EuCIA Eco Impact Calculator

Background report

Version 1.4

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Building a better working world

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1 Executive summary

EuCIA is the Brussels - based leading Association of the European Composites Industry, representing European National composite Associations as well as industry specific sectors. Over 10.000 companies and an estimated 150.000 employees are actively involved in composite products manufacturing across Europe.

One of the focus areas of EuCIA is the notion that composites can contribute to a more sustainable society. The best methodology for quantifying environmental impacts of products is Life Cycle Assessment (LCA). However, development and use of LCA in the composite industry is low in comparison to other sectors. The execution and reporting is very time consuming and expensive: it requires specialized software and expertise as well as independent verification of data and methodology. For small companies this is not affordable, especially as products are very diverse and production series often small. This is the main reason why in 2015, EuCIA has asked EY Climate Change and Sustainability Services (EY CCaSS) to develop the Eco Impact Calculator tool for composite products.

The main objective of this tool is to provide the possibility of making a calculation of the impact of composite products without having specialized knowledge on environmental impact calculations: The tool is designed to enable non-specialists to make an environmental impact calculation of their composite products. The tool calculates the environmental impact of a composite product from cradle to gate, hence including the raw materials, transport, processing and waste generation up to the point-of-sale.

The project was launched with a kick-off in May 2015, and an working group and steering committee with industry representatives were appointed to ensure an efficient process with a high-quality result. To build the Eco Impact Calculator data on materials and processes was gathered and/or developed. Together with the working group, the main materials and processes used by the European composites industry were identified, resulting in a list of 43 materials and 8 conversion processes.

The 43 selected materials were matched with available data in the EcoInvent 3.1 database, or modelled using available proxies. This will provide the user with the ability to generate many different material compositions of composite products.

In parallel, a questionnaire was developed to obtain data on the conversion processes. This questionnaire was distributed through EuCIA to all national composite sector organizations in Europe, which in turn have passed it on to their members. The data on material and energy flows related to the conversion processes for European composite manufacturers were collected by EY using the questionnaire. When at least three complete data-sets are received for a conversion process, the available data-sets of individual producers are averaged to generate an EU representative data-set for each conversion process, ensuring adequate representation as well confidentiality for the composite manufacturers.

The aim of EuCIA is to include the 17 conversion processes which are estimated to cover over 95% of the production processes used by the European composites industry, however due to lack of data provided by the industry only eight processes could be incorporated in the first version of the Eco Impact Calculator: 5 based on industry data and three based on comparative modelling (see below). EuCIA and EY CCaSS are putting continuous efforts in expanding and improving the data on conversion processes. Apart from the pre-set processes the tool can be used to tailor the conversion process as is needed: a bill of materials solely, a modified process and a process based on own input data.

The calculation follows from the inputs given by the user by selecting one or more of the 43 materials currently available in the tool, and consequently using these materials as input for the conversion processes. To facilitate the user the tool includes a number of subsequent screens with pull down menus.

The output of the tool is available in an Eco Report (PDF) which contains the results of the environmental impact calculations in three indicators according to three impact assessment methods: Carbon footprint (kg. CO_2 eq.), Cumulative Energy Demand (MJ) and ILCD (16 impact categories). Additionally, the tool has the unique functionality of generating a SimaPro CSV file, which can be used by downstream stakeholders to import into their SimaPro LCA software to further facilitate environmental impacts assessments of assemblies containing composite products. A similar solution was foreseen for Gabi LCA software but this turned out to be impossible at this moment due to compatibility issues.

The calculations and modelling used in the tool are based upon LCA standards and guidelines, however full compliance has been left out-of-scope for this version of the tool, since e.g. independent verification of all materials and processes in the tool would compromise the feasibility of this version of the tool. The output as desired by the EuCIA is very similar to the so called Environmental Product Declaration (EPD) or Type III environmental declarations, a way to communicate LCA results in a transparent, dense format. The development of such a declaration is described in ISO 14025. Following the complete procedure is out of scope for this project but it has provided useful additional guidance to enhance quality, reliability and transparency.

The tool is made available online (http://ecocalculator.eucia.eu) and will be available free of charge until further notice.

2 Introduction

2.1 Background

EuCIA is the Brussels - based leading Association of the European Composites Industry, representing European National composite Associations as well as industry specific Sector. More than 10.000 companies and an estimated 150.000 employees are actively involved in composite products manufacturing across Europe.

The composites industry is characterized by a large number of small manufacturing companies that produce composite products in small series or as one-off products. The clients of the composite industry include large multinational companies such as the automotive sector and composite products are used in large building and infrastructural projects. The suppliers to the composite product manufacturing sector are also mostly large companies.

In all sectors the pressure on sustainable performance is increasing. National and European initiatives (like the EU Product Environmental Footprint (PEF) Guide) promote the development of standards and product specific guidelines. More and more the suppliers of materials and components are asked to come up with detailed information on the Life Cycle performance of their products or components. The industry that produces the end products frequently uses Life cycle Assessment (LCA) data to improve the environmental performance of its products. Increasingly information on environmental impacts is used in external communication as well as in supply chains, both up- and down-stream. This means the provision of such information is becoming more and more important.

One of the focus areas of EuCIA is the notion that composites can contribute to a more sustainable society. However, development and use of LCA's in the composite industry is low in comparison to other sectors. The official method for executing and reporting LCA's is time consuming and expensive: it requires special software and specialized consultants. For a small composite manufacturing company this is not affordable, especially as products are very diverse and production series often small. This is the main reason why in 2014, EuCIA has initiated this project for the development of an Eco Impact Calculator tool for composite products and components.

The main objective of this tool is to provide the possibility of making a calculation of the environmental impact of a composite product without the specialized knowledge on LCA's. The tool calculates the environmental impact of a composite product from cradle to gate.

2.2 Initiator

EuCIA represents European National composite Associations as well as industry specific Sector Groups. Their main mission is representation of National Composite Associations, targeting end-segments sectors or potential product groups or processes at EU level. The mission of EuCIA is structured in 3 pillars:

- We Know, Industrial education and sharing of best practices
- We Show, Being active at EU level and influencing decision making
- We Grow, Industrial growth and membership expansion across Europe

2.3 Execution and responsibilities

2.3.1 Team

As the success of this project is dependent on a lot of different companies in different countries, the project group consists of several country representatives.

2.3.2 Steering committee

The steering committee is the entire project group who makes sure the project is going in the right direction. The committee consists of the following people:

- Jaap van der Woude, Chairman, (formerly) PPG
- Axel Jorns, GlassFibreEurope
- Benedikte Jørgenson, Dk Composite Association
- Christian Wiedergut, Flowtite Technology
- Julie Leroy, EuCIA
- Lilian Maginet, EuCIA
- Elmar Witten, AVK
- Volker Mathes , AVK
- Andrew Walker, CEFIC-UPR
- Ben Drogt, BiinC
- Roberto Frassine, EuCIA / Assocompositi
- Victor Vladimirov
- Guy Castelan, Plastics Europe
- Caroline Léonard, 3B

2.3.3 Action group

For the operational decisions an action group was set up.

- Jaap van der Woude, Chairman and overall project manager
- Ben Drogt, Technical expert on composites, Biinc
- Ramaka Grund, IT project leader, EY
- Alexander van der Flier, Project management, EY
- Arno Scheepens, Project content, EY

The action group performs the practical work and communicates status updates and important decisions to the steering committee. This report has been prepared by Arno Scheepens under supervision of Michel van Wijk as well as the action group.

2.3.4 Project team EY

The execution of the project is supervised by Michel van Wijk. The full team of EY who works on this project consists of:

- Arno Scheepens
- Alexander van der Flier
- Ramaka Grund
- Dion Engels
- Anjelika Romeo-Hall
- Roy Veugen

2.4 Project approach

The envisaged project approach was to first collect the data for the materials and processes, and consequently build the tool incorporating the data and calculation methodology into the ICT tool. However during the project it turned out to be quite difficult to obtain the data, especially for the conversion processes, which led to the decision during the project to build the tool and collect the data simultaneously. So this meant that the tool was first built and then filled with the available data. Though this is not ideal, this was the only way to build the tool and meet the deadline for launching the tool for the industry in the 2nd quarter of 2016.

3 Goal and scope

This chapter discusses the goal and scope of the study. It also discusses the functional unit and the choices concerning allocation, system boundaries and assessment methods.

3.1 Goal

The goal of this project is the development of an Eco Impact Calculator tool including a tailor made dataset for the composite industry and a report on the LCA methodology and developed data.
The tool has to provide a reliable calculation of the ecological impact. This means that both the underlying data as the way that the data is processed is reliable. The tool comes with initially 5 years of support. EY will select the best available data and adjust existing datasets where required. The calculation methods will comply with international standards and guidelines. Primary users are the people working at the composite component manufacturers in production, product development, R&D etc. They have technical knowledge of composites but limited knowledge on LCA or calculating environmental impacts.

This means that the variables that the users can choose are all technical, not environmental. The interface is self-explanatory (no or short instruction needed) and easy and quick to use. The main objective of the tool is to make a reliable calculation of the ecological impact of a composite part.

The output of the tool will have the quality level that it can be used in downstream LCA analyses and is based on ISO 14040/44. The output is very similar to the so called Environmental Product Declaration (EPD) or Type III Environmental declarations, a way to communicate LCA results in a transparent, dense format. The development of such a declaration is described in ISO 14025. The results of the tool can however not be used as an official EPD, since the approach, methodology and data used for the current version of the tool has not been independently verified.

The target audience of this study is first of all EuCIA, the Association of the European Composites Industry, representing European National composite Associations as well as industry specific Sector Groups which in turn represent individual companies in the composites industry. In addition all composite part practitioners, like OEM’s, academia as well as the public in general, are targeted. The results of this project can be used to supply the users of the tools mentioned above with the company specific data of the composite panel of this study.

3.2 Functional unit

The functional unit of the environmental profile that the Eco Impact Calculator Tool will provide is the production of a composite product, with or without core, shaped to its final dimensions and painted if applicable. The products for which the users of the Eco Impact Calculator Tool will make an environmental profile have a broad variety in compositions, sizes and shapes. The tool contains environmental data for the production of 1 kg product. By filling out the amounts used, the Eco Impact Calculator will calculate the environmental profile for a specific product.

3.3 System boundaries

The process flow diagram below shows the life cycle phases included in the study and the system boundaries of the life cycle as assessed. The system boundary determines the unit processes that are included in the life cycle of the product system in this study. The boxes with the light grey background can optionally be included in the life cycle of the product system. The production of the used machines, moulds (also if they are only used once) and use of brushes etc. are not part of the calculation The assessments are performed cradle to gate, excluding the Use-phase and End-of-Life phase as well as transport to the client. The system boundaries and the included materials and processes for the tool are shown in Figure 1.

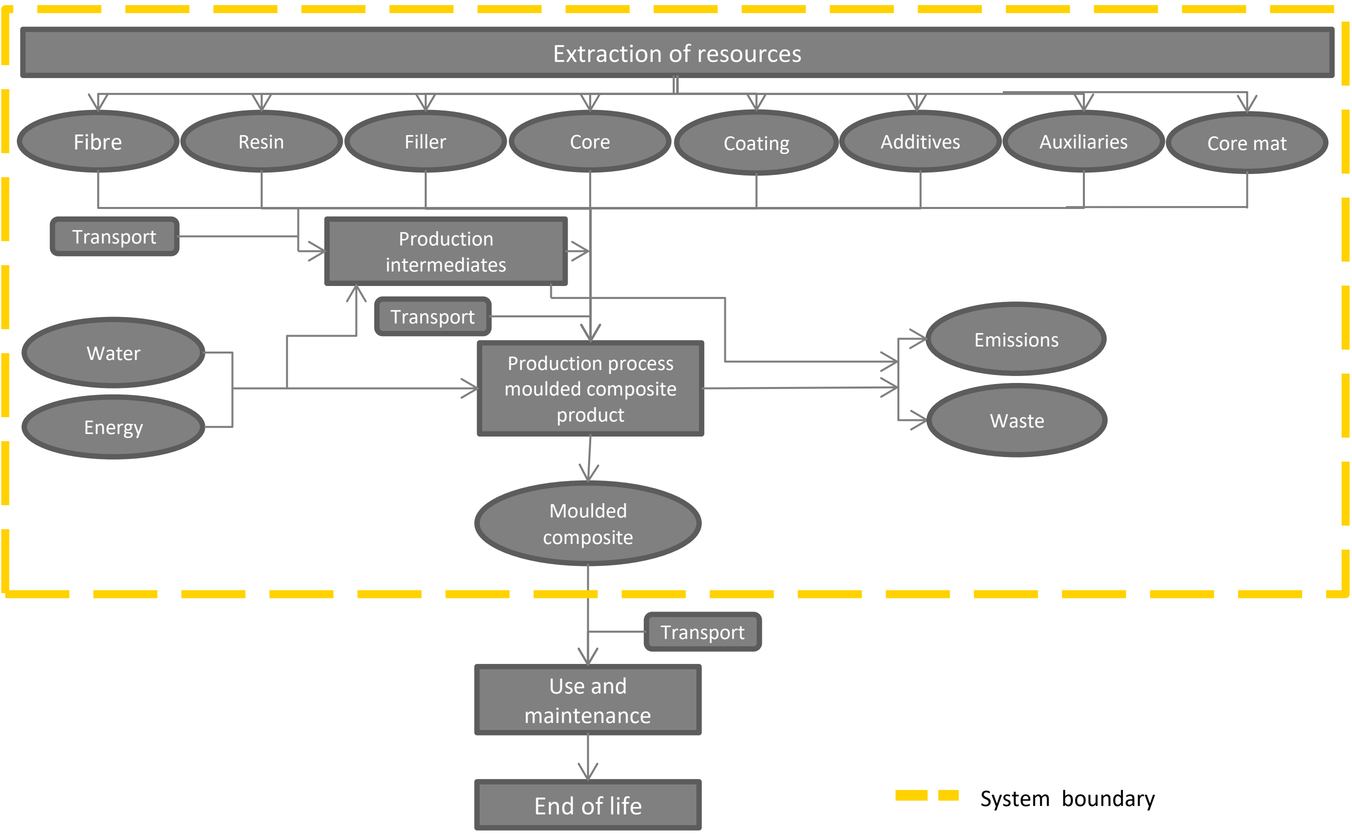


Figure 1: System boundaries for the materials and processes in the Eco Impact Calculator

4 The Eco Impact Calculator

This provides background information about The Eco Impact Calculator tool and its calculation methods.

4.1 Structure

The tool is structured in such a way that non-experts can use the tool easily to make environmental impacts assessment of their composite products from cradle to grave. The high-level tool architecture is depicted in Figure 2.

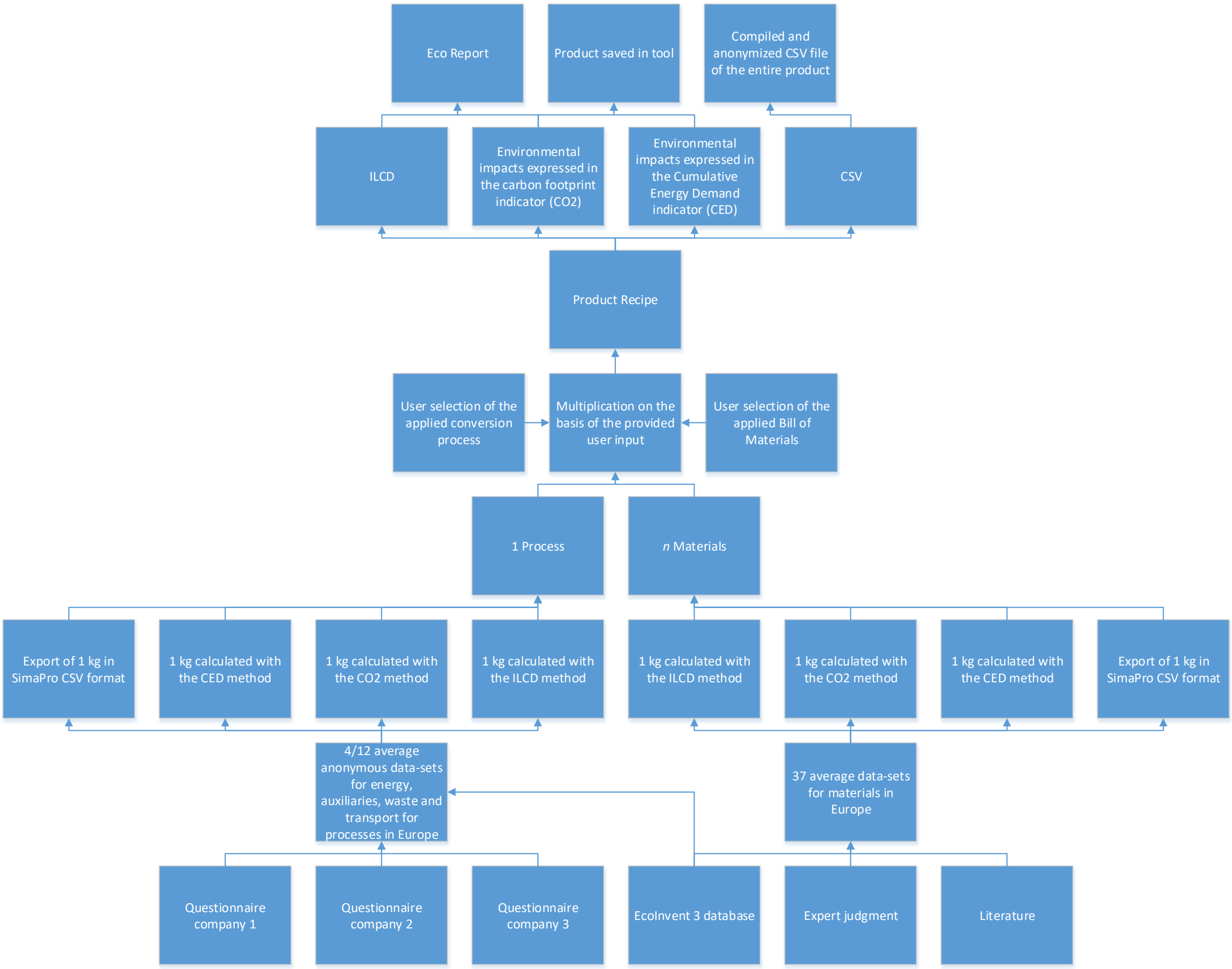


Figure 2: Tool architecture

4.1.1 Input

There are two different types of input for the tool. User input and input data. User input is described as the technical information of composite product manufacturing, and is provided by the users of the tool. The input data for the tool is two-sided. On the one hand there is the data for the conversion processes themselves, and on the other there is the data on the materials. For the materials, 1 kg is modelled based on the available processes in the EcoInvent database enriched through expert judgement and literature. For some materials, proxy selection was required, of which the details can be found in Chapter 6. The materials were thereafter run through LCA software for three different assessment methods: The GHG protocol, Cumulative Energy Demand and International Reference Life Cycle Data System (ILCD). The results are transferred to the tool library (materials section). During the data collection process, several decisions are made concerning the materials in consultation with the Action Group. Chapter 6 shows a full list of the available materials in the tool in combination with the related database processes.

For the conversion processes, 17 processes have been identified that are able to cover most of the composite manufacturing companies in Europe. Due to the limitations relating to confidentiality and unexpected low data submission, for 5 processes enough questionnaires or industry data were received to be part of the first version of the tool. 3 processes have been modelled on basis of process analysis for energy and in comparence with existing EcoInvent process data the other impact categories.
The data delivered through the questionnaire is on energy use, waste, emissions excluding the materials, since these are separately provided in the materials database. The units for the data (e.g. kWh electricity) are also pre-calculated through LCA software for three different assessment methods. The results are transferred to the tool library (conversion processes section), and in the tool are multiplied by the average "score" for each unit to enable the user to calculate the environmental impacts of a specific process. The tool is structured this way in order to allow the user to input their own data as well for any conversion process they like.

4.1.2 Output

The output of the tool consists of an on-screen calculation of the environmental impacts of any product entered in the tool. Additionally users are able to download a PDF Eco Report, describing in detail the environmental impacts and how these are calculated. The products that are entered in the tool are automatically saved for further reference or recalculations etc.

Special attention is paid to the development of an export functionality. This export functionality is intended to facilitate easy communication of the detailed environmental data without compromising confidentiality, with clients of the composite industry. A SimaPro-CSV file can be generated for each calculated product, which can be imported directly by the client. It was attempted to include a file for GaBi users as well, however due to technical difficulties this has not been achieved.

In the future, saving the products in the tool and the PDF and SimaPro-CSV download options will be subject to a membership fee.

4.2 Life cycle inventory

EY has assessed which materials and processes are available in the European databases EcoInvent, European reference Life Cycle Database (ELCD) inlcuding those developed by Plastics Europe. Besides that EY has used the data that EY generated in previous LCA studies in the composite sector. The main objective is to try and obtain LCI data from EcoInvent where possible, to maximize consistency and comparability within the tool. For the materials for which data is not available, where possible, EY will collect, estimate or find proxies for data, with the help of literature and expert opinions.
For each production process EY will collect data on the production of a composite product from manufacturers in Europe. The manufacturers are requested, using a questionnaire, to provide data.

Input and output data are collected on the following categories:

- Use of resources
- Emissions to air

- Discharges to water and soil

The non-elementary flows energy and waste are also included in the data inventory.

4.3 Data quality

The material, waste and energy flows for production processes in Europe are based on foreground data of one year between 2010 and 2014. The data is thus relevant for production in Europe. The manufacturers are asked to provide at least all data that are included in their environmental licence. For some essential composite production processes, no industry data was provided to enable the calculation of impacts in the EcoCalculator. This required calculation of several processes, the quality of which is elaborated upon in Section 0. For the materials, background data is used as input for the tool wherever possible.

4.4 Allocation

Allocation is the split of environmental flows between two or more products or processes. This occurs with multi-input, multi-output, reuse and recycling processes.

- Multi-input and multi-output processes are not part of this study, hence no allocation is used. The end of life stage is not included in this LCA.

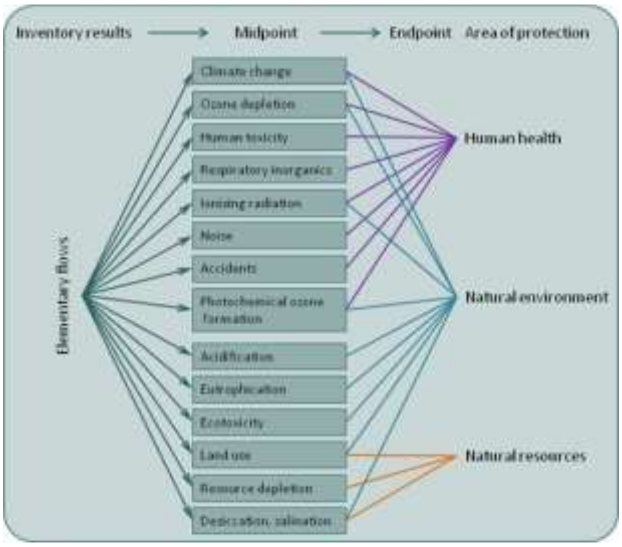
4.5 Impact assessment methods

Three environmental impact assessment methods have been selected for this project. Each data point used for calculation of the final product entered in the tool, is calculated according to the following environmental impact assessment methods:

- International Reference Life Cycle Data System (ILCD) 2011 Midpoint+ V1.06 / EU27 2010, equal weighting
- Greenhouse Gas Protocol V1.01 / C02 eq (kg)
- Cumulative Energy Demand V1.09 / Cumulative energy demand

These impacts assessment methods are continuously evolving. Therefore it is recommended to update the calculations upon releases of new impacts assessment methods (e.g. adapted characterisation factors). As of September 2019, V1.10 is used for the Cumulative Energy Demand method as V1.09 was not longer accessible.

4.5.1 International Reference Life Cycle Data System (ILCD)



The ILCD provides a common basis for consistent, robust and quality-assured life cycle data, methods and assessments. This so-called Life Cycle Impact Assessment (LCIA) considers multiple impact categories that influence human health, natural environment and natural resources. The emissions and resources derived from a Life Cycle Inventory are assigned to each of these impact categories. They are then converted into indicators using factors calculated by impact assessment models. These factors reflect pressures per unit emission or resource consumed in the context of each impact category.

The development of the ILCD was coordinated by the European Commission and has been carried out in a broad international consultation process with experts, stakeholders, and the general public. **More information can be found on the website of the European Platform on Life Cycle Assessment.**

The impact categories included in the Eco Impact Calculator follow the International Reference Life Cycle Data System (ILCD) 2011 Midpoint+ V1.06 / EU27 2010, equal weighting. They are listed below:

Impact category	Unit
Climate change	kg CO2 eq
Ozone depletion	kg CFC-11 eq
Human toxicity, non-cancer effects	CTUh
Human toxicity, cancer effects	CTUh
Particulate matter	kg PM2.5 eq
Ionizing radiation HH	kBq U235 eq
Ionizing radiation E (interim)	CTUe
Photochemical ozone formation	kg NMVOC eq
Acidification	molc H+ eq
Terrestrial eutrophication	molc N eq
Freshwater eutrophication	kg P eq
Marine eutrophication	kg N eq
Freshwater ecotoxicity	CTUe
Land use	kg C deficit
Water resource depletion	m3 water eq
Mineral, fossil & ren resource depletion	kg Sb eq

4.5.2 Cumulative Energy Demand

Cumulative Energy Demand (CED) is the total measure of energy resources necessary for the supply of a product or a service. The CED specifies all non-renewable (i.e, fossil & nuclear energy) and renewable energy sources as primary energy values. Since the very first LCA studies, the cumulative energy demand CED (also called ‘primary energy consumption’) has been one of the key indicators being addressed. It includes the following impact categories:

Impact category	Unit
Non-renewable (fossil)	MJ
Non-renewable (nuclear)	MJ
Non-renewable (biomass)	MJ
Renewable (biomass)	MJ
Renewable (wind, solar, geothermal)	MJ
Renewable (water)	MJ

4.5.3 Greenhouse Gas Protocol

The Greenhouse Gas (GHG) Protocol is a multistakeholder partnership of businesses, non-governmental organizations (NGOs), governments, and others convened by the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD). Launched in 1998, the mission of the GHG Protocol is to develop internationally accepted greenhouse gas (GHG) accounting and reporting standards and tools, and to promote their adoption in order to achieve a low emissions economy worldwide.

The GHG Protocol follows a broad, inclusive, consensus-based multi-stakeholder process to develop these standards with balanced participation from businesses, government agencies, non-governmental organizations, and academic institutions from around the world.

In the Eco Impact Calculator the following CO2 impact categories are included:

Impact category	Unit
Fossil CO2 equivalent	kg
Biogenic CO2 equivalent	kg
CO2 equivalent from land transformation	kg
CO2 uptake	Kg

5 Conversion processes

The conversion processes are the production processes of composite parts. The production processes are modelled on the basis of primary information of European composites manufacturers retrieved through questionnaires, unless industry has not been able to deliver data for the development of the tool. In these cases, where the conversion processes are deemed essential for the development of the tool, these processes have been modelled, see section 0.

The ultimate aim of EY and EuCIA is to include at least 16 moulding processes which have been identified as representative for the conversion processes used in the European composites industry. From the received questionnaires, five processes could be modelled, since the minimum of received data-sets required for incorporation of processes in the tool is set to 3 in accordance with the action group and steering committee. The processes are averaged based on the minimum of 3 questionnaires of separate European composite manufacturers using the specific process, to ensure data quality as well as anonymity.
The following processes are currently included in the tool:

- Pultrusion
- Resin infusion (RI)
- Resin transfer moulding (RTM)
- SMC compounding
- SMC compression moulding
- Thermoplastic compounding [1]
- Long Fibre Thermoplastics compounding [1]
- Thermoplastic injection moulding [1]

Painting and gel coating are included in the materials, since the material cannot be applied without these processes, and cutting is integrated on the basis of cutting length. Overhead is not included in the calculations of the tool, rather it is used to enable allocation of remaining inputs and outputs. 1 intermediate product has been prepared for the tool.

The conversion processes that EuCIA still wants to include in the Eco Impact Calculator are:

- Centrifugal casting
- Filament winding
- Spray-up
- Pre-forming
- Pre-preg autoclaving
- BMC compounding
- BMC injection moulding

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[1] Modelled processes based on calculations

5.1 Modelled conversion processes: TP compound, TP Injection moulding and Long Fibre Thermoplastics compounding

For most conversion processes the EcoCalculator development team and partners were unable to obtain data from industry on the production process in- and out-puts in the questionnaire developed for this purpose. Therefore, for key industry processes, such as injection moulding, EuCIA has decided to model these processes in the tool using publicly available data and existing data-sets in EcoInvent. This section describes how calculations are combined with existing data and data-sets to arrive at modelling on first principles basis of the most important conversion processes currently missing in the tool. These processes are Thermoplastic compounding, thermoplastic injection moulding and LFT. The below paragraphs describe the calculation and modelling approaches for each of these conversion processes frequently used in the European composites industry.

5.1.1 Conversion of Glass Fiber and Thermoplastics into compounds and parts

Conversion of thermoplastic resins and reinforcement fibers and fillers either by extrusion or LFT processes into compounds and consequently by molding into parts are key technologies. Over 90% of the materials used is based on three base resins, polyamide, polypropylene and polyester reinforced with fiber glass, often in combination with small amounts of key additives. These resins as well as glass fiber form the center piece of this analysis.

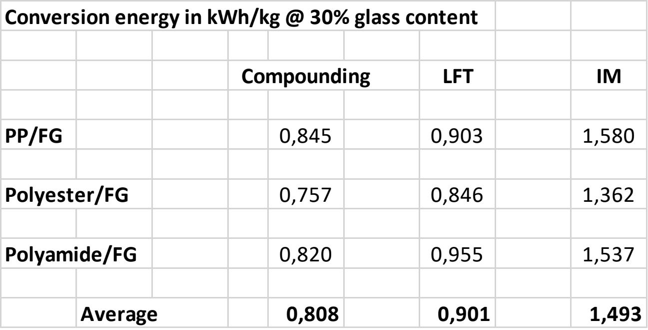
The EcoCalculator calculates Eco Factsheets for composites and compounds based on industry generated quality data as well as eco inventories in a transparent way following ISO 14.040/044 standards. Regrettably in this case industry based data have not come available. This has prompted EuCIA to take a different approach: modeling of the compounding and molding processes on first principles following of course real industry practice. This has been done for energy as thermodynamic data are known for these materials. The result is referenced with data available from EcoInvent that match the processes for compounding and injection molding. The model for compounding and LFT includes heating and melting of the resins as well as the heating for the glass fiber, followed by cooling of the strand and processing into granulate. For the molding process the energy to heat and inject and the cooling is obtained from literature data. Heat losses and the energy for auxiliary equipment were based on reasonable assumptions. These include higher losses at higher glass content, compensating for the lower throughput. The heat losses for LFT were assumed to be higher as the temperatures are higher and throughputs lower at a given glass content. In all cases the most conservative approach was taken: either the data as calculated i.e. compounding or as in the inventory i.e injection molding, whichever was the highest. The model data were then adjusted as such. This analysis has resulted in some interesting results. Table 1 below presents the total energy data calculated for polypropylene:

	Compounding	LFT	Injection Moulding		
Fiber content (%)	*Total all electric (kWh/kg)*	*Total all electric (kWh/kg)*	*Total all electric (kWh/kg) extrapolated*	*Total natural gas (m3/kg) extrapolated*	*Total LPG (l/kg) extrapolated*
20	0,864	na	1,4894	0,1339	9,484E-03
30	**0,845**	**0,903**	**1,4783**	**0,1329**	**9,413E-03**
40	0,824	0,887	1,4586	0,1311	9,288E-03
50	0,801	0,866	1,4302	0,1285	9,107E-03
60	0,775	0,841	1,3931	0,1252	8,870E-03
70	na	0,812	1,3472	0,1211	8,578E-03

Table 1. Total energy data calculated for polypropylene for the different thermoplastic conversion processes. The amounts for 30% glass fiber content have been applied as energy values in the tool.

It can be concluded that the variation in energy needed for each process is very small. For instance for compounding all data lie within +/- 10% of the 30% G/F value. Given this observation it is concluded that only one value for PP compounding suffices in the model given the assumptions in the model itself. Another observation is the small contribution of the conversion process compared to the CED of the resins. The CED for polypropylene, polyester and polyamide are 76, 83 and 131 MJ/kg respectively. The CED for glass fiber is 27 MJ/kg.

Table 2 below, shows that the variation between the resins lies close around the same value. Although different peak temperatures were set (see below) the thermodynamic data seems to compensate for it as well as the use of auxiliary equipment.



Conversion energy in kWh/kg @ 30% glass content

	Compounding	LFT	IM
PP/FG	0,845	0,903	1,580
Polyester/FG	0,757	0,846	1,362
Polyamide/FG	0,820	0,955	1,537
Average	**0,808**	**0,901**	**1,493**

Table 2. Total energy per conversion process calculated for three different resin and glass fiber combination.

Our conclusion is therefore that one energy value per conversion process is adequate independent of glass content or resin. As mentioned above these data match the data in EcoInvent for comparable processes very well for energy. It is therefore a reasonable assumption to use the other process data to construct all data for these processes. The appendix explains in detail the above mentioned observations for thermoplastic compounding.

5.1.2 Thermoplastic compounding

In conclusion: Due to the lack of industry data EuCIA has created energy consumption data for key conversion processes through modelling based on first principles and reasonable process assumptions. It has also been concluded that per process one data set suffices irrespective of resin and glass fiber content as can be concluded from the data as modelled. With the above assumptions we use the energy values for thermoplastic compounding at 30% m/m glass content.

For thermoplastic composite compounding [Extrusion, plastic pipes {RER}| production | Alloc Rec.] is used as a proxy to obtain the additional process parameters, such as ancillary materials, water use, waste etc. Though EuCIA feels that this approach is adequately supporting the needs for a trustworthy EcoCalculator Tool, we welcome any comment from industry to either confirm or to improve on the proposed data set for thermoplastic processing.

Section 5.1.5 provides more detail regarding the Thermoplastic comounding process.

5.1.2.1 In more detail: Thermoplastic Compounding

The short fiber thermoplastic compounding process is pictured below.

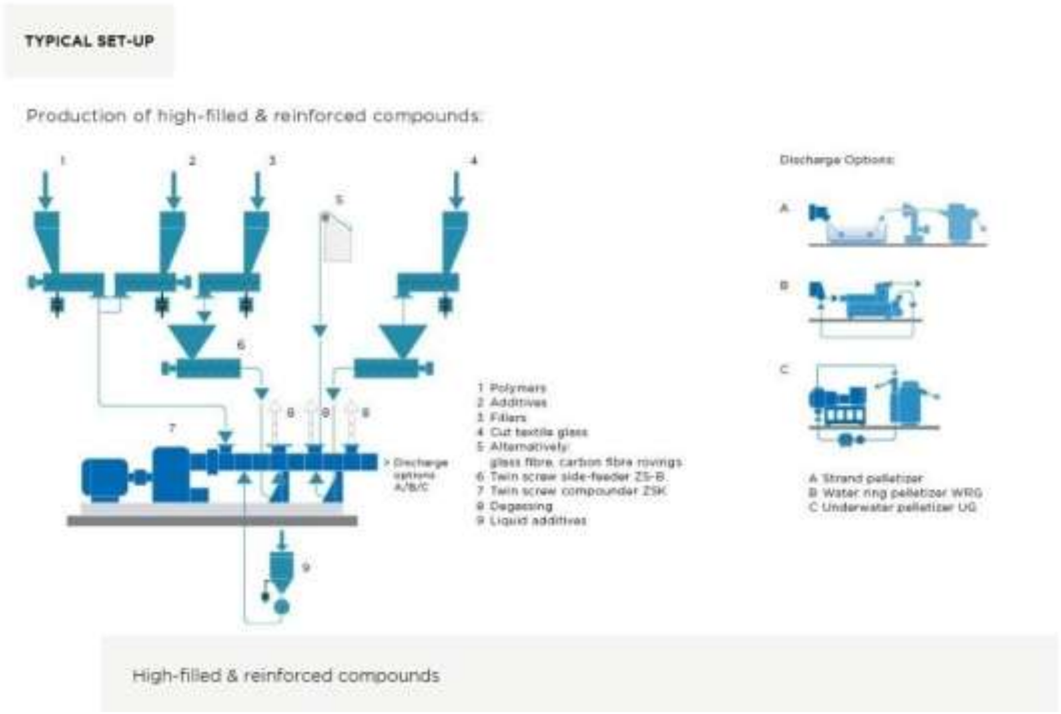
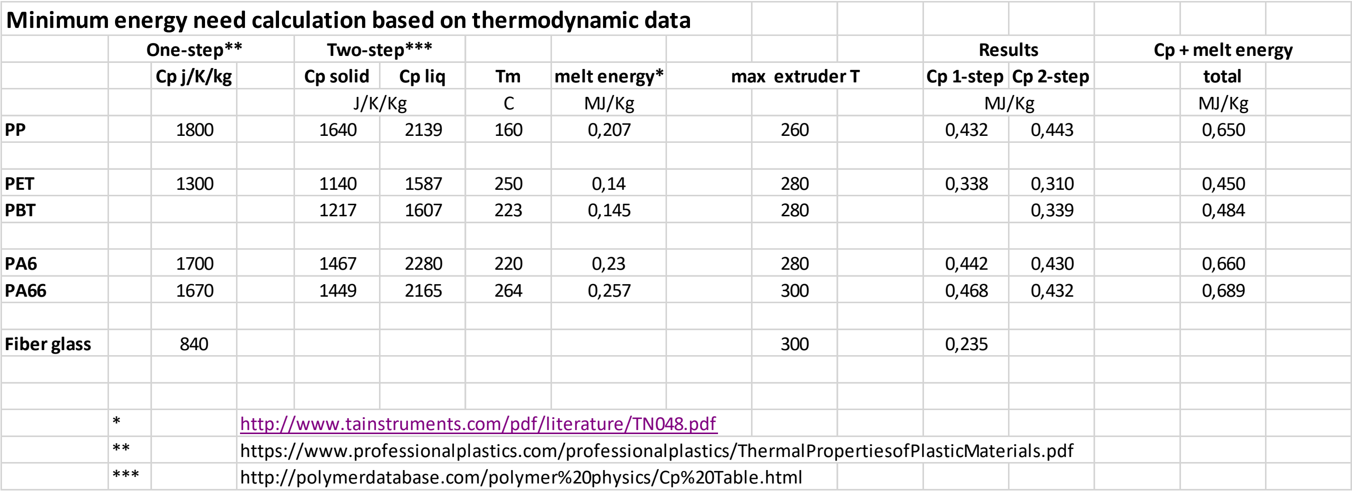


Figure 3 https://www.coperion.com/en/industries/plastics/compounding/

Intertwining screws of proprietary design are driven by a high powered electromotor receiving at various openings the resin, additives and eventually when all is properly molten the fiber glass reinforcements. The latter are added generally as chopped strands and will be reduced to lengths varying from around 200 to 500 microns, depending on conditions, and fully dispersed. The mixture will exit the extruder as strands, immediately water cooled and at a residual temperature of 60 to 90C chopped into granulate. This is the product that is bagged to be shipped to parts producers. Openings in the extruder allow for degassing i.e. water vapor and some volatiles that form during the heating process. Virtually all energy that is used in this process is electrical. The high powered electromotor increases the friction in the resin mixture, increasing the temperature significantly by itself, while the screw housing is heated in various zones to allow the right properties for the granulate. Extruder throughputs can be several or more metric tons per hour to maximize the use of capital invested specifically for the larger volume applications

To allow an estimate for the energy needed for the conversion processes a calculation based on available data from the open literature is performed. This can be seen as a first principles approach, which will form the basis for further estimates for the total energy needed for thermoplastic compounding. In Table 3 the calculation is shown for heating the resins to their typical extrusion temperatures. From this calculation it becomes clear that the use of a single average coeffient of thermal expansion C_p or two, one for the solid phase and one for the liquid is not resulting in a large difference, reason why the two phase approach is used for further calculations. The total energy of melting is surprisingly identical for these resins and quite higher than the energy needed to heat glass fiber to comparable temperatures. Later we will see that increased content of glass fibers, allthough affecting extruder throughput will lead to a small reduction in energy needed for higher glass contents by this approach.

NB Although the polyester melting energy is clearly lower, inclusion of the auxilary equipment will make the difference relatively small, justifying the conclusion for one data set for all resins.



Minimum energy need calculation based on thermodynamic data

	One-step**	Two-step***					Results		Cp + melt energy
	Cp j/K/kg	Cp solid	Cp liq	Tm	melt energy*	max extruder T	Cp 1-step	Cp 2-step	total
		J/K/Kg		C	MJ/Kg		MJ/Kg		MJ/Kg
PP	1800	1640	2139	160	0,207	260	0,432	0,443	0,650
PET	1300	1140	1587	250	0,14	280	0,338	0,310	0,450
PBT		1217	1607	223	0,145	280		0,339	0,484
PA6	1700	1467	2280	220	0,23	280	0,442	0,430	0,660
PA66	1670	1449	2165	264	0,257	300	0,468	0,432	0,689
Fiber glass	840					300	0,235		

* http://www.tainstruments.com/pdf/literature/TN048.pdf

** https://www.professionalplastics.com/professionalplastics/ThermalPropertiesofPlasticMaterials.pdf

*** http://polymerdatabase.com/polymer%20physics/Cp%20Table.html

Table 3. Detailed overview of the calculation for heating different types of resins to their typical extrusion temperatures. This table does not include energy data related to auxiliary equipment.

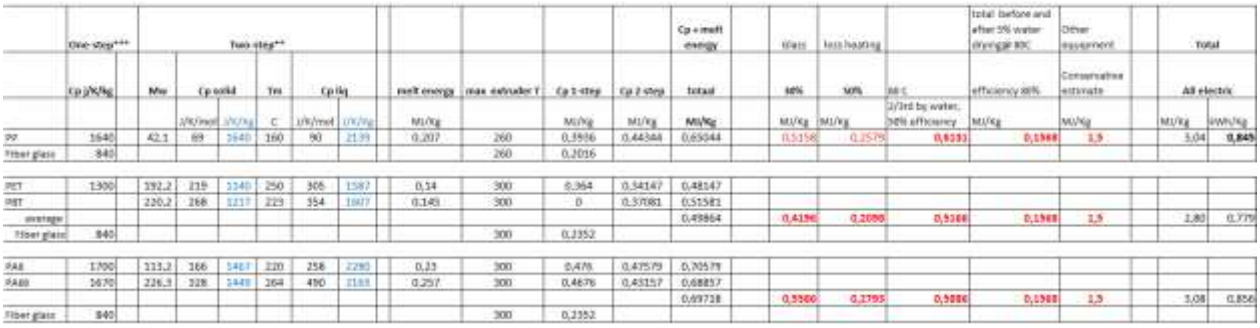
Conversion process energy calculation

A full calculation has to allow for the variability of the glass content, the heat loss during the compounding itself, the cooling of the water used for reducing the strand temperature of the strand, the granulating process as wel as the energy used by the hoppers and the feeding system. As mentioned already estimates have to be made as no industrial data were available. In order not to understate the impact of the conversion process on the eventual composite parts a conservative approach has been followed. In the first place it is recognized that extruder througput reduces as glass content is increased. In Table 4 below our assumptions are presented.

Assumptions heat loss	
glass %	Loss %
20	40
30	50
40	60
50	70
60	80

Table 4. Assumption of heat loss percentages during thermoplastic compounding for different glass fiber contents.

As we hope to receive data from industrial parties, we may be able to be potentially more accurate. This holds also true for our estimate for the energy needed to re-use the cooling water. In addition it is estimated that 5 % m/m water has to be evaporated, either through pre-drying of the granulate or evaporation. In calculations for injection molding it is assumed that the granulate input then is bone dry. Finally all auxiliary equipment has to be powered, including choppers, pumps, hoppers, etc. For that a fixed amount per kg is included. The calculations for typical 30% m/m glass fiber compounds are presented in Table 5.



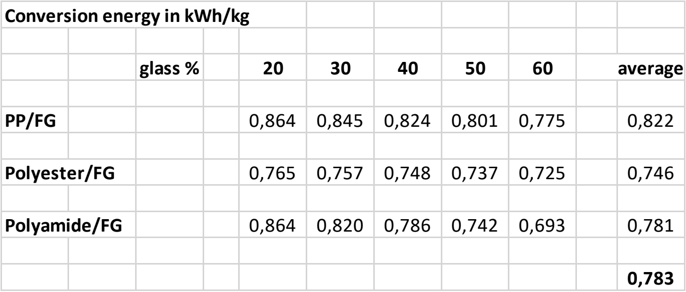
	One-step***	Two step**										Cp + melt energy	Glass	loss heating		total before and after 5% water drying@ 80C	Other equipment	Total	
	Cp J/K/kg	Mw	Cp solid		Tm	Cp liq		melt energy	max extruder T	Cp 1-step	Cp 2 step	total	[illegible]	50%	80 C	efficiency 80%	Conservative estimate	All electric	
			J/K/mol	J/K/kg	C	J/K/mol	J/K/kg	MJ/Kg		MJ/Kg	MJ/Kg	MJ/Kg	MJ/Kg	MJ/kg	2/3rd by water; 30% efficiency	MJ/Kg	MJ/Kg	MJ/Kg	kWh/kg
PP	1640	42,1	69	1640	160	90	2139	0,207	260	0,3936	0,44344	0,65044	0,5158	0,2579	0,6131	0,1988	1,5	3,04	0,845
Fiber glass	840								260	0,2016									
PET	1300	192,2	219	1140	250	305	1587	0,14	300	0,364	0,34147	0,48147							
PBT		220,2	268	1217	223	354	1607	0,145	300	0	0,37081	0,51581							
average												0,49864	0,4196	0,2098	0,5166	0,1988	1,5	2,80	0,779
fiber glass	840								300	0,2352									
PA6	1700	113,2	166	1467	220	258	2280	0,23	300	0,476	0,47579	0,70579							
PA66	1670	226,3	328	1449	264	490	2165	0,257	300	0,4676	0,43157	0,68857							
												0,69718	0,5580	0,2795	0,5886	0,1988	1,5	3,08	0,856
Fiber glass	840								300	0,2352									

Table 5. Energy calculations per kg of end product for a typical 30% m/m glass fiber compound. The amount of 0,845 kWh/kg has been used to model thermoplastic compounding.

The total amount of energy needed is for all resins about equal and compares well with data available in literature (**EcoInvent**). With the above assumptions we may assume then that acceptable values for energy use for thermoplastic compounding at 30% m/m glass content have been determined.
For thermoplastic composite compounding [Extrusion, plastic pipes {RER}| production | Alloc Rec.] is used as a proxy to obtain the additional process parameters, such as ancillary materials, water use, waste etc.

Dependency on glass content

With a model that seems to provide reasonable results comparable with literature sources, it can be investigated what the effect is of the glass content on the total energy needed. Here a key assumption is provided in Table 6. With increased glass content throughputs will be lower to allow in the first place for less friction and thus fiber degradation, so total energy use will be up. The longer dwell time, be it short, will result in more heat losses. Additional heating around the extruder itself has to be provided. The data in table 2 are estimates as mentioned before, but clearly show our idea of the dependency of energy needed at higher glass content. The other dependencies i.e. cooling,



Conversion energy in kWh/kg							
	glass %	**20**	**30**	**40**	**50**	**60**	**average**
PP/FG		0,864	0,845	0,824	0,801	0,775	0,822
Polyester/FG		0,765	0,757	0,748	0,737	0,725	0,746
Polyamide/FG		0,864	0,820	0,786	0,742	0,693	0,781
							0,783

Table 6. Overview conversion energy for different glass fiber percentages

Hoppers and choppers are assumed identical per kg produced. Table 6 shows the results. These show that the use of energy decreases slightly with increased glass content, which follows from the original thermodynamic data. We are very well aware that some variation in the use of energy specifically with choppers and other auxiliary equipment may change, but it is a fair assumption that with all the unknowns variations are minor for the conversion of fiber glass reinforced compounds. We assume that the effect will not be largely different either with other fillers like mica, talcum or clay for comparable reasons. Special compounds, especially at the high end for automotive like high temperature resistant applications may require more energy, but the above calculations can give already an indication of the magnitude of that effect.

In summary, the abovementioned analysis supports the conclusion that within the accuracy of all assumptions it is allowed to present one number for the energy of conversion of glass fiber and thermoplastics into compound for three quite different resins and over a broad range of glass contents. This is based on a proper analysis of the underlying thermodynamics for heating and cooling of the materials.

5.1.3 Long Fibre Thermoplastic Compounding

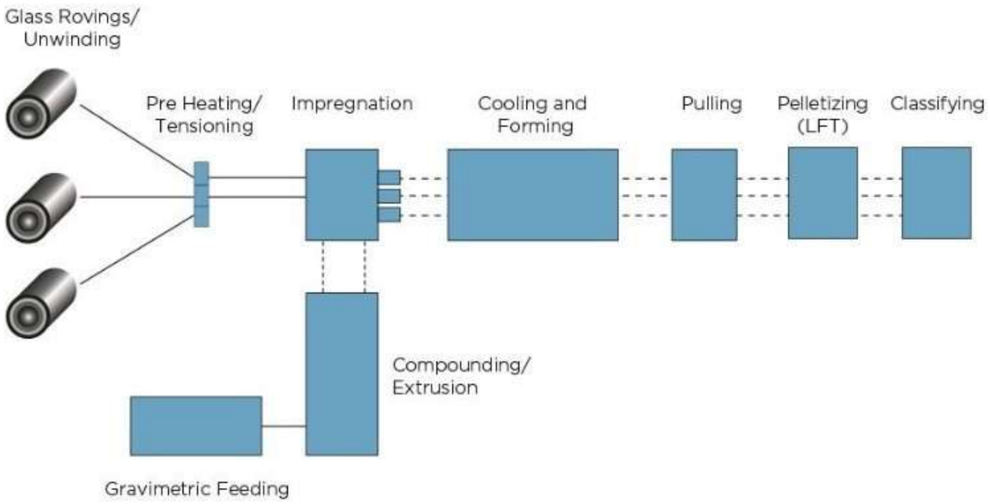
In conclusion: Due to the lack of industry data EuCIA has created energy consumption data for key conversion processes through modelling based on first principles and reasonable process assumptions. It has also been concluded that per process one data set suffices irrespective of resin and glass fiber content as can be concluded from the data as modelled. With the above assumptions we use the energy values for LFT compounding at 30% m/m glass content.

For LFT compounding [Extrusion, plastic pipes {RER}| production | Alloc Rec.] is used as a proxy to obtain the additional process parameters, such as ancillary materials, water use, waste etc.

Though EuCIA feels that this approach is adequately supporting the needs for a trustworthy EcoCalculator Tool, we welcome any comment from industry to either confirm or to improve on the proposed data set for thermoplastic processing.

5.1.3.1 In more detail: Long Fibre Thermoplastic Compounding

A typical process scheme for LFT processing is shown below:



https://www.coperion.com/en/industries/plastics/lft-long-fiber-reinforced-thermoplastics/

For LFT the same assumptions have been used as for short fiber thermoplastic compounding with two differences. In the first place peak temperatures have been set higher i.e. 300, 360 and 400 C for polypropylene, polyester and polyamide respectively. In addition, as mentioned before the heat losses have been assumed higher for the slower process rates. Table 7 shows the assumptions used.

Glass % m/m	Heat loss %
30	60
40	75
50	90
60	105
70	120

Table 7. Assumption of heat loss percentages during LFT compounding for different glass fiber contents.

Auxilary equipment energy is assumed the same as for SF-TP compounding.

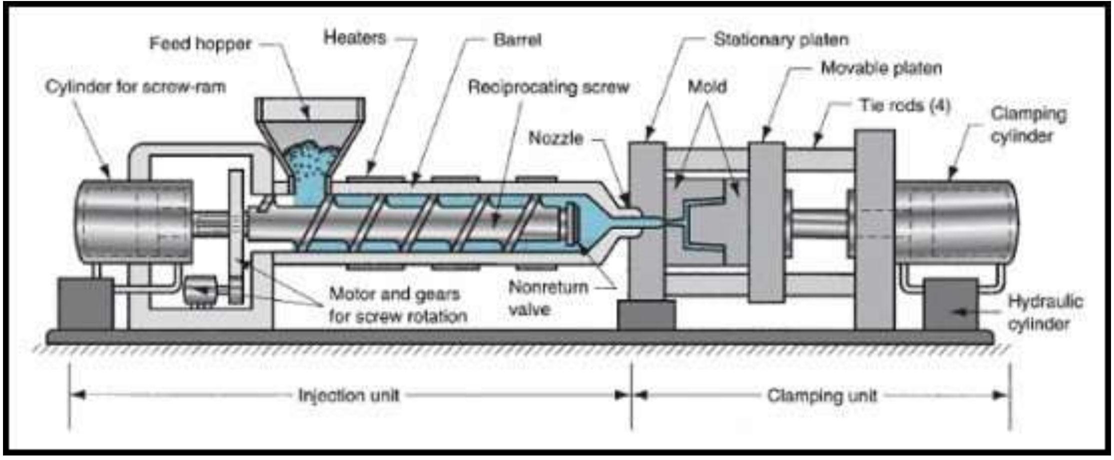
5.1.4 Thermoplastic Injection Moulding

In conclusion: Due to the lack of industry data EuCIA has created energy consumption data for key conversion processes through modelling based on first principles and reasonable process assumptions. It has also been concluded that per process one data set suffices irrespective of resin and glass fiber content as can be concluded from the data as modelled. With the above assumptions we use the energy values for Thermoplastic Injection Moulding 30% m/m glass content. Additional input and output parameters such as water use, ancillary materials and waste are modelled based on the available proxy processes in the EcoInvent database. For thermoplastic composite injection moulding, these additional parameters are based on [Injection moulding {RER}| processing | Alloc Rec], which is used as a proxy.

Though EuCIA feels that this approach is adequately supporting the needs for a trustworthy EcoCalculator Tool, we welcome any comment from industry to either confirm or to improve on the proposed data set for thermoplastic processing.

5.1.4.1 In more detail: Thermoplastic Injection Moulding

A typical scheme for injection moulding of thermoplastic parts is shown below.



http://www.mechscience.com/injection-moldinginjection-molding-machineinjection-molding-processinjection-molding-on-plastics/

Granules are plastisized in a single screw set up driven by an electromotor and heated to the desired temperature. Intermittently the mould , kept at at a temperature significantly below the melting temperature of the resin, is being filled. This requires adequate cooling. The screw will contain several shots. For our calculations the same peak temperature is used as for compounding. To estimate the relative energy use for heating, injection and cooling a ratio for energy use of 50, 35 and 15 has been used, based on literure input. (http://www.pitfallsinmolding.com/energyeffic1.html). The heating energy calculation is based on the same principles as in Table 5 assuming barrel heat losses as in Table 8. Energy for auxiliary equipment on the same basis as for the above processes has been included, lacking adequate data, while assuming that drying was not needed as it is included in the compounding process.

glass %	Loss %
20	40
30	50
40	60
50	70
60	80

Table 8. Assumption of heat loss percentages during thermoplastic injection moulding for different glass fiber contents.

6 Materials

This section describes the materials that are available in the tool upon release.
The amount with which the process impacts need to be multiplied is determined by the amount of material indicated by the users for specific composite parts. In accordance and agreement with the action group a proposal is made to the steering committee for a "wish-list" of materials the user should be able to select from when calculating the environmental impacts of their composite products. All materials have been modelled and calculated for 1 kg., unless otherwise indicated. The materials in the tool are modelled using the EcoInvent database, and in some cases refined and used as proxies to approach the materials used in the composites industry. The database processes from EcoInvent used to model the materials have specific naming, which is provided between brackets: […]

The materials that can be selected as input for the calculation of the environmental impacts of the users' products are listed below per material input category for the conversion processes.

6.1 Fibres

6.1.1 Glass Fibre Assembled Roving

This material is modelled using the process [Continuous filament glass fibre (assembled rovings), at plant RER]. This process is representative for this type of glass fibre production in Europe. However, it does not include transport impacts since there is no "market for" process available, which is required for the chosen system boundaries. To incorporate these impacts, the EcoInvent 3 process [Glass fibre | market for | Alloc Rec] is adjusted: the process [Glass fibre {RER}| production | Alloc Rec] is replaced with the process [Continuous filament glass fibre (assembled rovings), at plant RER] set to 1 kg., and [Glass fibre {RoW}| production | Alloc Rec] is set to 0 kg. New data for [Continuous filament glass fibre (assembled rovings), at plant RER] has been made available in 2017, and is incorporated in the EcoCalculator in January 2018 in a similar manner as described above. Furthermore, an update has been done in November 2019 to ensure the available dataset in SimaPro represents the original dataset correctly from the ELCD database.

6.1.2 Glass Fibre Wet Chopped Strands

This material is modelled using the processes [Continuous filament glass fibre (wet chopped strands), at plant RER]. These processes are representative for this type of glass fibre production in Europe. However, it does not include transport impacts since there is no "market for" process available, which is required for the chosen system boundaries. To incorporate these impacts, the EcoInvent 3 process [Glass fibre | market for | Alloc Rec.] is adjusted: the process [Glass fibre {RER}| production | Alloc Rec] is replaced with the process 1 kg. of [Continuous filament glass fibre (wet chopped strands), at plant RER], and [Glass fibre {RoW}| production | Alloc Rec] is set to 0 kg. New data for [Continuous filament glass fibre (wet chopped strands), at plant RER] has been made available in 2017, and is incorporated in the EcoCalculator in January 2018 in a similar manner as described above. Furthermore, an update has been done in November 2019 to ensure the available dataset in SimaPro represents the original dataset correctly from the ELCD database.

6.1.3 Glass Fibre Dry Chopped Strands

This material is modelled using the processes [Continuous filament glass fibre (dry chopped strands), at plant RER]. These processes are representative for this type of glass fibre production in Europe. However, it does not include transport impacts since there is no "market for" process available, which is required for the chosen system boundaries. To incorporate these impacts, the EcoInvent 3 process [Glass fibre | market for | Alloc Rec.] is adjusted: the process [Glass fibre {RER}| production | Alloc Rec] is replaced with the process 1 kg. of [Continuous filament glass fibre (dry chopped strands), at plant RER], and [Glass fibre {RoW}| production | Alloc Rec] is set to 0 kg. New data for [Continuous filament glass fibre (dry chopped strands), at plant RER] has been made available in 2017, and is incorporated in the EcoCalculator in January 2018 in a similar manner as described above. Furthermore, an update has been done in November 2019 to ensure the available dataset in SimaPro represents the original dataset correctly from the ELCD database.

6.1.4 Glass Fibre Direct Roving

This material is modelled using the process [Continuous filament glass fibre (direct rovings), at plant RER]. This process is representative for this type of glass fibre production in Europe. However, it does not include transport impacts since there is no "market for" process available, which is required for the chosen system boundaries. To incorporate these impacts, the EcoInvent 3 process [Glass fibre | market for | Alloc Rec.] is adjusted: the process [Glass fibre {RER}| production | Alloc Rec] is replaced with the EcoInvent 3 process [Continuous filament glass fibre (direct rovings), at plant RER] set to 1 kg., and [Glass fibre {RoW}| production | Alloc Rec] is set to 0 kg. New data for [Continuous filament glass fibre (direct rovings), at plant RER] has been made available in 2017, and is incorporated in the EcoCalculator in January 2018 in a similar manner as described above. Furthermore, an update has been done in November 2019 to ensure the available dataset in SimaPro represents the original dataset correctly from the ELCD database.

6.1.5 Glass Fibre Mats

This material is modelled using the process [Continuous filament glass fibre (mats), at plant RER S]. This process is representative for this type of glass fibre production in Europe, but based on a limited number of production plants. This dataset is not available via Ecoinvent but has been made available for use in the EcoCalculator by the owner, Glass Fibre Europe. However, it does not include transport impacts since there is no "market for" process available, which is required for the chosen system boundaries. To incorporate these impacts, the EcoInvent 3 process [Glass fibre | market for | Alloc Rec.] is adjusted: the process [Glass fibre {RER}| production | Alloc Rec] is replaced with the EcoInvent 3 process [Continuous filament glass fibre (mats), at plant RER S] is set to 1 kg, and [Glass fibre {RoW}| production | Alloc Rec] is set to 0 kg. The data for glass fiber mats has been made available in the EcoCalculator in October 2018. Furthermore, an update has been done in November 2019 to ensure the available dataset in SimaPro represents the original dataset correctly.

6.1.6 Carbon Fibre

Overall, at the industry/commercial level and academic level, modelling the production of carbon fibre proves to be a challenge in terms of data availability. At the industrial level, this is due to the fact that such data often remains proprietary. At the academic level, there are only a few key studies with information publically available. For this specific modelling, the data was obtained from the following sources: via a set of researchers from universities such as KU Leuven, Nottingham University, data from the EU level via the European Life Cycle Database, and via research conducted from the Institut für Textiltechnik (ITA) of the RWTH Aachen University led by Tim Roeding. The data was consolidated across various sources and when appropriate, averaged if there were multiple options for the relevant input or output. Specifically, this material is modelled using two processes: AN to PAN, and PAN to CF, which are described below in the supplementary information. These processes are representative for carbon fibre production in Europe.

When modelling CF production in SimaPro, two general processes are modeled: first PAN production and then the conversion from PAN to CF. Data for raw materials was obtained from the studies of KU Leven, Nottingham University, and a presentation developed by the ITA from Aachen University titled "Carbon Fibre Production: Primary Energy Consumption". Following the research of ITA, a PAN to carbon fibre conversion factor (yield) of 42% was used. This converstion factor is based off of insights conducted on an experimental basis. The latest data in the tool contains the data inputs from Aachen University whereas the first carbon fibre data set uploaded into the tool used an average of the conversion factors based on studies from Nottingham University and KU Leuven, being 53% conversion efficiency for PAN to CF.

Energy input values for electricity and natural gas heat were referenced from the research of ITA (2019). For the natural gas and electricity processes, average European datasets were used. For electricity, this included a mixed process. Each energy input value obtained from ITA (2019) was divided by a primary energy factor in order to reduce double counting in the model, as the Cumulative Energy Demand method used to calculate the total MJ results applies a primary energy factor as well. Within the model, the primary energy factors of 1.1 for natural gas and 2,5 for electricity were used.

Material inputs which are discussed in the paper from Nottingham University (Meng et al., 2017) include: 1,89 kg [Polyacrylonitrile fibres (PAN), from acrylonitrile and methacrylate, prod. mix, PAN w/o additives EU-27 S], 2,77 kg [Water, decarbonised, at user {GLO}| market for | Alloc Def, S], 0,01 kg [Epoxy resin, liquid {GLO}| market for | Alloc Def, S], and 0,02 kg [Sulphuric acid, liquid, at plant/RER S]. Furthermore, from the ITA research, three material inputs were used: 0,1 kg [Potassium permanganate {GLO}| market for | APOS, S], 0,02 kg [Ammonium bicarbonate {GLO}| market for | APOS, S], and 0,01 kg [Polydimethylsiloxane {GLO}| market for polydimethylsiloxane | APOS, S]. The last input mentioned is used as a proxy for the raw material silicone oil agent mentioned in ITA's research. Regarding transport, a standard transport factor of 500km is used for the process [Transport, lorry 16-32t, EURO5/RER U] with a 50% load factor.

The primary emissions reported include CO_2 and NO_x gases (Meng et al., 2017). Regarding outputs, 0,63 kg CO_2 and 1,0 kg NO_x of emissions are modelled per 1kg of CF. NO_x is modelled as the aggregation of 0,33 kg of NO and 0,63 kg NO_2. The pollution abatement systems onsite at plants are not modelled.

With this data, the total cumulative energy demand results in 1040 MJ. Please note this data is the latest value as an update has been performed in November 2019.

6.1.6.1 In more detail: Carbon Fibre

The first process is the production of AN (acrylonitrile) to PAN (polyacrylonitrile) where a polyacrylonitrile precursor is formed via a solvent-based polymerization process (Das, 2011). Specifically, the fibres are obtained by the polymerisation of AN using dimethylformamide(DMF) as a solvent (Duflou et al., 2009). The specific process used to model this is [Polyacrylonitrile fibres (PAN), from acrylonitrile and methacrylate, prod. mix, PAN w/o additives EU-27 S], sourced from The two flowcharts shown below sourced show an overview of the inputs/outputs used during the PAN production process. Important for this process is the strength of precursor used. The necessity for using a higher precursor strength will be influenced by what grade of CF is being produced and for what purpose, e.g. automotive, aerospace, advanced aerospace/ satellite. Lower industrial grades used for automotive purposes can tolerate relatively higher impurity for precursor content (Das, 2011).

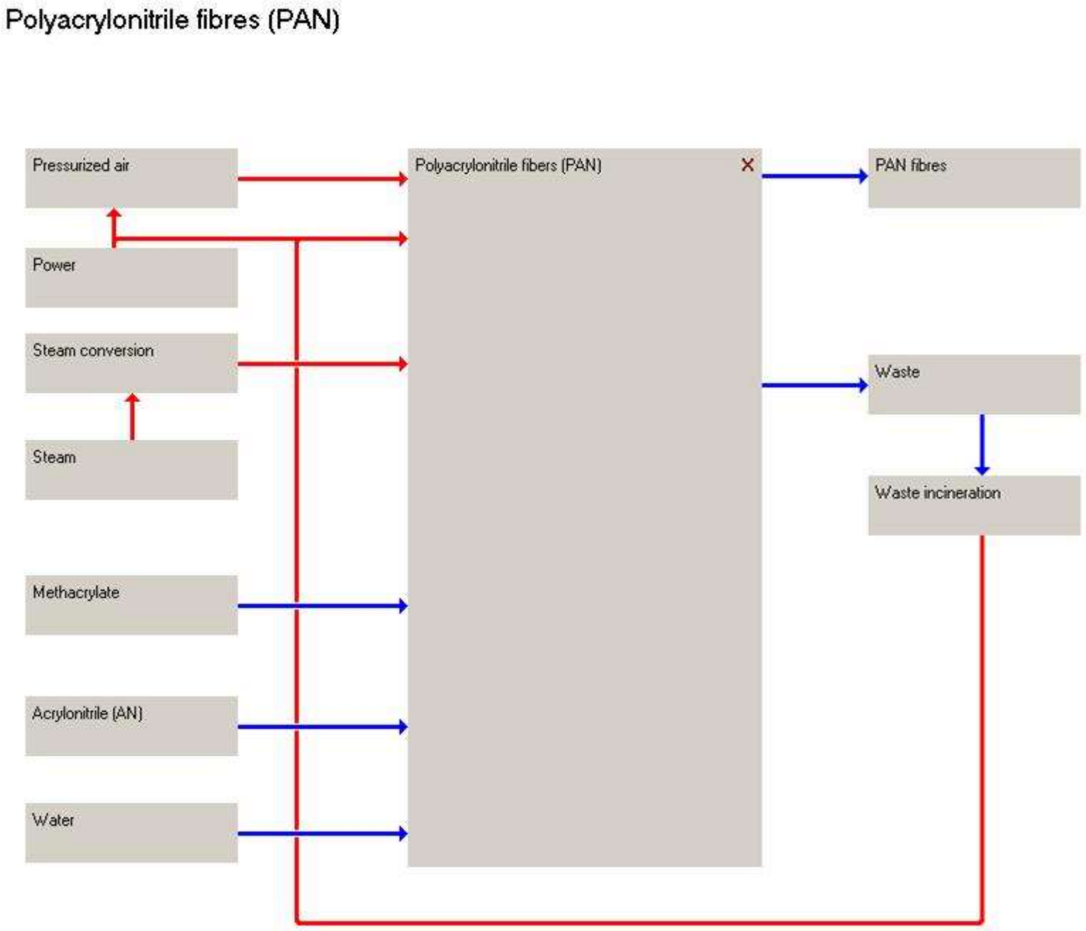


Figure 1. Overview PAN Production (Thinkstep, 2018) (Website: http://gabi-documentation-2018.gabi-software.com/xml-data/processes/db00901a-338f-11dd-bd11-0800200c9a66.xml.)

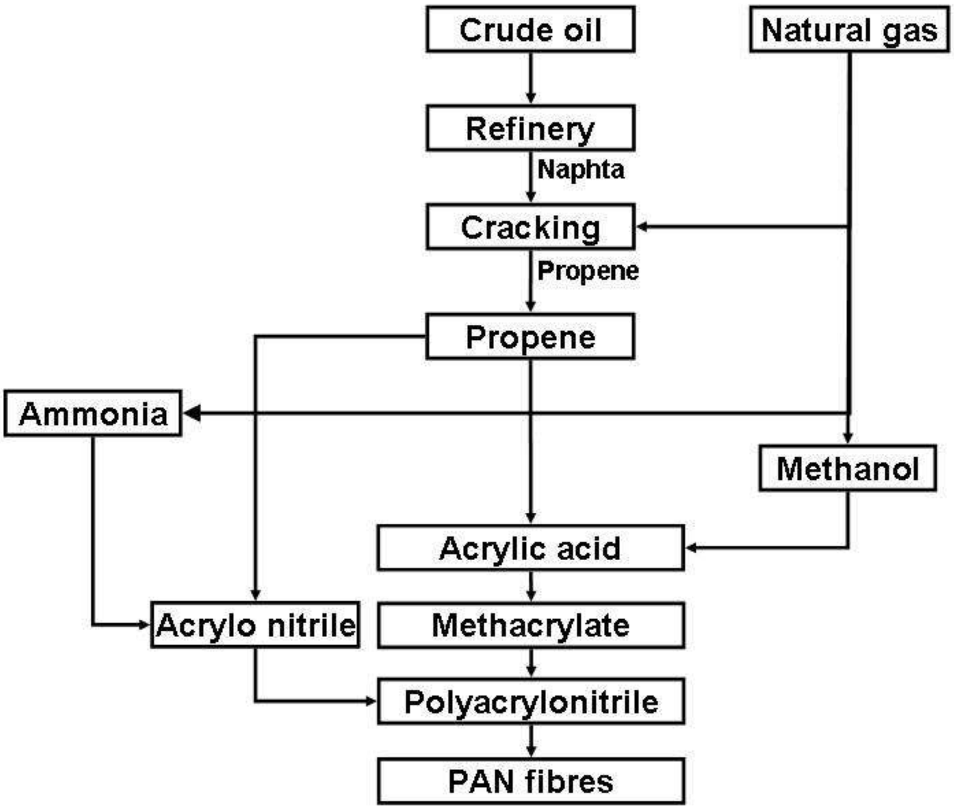


Figure 2. Overview CF Production (Thinkstep, 2018) (Website: http://gabi-documentation-2018.gabi-software.com/xml-data/processes/db00901a-338f-11dd-bd11-0800200c9a66.xml.)

Second is the production from PAN into CF which includes various sub processes. Such sub processes involve the following and are described by Das (2011): oxidation, pre-carbonization, surface treatment, washing, drying, sizing, an additional drying stage, and finally winding. Graphitization is an additional process but will not be included in this modelling of production of CF as this is less common and is primarily used in university studies. The oxidation stage lasts for a duration of 30 minutes to an hour at a temperature of 300 C. This sub process consumes the most energy and is exo-thermic, thereby posing risks for combustion onsite at a plant. Next, pre-carbonization occurs for only a few minutes at a high temperature of 1100 C, and potential emissions include cyanide and tarry gases. Following is carbonization, operating at two temperature stages: low and high ranging from 300-1800 C. The duration of this stage is a few minutes where PAN fibre is pyrolyzed to CF. During this stage, 50-60% of the original PAN weight is lost. In the next stage, surface treatment, this involves an anodic surface treatment bath where carboxyl groups are formed. Thereby improving the cohesion between fiber and resin used in the final composite. Subsequently is the washing stage, where electrolytes are removed via a warm water wash and carbon fibres pass through dip baths with a counter current water flow. After is drying, where carbon fibre strands are pre-dried before sizing via contact with air and a roller dryer. The material is then sized via a sizing bath including the dispersion of water and expoxy particles. An additional drying stage is followed by the sizing, and finally the last stage is winding, whereby winders produce CF spools up to 12kg in weight.

References:

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- Meng, F., Jon McKechnie, T. A. Turner, and S. J. Pickering. "Energy and environmental assessment and reuse of fluidised bed recycled carbon fibres." *Composites Part A: Applied Science and Manufacturing* 100 (2017): 206-214. https://www.sciencedirect.com/science/article/pii/S1359835X17301914.

- Roeding, Tim. "Carbon Fibre Production: Primary Energy Consumption." Institut für Textiltechnik (ITA) of the RWTH Aachen University. (2019).

6.1.7 Other fibres (not yet included in the tool due to lack of data)

The materials below are not yet included. We would welcome reliable and high-quality data for these materials to be integrated in the tool.

- Glass Fibre Pre-form
- Glass Fibre Woven Roving
- Glass Fibre Non Crimp Fabric
- Carbon Fibre Fabrics
- Carbon Fibre Non Crimp Fabric

6.2 Resins

6.2.1 PolyAmide Resin (PA)

This material is modelled using 0,5 kg. of the EI 3 Process [Nylon 6-6 {GLO}| market for | Alloc Rec] and 0,5 kg. of the EI 3 process [Nylon 6 {GLO}| market for | Alloc Rec].

6.2.2 Polypropylene Resin (PP)

This material is modelled using the EI 3 Process [Polypropylene, granulate {GLO}| market for | Alloc Rec].

6.2.3 Polyethylene terephthalate Resin (PET)

This material is modelled using the EI 3 Process [Polyethylene terephthalate, granulate, bottle grade {GLO}| market for | Alloc Rec].

6.2.4 Other Thermoplastics Resins

Polybutylene Terephthalate Resin (PBT) was not included in this version of the tool, since no data was available for this material.

6.2.5 Polyurethane Resin (PU)

This material is modelled using 0,55 kg. of the EI 3 Process [Methylene diphenyl diisocyanate {GLO}| market for | Alloc Rec] and 0,45 kg. of the EI 3 Process [Diethylene glycol {GLO}| market for | Alloc Rec].

6.2.6 Epoxy Curing Agents

Two types of Epoxy Curing Agents have been included in the EIC tool, Phthalic Anhydride and Ethylene diamine (EDA).

6.2.6.1 Phthalic anhydride

Phthalic anhydride is modelled using the EI3 Process [Phthalic anhydride {GLO}| market for | Alloc Rec].

6.2.6.2 Ethylene diamine

Ethylene diamine is modelled using the EI3 Process [Ethylenediamine {GLO}| market for | Alloc Rec].

6.2.7 Epoxy Resin

This material is modelled using the EI 3 Process [Epoxy resin, liquid {RER}| production | Alloc Rec]
There is no “market for” process available to include the upstream transport impacts.

6.2.8 Isocyanate Resin

This material is modelled using the EI Process [Methylene diphenyl diisocyanate {GLO}| market for | Alloc Rec].

6.2.9 Phenolic Resin

This material is modelled using the EI 3 Process [Phenolic resin {GLO}| market for | Alloc Rec].

6.2.10 DCPD-based Unsaturated Polyester Resin (UP)

This material is modelled using the process [Dicyclopentadiene based unsaturated polyester resin {GLO}| market for | Alloc Rec].

6.2.11 Isophthalic acid-based Unsaturated Polyester Resin (UP)

This material is modelled using the process [Isophthalic acid based unsaturated polyester resin {GLO}| market for | Alloc Rec].

6.2.12 Orthophthalic acid-based Unsaturated Polyester Resin (UP)

This material is modelled using the process [Orthophthalic acid based unsaturated polyester resin {GLO}| market for | Alloc Rec].

6.2.13 Pure Maleic Unsaturated Polyester Resin (UP)

This material is modelled using the process [Maleic unsaturated polyester resin {GLO}| market for | Alloc Rec].

6.2.14 Unsaturated Polyester Resin (unspecified) (UP)

This material is modelled using the average of the four UP resin processes listed above. This is done to facilitate users that do not have specific information on the type of UP Resin their company is using.

6.2.15 Bisphenol A-based Vinyl Ester Resin (VE)

This material is modelled using the process [Bisphenol A epoxy based vinyl ester resin {GLO}| market for | Alloc Rec].

6.3 Fillers

6.3.1 Aluminium TriHydrate (ATH)

This material is modelled using the EI 3 Process [Aluminium hydroxide {GLO}| market for | Alloc Rec].

6.3.2 Calcium Carbonate

This material is modelled using the process [Calcium carbonate > 63 microns, production, at plant EU-27]. There is no “market for” process available to include the upstream transport impacts. This will be addressed by including a transport scenario for Calcium Carbonate.

6.3.3 Sand

This material is modelled using the EI 3 Process [Sand {GLO}| market for | Alloc Rec].

6.3.4 Talc

For Talc, no EI 3 process could be identified. Therefore as a proxy, this material is modelled using the EI 3 Process [Feldspar {GLO}| market for | Alloc Rec].

6.4 Cores

6.4.1 Balsa

This material is modelled using the EI 3 Process [Glued laminated timber, for indoor use {GLO}| market for | Alloc Rec].

6.4.2 Polyethylene terephthalate (PET) Is already mentioned above

This material is modelled using 0,502 kg. of the EI 3 Process [Polyethylene terephthalate, granulate, amorphous {GLO}| market for | Alloc Rec] and 0,502 kg. of the EI 3 Process [Polyethylene terephthalate, granulate, bottle grade {GLO}| market for | Alloc Rec] as well as 1 kg. of the process for [Polymer foaming {GLO}| market for | Alloc Rec].

6.4.3 Polyisocyanurate (PIR)

This material is modelled using the EI 3 Process [Polyurethane, rigid foam {GLO}| market for | Alloc Rec].

6.4.4 Polyvinylchloride (PVC)

Based on primary information from Plastics Europe the dataset for this material has been updated. The dataset was model originally modelled as 50% bulk polymerisations (0,502 kg per kg of PVC) and 50% suspension polymerisation (0,502 kg per kg of PVC).This has been amended to 100% suspension polymerisation as this is the most widely used production process currently in Europe.

The new dataset has been modelled as 1,004 kg of the EI 3 Process [Polyvinylchloride, suspension polymerised {GLO}| market for | Alloc Rec] and 1 kg. of the process for [Polymer foaming {GLO}| market for | Alloc Rec]. The impact of this update has resulted in a lower environmental impact score (on average between 1% and 5%) for all impact categories. The new dataset has become available in July 2018.

6.5 Coatings

6.5.1 Gelcoat

1,02 kg. of this material is modelled using 0,75 kg. of the EI 3 Process [Isophthalic acid-based UP resin], 0,1 kg of [Titanium dioxide {RER}| market for | Alloc Rec], 0,05 kg. of [Aluminium hydroxide {GLO}| market for | Alloc Rec], 0,05 kg. of [Feldspar {GLO}| market for | Alloc Rec], 0,05 kg. of [Calcium carbonate > 63 microns, production, at plant EU-27] and 0,02 kg. of [Chemical, organic {GLO}| market for | Alloc Rec].

6.5.2 Protective Acrylic Urethane

This material is based on data provided by a leading European PAU manufacturer.

6.6 Additives

6.6.1 Accelerators

This material is modelled using the EI 3 Process [Chemical, organic {GLO}| market for | Alloc Rec].

6.6.2 Flame Retardants

Two out of four selected flame retardants are represented in the tool. No data was available for brominated polystyrene and antimony oxide.

6.6.2.1 ATH

ATH is modelled using the EI 3 Process [Aluminium hydroxide {GLO}| market for | Alloc Rec].

6.6.2.2 Diammonium Phosphate

Diammonium Phosphate is modelled as [Diammonium phosphate, as P2O5, at regional storehouse/RER].

6.6.3 Peroxide

It has been extensively attempted to incorporate primary data for peroxides used by the European composites industry in the tool, since no data-set is currently available. We were provided with a data-set generated by Gabi software by a large multinational chemicals production company, but were unable to import the data into the SimaPro software package. The SimaPro software provider (Pré consultants) were unable to achieve an import as well. Attempts to import the LCIA results also failed since the two software packages used different versions of LCIA methods or Gabi was not able to provide us with one or more of the LCIA results for the LCIA methods selected for the tool. At this point we were forced to abandon the route of primary data and fall back on choosing a proxy from the database. This material is modelled using the EI 3 Process [Chemical, organic {GLO}| market for | Alloc Rec].

6.7 Auxiliaries

6.7.1 Plastic Film

This material is modelled using the EI 3 Process [Packaging film, low density polyethylene {GLO}| market for | Alloc Rec], where the process [Packaging film, low density polyethylene {RER}| production | Alloc Rec] was replaced by the process [Packaging film, PA {RER}| production | Alloc Rec], which in turn is an adaptation of [Packaging film, low density polyethylene {RER}| production | Alloc Rec] where [Polyethylene, low density, granulate {GLO}| market for | Alloc Rec] was replaced by [PolyAmide, granulate {GLO}| market for | Alloc Rec]. This resulted in the creation of the process [PA Plastic Film {GLO}| market for | Alloc Rec].

6.7.2 Release Agent

This material is modelled using the EI 3 Process [Chemical, organic {GLO}| market for | Alloc Rec].

6.7.3 Methyl Ethyl Ketone

This material is modelled using the EI 3 Process [Methyl ethyl ketone {GLO}| market for | Alloc Rec].

6.7.4 Acetone

This material is modelled using the EI 3 Process [Acetone, liquid {GLO}| market for | Alloc Rec].

6.8 Core Mats

Core Mats represent non-woven mats volumized with micro-spheres. The environmental impacts per variant described below are calculated using as a basis a LCA study performed in 2013 by Lantor in cooperation with the University of Utrecht. This data has been updated and adjusted to take into account primary data for 2016 production for the different core mats. The scope of this LCA is from Cradle-to-Gate at Lantor. The contents of this report are confidential, and therefore cannot be disclosed in this report.

For eight types of core mats the environmental impacts are modelled in the tool. They can be distinguished by thickness and weight per square meter:

Product	Name in Eco calculator
Soric TF 1.5	Core mat - surface enhancer (t=1,5 mm; 90g=1m2)
Soric TF 2	Core mat - surface enhancer (t=2 mm; 120g=1m2)
Soric TF 3	Core mat - surface enhancer (t=3 mm; 160g=1m2)
Soric XF 2	Core mat - flow medium (t=2 mm; 135g=1m2)
Soric XF 3	Core mat - flow medium (t=3 mm; 180g=1m2)
Soric XF 4	Core mat - flow medium (t=4 mm; 250g=1m2)
Soric XF 5	Core mat - flow medium (t=5 mm; 320g=1m2)
Soric XF 6	Core mat - flow medium (t=6 mm; 345g=1m2)

The modelling choices of the major constituents of Core Mats are listed below (Chapter 6.8.1– 6.8.3)

6.8.1 PET staple fibres

This material is modelled using the EI 3 Process [Polyethylene terephthalate, granulate, amorphous {GLO}| market for | Alloc Rec, S].

Since half of the PET staple fibres are recycled content, the EI3 process [Mixed plastics (waste treatment) {GLO}| recycling of mixed plastics | Alloc Def, U] and [Electricity, high voltage {DE}| production mix | Alloc Rec, S] were used. The mixed plastics process has been modified by using only the PET LCI.

6.8.2 Microspheres

This material is modelled using the EI 3 Processes:

- [Methyl methacrylate {GLO}| market for | Alloc Rec, S]
- [Acrylonitrile {GLO}| market for | Alloc Rec, S]
- [Chemical, organic {GLO}| fraction 8 from naphtha separation to generic market for | Alloc Rec, S]
- [Butane {GLO}| market for | Alloc Rec, S]
- [Tap water {CH}| market for | Alloc Rec, S]
- [Magnesium oxide {GLO}| market for | Alloc Rec, S]

6.8.3 Binder

This material is modelled using the EI 3 Processes:

- [Tap water {CH}| market for | Alloc Rec, S]
- [Ammonia, liquid {RER}| market for | Alloc Rec, S]
- [Acrylic binder, without water, in 34% solution state {GLO}| market for | Alloc Rec, S]

7 Looking ahead

7.1 Methodology

As mentioned in Section 2.1, there are exciting developments on an European level for unified LCA approaches for selected product categories: The Product Environmental Footprint project and its pilots being the EU flagship. When the development of this tool was initiated, no (PEF)CR or other data quality and methodology requirements were available to the project team for incorporation or consideration in the tool development.

At this time the PEF pilots are almost finished and a lot of experience has been gained regarding the new methodology. The composite sector is looking into applying the PEF methodology.

7.2 Data acquisition

The main barrier for full development of the tool is data acquisition from the composite product manufacturers in Europe. Even though there have been numerous attempts to retrieve more data, response is currently lower than expected. And of the returned questionnaires, some were not usable due to incomplete data filled in by the companies (mostly the allocation appeared to be an issue).

7.2.1 Questionnaire update

In order to address the lack of data, EY has updated the questionnaire. The new questionnaire format can be found here:

Questionnaire-EuCIA.xlsx

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The main aim of redesigning the questionnaire is to make it more clear for the companies how and what to fill in. The new questionnaire has been re-sent to companies that delivered incomplete data as well as new companies that have indicated that they would deliver data.

7.3 Data Quality

Furthermore, data quality is influenced by (amongst other factors) time-representativeness. Both for the process data as well as the materials, the tool should be able to be updated regularly according to new data, progressive insights in existing data as well as assessment methods. As the tool grows, this will increasingly require significant efforts to keep the tool up-to-date and of high quality.

Another issue around data-quality is that the data provided for the tool are not audited. Therefore there is an uncertainty with these data points.

A possible solution for this risk could be the development of an interactive dashboard, where companies can provide the required data as well as its underlying evidence directly in the tool. Using a company dashboard will have the added benefit of easier keeping the tool up to date in the long run and, when the evidence is also audited, increase the confidence in the provided data.

8 Limitations

An important limitation is the data on the conversion processes. The data is delivered by the composite product manufacturers themselves and is not audited at this time. Therefore there is an uncertainty with these data points.

Data used for conversion processes are another important limitation. For energy and waste, only 1 average data point could be used for the environmental impacts. For the 2.0 version of the tool, it is recommended to restructure this part, so that country-specific energy mixes can be selected to calculate the average environmental impacts

Another limitation of the tool, is that no update procedure is currently in place. Meaning that the data for 1 year of production (of at least 3 companies) is used to model the conversion processes. It is likely that the environmental impacts of the conversion processes will change in the (near) future. If these changes, reflecting innovations implemented by composite product manufacturers, either by own initiative or enforced through increasingly stringent regulation, are not taken into account in the tool, this might jeopardize the reliability of the tool in the near future.

Furthermore the tool could benefit strongly from inclusion of the ability to include transport distances of each material supplier that a user has in his company. This would further enhance the completeness and reliability of the tool, although transport is considered quite a minor contribution at this time to the environmental footprint of composite manufacturing.