EuCIA EU Eco Impact Calculator

Background report: Version 2.1

March 2026

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Transparency Register : REG 244941896103-90

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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 LCAs in the composite industry is still low but growing in comparison to other material sectors. The official method for executing and reporting LCAs is time-consuming, expensive and often data is not sufficiently available: it requires specialized software and expertise. For small companies, this is not affordable, especially as products are very diverse and production series are often small. This is the main reason why EuCIA started to develop the EU Eco Impact Calculator tool for composite products in 2015.

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 a working group and steering committee with industry representatives were appointed to ensure an efficient process with a high-quality result. Data on materials and processes were gathered and/or developed to build the Eco Impact Calculator. Together with the working group, the main materials and processes used by the European composites industry were identified, resulting in a list of 46 materials and 8 conversion processes.

The 46 selected materials were matched with available data or modelled using available proxies in LCA databases, such as the EcoInvent (EI 3.8) and ELCD database (ELCD 3) (including those developed by Plastics Europe) and Glass Fibre Europe. An important update of the data in the tool has taken place in 2022 and 2023 to update all the environmental impact results with information in current LCA databases and impact methods.

The conversion processes are the production processes of composite parts. The production processes are modelled based on primary information of European composites manufacturers retrieved through questionnaires, unless industry was not able to deliver data for the development of the tool. The latter holds for three conversion processes, which were deemed essential for the development of the tool, and were eventually modelled. The ultimate aim of EuCIA is to include at least 15 conversion processes which were identified as representative of the conversion processes used in the composites industry. EuCIA is putting continuous efforts in expanding and improving the data on conversion processes.

In the Eco Impact Calculator tool, users can perform environmental impact calculations by selecting one or more of the materials available in the tool and using them as input for the conversion processes. Subsequently, the user can create their own composite material by combining different available materials. Finally, the user can access the results of the calculation, where a general description of the product is presented as well as the final environmental impact results.

The output of the tool is an Eco Report in PDF format 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.

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, because this is not a requirement for the sector yet. The output is very similar to an Environmental Product Declaration (EPD) or Type III environmental declarations, a standardized format to communicate LCA results in an easy and transparent way to consumers and final users. The development of such a declaration is described in ISO 14025. The results of the tool cannot however be used as an official EPD, since the approach, methodology and data used for the current version of the tool have not been independently verified.

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

2 Introduction

2.1 Background

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 in sectors such as the automotive sector, and composite products are used in large buildings 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 (e.g. 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. Industries that produce end products frequently use Life Cycle Assessment (LCA) data to improve the environmental performance of their products. Increasingly information on environmental impacts is used in external communication as well as in supply chains, both up- and downstream. This means the provision of such information is becoming more and more important.

EuCIA is the Brussels-based leading Association of the European Composites Industry, representing European National Composite Associations as well as industry specific sectors. One of the focus areas of EuCIA is the notion that composites can contribute to a more sustainable society. However, development and use of LCAs in the composite industry is still low but growing in comparison to other material sectors. The official method for executing and reporting LCAs is time-consuming, expensive, and often data is not sufficiently available: it requires specialized software and expertise. For a small composite manufacturing company, this is not affordable, especially as products are very diverse and production series are often small. This is the main reason why EuCIA in 2015 initiated the development of the Eco Impact Calculator tool for composite products and components.

In the meantime, an important update of the data in the tool has taken place in 2022 and 2023 to update all the environmental impact results with information in current LCA databases and impact methods. 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 LCAs. The tool calculates the environmental impact of a composite product from cradle to gate. This report describes the methodology and datasets used in the EU Eco Impact Calculator.

2.2 Initiator

EuCIA represents European National Composite Associations as well as industry specific sectors. More than 10,000 companies and an estimated 150,000 employees are actively involved in composites production across Europe. 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 Steering group

A steering group has been set up to guide the development of the EU Eco Impact Calculator, which consists of the following people:

- Roberto Frassine, President, EuCIA
- Raphaël Pleynet, Managing Director, EuCIA
- Jaap van der Woude, Chairman and overall project manager, EuCIA

The steering group is responsible for making operational decisions and discussing the progress of the project.

2.4 Project approach

The project approach consisted of using input and output data from the EU Eco Impact Calculator as used in the period 2015-2021, updating these datasets based on the most recent information in LCA databases.

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 was the development of the EU Eco Impact Calculator tool which includes tailor- made datasets for the European composite industry and a report on the LCA methodology. The tool provides a reliable calculation of the environmental impact, meaning that both the underlying data as well as the way that the data is processed are reliable. The best available data was selected, and existing datasets were adjusted where required. The calculation methods comply with international standards and guidelines.

Primary users are the people working at the composite component manufacturers in production, product development and R&D. These users have technical knowledge of composites, but limited knowledge on LCA or calculating environmental impacts. The EU Eco Impact Calculator therefore only allows users to adjust variables that are technical rather than environmental. The interface is self-explanatory (no- or limited instruction needed) and easy and quick to use. The main objective of the tool is to make a reliable calculation of the environmental impact of a composite part: intermediate material, semi-finished, finished product.

The output of the tool has the quality level required for downstream LCAs and is based on ISO 14040/44. The output is very similar to an Environmental Product Declaration (EPD) or Type III Environmental declarations, which is a standardized format to communicate LCA results in an easy and transparent way to consumers and end-users. The development of such a declaration is described in ISO 14025. However, the results of the tool cannot be used as an official EPD, since the approach, methodology and data used for the current version of the tool have not been independently verified.

The target audience of this tool is EuCIA, the Association of the European Composites Industry, representing European National Composite Associations as well as industry specific sectors, which in turn represent individual companies in the composite industry. In addition, the Eco Impact Calculator can be used for all composite practitioners, such as original equipment manufacturers (OEMs), academia as well as the public in general.

3.2 Functional unit

The functional unit (or more precisely the declared unit) of the environmental profile that the EU Eco Impact Calculator tool provides is the production amount in kg (specified by the user) 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 EU Eco Impact Calculator tool make an environmental profile have a broad variety of compositions, sizes and shapes. By filling out the desired amounts per material, the EU Eco Impact Calculator calculates the total environmental profile for a specific product. It should be noted that, when re-usable materials and semi-finished products are modelled as inputs for respectively semi-finished and finished products, the required quantities should be set to 1 kg in order not to overstate the total environmental impact. The main output of the tool, the Eco Report in PDF format, contains the environmental impact data of the respective product based on the specified production amount.

3.3 System boundaries

The process flow diagram below shows the life cycle phases and the system boundaries included in the Eco Impact Calculator tool. The system boundary determines the processes that are 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 using a cradle to gate approach, 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 below.

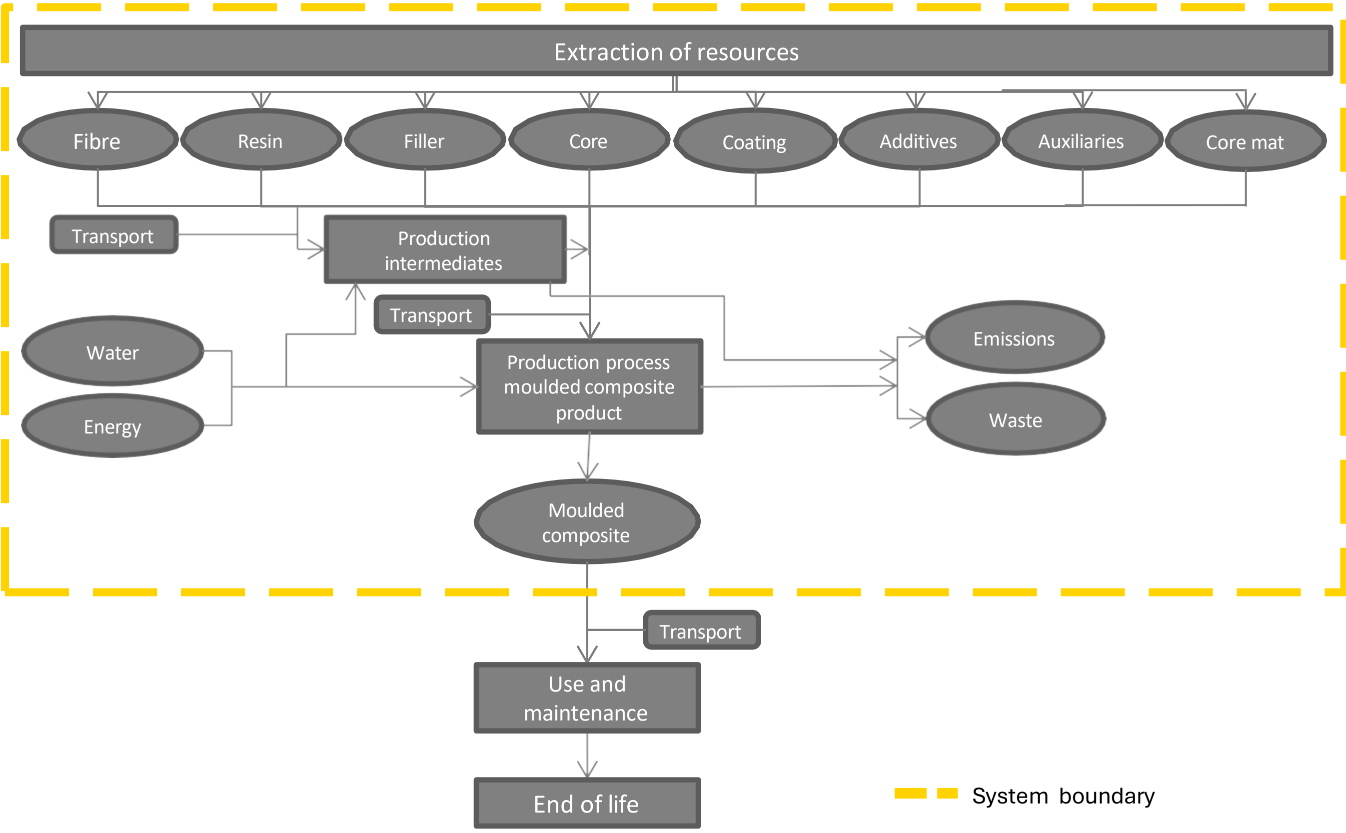

Figure 1: System boundaries for the materials and processes in the Eco Impact Calculator

4 The Eco Impact Calculator

This chapter 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 impact assessment of their composite products from cradle to gate. The high-level tool architecture is depicted in Figure 2.

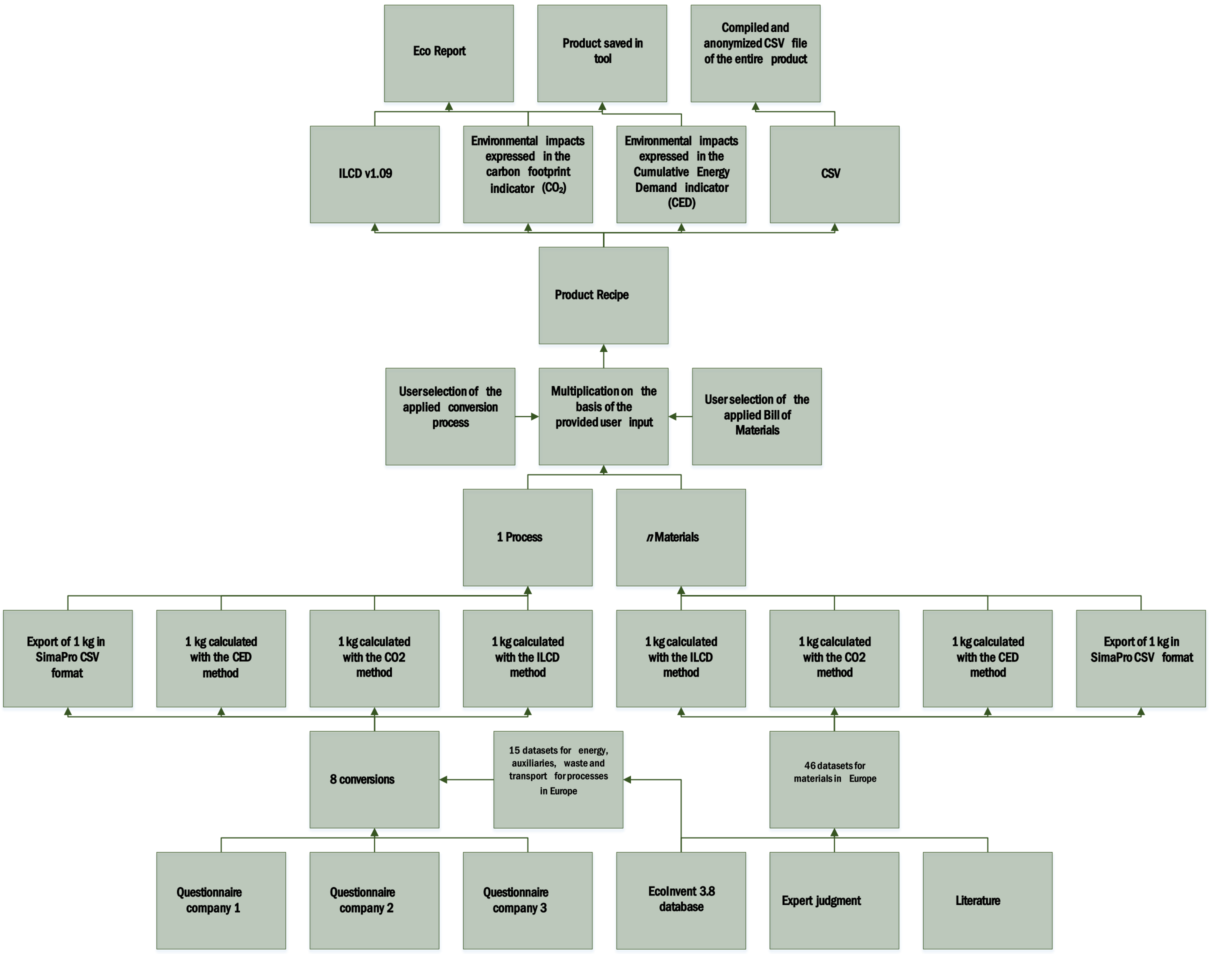

Figure 2: Tool architecture

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: there is data for the conversion processes and data on the materials. For the materials, 1 kg is modelled based on the available processes in the LCA databases enriched through expert judgement and literature. For some materials, proxy selection was required, of which the details can be found in Chapter 6. Any decisions regarding the use of proxies were made in consultation with the Steering Group. The materials were thereafter run through LCA software for three different assessment methods: Greenhouse Gas (GHG) protocol, Cumulative Energy Demand (CED) and International Reference Life Cycle Data System (ILCD). The results are transferred to the tool library (materials section). Chapter 6 contains a full overview of the available materials in the tool in combination with the related database processes.

For the conversion processes, 15 processes were identified that are able to cover most of the composite manufacturing in Europe (see Chapter 5). Due to the limitations relating to confidentiality and unexpectedly low data submission, enough questionnaires or industry data for 5 processes were received to be part of the first version of the tool. Three conversion processes have been modelled based on a process analysis. This was done based on scientific literature information, energy flows and process data of comparable processes in LCA databases. In total, 8 conversion processes are thus available in the tool.

The data delivered through the questionnaire is on conversion process factors such as 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 can download a PDF version of the 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.

The tool also has an export functionality, which aims to facilitate easy communication of the detailed environmental data without compromising confidentiality with clients of the composite industry. A SimaPro-CSV file can thus be generated for each calculated product, which can be imported directly by the client.

4.2 Life cycle inventory

It has been assessed which materials and processes are available in the databases EcoInvent and European reference Life Cycle Database (ELCD) including those developed by Plastics Europe. In addition, data has been used from previous LCA studies for the composite sector. The main objective was to obtain LCI data from EcoInvent where possible to maximize consistency and comparability within the tool. For the materials for which data was not available, proxies for data (where possible) were collected, estimated or used with the help of literature and expert opinions. For each production process, data was collected on the production of a composite product from manufacturers in Europe. Questionnaires were sent to manufacturers in 2014 to provide data for the EU Eco Impact Calculator.

Input and output data were collected regarding the following categories:

- Use of resources
- Emissions to air
- Discharges to water and soil

The non-elementary flows of energy and waste were 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 considering data from between 2015 and 2022. For some essential composite production processes, no industry data was provided to enable the calculation of impacts in the Eco Impact Calculator. This required calculation of several processes, the quality of which is elaborated upon in Chapter 5. For the materials, background data from the Ecoinvent 3.8 database was used as input for the tool wherever possible. In other cases, company specific data was used for core mat products and a mix of scientific research and empirical manufacturing data for carbon fibre.

4.4 Allocation

Allocation is the distribution of environmental burdens between two or more products or processes using several approaches as described in ISO 14040/44. This occurs with multi-input, multi-output, reuse and recycling processes. However, multi-input and multi-output processes are not part of this study, hence no allocation is used. Additionally, the end-of-life stage is not included within the scope of the Eco Impact Calculator.

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) ILCD 2011 Midpoint+ (v1.09) V1.09 / EU-27 2010, equal weighting
- Greenhouse Gas Protocol (v1.02) V1.02 / C02 eq (kg)
- Cumulative Energy Demand Cumulative Energy Demand V1.11 / 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).

4.5.1 International Reference Life Cycle Data System (ILCD)

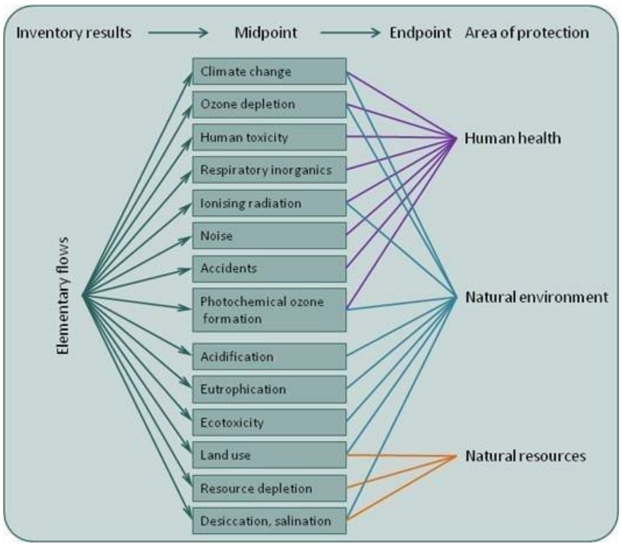

Figure 3: The life cycle assessment impact categories schematic

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 (Figure 3). 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) ILCD 2011 Midpoint+ (v1.09) V1.09 / 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 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.
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 based on primary information of European composites manufacturers retrieved through questionnaires. When data was not made available by industry for the development of the tool, the conversion processes were modelled (if deemed essential for the development of the tool), as shown in section 5.1.

In 2015, the ultimate aim of EuCIA was to include at least 15 moulding processes which were identified as representative of the conversion processes used in the composites industry. From the questionnaires received, 5 processes could be modelled, since the minimum of received datasets required for incorporation of processes in the tool was set to 3 in accordance with the EuCIA steering committee. The processes were 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 8 processes are currently included in the tool:

- Pultrusion[1]
- Resin infusion (RI)[1]
- Resin transfer moulding (RTM)[1]
- SMC compounding[1]
- SMC compression moulding[1]
- Thermoplastic compounding [2]
- Long Fibre Thermoplastics compounding[2]
- Thermoplastic injection moulding[2]

Painting and gel coating are included in the materials, since the material cannot be applied without these processes. All activities not related to production (e.g. office buildings and R&D) are not included in the calculations of the tool but only considered in light of energy allocation.

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

[1] Conversion processes modelled based on data provided directly from manufacturers (no extra description of these processes included in this report due to data confidentiality)

[2] Conversion processes modelled based on publicly available data

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

For some conversion processes, the Eco Impact Calculator development team and partners were unable to obtain input and output data from industry on the production process from the developed questionnaire sent to manufacturers. Therefore, EuCIA has decided to model key industrial conversion processes, such as injection moulding, in the tool using publicly available data and existing datasets in EcoInvent. This section describes how calculations are combined with existing data and datasets 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 long fibre thermoplastics (LFT). The paragraphs below 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

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

The Eco Impact Calculator generates Eco Reports for composites and compounds based on industry generated data in a transparent way following ISO 14040/044 standards. Unfortunately, industry-based data has not come available for 3 out of 8 conversion processes, as mentioned in section 5. Therefore, EuCIA took a different approach by modelling the compounding and moulding processes on first principles following real industry practices. This modelling procedure was done for calculating the energy requirements of the conversion processes, as thermodynamic data are known for these materials. The result is referenced with data available from EcoInvent that matches the processes for compounding and injection moulding.

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 moulding process, the energy required for heating, cooling and injecting 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 fiber 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 fiber 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 moulding, whichever was the highest. The model data were then adjusted. The results from this analysis have been summarized in Table 1 that presents the total energy data calculated for polypropylene (PP):

	Compounding	**LFT**	**Injection Moulding (IM)**		
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	n/a	0.812	1.3472	0.1211	8.578E-03

Table 1: Total energy data calculated for polypropylene (PP) for the different thermoplastic conversion processes.

The total energy data for 30%w/w glass fiber (GF) has been applied as energy values in the tool.

Table 1 shows that the variation in total energy needed for each process is very small. For instance, the total energy for compounding for different glass fiber content varies approximately 10% compared to the 30%w/w glass fiber content. Given this observation, only one value for PP compounding suffices in the model given the assumptions in the model itself. Additionally, the conversion process made a small contribution to the CED compared to the resins. The CED for polypropylene, polyester and polyamide are 82, 76 and 132 MJ/kg respectively, whereas the CED for glass fiber is 36 MJ/kg.

Table 2 shows that the variation between the resins lies closely 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%w/w glass fiber content		
Material	**Compounding**	**LFT**	**IM**
PP/GF	0.845	0.903	1.580
Polyester/GF	0.757	0.846	1.362
Polyamide/GF	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 combinations.

Therefore, the energy value per conversion process is independent of the glass fiber content or resin type. As mentioned above, the results from the total energy of the modelled conversion processes match the data in EcoInvent for comparable processes. It is then a reasonable assumption to complement the existing datasets in EcoInvent with the energy data calculated in this report.

5.1.2 Thermoplastic compounding

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. As described in section 5.1.1, the total energy values per conversion process did not change irrespective of the type of resin and the glass fiber content. Therefore, the total energy values for thermoplastic compounding at 30% w/w glass fiber content were used.

For thermoplastic composite compounding is modelled using the Ecoinvent process [Extrusion, plastic pipes {RER}| production | Cut-off, S]. This process was used as a proxy to obtain the additional process parameters, such as ancillary materials, water use, waste, among others. Though EuCIA feels that this approach is adequately supporting the needs for a trustworthy tool, we welcome any comment from industry to either confirm or to improve on the proposed dataset for thermoplastic processing.

Section 5.1.2.1 below provides more details regarding the thermoplastic compounding process

5.1.2.1 In more detail: Thermoplastic Compounding

Intertwining screws of proprietary design are driven by a high-powered electromotor receiving at various openings the resin, additives and (when all is properly molten) the glass fiber reinforcements. The latter are added generally as chopped strands and are reduced to lengths varying from 200 to 500 microns, depending on the operative conditions, and fully dispersed. The mixture exits the extruder as strands, immediately water cooled and chopped into granulate at a residual temperature of 60 to 90°C. The product from this procedure is bagged to be shipped to parts producers. Openings in the extruder allow for degassing of water vapor and some volatiles that are formed 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, while the screw housing is heated in various zones to allow the right properties for the granulate. The extruder throughputs can be several or more metric tons per hour to maximize the use of capital invested specifically for the larger volume applications. Figure 4 presents a schematic representation of the thermoplastic compounding process.

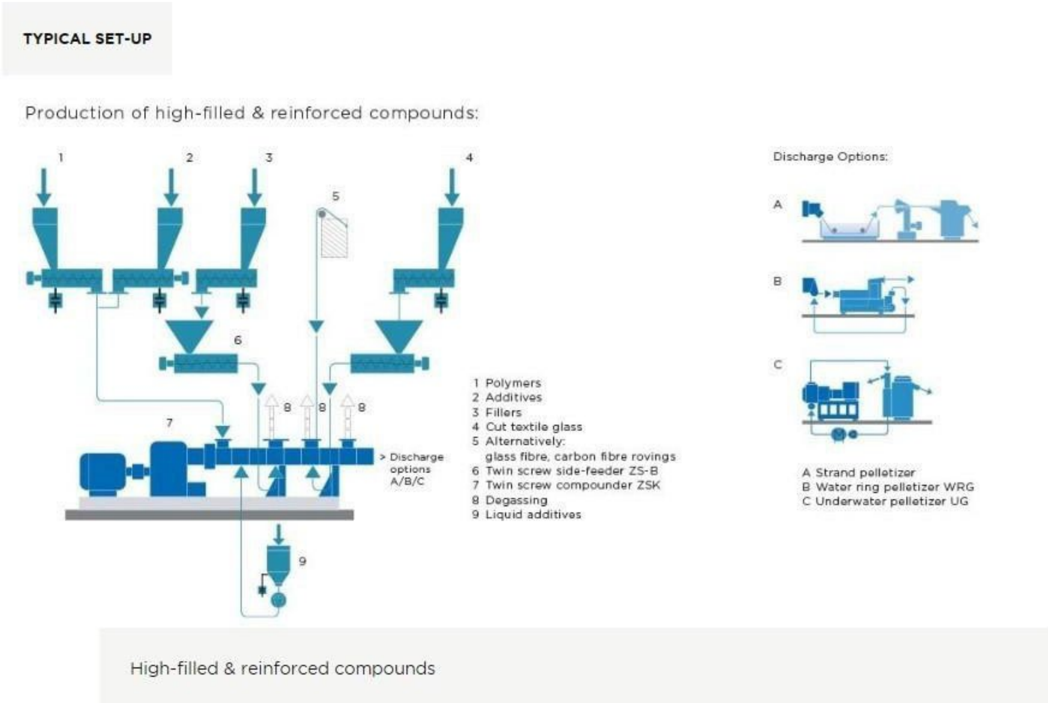

Figure 4: Schematic representation of the thermoplastic compounding process. Source: https://www.coperion.com/en/industries/plastics/compounding/

The amount of energy needed for the conversion processes is estimated based on available data from the scientific literature. This can be seen as a first principles approach, which is the basis for further estimates for the total energy needed for thermoplastic compounding. Table 3 describes the calculation for estimating the heating requirements of different types of resins (polypropylene (PP), polyethylene terephthalate (PET), polybutylene terephthalate (PBT) and polyamide (PA) 6 and 66) to reach their typical extrusion temperatures. Two approaches were used to estimate the heating requirements for the different types of resins: a one-step approach that considers the use of a single average coefficient of thermal expansion (C_p) and a two-step approach that considers both C_p for the solid and liquid phases of the resins.

From Table 3, it is clear that the use of the one-step or the two step-approach resulted in small differences. Therefore, the two -step approach is used for further calculations. The total energy of melting is similar for these resins and higher than the energy needed for heating glass fiber to comparable temperatures. Later we will see that the increased content of glass fibers, although affecting extruder throughput, will lead to a small reduction in energy needed for higher glass fiber contents using this two- step approach.

It should be noted that although the polyester melting energy is lower, inclusion of the auxiliary equipment will make the difference relatively small, justifying the use 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 requirements of different types of resins to their typical extrusion temperatures. This table does not include energy data related to auxiliary equipment.

Conversion process energy calculation

The calculation of the energy requirement for the thermoplastic compounding process should include the variability of the glass fiber content, the heat loss during the compounding itself, the cooling of the water used for reducing the strand temperature, the energy needed in the granulating process, and the energy used by the hoppers and the feeding system. As mentioned before, estimates were made as no industrial data was available. Therefore, a conservative approach has been followed to consider the impact of the conversion process on the production of the composite parts. First, it is recognized that extruder throughput reduces as the glass fiber content increases. Table 4 describes the assumptions considered for the heat loss during compounding.

Glass fiber content (%w/w)	% Heat 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 on the modelling approach of this conversion process. The same applies for the assumptions on estimating the energy needed to re-use the cooling water. In addition, it is estimated that 5 % of the water content has to be evaporated, either through pre-drying of the granulate or evaporation. In calculations for injection moulding, it is assumed that the input granulate is completely dry. Finally, all auxiliary equipment has to be powered (e.g., choppers, pumps, and hoppers). For this a fixed amount per kg of end product is included. The calculation of the energy requirements of thermoplastic compounding for typical 30% w/w glass fiber compounds is 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	totaal		30%	50%	60 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, 50% 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**	**0,1568**	**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**	**0,1568**	**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		**0,5586**	**0,2793**	**0,5886**	**0,1568**	**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% w/w glass fiber content 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 requirements for thermoplastic compounding at 30% w/w glass fiber content have been determined. For thermoplastic composite compounding [Extrusion, plastic pipes {RER}| production | Alloc Rec.] was used as a proxy to obtain the additional process parameters, such as ancillary materials, water use, waste etc. The dataset described above is not directly used in modelling, but the input data is used to estimate input parameters for thermoplastic compounding. Since the input data is not expected to have changed significantly, these input values have not been updated using the latest EcoInvent datasets.

Dependency on glass content

With a model that seems to provide reasonable results comparable with literature sources, the effect of the glass fiber content on the total energy needed can be further investigated. Table 6 presents an overview of the conversion energy for different glass fiber contents in compounds. With increased glass fiber content, throughputs decrease - to allow in the first place for less friction and thus, fiber degradation - and the total energy use increases. The longer dwell time, be it short, will result in more heat losses. Additional heating around the extruder has to be provided. The data in Table 6 are estimates as mentioned before but clearly show the dependency of energy needed at higher glass fiber content.

Glass fiber content in %w/w						
Material	**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

Table 6: Overview conversion energy in kWh per kg for different glass fiber content

The energy requirements of hoppers and choppers are assumed to be identical per kg of end-product. The results in Table 6 show that the use of energy decreases slightly with increased glass fiber content, which follows the original thermodynamic data. Some variations in the use of energy, specifically with choppers and other auxiliary equipment, may change. However, it is a fair assumption that variations are minor (considering all the unknowns) for the conversion of glass fiber reinforced compounds. It is assumed that the effect will not be largely different with other fillers like mica, talcum or clay. Special compounds, especially at the high-end for automotive such as high temperature resistant applications, may require more energy. However, the above calculations can provide an indication of the magnitude of that effect.

In summary, the abovementioned analysis supports the assumption to use one single value for the total energy required for the conversion of glass fiber and thermoplastics into compounds for three different resins (PP, polyester and PA). 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

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. As described in section 5.1.1, the total energy values per conversion process did not change irrespective of the type of resin and the glass fiber content. Therefore, the total energy values for LFT compounding at 30% w/w glass fiber content were used.

LFT compounding is modelled using the Ecoinvent process [Extrusion, plastic pipes {RER}| production | Cut-off, S]. This process was used as a proxy to obtain the additional process parameters (e.g. ancillary materials, water use, waste). The dataset described above is not directly used in modelling, but the input data is used to estimate input parameters for thermoplastic compounding. Since the input data is not expected to have changed significantly, these input values have not been updated using the latest EcoInvent datasets. Though

EuCIA feels that this approach is adequately supporting the needs for a trustworthy Eco Impact Calculator, we welcome any comment from industry to either confirm or to improve on the proposed dataset for thermoplastic processing.

Section 5.1.3.1 below provides more details regarding the LFT compounding process.

5.1.3.1 In more detail: Long Fibre Thermoplastic Compounding

A typical process scheme for LFT processing is shown in Figure 5:

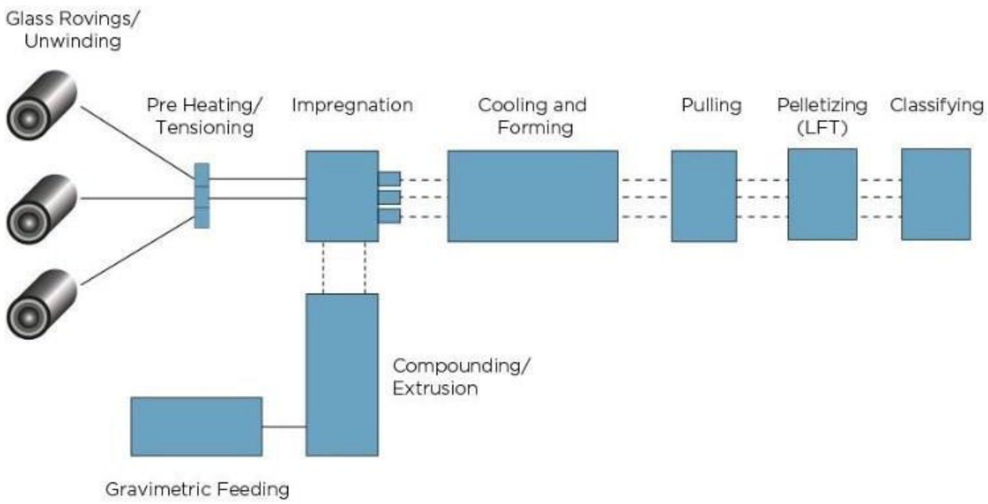

Figure 5: Schematic description of the LFT processing.
Source: https://www.coperion.com/en/industries/plastics/lft-long-fiber-reinforced-thermoplastics/

For LFT, the same assumptions have been used as for short fiber thermoplastic compounding (SF-TP) with two differences. Peak temperatures are set higher i.e. 300, 360 and 400°C for polypropylene, polyester and polyamide, respectively. In addition, heat losses have been assumed to be higher for the slower process rates as mentioned before. Assumptions for heat losses from LFT compounding are presented in Table 7.

Glass fiber content (%w/w)	% Heat loss
30	60
40	75
50	90
60	105
70	120

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

Auxiliary equipment energy is assumed to be the same as for SF-TP compounding.

5.1.4 Thermoplastic Injection Moulding

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. As described in section 5.1.1, the total energy values per conversion process did not change irrespective of the type of resin and the glass fiber content. Therefore, the total energy values for Thermoplastic Injection Moulding at 30% w/w glass fiber content were used.

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 Injection Moulding these additional parameters are based on [Injection moulding {RER}| processing | Cut-off, S]. The dataset described above is not directly used in modelling, but the input data is used to estimate input parameters for thermoplastic injection moulding. Since the input data is not expected to have changed significantly, these input values have not been updated using the latest EcoInvent datasets.

Though EuCIA feels that this approach is adequately supporting the needs for a trustworthy Eco Impact Calculator, we welcome any comment from industry to either confirm or to improve on the proposed dataset for thermoplastic processing.

Section 5.1.4.1 below provides more details regarding the Thermoplastic Injection Moulding process.

5.1.4.1 In more detail: Thermoplastic Injection Moulding

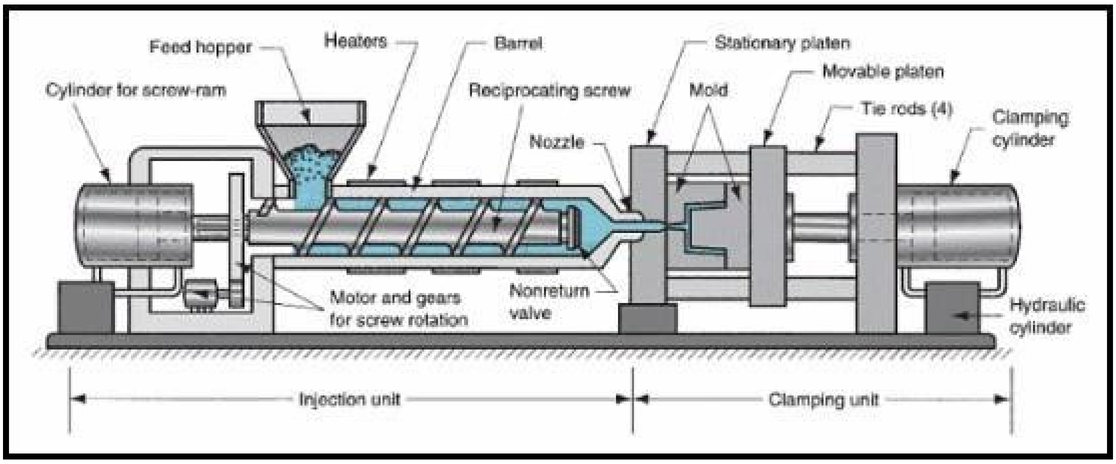

Figure 6 A typical scheme for injection moulding of thermoplastic parts.
Source: http://www.mechscience.com/injection-moldinginjection-molding-machineinjection-molding-processinjection-molding-on-plastics/

Granules are plasticized in a single screw set up driven by an electromotor and heated to the desired temperature (Figure 6). The mould is intermittently filled while kept at a temperature significantly below the melting temperature of the resin. This requires adequate cooling. The screw will contain several shots. For our calculations the same peak temperature as for compounding is used in this project. An energy use ratio of 50, 35 and 15 was used to estimate the relative energy use for heating, injection and cooling, respectively. The heating energy calculation is based on the same principles as in Table 4, assuming heat losses as in Table 8. Energy for auxiliary equipment on the same basis as for thermoplastic and LFT compounding has been included, while assuming that drying was not needed as included in the compounding processes.

Glass fiber content (%w/w)	% Heat loss
20	40
30	50
40	60
50	70
60	80

Table 8**:** Assumption of heat loss 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 by which the impact of the production needs to be multiplied is determined by the amount of material indicated by the users for specific composite parts. All materials have been modelled and calculated for 1 kg, unless otherwise indicated. The materials in the tool are modelled using LCA databases, such as the EcoInvent (EI 3.8) and ELCD database (ELCD 3), and are in some cases refined. For some materials, a proxy dataset is used to approach the materials used in the composites industry. The database processes used to model the materials have specific naming, which is provided between brackets: [...]. As a standard Ecoinvent is used as the LCA database unless otherwise described.

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.

6.1 Transport

Transport is added to all the materials modelled. It represents the transport of the product from its (raw material) supplier to the next phase in the product life cycle. In this case this is the location where the processing of the material into an end-product or intermediate product takes place. For Europe the following assumptions on transportation are included:

- 90% of the composite (raw) materials for Europe are produced within Europe
    - Transport within Europe assumes on average of 500 km by truck. The following split is assumed between EURO5 and EURO6 type trucks.
        - 75% of the trucks are EURO6
            - Dataset: [Transport, freight, lorry 16-32 metric ton, EURO6 {RER}| transport, freight, lorry 16-32 metric ton, EURO6 | Cut-off, S]
        - 25% of the trucks are EURO5
            - Dataset: [Transport, freight, lorry 16-32 metric ton, EURO5 {RER}| transport, freight, lorry 16-32 metric ton, EURO5 | Cut-off, S]
- 10% of the composite (raw) materials for Europe are produced somewhere else in the World. For these materials the following transport assumptions are included:
    - Transport from company to a train station anywhere in the World is assumed to be on average 100 km by truck.
        - Dataset: [Transport, freight, lorry 16-32 metric ton, EURO5 {RoW}| transport, freight, lorry 16-32 metric ton, EURO5 | Cut-off, S]
    - Transport from the train station to a harbour anywhere in the World is assumed to be on average 200 km by freight train.
        - Dataset: [Transport, freight train {GLO}| market group for | Cut-off, S]
    - Transport from a harbour anywhere in the World to a harbour in Europe is assumed on average 14,000.0 km by ship. It is assumed that most of the materials are sourced from Malaysia, Singapore and Japan. Using a sea route calculator the distance of going from the port of Singapore to the port of Marseille and from the port Singapore to the port of

Rotterdam was determined. The average of the two distances was used to estimate the transport distance by ship from a harbour anywhere in the world to a harbour in Europe. As there are different types of materials in the tool a distinction is made between shipping transport for solid materials and for liquid materials.

- For solid materials: Container ship
    - Dataset: [Transport, freight, sea, container ship {GLO}| market for transport, freight, sea, container ship | Cut-off, S]

- For liquid materials: Tanker
    - Dataset: [Transport, freight, sea, tanker for liquid goods other than petroleum and liquefied natural gas {GLO}| market for transport, freight, sea, tanker for liquid goods other than petroleum and liquefied natural gas | Cut-off, S]

- Transport from the harbour within Europe to the processing site within Europe is assumed to be on average 500 km by truck. The following split is assumed between EURO5 and EURO6 type trucks.
    - 75% of the trucks are EURO6
        - Dataset: [Transport, freight, lorry 16-32 metric ton, EURO6 {RER}| transport, freight, lorry 16-32 metric ton, EURO6 | Cut-off, S]

    - 25% of the trucks are EURO5
        - Dataset: [Transport, freight, lorry 16-32 metric ton, EURO5 {RER}| transport, freight, lorry 16-32 metric ton, EURO5 | Cut-off, S]

6.2 Fibres

6.2.1 Glass Fibre

The continuous filament glass fibre (CFGF) material datasets have been provided by Glass Fibre Europe, the European Glass Fibre Producers Association. Manufacturing data from 2021 was collected from 11 plants located in the European Union, the United-Kingdom and Norway. More information about the CFGF material datasets can be found on the website of Glass Fibre Europe[1].

The transport by truck, barge and train has been taken into account in the production of the CFGF materials. The datasets represent the service of 1 ton of product transported over 1 km. They are built on average European journeys, average load factors and average empty trips.

The two transport steps taken into account in the study are: i) the transportation of raw material to the CFGF production site and ii) the transportation of waste from the site to the treatment plant.

Given the system boundaries of the tool, the standard transport scenario outlined in Chapter 6.1 has also been included in each of the glass fibre material datasets. The transport scenario represents the different transportation stages included in the production of glass fibre materials from the supplier to the composite manufacturer. However, due the fact that the CFGF materials are produced in Europe, the transport scenario has been allocated to 100% in Europe rather than the 90% Europe and 10% World split, as outlined in Chapter 6.1.

6.2.1.1 Glass Fibre Assembled Roving

[1] Life Cycle Assessment of Continuous Filament Glass Fibre Products – Glass Fibre (glassfibreeurope.eu)

New data for Glass fibre assembled roving has been made available in 2022 and is incorporated in the Eco Impact Calculator in 2023. This material is modelled using 1 kg of the process [2023 Continuous filament glass fibre (assembled rovings), at plant {RER} [LCI result] with transport System]. This process is representative of this type of glass fibre production in Europe. An adjusted version of the standard transport scenario for solid materials was used. More information on the transport scenario can be found in Chapter 6.1.

6.2.1.2 Glass Fibre Wet Chopped Strands

New data for Glass fibre wet chopped strands has been made available in 2022 and is incorporated in the Eco Impact Calculator in 2023. This material is modelled using 1 kg of the process [2023 Continuous filament glass fibre (wet chopped strands), at plant {RER} [LCI result] with transport System]. This process is representative of this type of glass fibre production in Europe. An adjusted version of the standard transport scenario for solid materials was used. More information on the transport scenario can be found in Chapter 6.1.

6.2.1.3 Glass Fibre Dry Chopped Strands

New data for Glass fibre dry chopped strands has been made available in 2022 and is incorporated in the Eco Impact Calculator in 2023. This material is modelled using 1 kg of the process [2023 Continuous filament glass fibre (dry chopped strands), at plant {RER} [LCI result] with transport System]. This process is representative of this type of glass fibre production in Europe. An adjusted version of the standard transport scenario for solid materials was used. More information on the transport scenario can be found in Chapter 6.1.

6.2.1.4 Glass Fibre Direct Roving

New data for Glass fibre direct roving has been made available in 2022 and is incorporated in the Eco Impact Calculator in 2023. This material is modelled using 1 kg of the process [2023 Continuous filament glass fibre (direct rovings), at plant {RER} [LCI result] with transport System]. This process is representative of this type of glass fibre production in Europe. An adjusted version of the standard transport scenario for solid materials was used. More information on the transport scenario can be found in Chapter 6.1.

6.2.1.5 Glass Fibre Mats

New data for Glass fibre mats has been made available in 2022 and is incorporated in the Eco Impact Calculator in 2023. This material is modelled using 1 kg of the process [2023 Continuous filament glass fibre (mats), at plant {RER} [LCI result] with transport System]. This process is representative of this type of glass fibre production in Europe. An adjusted version of the standard transport scenario for solid materials was used. More information on the transport scenario can be found in Chapter 6.1.

6.2.2 Carbon Fibre

Overall, modelling the production of carbon fibre proves to be a challenge in terms of data availability at the industry/commercial and academic levels. At the industrial level, this is because such data often remains proprietary. At the academic level, there are only a few key studies with information publicly available. For this project, the data was obtained from several different sources, including a set of researchers from universities such as KU Leuven and Nottingham University, data from the European Life Cycle Database (ELCD), and research conducted by Tim Roeding from the Institut für Textiltechnik (ITA) of the RWTH Aachen University. The data was consolidated across various sources and when appropriate, averaged if there were multiple options for the relevant input or output. Specifically, carbon fibres are modelled using two processes: acrylonitrile (AN) to polyacrylonitrile (PAN), and PAN to Carbon fibre (CF), which are described below. These processes are representative of 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 at KU Leuven, 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 conversion factor (yield) of PAN to carbon of 42%

was used.

Energy input values for electricity and heat vary depending on the production process stage outlined in the Table 9 below. For the electricity mix, 90% ratio sourced from Europe was created with the EI 3.8 dataset [Electricity, low voltage {Europe without Switzerland}| market group for | Cut-off, S]. For the remaining 10%, RoW datasets for low voltage electricity were not available in EI 3.8, therefore the dataset [Electricity, low voltage {KR}| market for | Cut-off, S] was selected.

To model heat the following process was included at 90% ratio [Heat, district or industrial, natural gas {Europe without Switzerland}| heat production, natural gas, at industrial furnace >100kW | Cut-off, S]. The remaining 10% ratio was modelled using the process [Heat, district or industrial, natural gas {RoW}| heat production, natural gas, at industrial furnace >100kW | Cut-off, S].

Production process step	Unit
Unwinding primary electricity use obtained from Aachen University	kWh
Unwinding primary gas use obtained from Aachen University	MJ
Oxidation primary electricity use obtained from Aachen University	kWh
Oxidation primary gas use obtained from Aachen University	MJ
Carbonization LT primary electricity use obtained from Aachen University	kWh
Carbonization LT primary gas use obtained from Aachen University	MJ
Carbonization HT primary electricity use obtained from Aachen University	kWh
Carbonization HT primary gas use obtained from Aachen University	MJ
Exhaust gas treatment primary electricity use obtained from Aachen University	kWh
Exhaust gas treatment primary gas use obtained from Aachen University	MJ
Elektrolysis primary electricity use obtained from Aachen University	kWh
Elektrolysis primary gas use obtained from Aachen University	MJ

Production process step	Unit
Washing primary electricity use obtained from Aachen University	kWh
Washing primary gas use obtained from Aachen University	MJ
Drying-I primary electricity use obtained from Aachen University	kWh
Drying-I primary gas use obtained from Aachen University	MJ
Avivage primary electricty use obtained from Aachen University	kWh
Avivage primary gas use obtained from Aachen University	MJ
Drying-II primary electricity use obtained from Aachen University	kWh
Drying-II primary gas use obtained from Aachen University	MJ
Spooling primary electricity use obtained from Aachen University	kWh
Spooling primary gas use obtained from Aachen University	MJ

Table 9: Energy inputs at each production step of carbon fibre and their units

Material inputs which are discussed in the paper from Nottingham University (Meng et al., 2017) include processes from EI 3.8:

- 2.38 kg of [Polyacrylonitrile fibres (PAN), from acrylonitrile and methacrylate, prod. mix, PAN w/o additives EU-27 S] – this dataset is from ELCD and there is no Global or Rest of World dataset, so this

EU dataset is used for RER and RoW at a 42% yield factor as reported by Aachen University data.

- 2.77 kg Water
    - 90% was sourced from Europe using process [Water, decarbonised {DE}| water production, decarbonised | Cut-off, S]
    - 10% was sourced outside of Europe using process [Water, decarbonised {RoW}| water production, decarbonised | Cut-off, S]

- 0.01 kg epoxy resin
    - 90% was sourced from Europe using process [Epoxy resin, liquid {RER}| production | Cut- off, S]
    - 10% was sourced outside of Europe using [Epoxy resin, liquid {RoW}| market for epoxy resin, liquid | Cut-off, S]

- 0.02 kg sulfuric acid
    - 90% was sourced from Europe using process [Sulfuric acid {RER}| market for sulfuric acid | Cut-off, S].
    - 10% was sourced outside of Europe using process [Sulfuric acid {RoW}| market for sulfuric acid | Cut-off, S]

Furthermore, from the ITA research, three material inputs were used:

- 0.1 kg of [Potassium permanganate {RER}| oxidation of manganese dioxide | Cut-off, S]

- 0.02 kg ammonium bicarbonite
    - 90% was sourced from Europe using process [Ammonium bicarbonate {RER}| production | Cut-off, S]
    - 10% was sourced outside of Europe using process [Ammonium bicarbonate {RoW}| market for ammonium bicarbonate | Cut-off, S]

- 0.01 kg of [Polydimethylsiloxane {GLO}| polydimethylsiloxane production | Cut-off, S] used as a proxy for the raw material silicone oil agent mentioned in ITA's research.

For transport in Europe, a transport scenario for solid materials was used. More information on the transport scenario can be found in Chapter 6.1.

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 1 kg of Carbon Fibre. Nitrogen oxide (NO_x) is modelled as the aggregation of 0.33 kg of Nitrogen monoxide (NO) and 0.67 kg Nitrogen dioxide (NO_2). The pollution abatement systems onsite at plants are not modelled.

6.2.1.1 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 for modelling in EI3.8 is [Polyacrylonitrile fibres (PAN), from acrylonitrile and methacrylate, prod. mix, PAN w/o additives EU-27 S], sourced from RWTH Aachen University led by Tim Roeding. Figures 7 and 8 show an overview of the inputs/outputs used during the PAN production process. The strength of the precursor used is important for this process. The need for using a higher precursor strength is influenced by the CF grade produced and its 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).

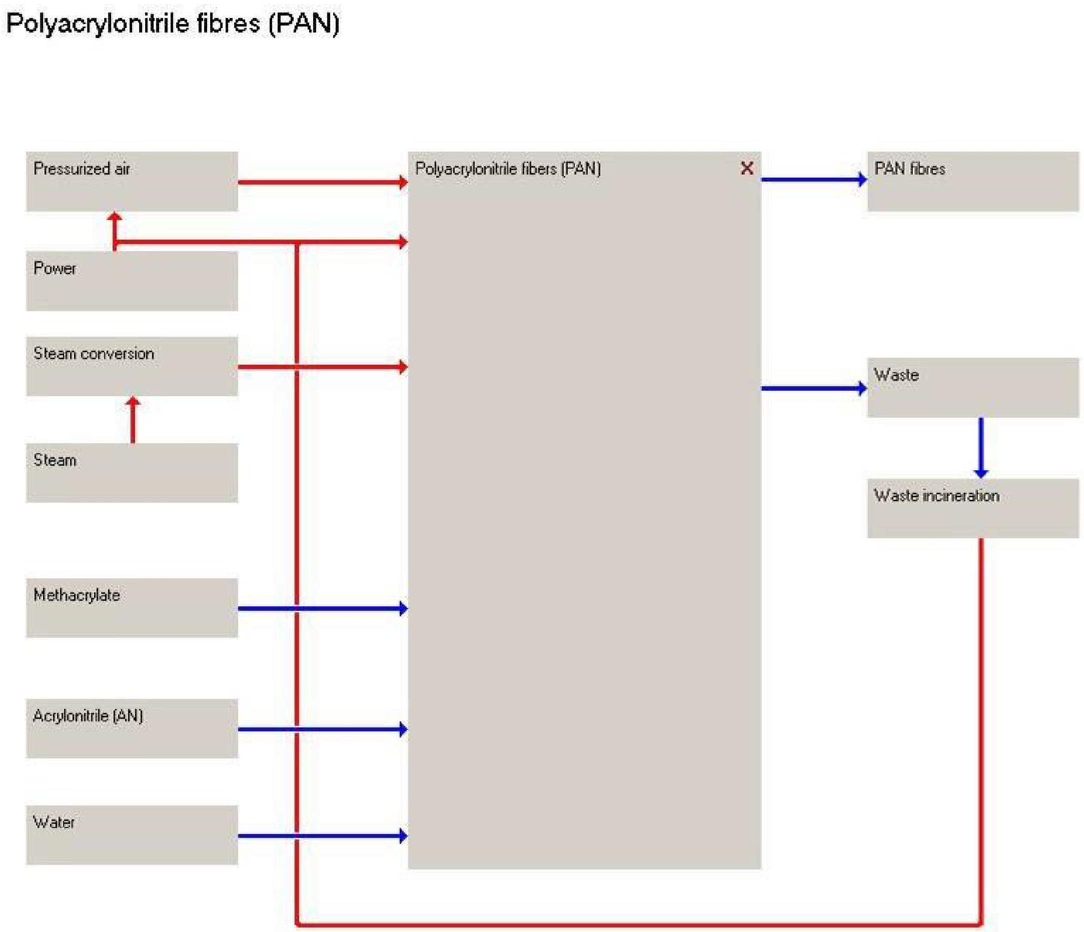

Figure 7: Overview PAN Production (Thinkstep, 2018)
Source: Gabi documentation

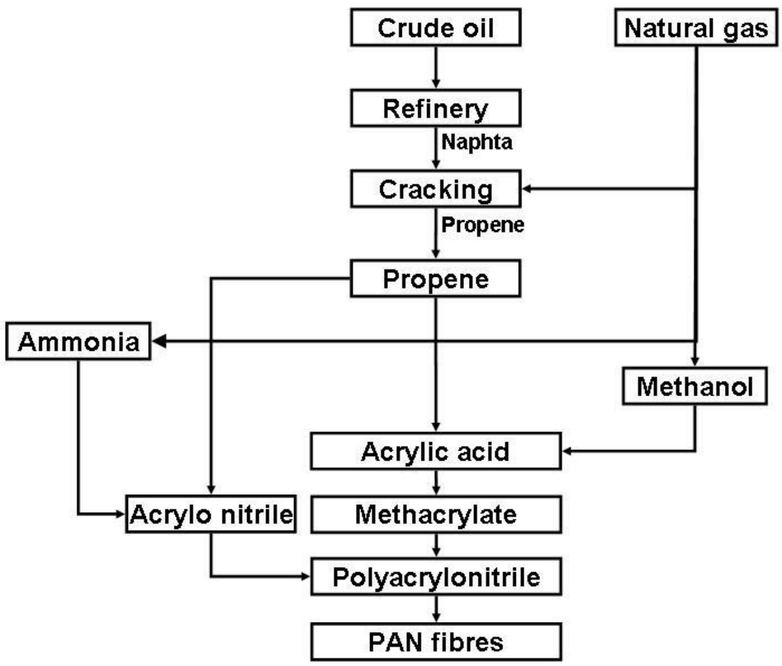

Figure 8: Overview CF Production (Thinkstep, 2018) Source: Gabi documentation

Second is the production of CF from PAN which includes various sub processes, including oxidation, pre-carbonization, surface treatment, washing, drying, sizing, an additional drying stage, and finally winding Das (2011). Graphitization is an additional process but is not included in the modelling of CF production as this is less common and is primarily used in university studies. The oxidation stage requires a processing time between 30 minutes to an hour at a temperature of 300°C. The oxidation stage has the highest energy consumption, and it is exothermic, thereby posing risks for combustion onsite. 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. The next stage, surface treatment, involves an anodic surface treatment bath where carboxyl groups are formed, improving the cohesion between fiber and resin used in the final composite. What follows is the washing stage, where electrolytes are removed via a warm water bath and CF pass through dip baths with a counter current water flow. Subsequently, carbon fibre strands are pre-dried before sizing via contact with air and a roller dryer. Then, the material is sized via a sizing bath including the dispersion of water and epoxy particles. An additional drying stage is followed by the sizing, and finally the last stage is winding, whereby winders produce CF spools up to 12 kg in weight.

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6.2.3 Fabrics

Fabrics made from the incumbent fibres are not yet included due to lack of data. We would welcome reliable and high-quality data for these materials to be able to integrate these also into the tool, such as:

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

6.3 Resins

6.3.1 PolyAmide Resin (PA)

This material is modelled using a 50%-50% mix of Nylon 6-6 and Nylon 6. The following distribution of processes in EI 3.8 were used to model the production of 1 kg of PA:

- 0.5 kg of Nylon 6-6 of which

    - 90% was sourced from Europe using EI 3.8 process [Nylon 6-6 {RER}| production | Cut-off, S]
    - 10% was sourced outside of Europe using EI 3.8 process [Nylon 6-6 {RoW}| production | Cut- off, S].

- 0.5 kg of Nylon 6 of which
    - 90% was sourced from Europe using EI 3.8 process [Nylon 6 {RER}| production | Cut-off, S],
    - 10% was sourced outside of Europe using EI 3.8 process [Nylon 6 {RoW}| production | Cut- off]

For transport in Europe, a transport scenario for solid materials was used. More information on the transport scenario can be found in Chapter 6.1.

6.3.2 Polypropylene Resin (PP)

This material is modelled using 0.9 kg of PP sourced from Europe using the EI 3.8 process [Polypropylene, granulate {RER}| production | Cut-off, S] and 0.1 kg of PP sourced outside of Europe using the EI 3.8 process [Polypropylene, granulate {RoW}| production | Cut-off, S.].

For transport in Europe, a transport scenario for solid materials was used. More information on the transport scenario can be found in Chapter 6.1.

6.3.3 Polyethylene terephthalate Resin (PET)

This material is modelled using 0.9 kg of PET sourced from Europe using the EI 3.8 process [Polyethylene terephthalate, granulate, bottle grade {RER}| production | Cut-off, S] and 0.1 kg of PET sourced outside of Europe using the EI 3.8 process [Polyethylene terephthalate, granulate, bottle grade {RoW}| production | Cut-off, S].

For transport in Europe, a transport scenario for solid materials was used. More information on the transport scenario can be found in Chapter 6.1.

6.3.4 Other Thermoplastics Resins

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

6.3.5 Polyurethane Resin (PU)

The production of 1 kg of PU is modelled as follows:

- 0.55 kg of Methylene diphenyl diisocyanate of which
    - 90% was sourced from Europe using EI 3.8 process [Methylene diphenyl diisocyanate {RER}| production | Cut-off, S]
    - 10% was sourced outside of Europe using EI 3.8 process [Methylene diphenyl diisocyanate {RoW}| production | Cut-off, S].

- 0.45 kg of Diethylene glycol of which
    - 90% was sourced from Europe using EI 3.8 process [Diethylene glycol {RER}| ethylene glycol production | Cut-off, S]
    - 10% was sourced outside of Europe using EI 3.8 process [Diethylene glycol {RoW}| ethylene glycol production | Cut-off, S].

For transport in Europe, a transport scenario for solid materials was used. More information on the transport scenario can be found in Chapter 6.1.

6.3.6 Epoxy Curing Agents

Two types of Epoxy Curing Agents have been included in the Eco Impact Calculator: Phthalic Anhydride and Ethylene diamine (EDA).

6.3.6.1 Phthalic anhydride

The production of 1 kg of Phthalic anhydride is modelled using the 0.9 kg of the EI 3.8 process [Phthalic anhydride {RER}| production | Cut-off] and 0.1 kg of the EI 3.8 process [Phthalic anhydride {RoW}| production | Cut-off].

For transport in Europe, a transport scenario for liquid materials was used. More information on the transport scenario can be found in Chapter 6.1.

6.3.6.2 Ethylene diamine

The production of 1 kg of ethylene diamine is modelled using 0.9 kg of the EI 3.8 process [Ethylenediamine {RER}| production | Cut-off] and 0.1kg of the EI 3.8 process [Ethylenediamine {RoW}| production | Cut- off].

For transport in Europe, a transport scenario for liquid materials was used. More information on the transport scenario can be found in Chapter 6.1.

6.3.7 Epoxy Resin

The production of 1 kg of epoxy resin is modelled using 0.9 kg of the EI 3.8 process [Epoxy resin, liquid {RER}| production | Cut-off] and 0.1 kg of the EI 3.8 process [Epoxy resin, liquid {RoW}| production | Cut- off].

For transport in Europe, a transport scenario for liquid materials was used. More information on the transport scenario can be found in Chapter 6.1.

6.3.8 Isocyanate Resin

The production of 1 kg of isocyanate resin is modelled using 0.9 kg of the EI 3.8 process [Methylene diphenyl diisocyanate {RER}| production | Cut-off] and 0.1 kg of the EI 3.8 process [Methylene diphenyl diisocyanate {RoW}| production | Cut-off].

For transport in Europe, a transport scenario for liquid materials was used. More information on the transport scenario can be found in Chapter 6.1.

6.3.9 Phenolic Resin

The production of 1 kg of phenolic resin is modelled using 0.9 kg of the EI 3.8 process [Phenolic resin {RER}| production | Cut-off] and 0.1 kg of the EI 3.8 process [Phenolic resin {RoW}| production | Cut-off].

For transport in Europe, a transport scenario for liquid materials was used. More information on the transport scenario can be found in Chapter 6.1.

6.3.10 DCPD-based Unsaturated Polyester Resin (UP)

The production of 1 kg of DCPD-based Unsaturated Polyester Resin (UP) is modelled using 0.9 kg of the EI 3.8 process [Dicyclopentadiene based unsaturated polyester resin {RER}| production | Cut-off] and 0.1 kg of the EI 3.8 process [Dicyclopentadiene based unsaturated polyester resin {RoW}| production | Cut- off].

For transport in Europe, a transport scenario for liquid materials was used. More information on the transport scenario can be found in Chapter 6.1.

6.3.11 Isophthalic acid-based Unsaturated Polyester Resin (UP)

The production of 1 kg of Isophthalic acid-based Unsaturated Polyester Resin (UP) is modelled using 0.9 kg of the EI 3.8 process [Isophthalic acid based unsaturated polyester resin {RER}| production | Cut-off] and 0.1 kg of the EI 3.8 process [Isophthalic acid based unsaturated polyester resin {RoW}| production | Cut-off].

For transport in Europe, a transport scenario for liquid materials was used. More information on the transport scenario can be found in Chapter 6.1.

6.3.12 Orthophthalic acid-based Unsaturated Polyester Resin (UP)

The production of 1 kg of Orthophthalic acid-based Unsaturated polyester resin (UP) is modelled using 0.9 kg of the EI 3.8 process [Orthophthalic acid based unsaturated polyester resin {RER}| production | Cut- off] and 0.1 kg of the EI 3.8 process [Orthophthalic acid based unsaturated polyester resin {RoW}| production | Cut-off].

For transport in Europe, a transport scenario for liquid materials was used. More information on the transport scenario can be found in Chapter 6.1.

6.3.13 Pure Maleic Unsaturated Polyester Resin (UP)

The production of 1 kg of Pure Maleic Unsaturated Polyester Resin (UP) is modelled using 0.9 kg of the EI 3.8 process [Maleic unsaturated polyester resin {RER}| production | Cut-off, S] and 0.1 kg of the EI 3.8 process [Maleic unsaturated polyester resin {RoW}| production | Cut-off, S].

For transport in Europe, a transport scenario for liquid materials was used. More information on the transport scenario can be found in Chapter 6.1.

6.3.14 Unsaturated Polyester Resin (unspecified) (UP)

The production of 1 kg of Unsaturated Polyester Resin (unspecified) is modelled as follows:

- 0.25 kg of Dicyclopentadiene based unsaturated polyester resin of which
    - 90% was sourced from Europe using EI 3.8 process [Dicyclopentadiene based unsaturated polyester resin {RER}| production | Cut-off, S]
    - 10% was sourced outside of Europe using EI 3.8 process [Dicyclopentadiene based unsaturated polyester resin {RoW}| production | Cut-off, S]

- 0.25 kg of Isophthalic acid based unsaturated polyester resin of which
    - 90% was sourced from Europe using EI 3.8 process [Isophthalic acid based unsaturated polyester resin {RER}| production | Cut-off, S]
    - 10% was sourced outside of Europe using EI 3.8 process [Isophthalic acid based unsaturated polyester resin {RoW}| production | Cut-off, S]

- 0.25 kg of Orthophthalic acid based unsaturated polyester resin of which
    - 90% was sourced from Europe using EI 3.8 process [Orthophthalic acid based unsaturated polyester resin {RER}| production | Cut-off, S]
    - 10% was sourced outside of Europe using EI 3.8 process [Orthophthalic acid based unsaturated polyester resin {RoW}| production | Cut-off, S]

- 0.25 kg of Maleic unsaturated polyester resin of which
    - 90% was sourced from Europe using EI 3.8 process [Maleic unsaturated polyester resin {RER}| production | Cut-off, S]
    - 10% was sourced outside of Europe using EI 3.8 process [Maleic unsaturated polyester resin {RoW}| production | Cut-off, S]

For transport in Europe, a transport scenario for liquid materials was used. More information on the transport scenario can be found in Chapter 6.1.

6.3.15 Bisphenol A-based Vinyl Ester Resin (VE)

The production of 1 kg of Bisphenol A-based Vinyl Ester Resin (VE) is modelled using 0.9 kg of the EI 3.8 process [Bisphenol A epoxy based vinyl ester resin {RER}| production | Cut-off, S] and 0.1 kg of the EI 3.8 process [Bisphenol A epoxy based vinyl ester resin {RoW}| production | Cut-off, S].

For transport in Europe, a transport scenario for liquid materials was used. More information on the transport scenario can be found in Chapter 6.1.

6.4 Fillers

6.4.1 Aluminium TriHydrate (ATH)

The production of 1 kg of Aluminium TriHydrate (ATH) is modelled using 0.9 kg of the EI 3.8 process [Aluminium hydroxide {IAI Area, EU27 & EFTA}| aluminium hydroxide production | Cut-off, S] and 0.1 kg of the EI 3.8 process [Aluminium hydroxide {RoW}| aluminium hydroxide production | Cut-off, S].

For transport in Europe, a transport scenario for solid materials was used. More information on the transport scenario can be found in Chapter 6.1.

6.4.2 Calcium Carbonate

The production of 1 kg of Calcium Carbonate is modelled using 0.9 kg of the EI 3.8 process [Calcium carbonate, precipitated {RER}| calcium carbonate production, precipitated | Cut-off, S] and 0.1 kg of the EI 3.8 process [Calcium carbonate, precipitated {RoW}| calcium carbonate production, precipitated | Cut- off, S].

For transport in Europe, a transport scenario for solid materials was used. More information on the transport scenario can be found in Chapter 6.1.

6.4.3 Sand

The production of 1 kg of Sand is modelled using 0.9 kg of the EI 3.8 process [Silica sand {DE}| production | Cut-off, S] and 0.1 kg of the EI 3.8 process [Silica sand {RoW}| production | Cut-off, S].

For transport in Europe, a transport scenario for solid materials was used. More information on the transport scenario can be found in Chapter 6.1.

6.4.4 Talc

For Talc, no exact LCA process could be identified in the LCA databases. The production of 1 kg of Talc is modelled using 0.9 kg of the EI 3.8 process [Feldspar {RER}| production | Cut-off, S] and 0.1 kg of the EI 3.8 process [Feldspar {RoW}| production | Cut-off, S].

For transport in Europe, a transport scenario for solid materials was used. More information on the transport scenario can be found in Chapter 6.1.

6.5 Cores

6.5.1 Balsa

For Balsa, no EI 3.8 process could be identified. Therefore, as a proxy, this material is modelled using the process [Glued laminated timber, average glue mix {RoW}| glued laminated timber production, average glue mix | Cut-off, S]. The production of 1 kg of Balsa[a] is modelled using 0.00237 m^3 of the EI 3.8 process [Glued laminated timber, average glue mix {Europe without Switzerland}| glued laminated timber production, average glue mix | Cut-off, S] and 0.000263 m^3 of the EI 3.8 process [Glued laminated timber, average glue mix {RoW}| glued laminated timber production, average glue mix | Cut-off, S].

The density of balsa ranges from roughly 60 to 380 kg/m^3 as the findings from Borrega et al., (2015) demonstrated. Based on this study we have used 370 kg/m^3 as the conservative figure.

Reference

- Borrega et al., (2015), Mechanics of balsa (Ochroma pyramidale) wood; doi:10.1007/s00226- 015-0700-5

For transport in Europe, a transport scenario for solid materials was used. More information on the transport scenario can be found in Chapter 6.1.

6.5.2 Polyethylene terephthalate (PET)

This material is modelled using 0.9 kg of PET sourced from Europe using the EI 3.8 Process [Polyethylene terephthalate, granulate, bottle grade {RER}| production | Cut-off, S and 0.1 kg of PET sourced outside of Europe using the EI 3.8 process Polyethylene terephthalate, granulate, bottle grade {RoW}| production | Cut-off, S]. These datasets are used as there is no specific PET core dataset, so this is the same as the dataset used for the PET resin.

For transport in Europe, a transport scenario for solid materials was used. More information on the transport scenario can be found in Chapter 6.1.

6.5.3 Polyisocyanurate (PIR)

The production of 1 kg of Polyisocyanurate (PIR) is modelled using 0.9 kg of the EI 3.8 process [Polyurethane, rigid foam {RER}| production | Cut-off, S] and 0.1 kg of the EI 3.8 process [Polyurethane, rigid foam {RoW}| production | Cut-off, S].

For transport in Europe, a transport scenario for solid materials was used. More information on the transport scenario can be found in Chapter 6.1.

6.5.4 Polyvinylchloride (PVC)

The production of 1 kg of Polyvinylchloride (PVC) is modelled as follows:

- 1.004 kg of Polyvinylchloride of which

- 0.904 kg were sourced from Europe using EI 3.8 process [Polyvinylchloride, suspension polymerised {RER}| polyvinylchloride production, suspension polymerisation | Cut-off, S]
- 0.1 kg were sourced outside of Europe using EI 3.8 process [Polyvinylchloride, suspension polymerised {RoW}| polyvinylchloride production, suspension polymerisation | Cut-off, S]

- 1 kg of Polymer foaming of which
  - 0.9 kg were sourced from Europe using EI 3.8 process [Polymer foaming {RER}| processing | Cut-off, S]
  - 0.1 kg were sourced outside of Europe using EI 3.8 process [Polymer foaming {RoW}| processing | Cut-off, S]

For transport in Europe, a transport scenario for solid materials was used. More information on the transport scenario can be found in Chapter 6.1.

6.6 Coatings

6.6.1 Gelcoat

The production of 1.02 kg of Gelcoat is modelled as follows:

- 0.75 kg of Isophthalic acid based unsaturated polyester resin of which
  - 0.675 kg were sourced from Europe using EI 3.8 process [Isophthalic acid based unsaturated polyester resin {RER}| production | Cut-off, S]
  - 0.075 kg were sourced outside of Europe using EI 3.8 process [Isophthalic acid based unsaturated polyester resin {RoW}| production | Cut-off, S]

- 0.1 kg of Titanium dioxide of which
  - 0.09 kg were sourced from Europe using a created Titanium dioxide production dataset for Europe modelled using EI 3.8 processes composing of rounded 0,24 kg of [Titanium dioxide {RER}| production, chloride process | Cut-off, S] and rounded 0,76 kg of [Titanium dioxide {RER}| production, sulfate process | Cut-off, S]
  - 0.01 kg were sourced outside of Europe using a created Titanium dioxide production dataset for Rest of World modelled using EI 3.8 processes composing of rounded 0,63 kg of [Titanium dioxide {RoW}| production, chloride process | Cut-off, S] and rounded 0,37 kg of [Titanium dioxide {RoW}| production, sulfate process | Cut-off, S]

- 0.05 kg of Aluminium hydroxide of which
  - 0.045 kg were sourced from Europe using EI 3.8 process [Aluminium hydroxide {IAI Area, EU27 & EFTA}| aluminium hydroxide production | Cut-off, S]
  - 0.005 kg were sourced outside of Europe using EI 3.8 process [Aluminium hydroxide {RoW}| aluminium hydroxide production | Cut-off, S]

- 0.05 kg of Feldspar of which
  - 0.045 kg were sourced from Europe using EI 3.8 process [Feldspar {RER}| production | Cut- off, S]
  - 0.005 kg were sourced outside of Europe using EI 3.8 process [Feldspar {RoW}| production | Cut-off, S]

- 0.05 kg of Calcium carbonate of which
  - 0.045 kg were sourced from Europe using EI 3.8 process [Calcium carbonate, precipitated {RER}| calcium carbonate production, precipitated | Cut-off, S]
  - 0.005 kg were sourced outside of Europe using EI 3.8 process [Calcium carbonate, precipitated {RoW}| calcium carbonate production, precipitated | Cut-off, S]

- 0.02 kg of Chemical, organic of which
    - 0,018 kg were sourced from Europe using EI 3.8 process [Chemical, organic {GLO}| production | Cut-off, S]
    - 0,002 kg were sourced from outside of Europe using EI 3.8 process [Chemical, organic {GLO}| production | Cut-off, S]

For transport in Europe, a transport scenario for liquid materials was used. More information on the transport scenario can be found in Chapter 6.1.

6.6.2 Protective Acrylic Urethane (PAU)

This material is based on data provided by a leading European PAU manufacturer. The exact numbers are confidential and therefore cannot be disclosed in this report. The modelled protective acrylic urethane consists of the following materials, modelled for both RER (Europe) and RoW (outside of Europe):

- Xylene
- Isopropyl acetate
- Polymethyl methacrylate, beads
- Butyl acetate
- Aluminium sulfate, powder
- Methylene diphenyl diisocyanate
- Butyl acetate
- Naphtha
- Silica fume
- Clay
- Titanium dioxide

For transport in Europe, a transport scenario for liquid materials was used. More information on the transport scenario can be found in Chapter 6.1.

6.7 Additives

6.7.1 Accelerators

The production of 1 kg of Accelerators is modelled using 0.9 kg of the EI 3.8 process [Chemical, organic {GLO}| production | Cut-off, S] and 0.1 kg of the EI 3.8 process [Chemical, organic {GLO}| production | Cut- off, S].

For transport in Europe, a transport scenario for solid materials was used. More information on the transport scenario can be found in Chapter 6.1.

6.7.2 Flame Retardants

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

6.7.2.1 Aluminium TriHydrate (ATH)

The production of 1 kg of ATH is modelled using 0.9 kg of the EI 3.8 process [Aluminium hydroxide {IAI Area, EU27 & EFTA}| aluminium hydroxide production | Cut-off, S] and 0.1 kg of the EI 3.8 process [Aluminium hydroxide {RoW}| aluminium hydroxide production | Cut-off, S].

For transport in Europe, a transport scenario for solid materials was used. More information on the transport scenario can be found in Chapter 6.1.

6.7.2.2 Diammonium Phosphate

The production of 1 kg of Diammonium phosphate is modelled using 0.9 kg of the EI 3.8 process [Diammonium phosphate {RER}| diammonium phosphate production | Cut-off, S] and 0.1 kg of the EI 3.8 process [Diammonium phosphate {RoW}| diammonium phosphate production | Cut-off, S].

For transport in Europe, a transport scenario for solid materials was used. More information on the transport scenario can be found in Chapter 6.1.

6.7.3 Peroxide

The production of 1 kg of Peroxide is modelled using 0.9 kg of the EI 3.8 process [Hydrogen peroxide, without water, in 50% solution state {RER}| hydrogen peroxide production, product in 50% solution state | Cut-off, S] and 0.1 kg of the EI 3.8 process [Hydrogen peroxide, without water, in 50% solution state {RoW}| hydrogen peroxide production, product in 50% solution state | Cut-off, S].

For transport in Europe, a transport scenario for solid materials was used. More information on the transport scenario can be found in Chapter 6.1.

6.8 Auxiliaries

6.8.1 Plastic Film

The production of 1 kg of Plastic film is modelled using 0.9 kg of the EI 3.8 process [EUCIA_Packaging film, PA {RER}| production] and 0.1 kg of the EI 3.8 process [EUCIA_Packaging film, PA {RoW}| production].

For transport in Europe, a transport scenario for solid materials was used. More information on the transport scenario can be found in Chapter 6.1.

6.8.2 Release Agent

The production of 1 kg of Release agent is modelled using 0.9 kg of the EI 3.8 process [Chemical, organic {GLO}| production | Cut-off, S] and 0.1 kg of the EI 3.8 process [Chemical, organic {GLO}| production | Cut- off, S].

For transport in Europe, a transport scenario for liquid materials was used. More information on the transport scenario can be found in Chapter 6.1.

6.8.3 Methyl Ethyl Ketone

The production of 1 kg of Methyl ethyl ketone is modelled using 0.9 kg of the EI 3.8 process [Methyl ethyl ketone {RER}| production | Cut-off, S] and 0.1 kg of the EI 3.8 process [Methyl ethyl ketone {RoW}| production | Cut-off, S].

For transport in Europe, a transport scenario for liquid materials was used. More information on the transport scenario can be found in Chapter 6.1.

6.8.4 Acetone

The production of 1 kg of Acetone is modelled using 0.9 kg of the EI 3.8 process [Acetone, liquid {RER}| production | Cut-off, S] and 0.1 kg of the EI 3.8 process [Acetone, liquid {RoW}| production | Cut-off, S].

For transport in Europe, a transport scenario for liquid materials was used. More information on the transport scenario can be found in Chapter 6.1.

6.9 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. No new primary data was made available by the respective company, so the model contains primary data for 2016 production for the different core mats and the latest EI 3.8 datasets as background data. The scope of this LCA is from Cradle-to-Gate at Lantor in The Netherlands. 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 (Table 10):

Product	Name in Eco impact 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)

Table 10**:** Core mats products and associated thickness and weights per square meter

The modelling choices of the major constituents of Core Mats are PET staple fibres, Microspheres, and Binder, which are described in the following sections below.

For transport in Europe, a transport scenario for solid materials was used. More information on the transport scenario can be found in Chapter 6.1.

6.9.1 PET staple fibres

This material is modelled using the EI 3.8 Process [Polyethylene terephthalate, granulate, amorphous {RER}| production | Cut-off, S].

Since half of the PET staple fibres are recycled content, the EI 3.8 process [Mixed plastics (waste treatment) {GLO}| recycling of mixed plastics | Cut-off, U] and [Electricity, high voltage {DE}| production mix | Cut-off, S] were used. The mixed plastics process has been modified by using only the PET LCI.

6.9.2 Microspheres

The modelled microspheres consist of the following materials, modelled for both RER (Europe) and RoW (outside of Europe):

- Methyl methacrylate
- Acrylonitrile
- Isobutane
- Tap water
- Magnesium oxide
- 2,3-dimethylbutan

- Fraction 8 from naphtha separation

6.9.3 Binder

The modelled binder consists of the following materials, modelled for both RER (Europe) and RoW (outside of Europe):

- Acrylic binder
- Ammonia, anhydrous
- Tap water

7 Looking ahead

7.1 Methodology

The use of LCAs for sustainability claims is growing in importance as companies and governments are working together to ensure that reported non-financial information is both transparent and accurate through the EU Taxonomy, the Corporate Sustainability Reporting Directive (CSRD) and Science Based Targets initiative (SBTi). At the time of the update in 2022 and 2023, no PEF Category Rules (PEFCR), Product Category Rules (PCR) or other data quality and methodology requirements were available to the project team for incorporation or consideration in the tool development.

7.2 Data acquisition

The main barrier for full development of the tool is data acquisition from the composite product manufacturers. Even though there have been numerous attempts to retrieve more data, response was lower than expected. To address the lack of data the questionnaire was updated. The main aim of redesigning the questionnaire is to make it clearer for the companies how and what to fill in. The questionnaire can be shared by EuCIA at request.

8 Limitations

An important limitation is the industry data used for the production processes. The production processes are modelled based on primary information of European composites manufacturers retrieved through questionnaires, unless industry data was not available for the development of the tool. This industry production data is used as inputs and outputs in the conversion processes available in the tool. The production in- and output data is delivered by the composite product manufacturers themselves and is not currently audited. Therefore, there is an uncertainty with these data points.

The industry production data used to model the conversion processes is for 1 year of production (of at least 3 companies). It is likely that the environmental impacts of the conversion processes will change over time. 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 future. For now, the focus has been on increasing the number of conversion processes and not updating the industry data of currently included conversion processes, but this is important for the future.

Packaging inputs are now included in the hazardous and non-hazardous waste datasets. For some processes the amount of waste is 20%, meaning that you also have 20% packaging material. This could be improved.

The transport scenario chosen is too conservative for bulk materials like sand, talc, and calcium carbonate. Here the impact of the transport scenario causes a much higher environmental impact per kg of product compared to the old used datasets. Furthermore, the tool could benefit from an additional functionality to include transport distances from each material supplier to the user's manufacturing site. This functionality would further enhance the completeness and reliability of the tool, despite that transport has a minor contribution (in this version of the tool) to the total environmental footprint of composite manufacturing.

Among other factors, data quality is influenced by time-representativeness. Both for the process data as well as the materials, the tool should be updated regularly based on new data (e.g. new manufacturing data), progressive insights into existing data (e.g. increased process efficiency) as well as assessment methods (e.g. EF method). As the tool continues to grow, the collection of data will increasingly require significant efforts to keep the tool updated and to improve the quality of the data.

A possible solution for this risk could be the development of an interactive dashboard, where companies can upload the required data as well as the underlying evidence directly to the tool. The use of a company dashboard has added benefits, such as the simplification of the regularly required updates of the tool, and, when the data evidence is also audited, increasing the confidence in the provided data.