EuCIA
European Composites
Industry Association

Eco Impact Calculator for Beginners

Fundamentals and Case Histories

ECO CALCULATOR
for composite materials

Issued: May 2021

1. INTRODUCTION

An analysis of the environmental impact of composites must cover the entire process flow, ranging from the synthesis of raw materials (resins and fibres), to the production of components, then moving on to their use until final disposal (Figure 1).

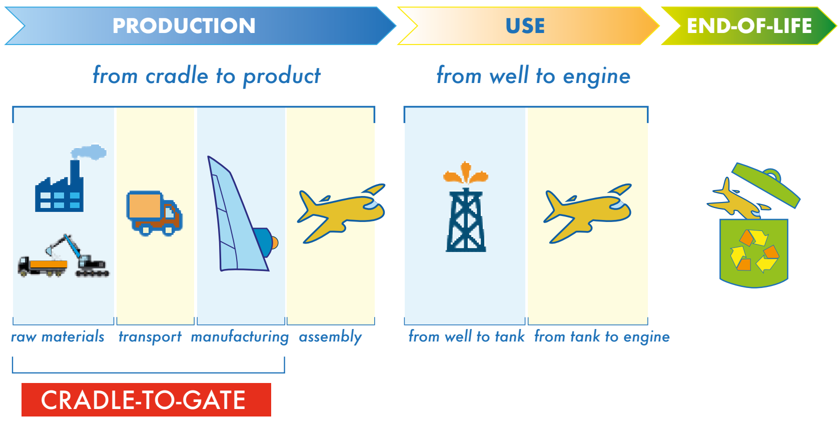

Figure 1: Life Cycle Assessment flow chart.

Composite materials distinguish themselves from other engineering materials by their extraordinary combination of stiffness, strength and lightweight, which facilitates transport and handling, assembly and installation, and – in the case of moving components such as wind turbine blades or parts of vehicles – also reduces energy consumption related to operation. All these advantages, combined with the superior durability of the material in the majority of operating conditions, makes it possible to conclude that (at least for the use phase) the environmental advantages linked to the use of composites are indisputable: lower energy consumption and lower greenhouse gas emissions, longer component life even in the absence of maintenance, better performance and greater safety. As for the other LCA phases, the most suitable method for quantifying the environmental impact of composite products - as well as for all other products - is undoubtedly the life cycle assessment (LCA). Conducting this analysis can be very time-consuming and costly: it requires specialised software and skills, as well as independent verification of data and methodology.

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Luckily, the European Composites Industry Association (EuCIA) has recently developed a free tool (**Eco Impact Calculator**) to quickly and easily calculate the main environmental impact factors related to the manufacturing processes for composite components according to the "cradle to gate" scheme, which takes into account the production of raw materials, transportation to the manufacturer and production of the component (Figure 1). The environmental impact assessments are performed using a comprehensive database relating to materials and production processes that has been collated through a collaboration between European institutions, research centres and industry that lasted several years. This information – which is accessible to the user – makes it possible to calculate the LCA of any component in only two simple steps: firstly, the choice of the manufacturing process, and secondly the "recipe" of the material (type and quantity of the raw materials used for the production of component).

The list of resources to be taken into account in the "from cradle to gate" analysis for a composite material is very broad. In fact, information is not only required on the fibres and the matrix – which constitute its main components - but also on the fillers, on core materials and coatings, additives and process auxiliaries. Then there are also the elements more closely related to the manufacturing process, such as energy and water consumption as well as emissions and by-products.

The system boundaries and the composite materials and processes included in the EuCIA's Eco Impact Calculator are shown in Figure 2.

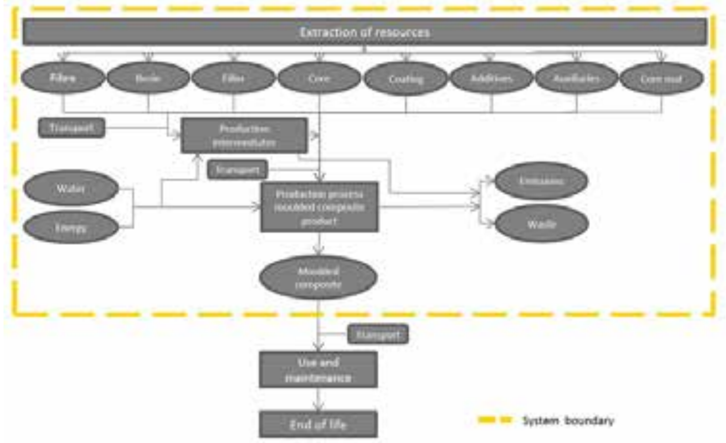

Figure 2: System boundaries for Cradle-to-Gate LCA in EuCIA's Eco Impact Calculator.

2. LIFE CYCLE ASSESSMENT FUNDAMENTALS

The set of different impact categories on the life cycle of a product is defined by an international protocol called the International Reference Life Cycle Data System (ILCD) which identifies the different elementary inputs and outputs (Figure 3). This protocol provides a common basis for consistent, reliable and good quality assessment considering multiple impact categories that affect human health, the natural environment and natural resources. Emissions and resources are assigned to each of these impact categories and are then converted into indicators that measure the environmental effect per unit emission or resource consumed. The development of the ILCD was coordinated by the European Commission in a broad international consultation process with experts, stakeholders and public bodies. More information is available on the website of the European Platform on Life Cycle Assessments.

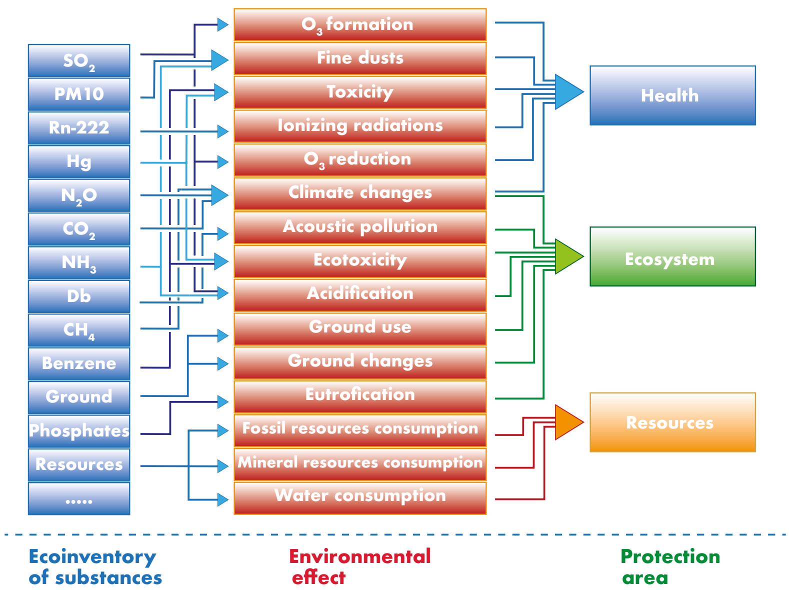

Figure 3: Input and output categories of the ILCD protocol.

Among all the indicators shown in Figure 3, the most easily understood – and therefore of greatest interest to non-expert users – are certainly the cumulative energy demand (CED) and the emission of greenhouse gases

(GHG). The CED is the total measure of the energy resources required for the supply of a product or service and refers to primary energy values for all activities related to the life cycle of the product. It takes into account not only the use of fossil and nuclear energy (non-renewable source) but also that from biomass (renewable and non-renewable) as well as that produced by wind, photovoltaic, geothermal and hydroelectric plants (renewable source).

On the other hand, the GHG protocol originates from a collaborative effort between companies, governments, non-governmental organisations (NGOs) and academic institutions convened by the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD). The initiative, launched in 1998, has enabled the development of internationally accepted standards and tools for identifying and quantifying greenhouse gases and has promoted their adoption in order to achieve a low-carbon economy worldwide. Of all the substances identified, CO_2 is undoubtedly the best known and most important which is divided into 4 categories of environmental impact: the fossil equivalent, the biogenic equivalent, the equivalent from soil transformation and absorption. The total emission of all greenhouse gases is usually measured with reference to CO_2 alone and for this reason the unit of measurement is expressed in CO_2 eq. For simplicity, this term is often referred to as the ecological carbon footprint, CF. Although the Eco Impact Calculator allows the calculation of all the categories listed in Figure 3, for the sake of simplicity the following analyses will be limited to CED and CF.

3. THE WORKFLOW

The tool is structured in such a way that it is easy for people with no experience of LCA calculations to make environmental impact assessments of their composite products. The workflow is shown in Figure 4. Following a simple registration process the calculation can be started.

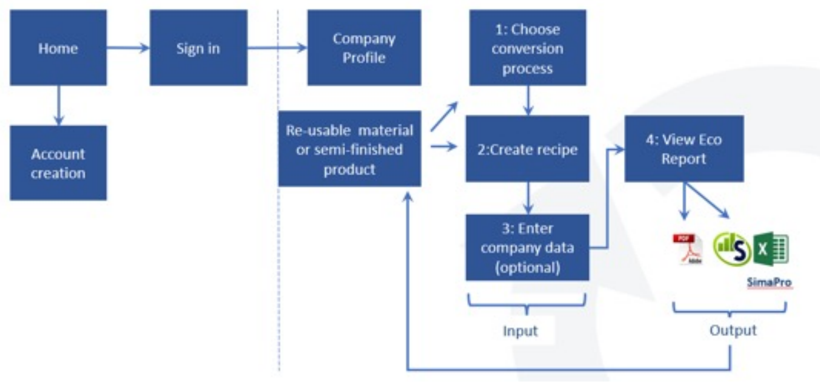

Figure 4: The workflow of EuCIA's Eco Impact Calculator.

The output can be personalised using a company profile and/or logo. Then, the tool allows for multiple options. Firstly, a material can be modified and stored to use as a new input, for example, a masterbatch or blend. Also, an intermediary process flow such as sheet moulding compound (SMC) compounding or thermoplastic extrusion can be selected, and followed by a pressing or injection moulding process respectively to make a part. A first step requires the choice of the conversion process. A set of pre-defined processes is available for the calculation to be made directly by the tool without the need of any input from the user. Additionally, if the user wishes to use a different conversion process, there is an option for them to introduce their own dataset.

A second step requires the recipe of materials to be formulated by selecting the type of raw material from a menu, followed by a specific raw material and the relevant quantity (by mass). The final step generates an Eco Impact Report in PDF format including information on the part as entered in the first step, calculation principles and the resulting GHG Protocol, CED and ILCD figures. A summary report can also be downloaded which includes the recipe details and can be shared on a discretionary basis. Additionally, the data can be exported to a SimaPro 8.2 Excel format for further life cycle calculations.

To ensure compliance with privacy legislation, all the data is only available to the registered user.

4. LCA ANALYSIS OF REAL INDUSTRIAL COMPONENTS

The first example of an LCA analysis conducted using the EuCIA's Eco Impact Calculator relates to a panel for a car interior produced by SMC technology. Since the production involves two distinct stages, firstly it will be required to calculate the LCA for the production of a typical SMC compound for general use; later, this compound will be used to produce the part by compression moulding. The recipe for making 1 kg of compound is shown in Figure 5. The LCA outputs of the compounding phase are then used as inputs for the second run of the analysis concerning the compression moulding phase of the part. The tool then provides the total values for CED and CF. The percentage of raw materials and conversion process contribution to LCA is also provided by the Eco Impact Calculator output and is shown in Figure 5.

COMPOUND RECIPE

Polyester resin	*300 g*
Glass fibre assembled roving	*350 g*
Calcium carbonate	*315 g*
Peroxide (Triganox C)	*20 g*
Release agent (zinc stearate)	*10 g*
Supporting plastic film	*5 g*
TOTAL:	*1 kg*

CONVERSION PROCESS

SHEET MOLDING COMPOUND (SMC)

COMPOUNDING STAGE

CED	*51,5 MJ*
CF	*3,02 kg CO_2 eq*

COMPRESSION MOULDING STAGE

CED	*77,3 MJ*
CF	*4,6 kg CO_2 eq*

TOTAL CED:	**138,8 MJ**
TOTAL CF:	**7,62 kg CO_2 eq**

Figure 5: LCA of a door panel produced by SMC. (Picture courtesy of the European Alliance for SMC/BMC.)

The second example is a 1 kg composite ladder rail made using glass fibres and produced through pultrusion. The majority of the material components are available in the tool and only one (the peroxide) had to be approached as proxy. Since only a small amount of peroxide is used in the part, the calculations closely represent the actual LCA values. In the calculation some degree of production waste and waste resulting from cutting was also included (Figure 6).

MATERIAL RECIPE

DCPD UP resin	*240 g*
Glass fibre direct roving	*340 g*
Glass fibre mat	*100 g*
ATH	*290 g*
Peroxide (Triganox C/Pergadox 16 mix)	*4 g*
Release agent (zinc stearate)	*2 g*
TOTAL:	*1,03 kg*

CED	**45,61 MJ**
CF	**2,41 kg CO_2 eq**

Raw materials: 78%
Conversion process: 22%

CONVERSION PROCESS

Figure 6: LCA of a glass fibre ladder rail produced by pultrusion.

The third example is an automotive spoiler made using carbon fibres and produced by the resin transfer moulding (RTM) process. The majority of the material components are available in the tool and only one (the epoxy-based MDA) had to be approached as proxy. However, since only a small amount of MDA is used in the formulation, the calculations closely represent the actual LCA values of the part (Figure 7). As in the previous example, an amount of production waste and waste resulting from cutting was included in calculations.

It is worth noting that when carbon fibres are used to produce the part, almost the entire environmental impact is generated by the raw material (carbon fibre) production and only about 1% relates to the conversion process.

MATERIAL RECIPE

Epoxy resin	*840 g*
Carbon fibre fabric	*1600 g*
Lantor surface veil	*100 g*
PU foam core	*1600 g*
MDA crosslinker	*560 g*
Release agent	*5 g*
Clear coat	*100 g*
TOTAL:	*4,805 kg*

CED	**2064 MJ**
CF	**97,32 kg CO_2 eq**

Raw materials: 99%
Conversion process: 1%

CONVERSION PROCESS

Figure 7: LCA of a carbon fibre car spoiler produced by RTM

The last example is a 6 kg automotive engine inlet manifold produced using polyamide (PA) 6.6 with short glass fibre reinforcement. As for the first example, since the production involves two distinct stages, firstly one should calculate the LCA for the production of the compound; later, this compound can be used to calculate the LCA associated with the production of the part by injection moulding. The recipe for making 1 kg of compound is shown in Figure 8. The LCA outputs of the compounding phase are then used as inputs for the second run of the analysis concerning the injection moulding phase of the 6 kg part. The tool finally provides the desired total values for CED and CHG. The Eco Impact Calculator database unfortunately does not detail a specific polyamide, with one single value encompassing the broad range of formulations ranging from PA 6, 6.6, 4.6 and 12 to the higher temperature grades of polyarylamides. Small amounts of stabilisers are also used to enhance durability at higher temperatures under extreme conditions.

COMPOUND RECIPE

Polyamide resin	*630 g*
Glass fibre chopped strand	*320 g*
Stabiliser	*50 g*
TOTAL:	*1 kg*

CONVERSION PROCESS

INJECTION MOULDING

COMPOUNDING (1 kg)

CED	95,76 MJ
CF	6,29 kg CO_2 eq

INJECTION MOULDING (6 kg)

CED	**732,76 MJ**
CF	**45,74 kg CO_2 eq**

Raw materials: 83%
Conversion process: 17%

Figure 8: LCA of a short glass fibre reinforced polyamide manifold produced by injection moulding.

A summary of the results of the analysis (normalised for the different components to the same weight of 1 kg) is shown in Figures 9 and 10.

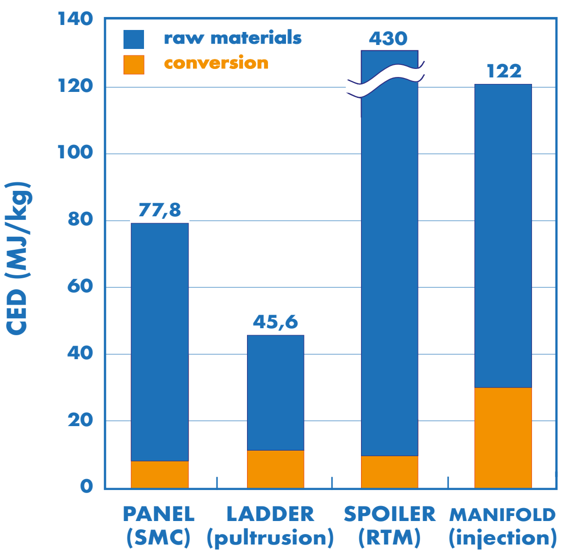

Figure 9: CED results of the different examples normalised to 1 kg mass.

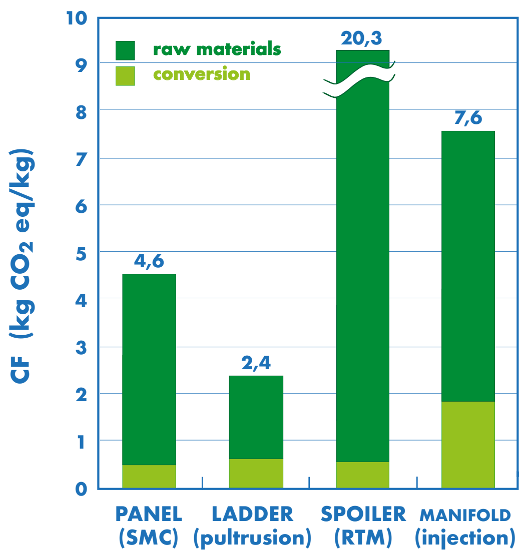

Figure 10: CF results of the different examples normalised to 1 kg mass.

5. OUTLOOK

Life cycle assessment of composites is becoming an essential requirement for material choices in a world that increasingly values a more sustainable society. To answer this need EuCIA developed the Eco Impact Calculator to enable LCA calculations by OEMs, institutes, academia, authorities and other interested parties. This will increase understanding of the utility of composites as well as enable comparisons with other materials in a multitude of applications. EuCIA is confident that the Eco Impact Calculator can help the composites industry to tackle the opportunities and challenges ahead.

In addition, it is important to continue to review the data used as well as fill gaps in materials and processes and update the tool as the needs of the industry evolve. Life cycle assessments are a continuous process and require our continued attention as new and improved materials and processes enter the market.

Finally, it is important to consider the disposal (end of life) of the products. The approach that increasingly dominates the European and world economic strategy is the so-called "circular economy", in which the traditional "linear" concept based on the typical "extract/produce/use/dispose" scheme exemplified in Figure 1 – that depends on the ready availability of large quantities of materials and energy at low prices – is modified into a cycle that closes on itself (Figure 11). The model of production and consumption is therefore radically transformed by involving the sharing, loan, reuse, repair, reconditioning and recycling of existing materials and products for as long as possible.

In this way, the life cycle of products is extended, helping to reduce the environmental impact of waste; once the product has finished its function, the materials it is made of are reintroduced, where possible, into the economic cycle. Thus, the materials can be continuously reused within the production cycle, generating additional value. With regard to the environmental impact in particular, as we have seen, the production processes of raw materials have a paramount impact in terms of energy consumption and greenhouse gases emissions. A more rational use of raw materials can therefore contribute on the one hand to limiting these factors, and on the other hand to give more continuity and security to the supply chain of the raw materials themselves.

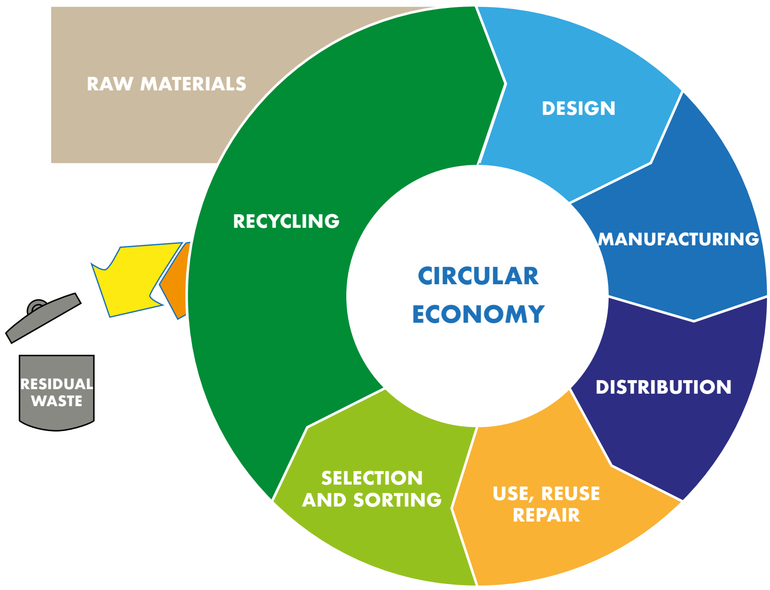

Figure 11: The circular economy workflow.

In a nutshell, it can be said that the fact that composite materials are very durable and damage resistant makes them the ideal materials for the circular economy because they lend themselves well to repair (if necessary), reuse in other structural applications, and to recycling.

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