FLOWER
Flax composites, LOW weight, End of life and Recycling

EUROPEAN UNION

Livrable n°T4.5.1

4.5.1 Rapport d’analyses de cycle de vie d’une coque en biocomposite - Life Cycle Analyses report of the hull made with the biocomposite

29/04/2022

Interreg
France (Channel Manche) England
European Regional Development Fund

Partners

PP Leader : UBS

Partners involved : Kairos, TVDC

Deliverable N° & name :

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1. Introduction

1.1. Context

Environmental regulations and governmental strategies is pushing global economy to using natural and renewable materials instead of synthetic. Flax fibres are one of these materials taking on new importance because of its good properties and its renewable and local aspect.

In this purpose, FLOWER project aims to develop flax fibre reinforcements produced locally for the composite industry at a lower cost. These innovative preforms will allow the emergence of new products for the automotive, sailing and point-of-sale advertising industries. This will ensure the development of high performance, light-weight, biodegradable or recyclable products with reduced environmental impacts.

The FLOWER project is a European project carried out with funding by Interreg program. It is a collaboration between France and England, consisting of four academic groups (University of Portsmouth, University of Cambridge, Université de Bretagne Sud and INRAe of Nantes) and four industrial companies (Ecotechnilin, Kaïros, Howa-tramico and Depestele).

1.2. Objectives

One of the objectives of the FLOWER project is to quantify the environmental impact of developed products, in part of deliverable 4.5.1. In this perspective, this document will present a Life Cycle Analysis of the boat hull made in reinforced flax composite. This is compared with the hull made in glass reinforced composite, which is currently used.

The collected information will be useful to find the most impacting studied parts and also to identify the steps which are the most influence on the environmental impacts. It could help the project partners in their industrial orientations.

1.3. Target audience

As a part of FLOWER project, this study is intended for project partners so that they can make an informed choice about the main environmental impacts of their products. In addition, this study can serve as a basis for partner’s pitch to its customers.

However, in the absence of a Critical Review, as required by ISO 14044, the results of this study may not be released externally for comparison with other equivalent products.

2. Method

2.1. Principles of life cycle analysis

Life Cycle Analysis (LCA) is a normalized methodology (ISO 14040 et ISO 14044) for assessing environmental impacts associated with all the stages of the life cycle of a product, process of service.

The following parts of LCA methodology (see Figure 2) are summarized below based on the ISO 14040 standard:

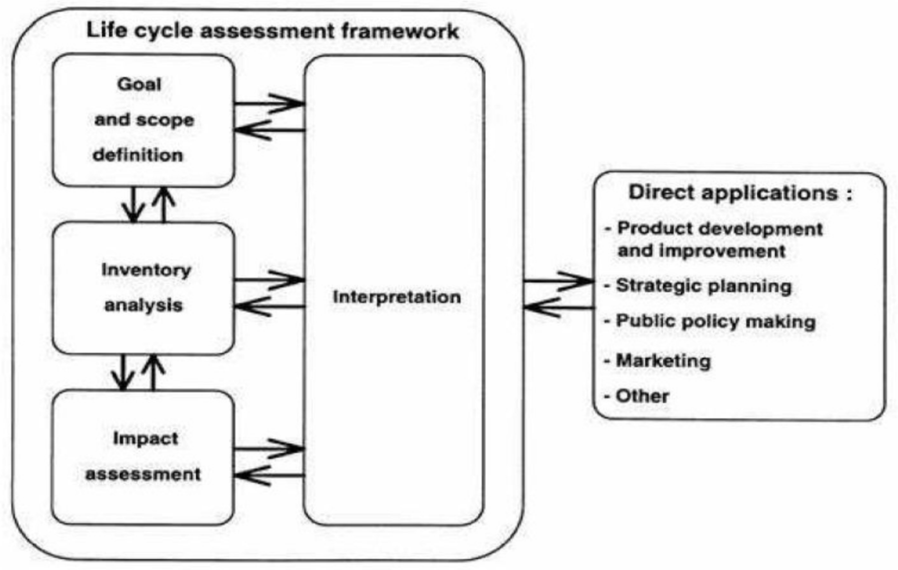

Figure 1 - Phases of an LCA (picture from ISO 14040)

- Goal and scope definition

The goal and scope definition is the initial step of every LCA study. At this stage the principle of the work is explained. Also the system boundaries of the product are defined. This step is one of the most important in LCA procedure, where the communication between the customer and analyst is crucial.

- Inventory analysis

Inventory analysis engages data collection and calculations to quantify the inputs and outputs of the system described in the “goal scope and definition” including raw materials, waste flows and emissions attributed to the products life cycle.

- Life cycle impact assessment (LCIA)

LCIA describes the environmental consequences of the environmental load quantified in the inventory analysis. It interprets the environmental loads from the inventory analysis into environmental impacts such as kilogram CO2 equivalents, acidification, biodiversity, etc.

- Interpretation

The inventory calculations in a quantitative LCA are typically large and are fairly difficult to interpret. Therefore, it is important to refine the raw results and present only a section with the most important result parameters together with initial goals.

2.2. Functional Unit

The environmental impacts are calculated for a same given service: the functional unit. The functional unit defines «the quantified performance of a product system for use as a reference unit».

In order to compare various manufacturing process and materials, the chosen functional unit is: “Producing one boat hull by industrial way”. Two systems will be studied: one hull made with flax composite and another one made in glass composite.

2.3. Studied system

The studied product is a hull used on the Birdyfish® boat (shown at fFigure 2), which is a 4.7m boat equipped with hydrofoils.

Figure 2 – Picture of Birdyfish

The two studied systems (made with flax or with glass) are close. They include the extraction of resources necessary to produce the components (raw material, energy), the manufacturing composite semi-products (in flax by *EcoTechnilin* and generic data for glass) and the composite manufacturing of the hull by *Rotteleur Composites*, the sub-contractor of *Kairos*. These steps are represented on the fFigure 3.

The differences between these two products will presented into the *Inventory of data* topic.

Therefore, the analysis is a Cradle-to-gate approach: it is an assessment of a product life cycle from the raw material extraction and manufacture ('cradle') to the factory exit gate (i.e. before it is transported to the customer). The use, the disposal phases and the end of life of the product are not covered.

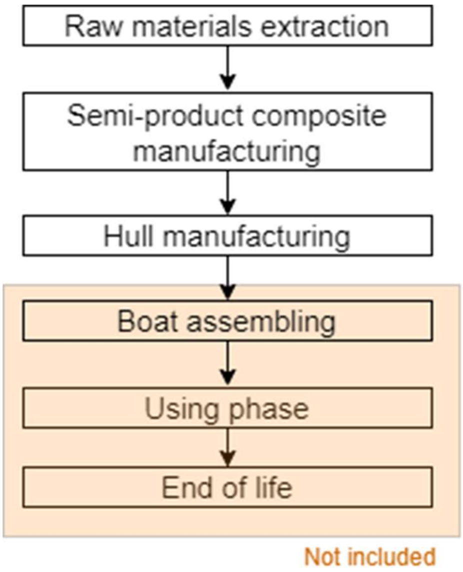

Figure 3 – Schematic boat hull stages of life

2.4. System Boundaries

In general, the considered systems exclude the production, maintenance and dismantling of infrastructure and capital goods (buildings, machines, roads). This consideration is take into account in this LCA.

For the reason that there are similarities between the two studied products and because it is a comparative LCA, some process (consumable, energy…) have not been considered into this study:

- The infusion consumables (seal, bleeder cloth, vacuum bag sealant, draining fabric…) haven't been considered.
- The gel coat is not considered.
- The catalyst product for the matrix is not considered.
- The aerosol adhesive is not considered.
- The machining tools are not considered.

For a process, electricity mix of the concerned country (France) is taking into account according to the place of the operation.

2.5. Allocation criteria

The default allocation criteria used is the allocation by mass.

2.6. Indicators and methods

There are different evaluation methods available applicable including ReCiPe[1], CML[2]. These methods are evaluated and recommended by the ILCD manual (International Life Cycle Data).

The following environmental impacts used in this present study have been selected in the method "CML-IA Baseline V3.06":

- Global Warming

Impacts on climate change over a 100-year time frame is assessed using the amount of greenhouse gas emissions, expressed in carbon dioxide equivalent. It specifically takes into account the "fossil" emissions CO2, N2O (these emissions are derived, for example, from the combustion of fuel and from natural gas) and CH4 emissions (for example from the fermentation of dumped waste) but does not take into account CO2 "biomass" emissions, resulting for example from the combustion of waste in incinerators. The greenhouse effect is expressed in kg eq. CO2.

- Depletion of abiotic resources

This indicator quantifies the depletion of the environment in terms of its mineral resources. Living resources and their associated impacts such as the disappearance of species or the loss of biodiversity are excluded from this category. This indicator provides more information about the depletion of different subjects than on the impact caused by their extraction from the natural environment. The calculation is made in comparison with estimated remaining stocks and with the consumption rate of the current economy. This

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[1] Goedkoop et al., 2009, "ReCiPe 2008 A life cycle impact assessment method which comprises harmonised category indicators at the midpoint and the endpoint level"

[2] Guinée et al., 2002, "Handbook on life cycle assessment: operational guide to the ISO standards"

indicator is expressed in kg eq antimony (antimony is a chemical element, atomic number 51). As an example, 1 kg platinum ore corresponds to 2.22 kg eq antimony, and 1 kg of boron corresponds to 0.00043 kg eq antimony (source: CML).

- Acidification

The acidification impact category represents an increase of acid compounds such as nitrogen oxides and sulphur oxides in the atmosphere. The characterisation factor of a substance is calculated in gram equivalent SO2, which can be produced per mole. CML4 developed the characterisation method used by PwC.

- Photochemical Oxidation

Under certain climatic conditions, the atmospheric emissions from industries and transport can react in a complex way under the influence of solar rays and lead to the formation of photochemical smog. A succession of reactions implicating volatile organic compounds and NOx, lead to the formation of ozone, a super-oxidizing compound. The potential for the formation of photochemical oxidizers is expressed in g eq. ethylene.

- Water Eutrophication

Eutrophication is defined as the enrichment of waters in nutritive elements, as a consequence of human intervention. Oxygen depletion is the possible consequence of such enrichment. The characterisation method used by PwC is based on the method developed by the Centre of Environmental Science (CML), Leiden University. It is based on the capacity of a substance to contribute to algae profusion. This contribution is translated into oxygen depletion taking into account the quantity of oxygen consumed when algae decompose. Characterisation factors are given in gram equivalent phosphate
The indicator Cumulative Energy Demand (V1.11), which evaluate the energy consumed during all the stages of the headliner’s life, has also been selected. This method is based on higher heating values (HHV).

2.7. Software

The LCA is done with *Simapro* software, version 9.1.1.1.

3. Inventory of data

The data collection was carried out directly in *Rotteleur Composites*, the sub-contractor manufacturer of *Kairos*.
Generic data have been used to model some processes and are mainly derived from Ecoinvent 3 database.

3.1. Boat hull made in glass composite

The quantity of each process have been measured directly on the Rotteleur Composites site by themselves. There is only one step which include all the process modelled to do the hull (presented at Figure 4). The electric consumptions of equipment are calculated from power rating and operating time. The energy of PET foam production is not considered.

Table 1 present all the steps included in the model of the product.

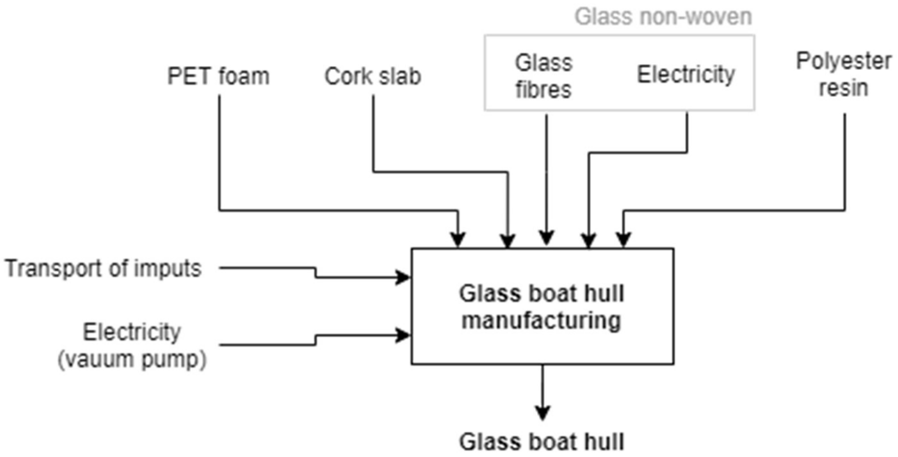

Figure 4 – Flowchart of the glass boat hull manufacturing in *Rotteleur Composites*

Table 1. Data corresponding to the glass boat hull manufacturing

Type	Name of process/flow in *Simapro*	Corresponding step	Quantity
Input	Polyethylene terephthalate, granulate {GLO}	PET foam	0.55 kg
	Cork slab {GLO}	Cork slab	7.0 kg
	Polyester resin, unsaturated {RER}	Polyester resin	30 kg
	Glass fibre {GLO}	Non-woven glass fibre	19.7 kg
	Electricity, medium voltage {FR}	Non-woven glass fibre	19.7 *
	Transport, lorry 16-32 metric ton, euro6 {RER}	PET foam transport	0.4kWh
	Transport, lorry 16-32 metric ton, euro6 {RER}	Cork slab transport	554 kgkm
	Transport, lorry 16-32 metric ton, euro6 {RER}	Non-woven transport	3233 kgkm
	Transport, lorry 16-32 metric ton, euro6 {RER}	Polyester resin transport	28600 kgkm
	Electricity, medium voltage {FR}	Vacuum pump	35400 kgkm
		Glass boat hull	1.5 kWh
Output			
			1 unit

3.2. Boat hull made in flax composite

The quantity of each process have been measured directly on the *Rotteleur Composites* site by Guillaume Barteau in 2021. Contrary to the glass boat hull, the measurement of the flax boat hull quantity was made on the prototype version. It involves an increase of materials consumption.

There is only one step which include all the process modelled to do the hull (presented at fFigure 5). The electric consumptions of equipment are calculated from power rating and operating time. The different kinds of flax tissue (Balanced, unidirectional, BX) are considered as *non-woven FLOWER 100%* flax from another FLOWER document "*LCA report Headliner HOWA TRAMICO*". All data for this product are available there. The energy of PET foam production is not considered.

Table 2 present all the steps included in the model of the product.

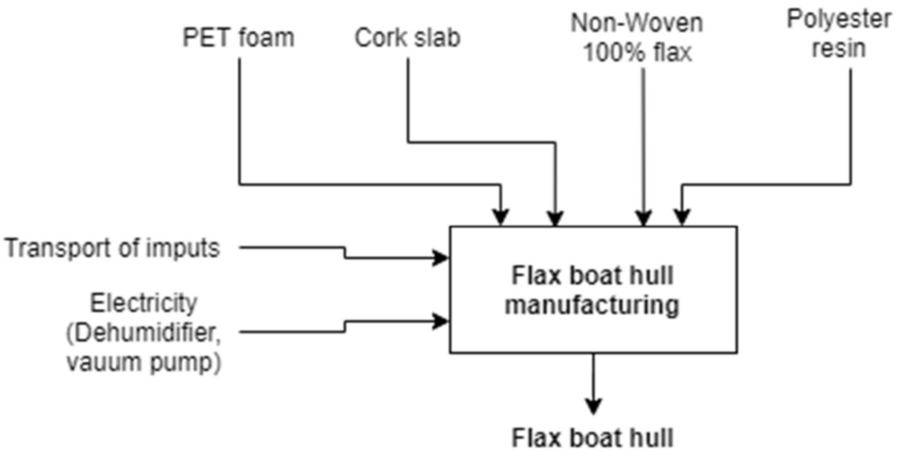

Figure 5 – Flowchart of the glass boat hull manufacturing in *Rotteleur Composites*

Table 2. Data corresponding to the glass boat hull manufacturing

Type	Name of process/flow in *Simapro*	Corresponding step	Quantity
Input	Polyethylene terephthalate, granulate {GLO}	PET foam	0.55 kg
	Cork slab {GLO}	Cork slab	7.0 kg
	Polyester resin, unsaturated {RER}	Polyester resin	48 kg
	FLOWER Non-woven 100% Flax	Flax fibres tissue	31.7 kg
	Transport, lorry 16-32 metric ton, euro6 {RER}	PET foam transport	554 kgkm
	Transport, lorry 16-32 metric ton, euro6 {RER}	Cork slab transport	3233 kgkm
	Transport, lorry 16-32 metric ton, euro6 {RER}	Non-woven transport	10800 kgkm
	Transport, lorry 16-32 metric ton, euro6 {RER}	Polyester resin transport	56600 kgkm
	Electricity, medium voltage {FR}	Desumidifier	204 kWh
	Electricity, medium voltage {FR}	Vacuum pump	1.5 kWh
Output		Glass boat hull	1 unit

4. Evaluation of environmental impacts and interpretation

4.1. Comparison results

In this section, general environmental impacts result of the cradle-to-gate LCA are presented. The considered steps are from the extraction of raw materials to the gate of the headliner factory.
Table 3 and Figure 6 are presented this results.

Table 3. Environmental impacts of the glass boat hull and the flax boat hull

Environmental impacts	Unity	Flax boat hull	Glass boat hull
Abiotic depletion	kg Sb eq	5,45E-03	6,12E-03
Global warming	kg CO2 eq	335,3	243,3
Photochemical oxidation	kg C2H4 eq	9,70E-02	6,99E-02
Acidification	kg SO2 eq	1,24	1,03
Eutrophication	kg PO4--- eq	5,18E-01	3,50E-01
Cumulative energy demand	MJ	2,65	1,52

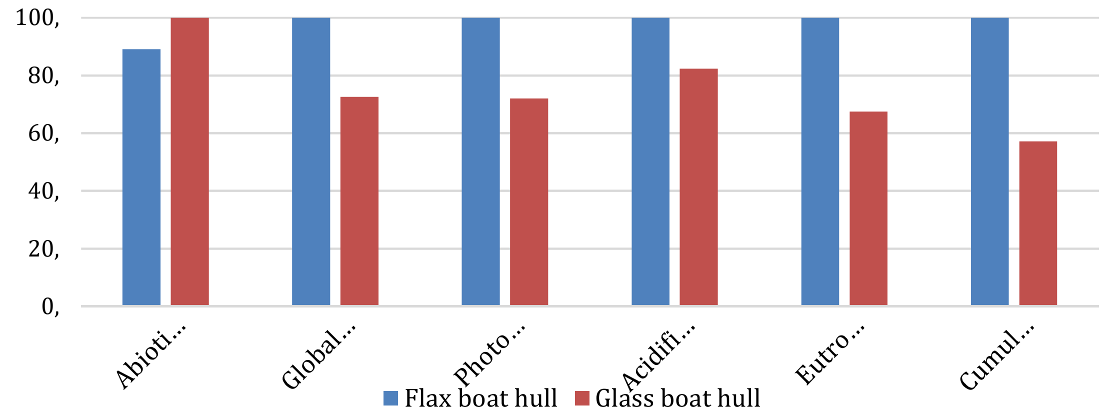

Figure 6 – Normalised *environmental impacts of the glass boat hull and the flax boat hull*

Except for abiotic depletion, the boat hull made with glass fibres is less impactful than the boat hull made with flax fibres. This difference is between 44% (for cumulative energy demand) and 19% (for acidification). Oppositely, for abiotic depletion, the glass boat hull is 11% more impactful than the flax boat hull.

It's important to notice the difference of weigth between the two boat hull. Indeed, the glass hull uses 19.7kg of glass fibres and 30kg of polyester resin while the flax hull uses 31.7kg of flax fibres and 47kg polyester resin. It could explain the better global environmental impact of glass hull. With an improvement and an optimisation of the flax hull manufacturing, the quantity of material could decrease and therefore the environmental impact as well.

4.2. Impact distribution

In this section, impact distribution by steps of the LCA study are presented for the two boat hull studied. The steps are polyester resin, fibres (glass or flax), transport, cork slab and others.

Figure 6 are presented this results.

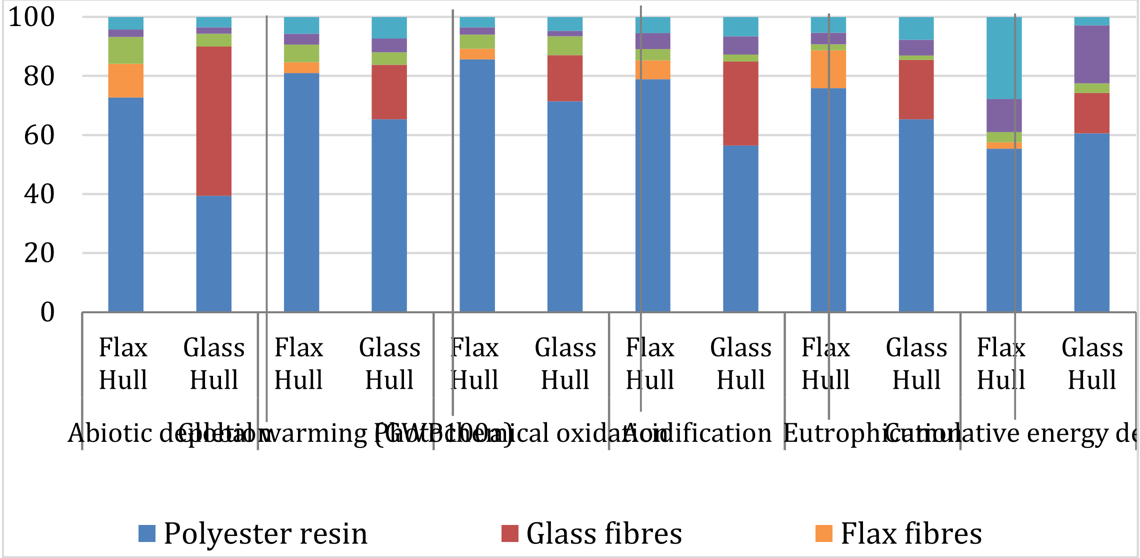

Figure 7 – Normalised *environmental impacts distribution by steps of the glass boat hull and the flax boat hull*

Globally, polyester resin is the main impactful step of the studied products, especially for the flax boat hull for which polyester resin is worth at least 72% of total impact for all indicators.

It can be noticed that the glass fibres are non-negligible for the glass boat hull. Indeed, the use of this material is equivalent from 52% of total impact for abiotic depletion to 16% of total impact for photochemical oxidation.

This graph shows also that, for a same quantity of polyester resin, the flax boat hull should be less impactful than the glass boat hull. This result could be realistic with an optimisation of the manufacturing process.

Moreover, we can see on Figure 7 that the step *others process*, which normally includes the manufacturing process, is weak. Due to assumptions taken, this process is widely under-estimated. We can't conclude anything on this observation.

5. Conclusion

This study, which is part of FLOWER project, try to give information about the environmental impact of the boat hull mad with glass fibres and flax fibres. Due to hypothesis, averaged data from databases and simplification, the results have to be use with caution. Additional work could be envisaged to go deeper into the subject. Nevertheless, some teaching can be learned:

- As things stand, the flax boat hull is more impactful than the glass boat hull (for 5 out of 6 environmental indicators).
- For both products, the polyester resin is the main impactful step of the modelled studied hull.
- With a manufacturing process optimisation of the hull made with flax fibres, a decrease of polyester resin used could be observed. This would result in a decrease of the environmental footprint of the hull, which will become less impactful than the boat hull made with glass fibres.