14044. The first provides general guidelines for good practices for performing LCA. The second offers technical assistance for carrying out LCA correctly [7]. The standardization of the method ensures "the robustness and the validity of the results obtained" [1]. Nevertheless, LCA studies appear to be very sensitive [8, 9].

LCA aims to help designers choose the best improvement targets for the product and compare several design solutions. LCA tools have been created to simplify this method by integrating databases and calculation methods directly into the software to extract environmental impacts. Some other works have been developed to link LCA with CAD software [10, 11, 12].

LCA software packages have their own characteristics because they do not all integrate the same databases, calculation methods, or even indicators. They comply with all the standards mentioned above, which justify their qualification as LCA software. There are no "rules" for choosing a tool and users are completely free to select the one they want. Making documentation available would help to guide users in their choices but there is still a lack of information and comparison of tools in the literature.

### 1.2 *Purpose of the study*

This paper aims to highlight Life Cycle Analysis software that is suitable for use by non-experts to carry out simplified studies. We have chosen to analyze the capacity of software to lead a user to a consistent conclusion whatever the subject of his study in the field of mechanical engineering. To fully compare the users' experiences, numerous aspects must be considered, such as the explanation given by the software for successfully performing a study or the time required to carry out the simplified LCA.

## 2 Materials and methods

This paper compares four LCA software tools through three different case studies. This type of comparison can be altered by the lived experiences and judgement capacity of those carrying out the case studies. To enable them to remain objective, a methodology was set up as objectivity was crucial to our study.

The reader should know that Artogreen (ArtoACV) and Altermaker (Ecodesign) propose a SaaS (Software as a service) solution and can adapt their software with ease.

### 2.1 Software and studies

The four software tools studied as part of this research are briefly presented below.

- **ArtoACV [13]**: Online software used at INSA Toulouse in Mechanical Engineering and created by ArtoGreen.
- **Bilan Produit [14]**: Developed by ADEME, this LCA software is free and therefore simplified in terms of database and modeling. Two accounts have been created on the website.
- **Ecodesign Studio [15]**: Created by Altermaker, Ecodesign Studio is an online platform allowing collaborative environmental analysis. Two licenses were obtained free of charge thanks to Altermaker.
- **Umberto LCA+ [16]**: Compared with the other software, Umberto is not an online tool and is more suitable for experts in LCA. Access to it was possible because Umberto is used in the department of Process Engineering at INSA Toulouse.

After a study of all the software, it was decided not to concentrate on Umberto LCA+ because it is intended for more expert users.

This paper concerns three case studies. A wind turbine was studied first with the four software tools mentioned above, thanks to a paper comparing several life cycle impact assessment (LCIA) software tools [17]. The second case studied was an ecological solution named Sylcat, created by SOFRINOV [18]. It allows wooden frameworks to be made from pallets connected by pieces of wood also named Sylcat (Sylcat A,B,C,D or E). The last study was of a hoverboard that was entirely disassembled to note and weigh all pieces. Umberto LCA+ was only used on the wind turbine study. Although its high level of flexibility is convenient for making detailed analyses, it requires considerable personal investment from a non-expert in LCA.

## ***2.2 Methods and hypothesis***

The difficulty of this research was to compare LCA software through case studies while remaining objective and neutral. To reduce influence throughout the work on the case studies, it was decided to perform two separate autonomous analyses in parallel. In this paper, the studies were carried out by two students in their first year of a Master's degree in mechanical engineering at INSA Toulouse. The evaluation grids drawn up aimed to list the criteria used to compare the tools. The objective of these grids was to keep a written record of anything done during the study and to have the same criteria at the beginning of the research work.

The criteria chosen to compare the LCA tools were various and could be objective or non-objective. They were chosen for their possible impact on the results or the conclusion about the software. The criteria or information used were:

- online/offline accessibility
- possibility import/export the results/data
- form of the results
- available languages
- databases
- relative cost of the tools
- possibility of collaboration
- information given by the software to help the user
- handling time
- average time to do a study

They are detailed in Table 1 and Table 2.

Making a simplified LCA requires making some hypotheses at the beginning of and during the study. It was decided to use only the information available in the case study documentation in order to avoid making very different assumptions. That is why there is no inflow and outflow for some points, such as transport, packaging, or the end of the product's life. Making hypotheses during the case study depends on the databases of the software and the user. A database cannot have all inflows available. Hence, the user could make some choices and therefore put forward a hypothesis. The results show that these choices could considerably change the conclusion of the user about his study.

### 3 Results and discussion

#### 3.1 Comparison of software from criteria

While using the software, we separately completed a grid of criteria useful to compare the tools with each other. The objective of this part is to summarize those criteria and compare software as clearly as possible. Table 1 presents criteria that depend only on the characteristics of the tools.

The accessibility of software is generally online (Online) except for Umberto LCA+, which is usable only on the computer on which it is installed (Local). Each tool provides the possibility to import and export data or results and the associated format is detailed in Table 1.

**Table 1.** Relevant information about LCA software

<i>Criterion</i>	<i>Bilan Produit</i>	<i>ArtoACV</i>	<i>Ecodesign Studio</i>	<i>Umberto LCA+</i>
Software location	Online	Online	Online	Local
Safeguards	Local	Online	Online	Local
LCA Data Exportation	Yes (.xml)	Yes (.xls)	Yes (.csv)	Yes (.umberto)
LCA Data Importation	Yes (.xml)	Yes (.xlsm)	Yes (.csv)	Yes (.umberto)
LCA Results Exportation	Yes (.xls)	Yes (.pdf or .xls)	Yes (.pdf or .xlsx)	Yes (.xls)
Form of the results	Graphs and percentages	Graphs, tables, labels and global impacts	Graphs detailed by impact factor	Excel with graphs and tables
Language	En, Fr	Fr	En, Fr	En, De
Databases	Base IMPACTS	ELCD APME Other French databases	Base IMPACTS FD E01-008	Ecoinvent 2 Ecoinvent 3
Relative Cost	0	+	+	++

It is particularly important for software to be in English (En) to make it more accessible. At the time of our studies, ArtoACV was only available in French (Fr), which could be a problem for international users.

Other criteria were also studied (Table 2) to compare software tools. Collaborative work was an important feature because it simplifies remote work by making it possible for users to access the same project and modify it simultaneously. Ecodesign Studio is particularly useful for group projects because it makes feedback available to the other members of the project throughout the study.

**Table 2.** Features useful for the user

<i>Criteria</i>	<i>Bilan Produit</i>	<i>ArtoACV</i>	<i>Ecodesign Studio</i>	<i>Umberto LCA+</i>
Collaboration	No	Yes	Yes	No
User guidance	Yes	Yes	Yes	Yes
Handling time	30 mn	1 h	1h30	10 h
Average time to do a study	45 mn	1h	1h	2 h

Each software tool helps the user during his/her study (Table 2). ArtoACV gives some information and advice directly on the software, which makes the tool easier to handle. The same is true for Bilan Produit, which gives complete information about the Base IMPACTS. Ecodesign Studio does not have information to guide the user within the tool because the tool itself is intuitive. Nevertheless, information about LCA is available on the Altermaker website, which could help non-expert users. Umberto LCA+ puts complete tutorials at the user's disposal for the LCA method and other features. In our case, for Umberto LCA+, only the tutorials concerning LCA were completed, which represent the half of the tutorials available.

By using software, we noticed some advantages and problems with each simplified LCA tool (excluding Umberto because he needs more time to handle). In addition to the previous comments, ArtoACV has the particularity of presenting its results in labels. This way of presenting the results includes an overall costing of the impact and consumption of water, electricity, and hazardous wastes. This can be useful for pedagogical purposes. ArtoACV has a large database composed, partly, of ELCD (European Life Cycle Database) and the APME (Association of Plastics Manufacturers in Europe) database. These databases made ArtoACV the most complete tool for inflow for the moment. However, this software presents a problem for studying an object when using the multiplication factor feature in the nomenclature part. That led to problems in graphics and expressions of mass in percentages in the results part.

Bilan Produit is a fast software tool which is free of charge and easy to use, and is a way to learn the LCA method. The editor does not guarantee full respect of ISO14040 and ISO14044 and orients the user toward other compliant LCA software for their models. It is not possible to use a database other than Base IMPACTS on Bilan Produit but it is easy to signal your need if a flow required for a given study is missing in Base IMPACTS.

Ecodesign Studio has the particularly interesting possibility to give very complete results with numerous graphs showing the impact of each component. Aside from using Base IMPACTS, Ecodesign Studio has another, specific database for mechanical studies (FD E01-008) (Table 1).

The following part aims to synthesize the results of the case studies made for this research project. They are then used to highlight what could influence the interpretation of the results by a non-expert user.

### 3.2 Results of case studies on four software

The objective of an LCA tool is to make the most impactful areas (component, phase of the life cycle, etc.) of its product clear to the user. Important parts that will then have to be redesigned or carefully developed are thus highlighted. These results aim to check the consistency of the possible conclusion drawn by the user with each tool. They are not necessarily easy to compare because the software packages studied do not always present the results in the same way (different impact factors, detailed information on the impact of the components). Let us now check that the results given by the different software tools converge towards the same conclusions or, if not, try to explain the differences.

It was decided that only the information already available would be used and that hypotheses would be avoided. This was to prevent the use of assumptions that were very different between the two students carrying out the study. That is why some parts, such as transportation and packages, did not have inflow and outflow.

The first case studied was a hoverboard, which is the only product that was disassembled to analyze the components. There were no difficulties in conducting this study and the results given by the various software tools were very close to each other.

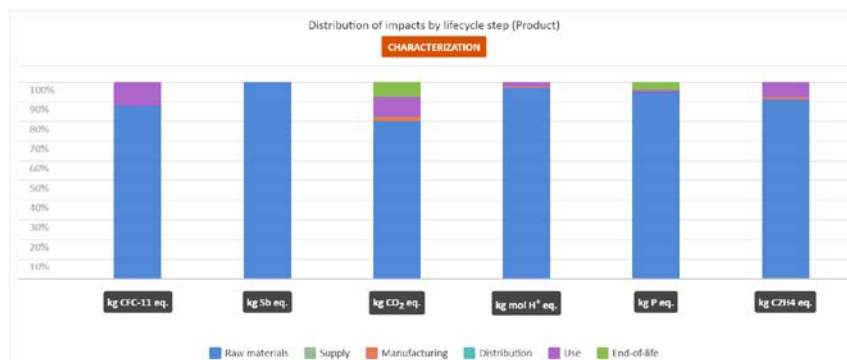


Fig. 1.a Environmental balance of the hoverboard on Ecodesign Studio.

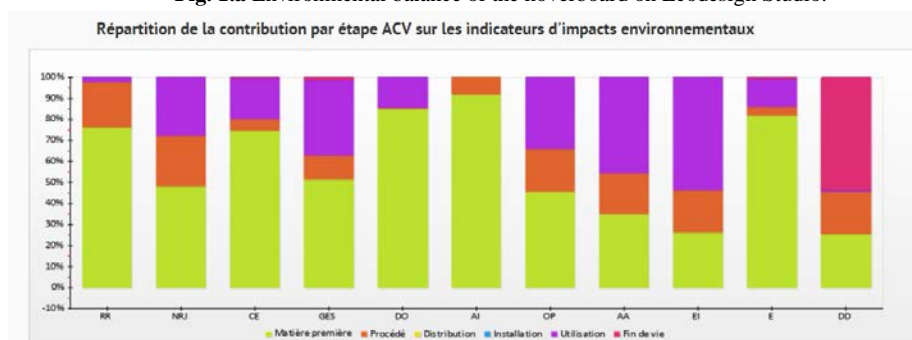
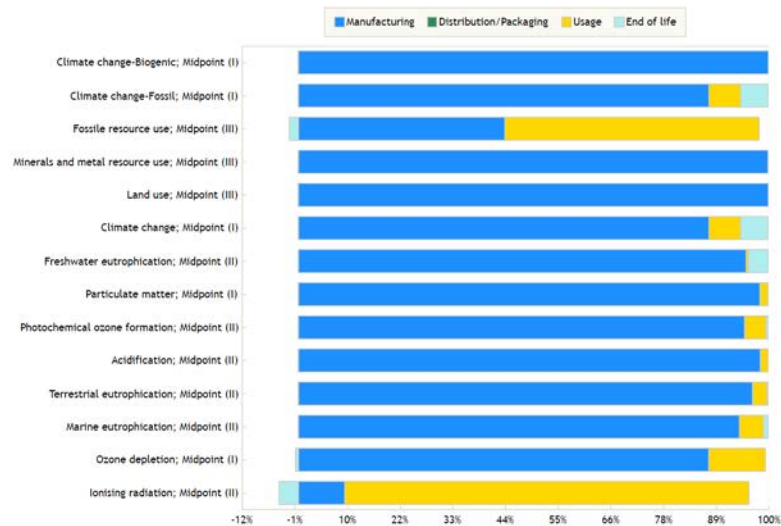


Fig. 1.b. Environmental balance of the hoverboard on ArtoACV





**Fig. 1.c.** Environmental balance of the hoverboard on Bilan Produit

The environmental balance (Figure 1.a., Figure 1.b. and Figure 1.c.) shows that “raw materials” and “use” are the two most impactful phases of the product. The designer should conclude that he needs to concentrate on the raw materials if he wants to reduce the environmental impact of his product. The global impact of the components indicates that the ferromagnetic core made with Nickel has the greatest environmental impact (Fig. 2). The user should conclude that he must concentrate specifically on this part of the product. Note that ArtoACV is the only software capable of giving the global impact of each component or material. It contains a dedicated part for sensitivity evaluation of materials or parts on each impact factor. The other software tools (Bilan Produit and Ecodesign Studio) give the impact of each component according to impact factors.

	% en masse	masse en g	% impacts
Ferromagnetic core	19.38	1938	33.17
Electronic card	6.75	675	14.83
Plastic crankcase	8.19	819	14.14
Rotor	14.72	1472	12.09
Metallic crankcase	6.65	665	5.54
Motor copper wire	4.5	450	4.81
Magnets (x15)	4.48	448	3.33

**Fig. 2.** Global impact of the hoverboard components on ArtoACV.

The second case study was about wood pieces and the results were more dispersed. This study is very interesting because few parts are involved, making it easier to visualize the importance of the choice of incoming flows on the result. The ArtoACV

balance sheet indicates that processes have a higher impact than raw materials. Since Bilan Produit does not differentiate between these two aspects, it is impossible to know which has more impact. We observe on Ecodesign Studio that the processes part is not significant (maximum 0.33%). The only process that is considered in this case study is the manufacture of the screws, which is present only in ArtoACV because it cannot be found in the Base IMPACTS database. Cold rolling was selected in the case of Ecodesign and Bilan Produit because they did not offer a greater choice of processes. However, it was not the manufacturing of the screws that generated the difference of impact but the calculation method employed in the software. It seems that ArtoACV considers not only the processes entered by the user but also those upstream at the level of the extraction of raw materials. This can be misleading as the user may think that the manufacturing of the screws has a huge impact. This problem showed that the calculation method can impact the understanding of the results.

Another problem with this study was the conclusion on the impact of the components. ArtoACV indicated that the pieces named Sylcat D (36.67% of the global impact) had a larger impact than the pallets (22.52%). Bilan Produit and Ecodesign Studio indicated the contrary (Fig. 3) in the acidification factor (chosen for this comparison).

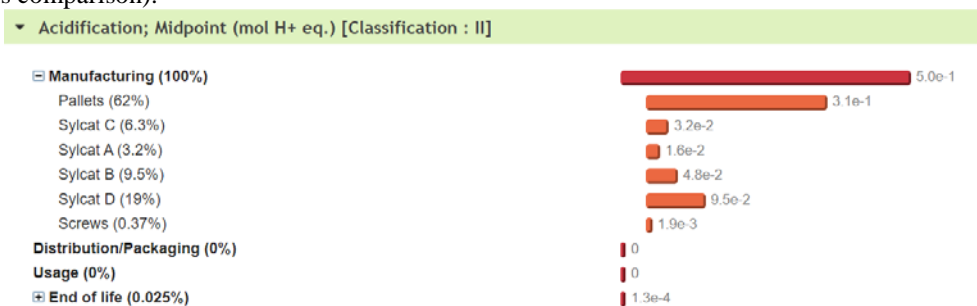


Fig. 3. Impact on acidification factor calculated by Bilan Produit.

This difference was due to a choice made for the inflows. On ArtoACV, the veneer wood used to make the Sylcat pieces was not a durable one, unlike the wood used for the pallets. On Bilan Produit and Ecodesign Studio, we found durable veneer woods and the results were greatly impacted (Fig. 3). This problem shows that a hypothesis made by the user about an inflow can change the results and so the conclusion. In the worst case, it can change the user's conclusions and eco-design decisions.

For the third study on the wind turbine, Umberto allowed the LCA to be carried out and even showed the flow of energy converted as described in the functional unit. The other tools can help in an LCA within the limits of their databases, which are evolutive. Concrete was available on ArtoACV and Umberto LCA+ but not on Ecodesign Studio and Bilan Produit because they use the Base IMPACTS database. This lack of inflow shows the importance of an exhaustive database if a study is to be conducted and consistent results obtained.

## 4 Conclusions and perspectives

The purpose of the study described in this paper was to compare some LCA (Life Cycle Assessment) software packages usable for simplified analysis. Through various case studies and criteria, we analyzed the capacity of LCA tools to combine ease of use and consistency of results. These data make a comparison of the possible tools and enable some advice to be proposed for non-expert users of LCA. The reader should be aware that ArtoACV and Ecodesign studio are Saas (Software as a service) and adaptable.

The results of this paper show that a “perfect” LCA tool, suitable for all studies, does not exist. The software choice depends strongly on the type of study and the needs of the designer. Through the cases studied, it appears that the quality of the results depends strongly on the hypotheses made by the user, the available incoming flow (databases), and the calculation methods.

From this point of view, ArtoACV had a very complete database which needed fewer hypotheses to be made than the other software studied in this paper (except Umberto LCA+). Nevertheless, this tool has the drawback of still being available only in French.

Ecodesign Studio is a very intuitive software and is accompanied by a website with quality content about LCA, which allows users to become informed about the issue. Its management of collaborative work makes this tool interesting and convenient for companies.

Bilan Produit, is an accessible, fast, free software with lots of information about the Base IMPACT database.

These three tools are particularly suitable for non-experts because they propose a simple form of results and the possibility to perform preliminary LCA. Even though Umberto LCA+ allows for some preliminary LCA too, it is more suitable for experts in the field.

The last step of this research project aims to have the tools tested by a larger number of people. It would be interesting to integrate the tools into an industrial context in companies and also to ask students to test them. The results and feedback will be collected and analyzed to know whether our preliminary conclusions can be generalized.

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