Development of an LCA-Tool for the Composites-Industry

EuCIA Eco Calculator: Cradle to Gate LCA for Composite Parts

Dr. JHA van der Woude[1], Ir. Ben Drogt[2] and Prof. R. Frassine[1]

[1]EuCIA, European Composite Industry Association, 80 Bd. A. Reyers LN 1030 Brussels, Belgium
Email: j,vdwoude@home.nl; roberto.frassine@polimi.it, Web Page: http://www.eucia.eu/
[2]BiincCo, Punterweg 20, 8042 PB Zwolle, Netherlands
Email: ben@biinc.nl, Web Page: http://www.biinc.nl/

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Abstract
Composites are increasingly used due to their light weight, corrosion resistance, cost effectiveness and capability for engineered product applications. Often composites are uniquely enabling as well as imparting light weight thus reducing the eco impact during its service life.
Until recently a user friendly method for determining the environmental impact or Life Cycle Analysis for composite parts based on European averages did not exist. The European Composirtes Industry Association (EuCIA) has undertaken the effort, with assistance of EY CSS and Biinc, to develop a tool, to be used by "the average professional" in composite technology, without a deep knowledge of Life Cycle Assessments. The model uses among others industry-based databases from eco-inventories for glass fibers and fillers, a variety of resins, both thermoplastic and thermosets, and additives provided by European sector groups and associations. More data have also been collected from major converters to allow an estimate for the overall environmental impact. The methodology has followed the LCA Guidelines as described in ISO 14040 and 14044 standards. The tool is web based and accessible through EuCIA website. The paper will review the Tool, its capabilities as well as the potential to further include materials and processes of interest.

1. Introduction

Fiber Reinforced plastics, both thermoplastic and thermoset based, are increasingly used because of their excellent properties with both performance and economical potential. They are often enabling, like rotor blades for wind energy and provide unique light weight potential for transportation. In short they are an interesting family of engineering materials allowing a wide variety of properties and freedom of design due to the nature of the materials and the multitude of conversion processes[1]. Increasingly, environmental and societal drivers have become prominent features as to key impact environmental factors and consumer safety (Table 1).

Table 1. Trends and Drivers For Fiber Reinforced Composites.

Economical & Performance	Environmental & Societal
Light Weight	Climate Change
Installation Cost	Energy Efficiency
Chemical & Heat Resistance	Emissions
Durability & Longevity	Sustainability
Maintenance	Re-use, Recycle, Renewable
Freedom of Design	REACH
Mechanical Properties	Food & Water Contact

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Life Cycle performace is a key feature of materials including its manufacturing, service life as well as end of life. A typical Fiber Reinforced Plastics life cycle is shown in Fig. 1. It shows that the manufacturing of a part can be measured in “days” or “weeks”, but that service life extents potentially over decades, where the benefits, both economic and environmental, of composites are harvested.

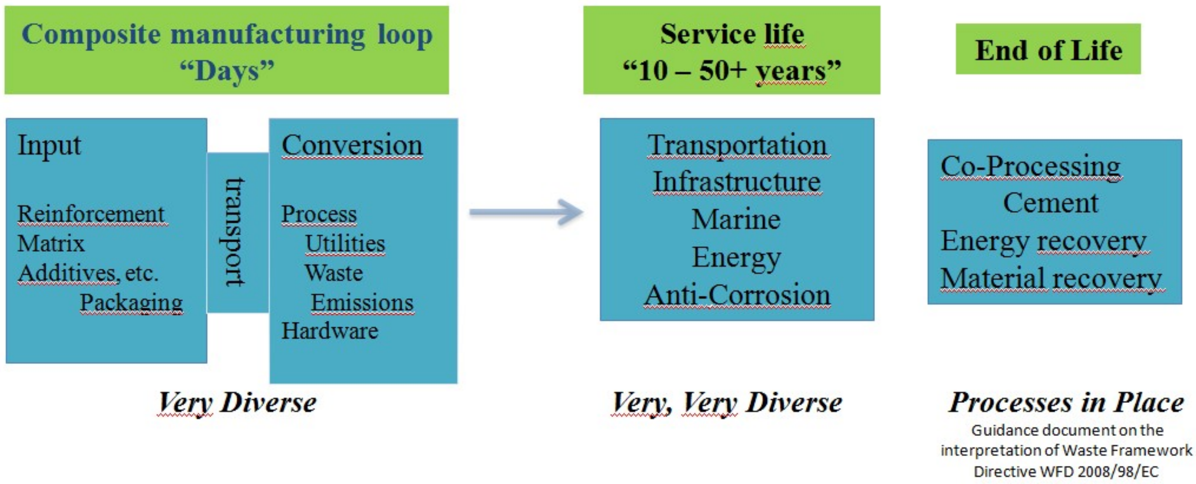

Figure 1. Fiber Reinforced Plastics Life Cycle

Clearly, the variety and form of fibers, fillers, resins, additives and processes available to the composites industry allow for a high degree of diversity of ways to make parts, which by itself are used in an even broader diverse way into service life. After many years parts can be processed into a new, sometimes different life for which processes have been defined and accepted[2].
Part users, often OEM’s, understand very well the environmental impact of the use of composites. Life cycle performance analysis is therefore increasingly used as a tool to select materials to support engineering and design. This often includes the need to understand the environmental impact of the manufacture of the composite part itself. Most manufacturers however will encounter difficulties if asked to produce the requested data. A user friendly method for determining the environmental impact for composite parts did not exist until recently. In light of future developments it is however essential to have such a method to allow composite part producers and OEM’s to compare the impact of the materials at his service to support adequate decision making during the engineering process.
EuCIA, has therefore undertaken the effort, with assistance of EY Cleantech and Sustainability Services and BiincCo, to develop a cradle-to-gate Eco Impact Calculator Tool, that can be used by “the average professional” in composite technology, without deep knowledge of full Life Cycle Assessments or LCA’s. The model uses existing and recently developed industry databases in addition to other material data from EcoInvent 3.1, for glass fibers, a variety of resins, both thermoplastic and thermosets, fillers and additives and handles also intermediate processes. EU based data have been collected for the main conversion processes the composite industry is using to allow an estimate for the overall environmental impact. The methodology has followed the LCA Guidelines as defined in ISO 14040 and 14044 standards. A formal LCA if warranted through proper peer reviews could be possible (Environmental Product Declaration or EPD). The tool is web based and accessable through EuCIA.
In this paper, we will shortly define the concept of LCA, describe the features of the EcoCalculator Tool, provide an example of typical key impact factors and summarize with an outlook.

2. Life Cycle Analysis

The method of LCA (Life Cycle Assessments) is a standardized procedure that allows the environmental damage – also termed footprint – related to a product, a process or a service to be quantified within a very specific context. From an operative standpoint, the assessment requires

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definition of objective and scope of the investigation. This first phase is followed by the so-called "inventory analysis", which analyzes the flow of material and energy of the different steps of the manufacturing process taking into account also the benefits. Once all balances are ready, the environmental impact analysis itself is performed, which identifies and quantifies the potential environmental effects and provides essential information for the final evaluation. The procedure is not only based on the energy and mass balances and the assessment of risk, but also on other contributions as moral principles, technical feasibility and socio-political and economic aspects. LCA Guidelines are contained in ISO 14040: 2006 and 14044: 2006. The main types of analysis are:

• Cradle-to-gate: this type of analysis is limited to the "gate" of the factory, i.e. before the item is transported to the consumer. One of the most important output of this approach is the preparation of the "Life Cycle Inventory" (LCI)
• Cradle-to-grave: a complete LCA that starts from raw material production to its use and disposal
• Cradle-to-cradle (closed circuit production): it is an extension of the cradle-to-grave LCA in which the disposal of the product is replaced with recycling.

3. EcoCalculator Tool

The EcoCalculator tool provides an easy way to calculate the environmental impact of composite products in terms of Global Warming Effect (CO_2 equivalent), cumulative energy demand and ILCD (International Reference Life Cycle Data Systems) indicators. The tool enables the calculation of the environmental impacts from “Cradle to Gate”: it includes raw materials, processing and waste impacts up to the points of sale to the end-user. The use phase of the composite products as well as the end-of-life phase is not part of the tool (Fig. 2).

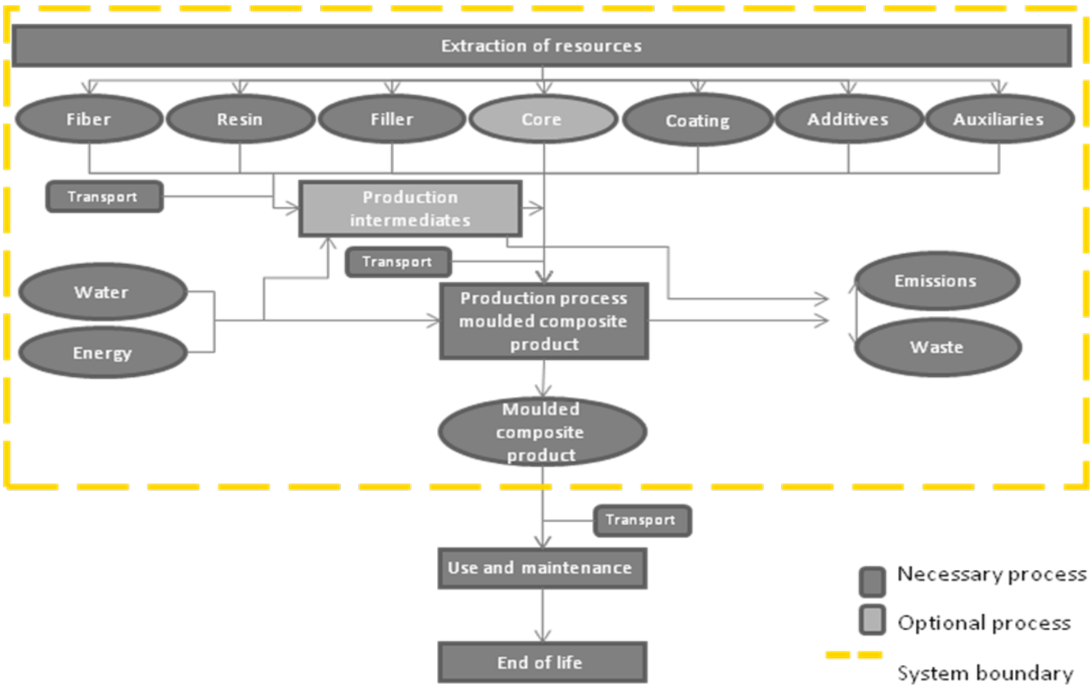

Figure 2. System Boundary: Cradle to Gate

The tool incorporates a pre-defined set of materials and processes, but is also open to proprietary data or special processes as well, to generate the most possible accurate results for specific products. The pre-defined conversion process data have been obtained from the European industry through questionnaires that were filled out by manufacturers for their respective processes. The questionnaires include material, water and energy use, emissions and both hazardous and non-hazardous waste. The processes targeted include RTM, SMC and BMC compounding and pressing, TP compounding and

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injection molding, GMT pressing, centrifugal casting, spray-up, pultrusion, filament winding, resin infusion, hand lamination, pre-preg autoclaving and casting marble stone, thereby including most (estimated 90 – 95%) of the composite industry processes. Conversion processes have been added to the tool based on a minimum of three inputs per process. All data have been treated under strict confidentiality. Data collection is seen as a continuous activity, striving to maximize the quality of the European process average, entering missing material data, as well as in realizing that over time footprint indicators may evolve or change. Therefore, more processes and materials are targeted at this stage of development.
Companies using the tool can enter data and logo, and results and products can be stored to allow for later use. The results can be printed out in the form of a personalized Eco Impact Report, including CO_2 emissions, cumulated energy demand and ILCD indicators as well as a summary of input data such as materials used and conversion process data, to be shared with customers and relations. Important here to stress is the option to use the output as input for further processing by third parties if warranted. At present, data can be stored in a SimaPro 8.0.2 compatible Excel format, and more options will be available in the future making the tool also suitable for reusable material as well as semi-finished product.

4. Example

The results of a typical example of a composite product, a 5 kg pultruded profile including fiber glass, filler, orthophtalic UP resin, accelerator and release agent is presented in an Eco fact sheet or report of which excerpts are shown below. Accelerator and release agent are entered as typical model chemicals at this point. The report will contain general information: date, company profile, product and functional unit and a content declaration informing that the report is a cradle to gate LCA and that the analysis contains all components present in more than 1% m/m. The LCA calculation rules are explained i.e. the system boundary and the use EcoInvent 3.1 as well as of SimaPro 8.0.2, and it is made clear that the report as such is not an Environmental Product Declaration or EPD as this would require if warranted peer reviewing. For this typical case, a 5 kg pultruded profiler the Carbon Footprint is presented in fig. 3.

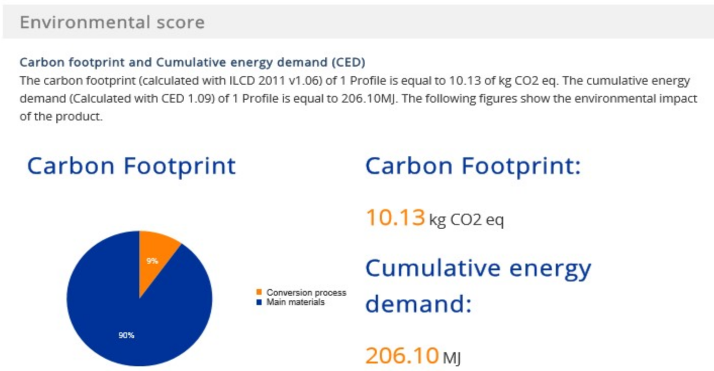

Figure 3. Carbon footprint and CED for a 5kg pultruded profile.

As can be seen the CO_2 material and process are separately shown. In addition the ILCD indicators are shown and the methodology referenced (Fig. 4).

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The International Reference Life Cycle Data Systems (ILCD)

The total score of 1 Profile is calculated with the ILCD 2011 midpoint+ (v1.06) methodology.

Category	Amount	Unit
Climate change	1.01e+1	kg CO2 eq
Ozone depletion	1.22e-6	kg CFC-11 eq
Human toxicity, non-cancer effects	5.95e-7	CTuh
Human toxicity, cancer effects	1.48e-7	CTuh
Particulate matter	4.10e-3	kg PM2.5 eq
Ionizing radiation HH	2.96e+0	kBq U235 eq
Ionizing radiation E (interim)	3.10e-3	CTUe
Photochemical ozone formation	9.59e-2	kg NMVOC eq
Acidification	3.93e-2	molc H+ eq
Terrestrial eutrophication	8.18e-2	molc N eq
Freshwater eutrophication	3.01e-4	kg P eq
Marine eutrophication	8.55e-3	kg N eq
Freshwater ecotoxicity	6.12e+0	CTUe
Land use	5.79e+0	kg C deficit
Water resource depletion	2.02e-2	m3 water eq
Mineral, fossil & ren resource depletion	1.46e-4	kg Sb eq

Figure 4. ILCD Indicators of example

As already mentioned, a summary report is produced including the EU average data for the use of energy, water, emissions, waste and packaging for this part as well as the materials recipe, all of them available for post-processing as well.

5. Conclusions

A web-based EcoCalculator tool has been developed by EuCIA to allow industry and academia to calculate the cradle to gate LCA of a composite part in the form of ILCD indicators. The tool, available through EuCIA website, is based on pre-defined EU based conversion processes and uses EcoInvent 3.1 material data, while following ISO 14040 and 14044 standards. The tool can be used without in-depth knowledge of LCA processes and – although being still a work in progress – it is fully functional and capable of analysing the majority of composite parts in the market today. Continued addition of process and material data is planned to broaden its application fields.

The tool is intended to provide engineers and designers environmental input data to make reliable material decisions for their ultimately intended use. At present, the tool can be used free of charge, but over time a small annual fee to cover maintenance is foreseen.

We hope that the composite industry, and consequently the society as a whole, could gain better understanding and confidence on the benefits and potential of composites, thanks to accurate and reliable calculation of their environmental footprint.

Acknowledgments

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