11th Hour Racing Team
IMOCA 60 Sustainable Design & Build Report
- 2021 -

SCENARIO ANALYSIS - 10M2 COMPOSITE PANEL

Supporting the main report, this document - **Scenario analysis - 10m2** compares composite materials and manufacturing processes

Measurements used are
Grams per square meter (gsm), kilos (kg),
metric tons (t), Greenhouse gas (tC02e) or (kgC02e)

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DISCLAIMER
The team's LCA results were calculated using MarineShift360.
Backed by 11th Hour Racing as Founding Sponsor, MarineShift360 is a purpose-built marine industry life cycle assessment tool. MarineShift360 is an ISO 14040:2006 & ISO 14044:2006 compliant and certified life cycle assessment tool. LCA results herein are calculated using MarineShift360, which is under development and is currently in beta stage.
No statements regarding accuracy are made and results may change over time as the development of MarineShift360 continues.

OBJECTIVE

Using a sample surface of 10m2 sample surface to compare different composite materials and processes. Where possible to adjust these findings to the relevant scale for an IMOCA and/or its component.

Context

Completing an lifecycle analysis of an IMOCA built in 2020 confirmed that more than 80% of greenhouse gas emissions are associated with the use of composite materials. This study will use various scenarios to analyse business as usual vs real and some hypothetical alternatives to better understand the potential of the following improvement paths:

- Replacing kg for kg carbon fibre with recycled carbon fiber (rCF) or flax in non-structural components. Example: 20% non-structural portion of molds
- Replacing epoxy resin for bio resin
- Choosing between processes infusion, prepreg and hand layup
- Defining minimum carbon cloth weights 300 gsm vs 150 gsm
- Choosing core materials Nomex, PET or monolithique structures

Scenarios

The scenarios are :

- Prepreg carbon cloth weights : 150 gsm vs 300 gsm
- Substitute epoxy resin with bio epoxy resin
- Infusion vs prepreg vs hand layup
- Comparing weight for weight impacts of fibers : CF vs Flax vs rCF

BASE SCENARIO
To test the overall LCA a sensitivity study was run, this provides us with the base scenario.

Description:
Prepreg: Carbon fiber/Epoxy
6 layers: BBC/IM/300 -45/45/-45/-45/45/-45
Laminating process : Prepreg cure at 95°C during 12h.
Built in France: 1 worker-1 day
Primary material transport : 1500km by road
End of life : Waste to energy

SCENARIO: 150gsm versus 300gsm

The table below highlights the difference between using the two prepreg cloth weights to construct the 10m2 panel

Table: Comparison 150 vs 300 gsm used to laminate 10m2
Calculated with MarineShift360 beta software on October 1, 2021

Cloth weight (g/m2)	150	300
N° of layers	12	6
Surface (m2)	120	60
Mf (kg)	18	18
Mm (kg)	7	7
Mcomp (kg)	25	25
Backing plastic (kg)	20.64	10.32
GHG (kgC02e)	1295	1249
Prepreg cure	12h at 95°C	

Observations:

The key aspects that will be impacted by the use of different cloth weights are:

- Number of layers of cloth doubles
- Total cloth area doubles
- Backing plastic doubles
- Labor/build time increases/doubles
- Other consumables increase
- Energy use increases (due to debulk and utilities)

This results in an increase of 4% (46kgC02e) greenhouse gas emissions

Conclusions:

Setting minimum cloth weight is an effective way to reduce environmental impacts without significantly affecting structural performance

SCENARIO: EPOXY vs BIO EPOXY RESIN

Bio-based resins have approximately 50% lower carbon footprint, use half the amount of scarce resources, and consume 50% less energy and water than an average non-bio-based resin. One of the most relevant advantages of bio-based resin for composite workers is its lower toxicity impacts for human health.

Table: Environmental impacts of epoxy vs bio epoxy used to laminate 10m2, Calculated with MarineShift360 beta software, October 1, 2021

	GWP (kg C02e)	Mineral resource scarcity (kg Cue)	Energy consumption (MJ)	Water consumption (m3)	Marine eutrophication (kg Ne)
CF/epoxy	1,252	1.82	30,217	10.77	0.18
CF/bio epoxy	1,233	1.75	29,822	10.52	0.18
Delta	19.27	0.07	391	0.25	0

Observations : Using the 10m2 scenario resin represents 3% of the ghg emissions, the choice of bio-resin reduces these impacts by 19 kgC02e, scaled to the full size of an IMOCA this becomes a relevant reduction.

SCENARIO: PREPREG vs INFUSION vs HAND LAYUP

In order to have a realistic comparison, a reference flow was calculated for each process based on the theoretical volume fraction of fibres.
This results in a difference of materials quantity.

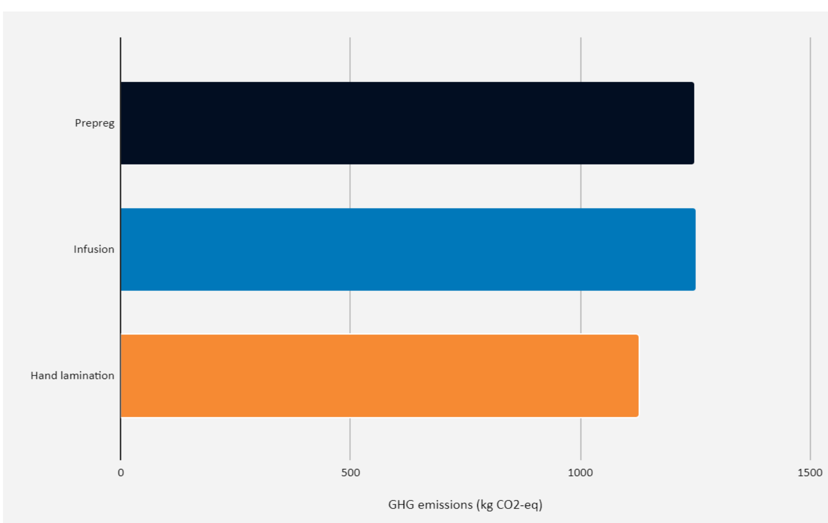

Figure: Comparative GHG emission of prepreg, infusion and hand lamination, calculated with MarineShift360 beta software on October 1, 2021

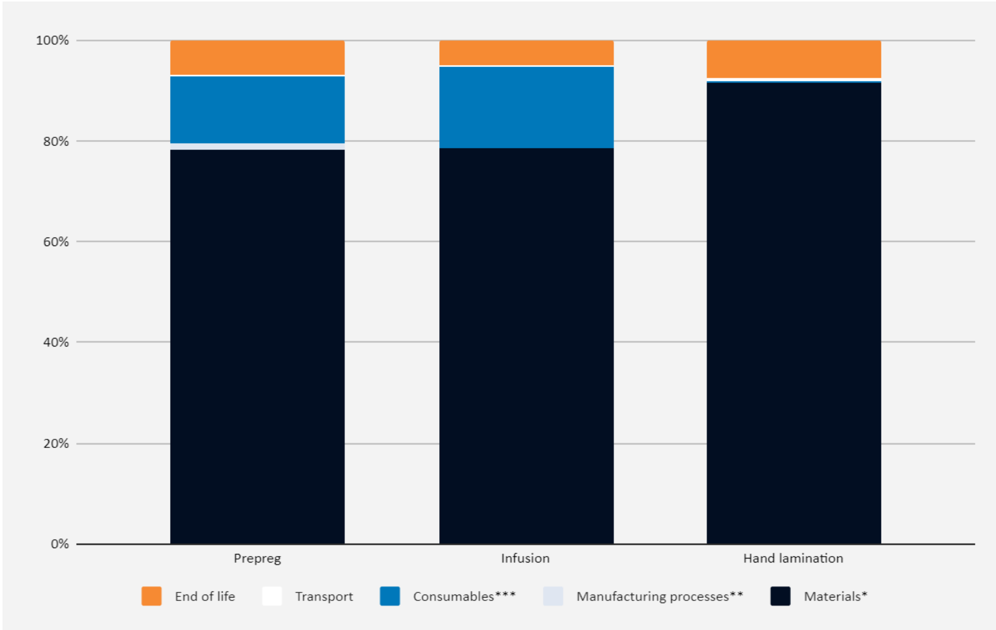

Figure: Breakdown of source of GHG emission from prepreg, infusion and hand lamination processes, calculated with MarineShift360 beta software on October 1, 2021

Observations :

Both the prepreg and infusion processes show a similar and higher impact, 1250kg vs 1130kgCO2-eq, than the hand lamination process. This outcome confirms the major contribution of the vacuum consumables (15%) even if more resin is needed for the hand lamination process. Also, it encourages thinking about the use of consumables with less impacts (biosourced plastics) or then quite simply in smaller quantities (power ribs).
The curing process of the prepreg only contributes to 1.2% of the GHG emissions.

SCENARIO: VIRGIN CARBON FIBER vs RECYCLED CARBON

Comparing the Global Warming Potential of composite fibers it is important to note that the graph below is based on weight and not on a comparable strength.

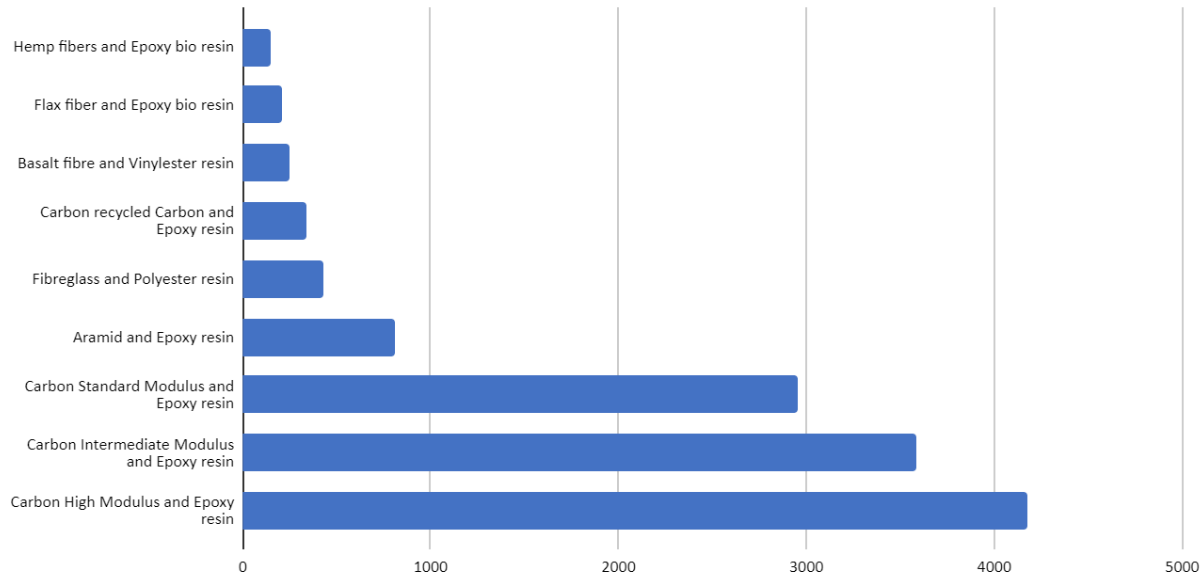

Figure: Comparing relative GHG impacts of different fibers, Source Michel Marie Calculated with MarineShift360 beta software on October 14th, 2021

The results presented below were calculated for the base scenario with the only difference being the infusion process.

Table: Comparing three different fibers used to build 10m2 composite, Calculated with MarineShift360 beta software on October 1, 2021

	GWP (kg C02e)	Mineral resource scarcity (kg Cue)	Energy consumption (MJ)	Water consumption (m3)	Marine eutrophication (kg Ne)
CF/epoxy	1,252	1.82	30,214	10.77	0.18
Flax/epoxy	336	0.77	8,400	12.84	0.14
rCF/epoxy	354	0.72	7,007	4.62	0.06

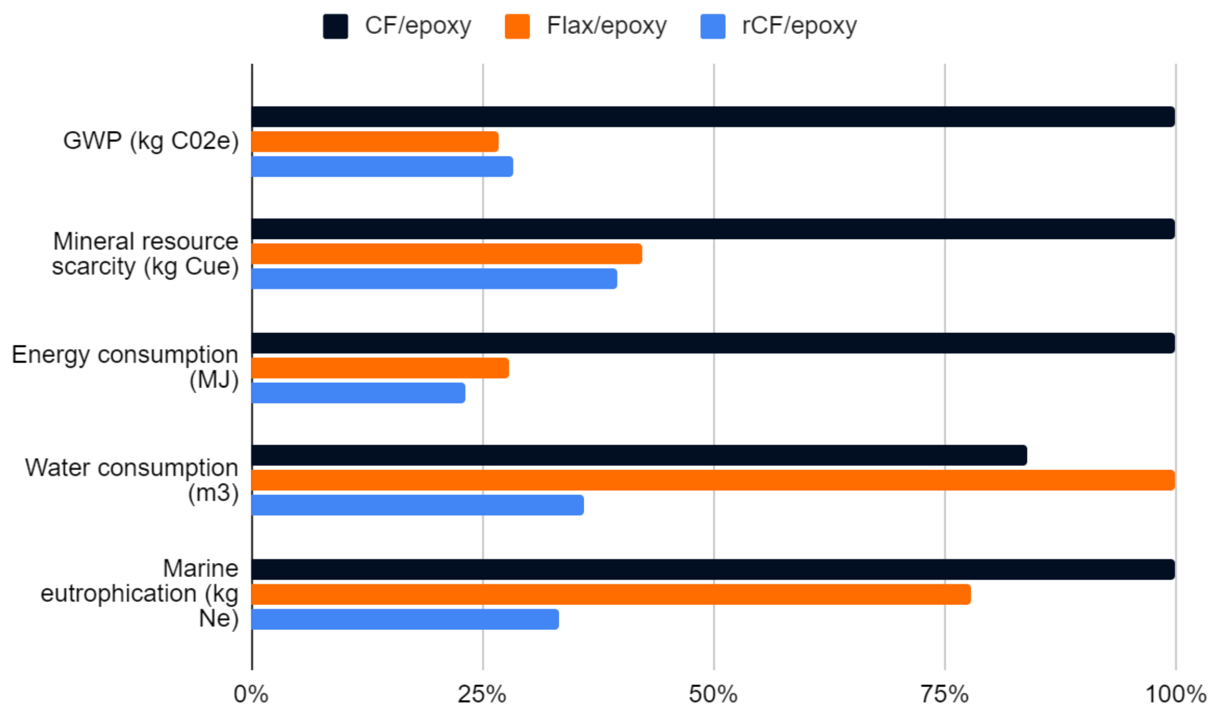

Figure x: Environmental impacts of three different fibers used to build 10m2 composite, calculated with MarineShift360 beta software on September 1, 2021

Observations :

The significantly greater environmental impacts of virgin carbon fiber compared to rCF and flax are a function of the high energy needs to transform the polyacrylonitrile (PAN) into carbon fiber. The one environmental impact that is higher for flax is water consumption (12.84m3) which is mainly linked to the cultivation of this bio material.

SCENARIO: CORE

To indicate the significant differences in greenhouse gas impacts of different core types, here is a simple comparison of 100kg material, adjusted by density for structural qualities in sheer,

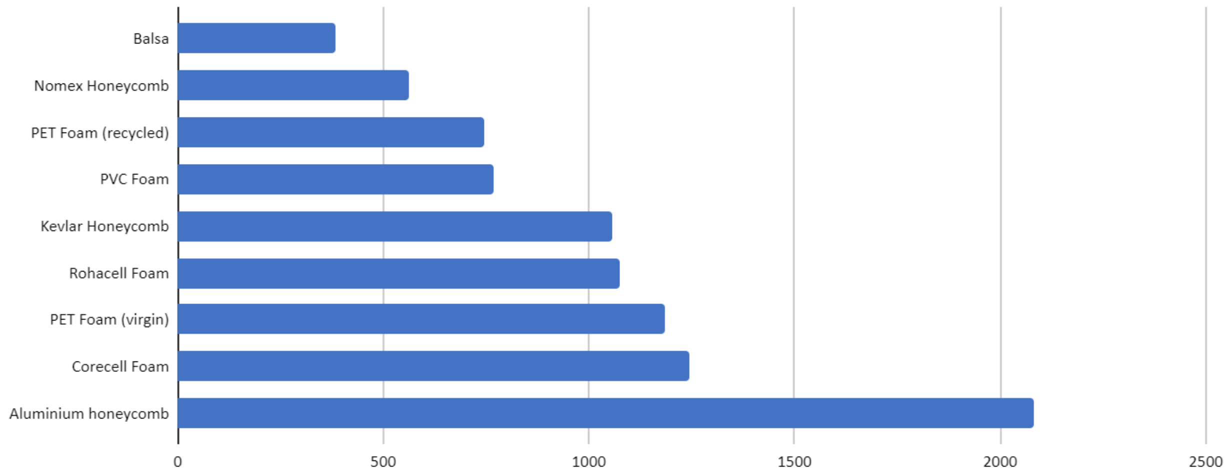

Figure x: Comparing the GHG impacts of core material, source Michel Marie Calculated with MarineShift360 beta software on October 14th, 2021

The Team used recycled PET core for some components of the design and build due to it having a 56% lower global warming potential than virgin PET core.

A set of cockpit hatches was made using balsa core, machined with lightning holes to optimise weight versus structural needs. The benefit of natural materials such as balsa, or products such as recycled PET can be seen below.

Discussion

These studies offer a baseline for understanding of the impacts of material choice, without consideration for structural performance unless otherwise stated.

The other main limitation of this study is the issue of scale; energy use, consumables and labor which will certainly be relatively less when manufacturing larger components and especially at the scale of a full hull or deck structure.

Taking into account these limitations one can still draw some initial conclusions and get a better perspective on improvement tracks related to composite material and processes choice.