Evaluating the environmental impact of a series of materials on an engineering part with the Sustainability tool of SolidWorks

Surname, name	Montañés Muñoz, Néstor (nesmonmu@upvnet.upv.es) Balart Gimeno, Rafael Antonio (rbalart@mcm.upv.es) Quiles Carrillo, Luís Jesús (luiquic1@epsa.upv.es)
Department	Department of Mechanical and Materials Engineering (DIMM)
Center	Escuela Politécnica Superior de Alcoy (EPSA) Universitat Politècnica de València (UPV)

1 Summary of the key issues

This article aims to study of the **environmental effects** of selecting different materials on an engineering part by using the "**Sustainability**" tool in SolidWorks. With this tool it is possible to assess the **ecoefficiency** of a particular material (or set of materials) in engineering applications.

2 Introduction

In the last years, a growing sensitiveness about environment has been detected. Topics as recycling, upgrading, life cycle assessment, and so on are of great interest in our society. When an engineer is working on the development of a new part or assembly must take into account not only **technical requirements** but also the **environmental impact** of his decisions in terms of material, manufacturing process, geometry, among others. Sustainable development is defined as the ability to optimize the current use of resources without compromising these resources for future generations. So that, engineers must manage, simultaneously, technical and economical restrictions as well as **environmental considerations**. This means engineers must fulfil the technical requirements at a competitive cost by taking into account the environmental impact during the life cycle. In fact, **Life Cycle Assessment** (LCA) has become a powerful tool to evaluate the environmental impact of the different stages of a product, from its initial concept until its End-of-Life is reached.

With the development of new technologies and computing tools, there is a wide variety of tools that can help engineers with the "take-decision" process during the development of a new engineering part or assembly. These tools include all stages of the engineering process such as **pre-design**, **dimensions**, **part-cost**, **assemblies**, and, of course, **environmental issues**.

Engineers must face important challenges related to several topics. One of the key topics in developing new parts/assemblies, is "**time**". The "**Time to market**" [1] has become one of the leading forces in **Research+Development+Innovation (R+D+i).** But this is not the only topic; in addition to "time", engineers must select the most suitable materials which ensure sustainable development together with environmentally friendly manufacturing processes. This is the only way to positively contribute to sustainable development.

Computer Aided Design and Engineering tools (CAD-CAE) play a key role in the training process of current engineers. Software packages such as **Autocad**®, **CATIA**®, **Solid Edge**®, **ANSYS**®, **Abaqus**®, **Matlab**®, **Comsol Multiphysics** ®, **SolidWorks**®, among others, are increasingly used in training future engineers [2-4]. Although traditionally there has been a clear separation of CAD-CAE packages into a series of individual tools, (one for cost-estimation, one for 2D design, one for 3D design, one to assign material, one to evaluate aerodynamics, one to mesh a 3d model, one to calculate deformations, and so on), today, most of these CAD-CAE packages include all necessary tools to assist engineers from the beginning to the end.

It is worthy to note that all these tools represent a **very powerful support to engineers**, but engineers need conventional training to reach the optimum when using these tools. CAD-CAE tools are **complementary**. Moreover, the success in using these software packages is directly linked to the engineer accumulated knowledge and capabilities. When using these tools, **engineers** must take some decisions about the **INPUTS** (design parameters, technical restrictions, materials, manufacturing stages,

environmental issues, and so on) to the CAD-CAE tool and after a complex mathematical process the **CAD-CAE tool** will **give** a series of **OUTPUTS** (dimensions, resultant forces, factor of safety, stress analysis, carbon footprint, among others).

 SolidWorks CAD-CAE package is becoming one of the most interesting from an engineering standpoint as it covers all the stages included in the development of a new part or complex assembly. In addition, the learning curve of all the included tools is relatively short compared to other available **CAD-CAE packages**. From an environmental point of view, SolidWorks includes a "**Sustainable**" tool that allows an approximate estimation of the CO_2 emissions related to the Life Cycle of an engineering part or assembly [5, 6].

 This article focuses on estimating the environmental impact of an engineering part by using the "**Sustainability**" tool included in SolidWorks, which allows obtaining the CO_2 emissions related to several stages of the Life Cycle: materials, manufacturing, use, transportation and End-of-life.

3 Objectives

Once you have read this article, you will be able to:

- **Know** how to estimate the CO_2 emissions related to an engineering part.

- **Assess** and **quantify** the environmental impact in terms of materials, manufacturing, use, transportation and end-of-life.

- **Analyse** and **compare** the effects that selecting several materials into the same engineering part has on overall environmental impact.

4 Development

 First let's define a simple engineering part which will serve as a reference. It consists on a conventional glass geometry as shown in Figure 1. You can construct this simple geometry by using SolidWorks and its features.
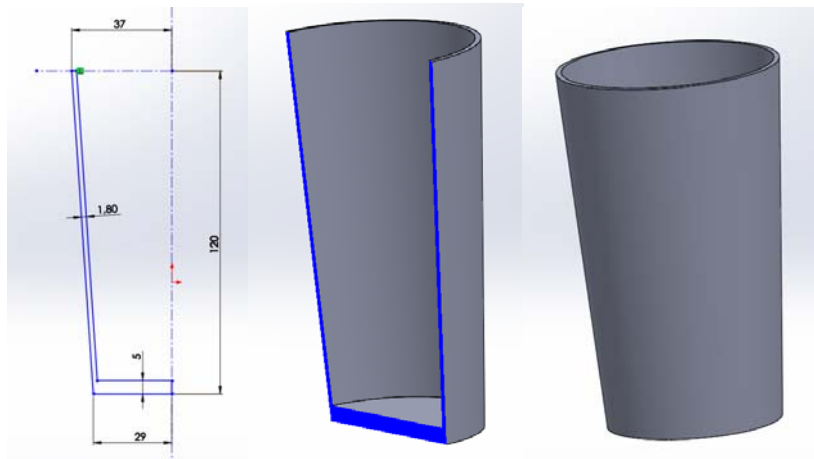

Figure 1. Cross section with dimensions and 3D representation of a glass.

4.1 Using the "Sustainability" tool in SolidWorks

As indicated previously, most of the **CAD-CAM-CAE** tools, also include environmental issues so that the corresponding software package is able to manage the whole design process. SolidWorks includes a "**Sustainability**" tool that allows estimating the carbon footprint in terms of CO_2 emissions (Figure 2, blue rectangle).

Obviously, to evaluate the environmental effects of a design, it is necessary to define the material. To this, once the 3D part is obtained, you can go to the "project" tree and you will see several options, which include "Materials" as it can be seen in Figure 2 (red rectangle).
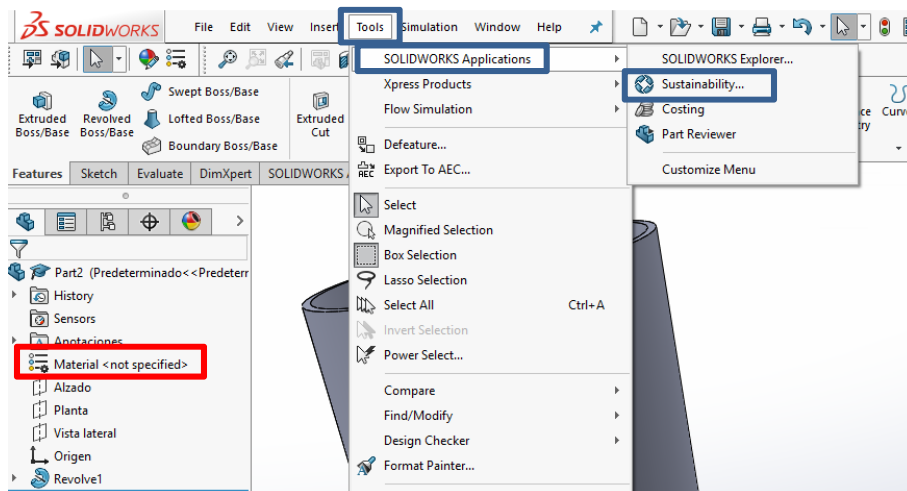

Figure 2. Location of the "Material" selection and the "Sustainability" tool in SolidWorks.

To define the appropriate material, you must right click the "**Materials**" icon in the project tree, and then, click on "**Edit material**". Then, the "materials" database of SolidWorks is opened and you can select one of the available materials (Figure 3). In this case, you can select "**PET**" from "Plastics". You can see the main properties (mechanical, thermal, and so on) of your selected material. Then, you click on "**Apply**". This way, the 3D object will behave as a **PET** object. The appearance of the 3D object changes depending on the applied material (transparent, translucent, opaque, etc.).

As you can see, the materials database of SolidWorks is quite complete and contains information of a wide variety of materials: steels, aluminium alloys, copper alloys, titanium alloys, zinc alloys, other alloys, other non-metals, silicones, rubbers, plastics, and so on. Although this database is quite complete, it is possible that a specific material is not available in this database. It is not a problem since you can define new materials and customize other existing ones. So that, the potential of SolidWorks is important.
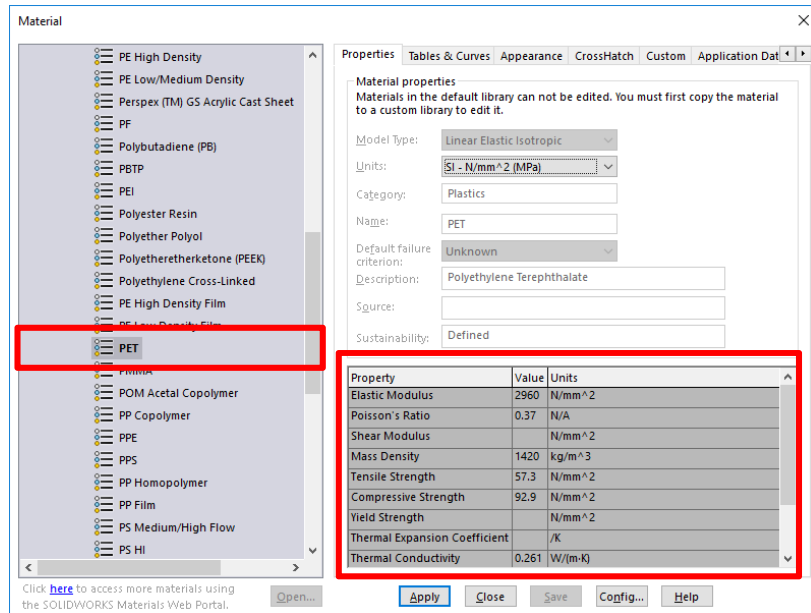
Figure 3. General appearance of the SolidWorks materials database.

Once the material has been selected, you can use the "**Sustainability**" tools in SolidWorks to evaluate the CO_2 emissions. To open this tool, click on "**Tools / SOLIDWORKS Applications**" and then "**Sustainability**" as indicated in Figure 2. As you will see, this application is shown at the right side of the window with different features related to environmental issues:

- Material.
- Manufacturing.
- Use.
- Transportation.
- End of Life.

If you click on "**Material**", you will see some of the features. For example, the total weight of the PET glass (78,73 g). In addition, typically, PET glass contain 100% raw material (Figure 4a). With regard to the "**Manufacturing**" process, you can select several options:

- Region of manufacturing.
- Estimated lasting.
- Process.
- Painting.

Imagine this product is going to be manufactured in Asia. First you select this region. Then you can provide an estimation of the lasting time in years. In this example, you can consider 1 year as an average value.

Regarding the manufacturing process, the database contains information about energy consumption of some materials and processes. In this case, you can select the "**Injection moulding**" process and, immediately, the corresponding values of electricity

and natural gas consumption will be displayed as well as typical "**Scrap rate**". If you have more detailed information about these numbers, you can customize the energy consumption by changing the corresponding values.

In the case your product needs painting, you can drop down the corresponding menu and you will be able to select several painting processes. In addition, information about the total surface area is given. For this glass, the total surface area is 53103,38 mm².
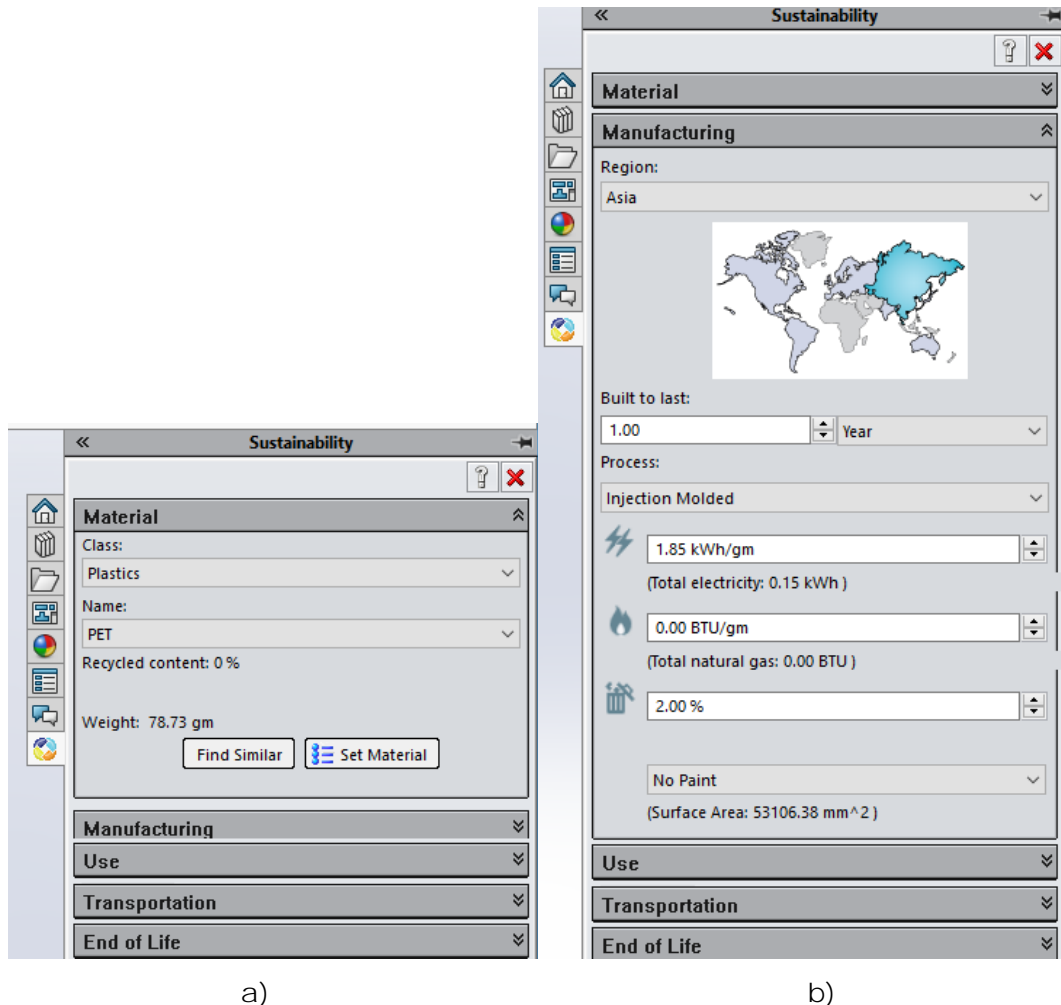

a)   b)

Figure 4. Submenus available in the "**Sustainability**" tool of SolidWorks for a) Material and b) Manufacturing.

The following option is the region of use, or where your main market is located. In Figure 5a you can select "Europe" as the most important market for your product. Then you can go to the "Transportation". As this product is going to be manufactured in Asia and the principal market is in Europe, the estimated number of kilometres by ship is 19000 km and 3000 km by truck.
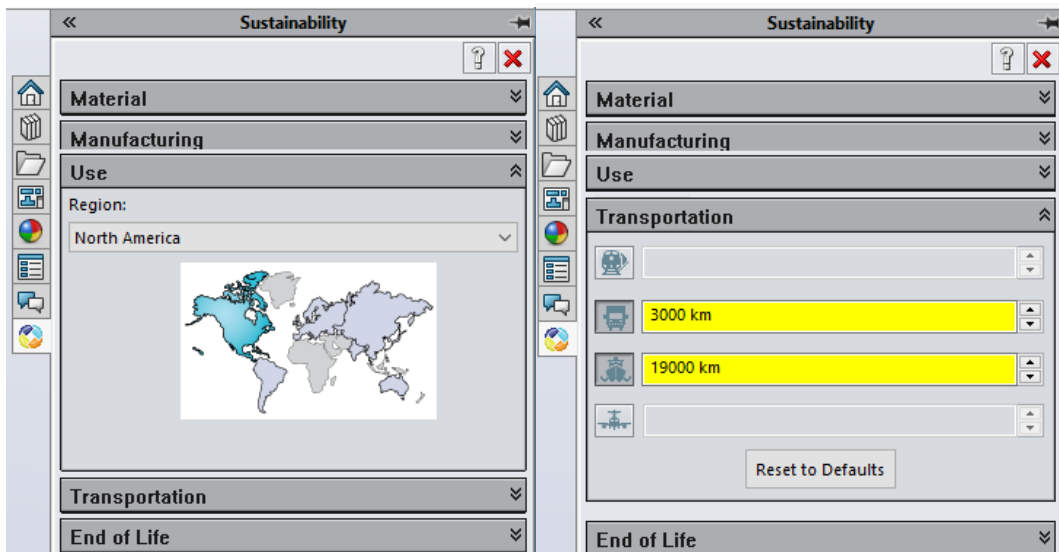
Figure 5. Submenus available in the "**Sustainability**" tool of SolidWorks for a) Use and b) Transportation.

The last parameters you can customize are related to the **End of Life** as shown in Figure 6. You can indicate the percentage values of this product subjected to recycling, incineration and deposited in landfills. As currently PET is being highly recycled the percentage recycling can be increased up to 50% while 13% is incinerated and, finally a residual 37% is deposited in controlled landfills.
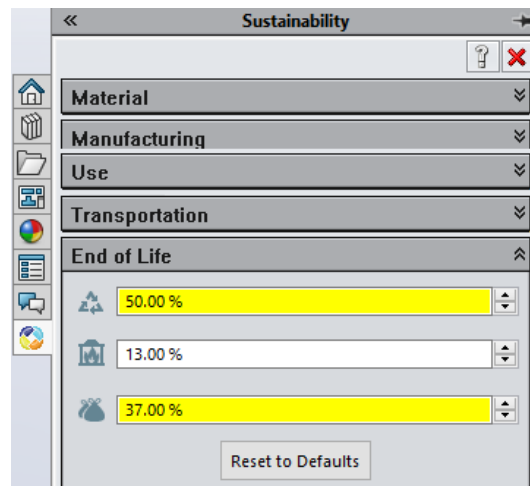

Figure 6. Submenu available in the "**Sustainability**" tool of SolidWorks for the "**End of Life**".

Once all this information is collected you can click on "**Environmental impact**" and you will visualize the results of the environmental impact of your product with all the assumption you have done regarding material, manufacturing, use, transportation and end of life. Figure 7a summarizes the environmental impact of all these five topics (material, manufacturing, use, transportation and end of life) on carbon footprint, energy

efficiency, environmental impact on air and water. If you click on one of these pie charts, you will see the different results for your design and assumptions.

Carbon: Carbon footprint measured in CO_2 emission (in kg).

Energy: Total energy consumption (in MJ).

Air: Air acidification in kg SO_2 which contributes to acid rain.

Water: Water eutrophication measured in units kg PO_4.
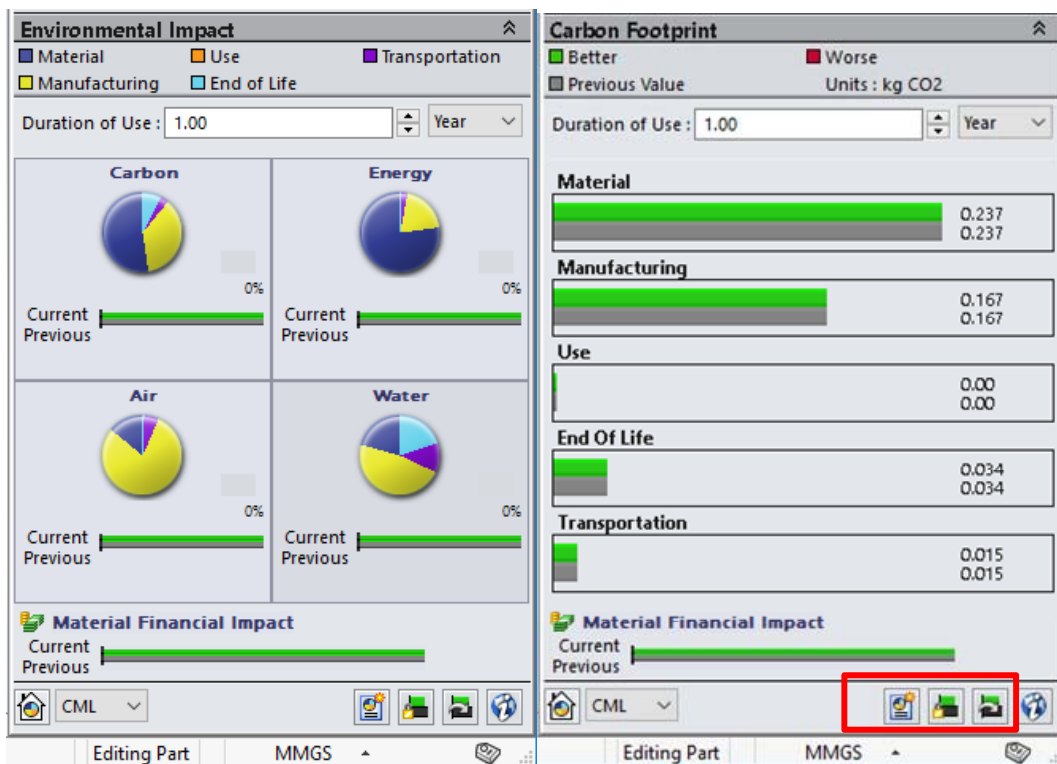
a)   b)

Figure 7. Results regarding sustainability of a part in SolidWorks, a) effect on carbon footprint, energy consumption, air acidification and water eutrophication and b) total CO_2 emissions regarding material, manufacturing, use, transportation and end of life.

The "Sustainability" tool allows exporting a report, defining the baseline or importing a baseline as shown in Figure 7 (red rectangle). If you want to compare this design with PET to other material (and its corresponding manufacturing process), you have to save this project as, for example "glass_PET.SLDPRT". Then, you can change whatever you want in terms of material, manufacturing process, and so on and, obviously, the environmental impact values will change. To compare with the PET glass, you just have to select "Import baseline" and select the "glass_PET.SLDPRT" project. For example, if you only change the material to PP homopolymer, you get some important changes. Regarding the weight, it is now 51,73 g and a comparison of the CO_2 emissions can be found in Figure 8. The PET glass is represented by the red bars and the PP option is represented in black colour. As you can see, some important differences in environmental issues can be detected by using these two polymers. The same changes

could occur for air acidification, water eutrophication and energy consumption. So I encourage you to explore all these changes in environmental effects due to changing PET to PP.
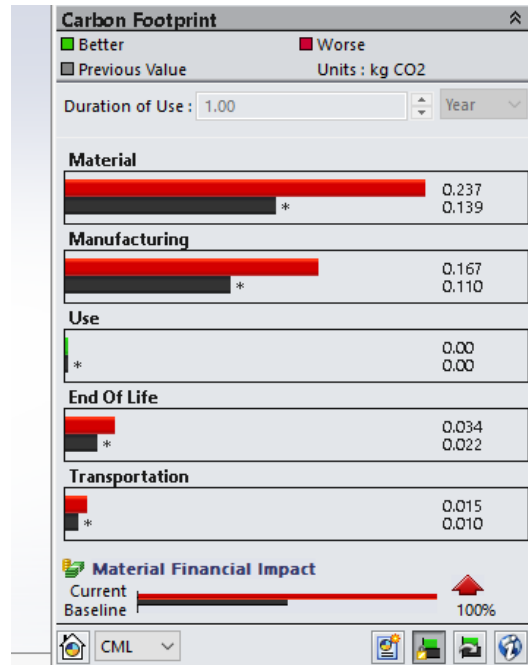

Figure 8. A plot bar comparison of the CO_2 emissions of a PET and PP homopolymer glass, obtained using the "Sustainability" tool of SolidWorks.

5 Conclusions

CAD-CAE tools are currently important tools to assist the engineering process. SolidWorks is one of a series of CAD-CAE tools that can help students in training. Among some interesting features SolidWorks can provide: finite element analysis, fluid simulation, etc. the most recent versions include a "Sustainability" package that can be used to obtain a first overview of the environmental impact of our design, part or assembly. This "Sustainability" tool requires some INPUTS in terms of:

- Materials.
- Manufacturing.
- Use.
- Transportation.
- End of life.

If these inputs are correctly introduced to the software, then some OUTPUTS are automatically generated, regarding the environmental impact of your designed part or assembly. These OUTPUTS include:

- Carbon footprint (kg CO_2).
- Energy consumption (in MJ).
- Air acidification (in kg SO_2).
- Water eutrophication (in kg PO_4).

Although this tool does not substitute an in depth analysis of the Life Cycle, it gives an overall idea of the environmental impact of our designs; so that, this tool could be very helpful to engineers.

6 References

[1] Charmey, C. "Time to Market. Reducing Product Lead Time", Ed. SME, Society of Manufacturing Engineers (1991)

[2] Khennane, A. "Introduction to Finite Element Analysis Using MATLAB® and Abaqus", Ed. CRC Press (2013).

[3] Lee, H-H. "Finite Element Simulations with ANSYS Workbench 16", Ed. SDC Publications (2015).

[4] Adams, V; Askenazi, A. "Building better products with finite element analysis", Ed. OnWord Press (1999).

[5] Hauschild, M; Rosenbaun, R.K; Olsen, S. "Life Cycle Assessment", Ed. Springer (2018).

[6] Senthilkannan Muthu, S. "The carbon footprint handbook", Ed. CRC Press (2015).