11TH HOUR RACING TEAM

SUSTAINABLE DESIGN AND BUILD REPORT

11TH HOUR RACING
SAILING TEAM

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ISO 14044

Every attempt has been made to comply with ISO 14044. This report has been expert reviewed with this in mind but has not been third party certified.

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INTRODUCTION

This report describes the design and build of an ocean racing boat for 11th Hour Racing Team (the Team), a high-performance offshore sailing team from Newport, Rhode Island, USA and operating from its temporary base in Brittany, France.

Co-founders Charlie Enright (USA) and Mark Towill (USA) have competed in the two previous editions of The Ocean Race (formerly the Volvo Ocean Race) using the worldwide sporting event in 2017-18 as a platform to promote ocean health and sustainability.

Supported by its sponsor, 11th Hour Racing, and a number of official partners and suppliers, the Team are preparing for The Ocean Race 2022-23. The competitive sporting goal to win the overall Ocean Race Trophy is also a platform to showcase how sporting performance can drive sustainability when embedded throughout a campaign, having a net positive impact.

Net positive describes the intention of 11th Hour Racing Team to affect regenerative change across the Team's sectors of operation and influence. Simply described - doing more good than harm and contributing more than you take.

The Team's Annual Sustainability Reports outline the broader context of the Team's operations. In this report the Team will focus on the design, build and optimization of a new IMOCA 60-foot racing yacht, from the drawing board to the launch, and explore what is needed to go beyond 'business as usual'.

A NEW CAMPAIGN

Following The Ocean Race 2017-18, Towill and Enright quickly established a new campaign in the IMOCA Class, which was chosen as the new performance class for The Ocean Race 2022-23, supported by its sponsor 11th Hour Racing. The campaign started in early 2019, with the purchase of the Team's IMOCA training boat, the former Hugo Boss 6, which was named by the Team 'Alaka'i', and is also known as '11.1'. Optimisation of Alaka'i started with a refit at Multiplast in Vannes, France.

Alongside sailing and optimizing 11.1, a new IMOCA would be designed and built, adapted for the fully-crewed format of The Ocean Race - the very first in this new generation of IMOCAs - using the most recent knowledge, data and technology available.

It was decided to undertake the build in Brittany, France, using:

- Marine architect - Guillaume Verdier Design Studio
- Boat builder - CDK Technologies
- Technical and performance partner - MerConcept

The selection of Brittany as the base for the Team's European operations fulfilled the following key objectives:

- Availability of specific knowledge of the IMOCA Class and skilled labor.
- Year-round access to relevant sailing venues, world class events and the regional sailing community.
- Proximity to The Ocean Race start venue - Alicante, Spain, and 11th Hour Racing home base - Newport, RI, USA.

The decision to be based in Brittany was taken specifically with performance in mind, and resulted in various benefits from a sustainability perspective that we will explore further in this report. A few of these benefits included:

- The opportunity for the Team and 11th Hour Racing to build partnerships within the global center of offshore performance sailing.
- The well-established marine industry in Brittany is the result of decades of regional development, with a specialized manufacturing network and supply chain. The effect of this close network provided many efficiencies, reduced environmental impacts, provided a skilled labor force, and a mature industry ready to explore opportunities beyond business as usual.
- Electricity emission factors in France are typically low compared with other countries. This results in significant upfront efficiencies across many supply chain products, services, and most importantly the boat building process.
- Both CDK Technologies and MerConcept had already embarked on a robust approach to onsite sustainability.
- The IMOCA Class were working to implement a sustainability program.

Other organizations such as La Vague, Eurolarge and most of the major French sailing events were starting to explore and implement sustainability initiatives. Being based in Brittany, allowed the Team to be fully-engaged with these discussions. The design of the new IMOCA known as '11.2' and named by the Team as 'Mālama', started in April 2019, and the actual build in early 2020. With a delay caused by COVID-19, the new race boat was launched at the end of August 2021, and raced for the first time in September 2021 in the Défi Azimut.

IMOCA

Founded in 1991, the [International Monohull Open Class Association](#) (IMOCA) is a Class of 60-foot open monohulls, blending innovative design, build innovation and on-water performance: a premier class in offshore ocean racing.

The ongoing development within IMOCA continues to drive innovation across the marine industry. From twin rudders to foils, swing keels to canting rigs, many new evolutions are making their way into the Class and beyond.

While getting the design and build phase right is paramount to achieving success on the water, resulting in an ongoing push to build new boats and components, IMOCA has more recently set sustainability as an important goal for the Class.

This paradox of sustainability versus performance is the perfect opportunity to tackle the task of implementing a sustainable transition within the marine industry.

OBJECTIVES

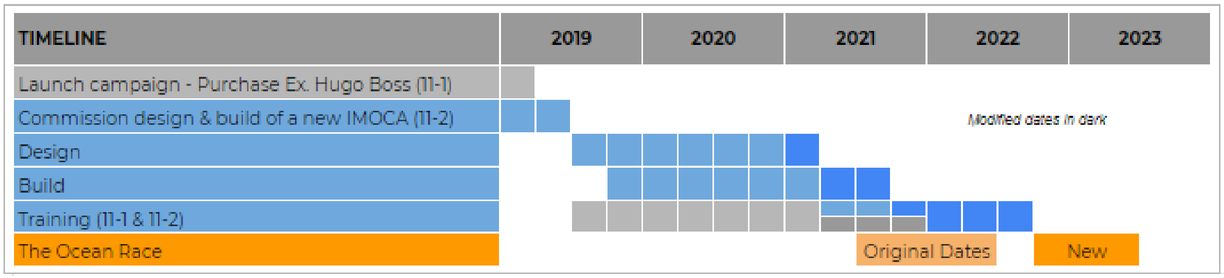
The underlying objective for the Team is to showcase sustainability through performance. The Team believes that only by placing itself within the industry can it understand the challenges, and explore the opportunities for change. Therefore, for this report the Team will start with the list of objectives related to performance, and end with those related to sustainability.

PERFORMANCE

BUILD MISSION

To design, build and optimize a new IMOCA, integrating the best knowledge and technology available, to achieve the best possible performance on the race track.

TIMELINE



TOO LATE, OR JUST IN TIME?

The design and build timeline mandated a ‘business as usual’ approach for both the designers’ and boat builders’ deliverables, focusing on what could be achieved within a two-year lead time from the start of The Ocean Race.

Validating new materials and establishing new build processes in any industry require a mandatory trial, testing and validation period. In the case of performance sailing, typically a minimum of 18 months is needed for anything but the simplest of changes.

Based on the original timeline these constraints precluded the possibility of a significant change of method or materials in any structural elements of the boat build. The focus was placed on applying sustainability initiatives to a ‘business as usual’ timeline.

Working within this reality, to achieve the best possible efficiencies during the design and build process, allowed the Team to develop an understanding of the challenges and opportunities, with the aim to provide guidance for future builds.

Bill Erkelens, 11th Hour Racing Team COO:

“The campaign’s goals were clear - to build a high-performance team, with the best possible boat, and implement exemplary sustainability operations throughout the program,achieving excellence both on and off the water. By placing ourselves at the center of the performance sailing sector, with similar performance goals and facing the same challenges as everyone else, the opportunity was to develop pragmatic solutions to the real issues facing our industry. It is about working from the inside-out.”

SUSTAINABILITY

OBJECTIVES

The primary sustainability objectives for the design and build process and outcomes were to:

- Understand the status quo:
  A sustainable design and build group was formed, including the design and build team and experts from the marine industry. A series of workshops helped to identify the information needed to outline the research required and define the best processes given the time and resources available.

- Research new sustainable design and build opportunities:
  Kairos Biocomposites were commissioned to provide:
    - The life cycle analysis study of an IMOCA built in 2010.
    - A review of existing alternative materials.
    - To stress test potential materials.
    - To source and provide a student intern to work with the boat builders to prepare a sustainability audit of the infrastructure and an assessment of efficiencies to be considered during the build.

- Apply beyond business as usual solutions where possible, and research and assess potential for future improvements.

- Capture the impact of real-life recommendations onsite:
    - Develop learning for the technicians onsite with regards to the practical challenges.

- Establish new, high-resolution life cycle assessment (LCA) benchmark:
    - Using LCA benchmark data from two previous builds and a theoretical study, the Team used the life cycle analysis tool, MarineShift360[1], to generate a new high-resolution picture of the impacts associated with the build of an IMOCA.

- Analyze results

- Coordinate the application of the overall LCA to provide a complete study of an IMOCA through to the launch and commissioning period.

- Take responsibility for the unavoidable impacts:
    - Aligned with the Team's Climate Action strategy and Net Positive approach, the unavoidable greenhouse gas emissions associated with the build would be compensated for by sequestering more carbon than was emitted by the build.

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[1] 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 and ISO 14044:2006 compliant and certified life cycle assessment(LCA) 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.

- Collaborate with the industry for better design and build practices, and influence policies throughout the value chain:
    - Build confidence with suppliers and service providers through open discussion about sustainability challenges and opportunities.
    - Increase value added with partners and suppliers.
    - Inspire and positively influence the broader marine industry.
    - Inform new policies and best practices.

- Provide legacy learnings, observations and, where relevant, recommendations.

- Define the pathway to Net Zero.

Amy Munro summarizes the team's strategy:

"We must measure our operations, so that we can understand our impacts, to inform the right action, and inspire others to collaborate for a Net Positive outcome"

The Team's high level design and build strategy:

STAKEHOLDERS

The Team's vision is to accelerate change through sporting excellence in sailing, ocean advocacy, and sustainable innovation. It was key to understand our build partners' areas of interest early on:

Guillaume Verdier Design Studio	CDK Technologies	MerConcept
Policy change Design innovation	Energy efficiency Waste reduction Supply chain mapping	Measurement MarineShift360 partners

Consultant interests:

Kairos	MarineShift360
MarineShift360 partners Sustainable innovation and development	Refine the life cycle analysis tool

Resources: while being a large project on a short timescale the Team had a number of available services provided by:

Collaborator*	Role	Risks and Opportunities
CDK Technologies	Builder	Key issues: material, waste, energy, supply chain Areas of opportunity: tooling, bio-resins, core, fiber
Guillaume Verdier Design Studio	Boat designers	Key Issues: server time - greenhouse gases, last minute design changes Areas of opportunity: in-house design
MerConcept	Performance partners	Key Issues: server time - greenhouse gases,, last minute design changes Areas of opportunity: in-house design
Kairos	Consultant services	Key issues: real time application of bio-composites to components based on project timeline Areas of opportunity: state of art report, bio-composites, material testing facilities, alternative material database development

*These key stakeholders formed the team's Sustainable Design and Build Working Group.

PLAN

To achieve the objectives, the Team followed a detailed plan:

Step One - establish a Working Group with the key stakeholders:

- A collaborative build and design working group with a remit that contributes to the boat building industry's uptake of circular economy principles.
- Hold regular meetings to present research and continue development of the plan.

Step Two - assess the starting point and set benchmarks:

- Produce an exploratory life cycle assessment report using historical data to generate a benchmark 'business as usual' study.
- Conduct boat yard audits to understand current infrastructure, personnel travel, materials, transport of materials, energy usage, water usage, waste management, build process, and end of life, to see where savings and recommendations could be made or systems improved.
- Commission a report to look at the current availability and properties of alternative sustainable materials.
- Identify projects to tackle using a biomimicry approach to problem solving.
- Take the list of 'higher impact suppliers' and complete a stakeholder discovery process.

- Audit and make recommendations e.g. insulation in shed roof, closed water coolant system, working with suppliers on plastic packaging, consolidating shipments, optimization of oven times and sizes.
- Understand and get clarification on race rules relating to onboard renewables.

Step Three - research feasibility and propose and implement set of sustainable solutions:

- Define a list of components that are candidates for the alternative materials, commission parts.
- Using the life cycle analysis tool, define best reduction strategies and apply resources.
- Define manufacturing opportunities and solutions with the aim of designing out waste and pollution.
- Identify opportunities to implement reverse cycles. Projects included collection, refurbishing and resale, establishing reverse supply chain, remanufacturing projects, leasing or sharing economy initiatives, packaging take-back schemes.
- Research and consider renewable energy options and feasibility, make recommendations to achieve a minimum of 30% renewable energy onboard.

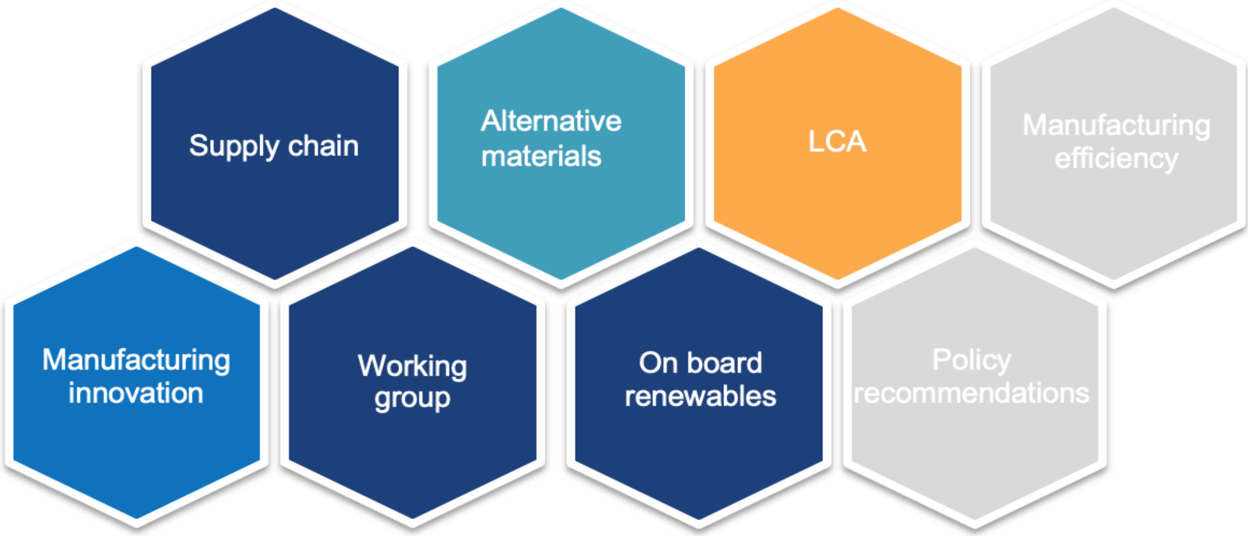
Step Four - review, communicate and develop legacy:

- Publish a full report on sustainable materials
- Encourage and facilitate learning legacy between suppliers and partners with regards to testing and use of alternative materials.
- Gain as-built bill of materials, compare with benchmark, communicate successes and challenges with stakeholders, make recommendations for future and for developing policy.
- Measure % change of the implementation of boatyard audit recommendations.

Challenge: To have a real chance of influencing long term change in marine industry design and build processes, prior research and materials or process testing needed to be done on a timeline that is relevant to the stakeholders. In the case of the Team's own build, CDK Technologies would have needed a minimum of 12-18 months to validate and test new materials and processes prior to confidently incorporating them into the build. CDK Technologies were designated as the team's builders 9 months prior to starting the build, so were immediately limited on options available for disruptive innovation.

Opportunity: The team defined specific areas such as transport, waste and energy optimizations that brought immediate positive impacts on the build footprint. In the long term, the team will work to facilitate cross-industry innovation and skill sharing around alternative materials and processes.

Targeted Workstreams:



BENCHMARKS & STANDARDS

OBJECTIVE

To understand the various points of reference across industry benchmarks, relevant legislation and Class policy to identify hot spots from previous builds. This will allow comparisons between past and future builds.

BENCHMARKS

The first step involved assessing the current industry benchmarks and putting together a roadmap for the design and build of an IMOCA for The Ocean Race, which is summarized in the graphic below.

A survey of existing life cycle assessment (LCA) studies for boats of a comparable size provided a shortlist of relevant benchmarks including:

- Kairos 2010 - LCA of an IMOCA 60
- MOD 70 - LCA of a 70' trimaran
- Vestas 11th Hour Racing - impact of use phase during the Volvo Ocean Race 2017-18

Using these benchmarks as the starting point, the Team ran two life cycle assessment (LCA) studies:

- LCA 1 - a theoretical study of an IMOCA built in 2018
- LCA 2 - an ISO report of the final race boat and components, launched and ready to sail

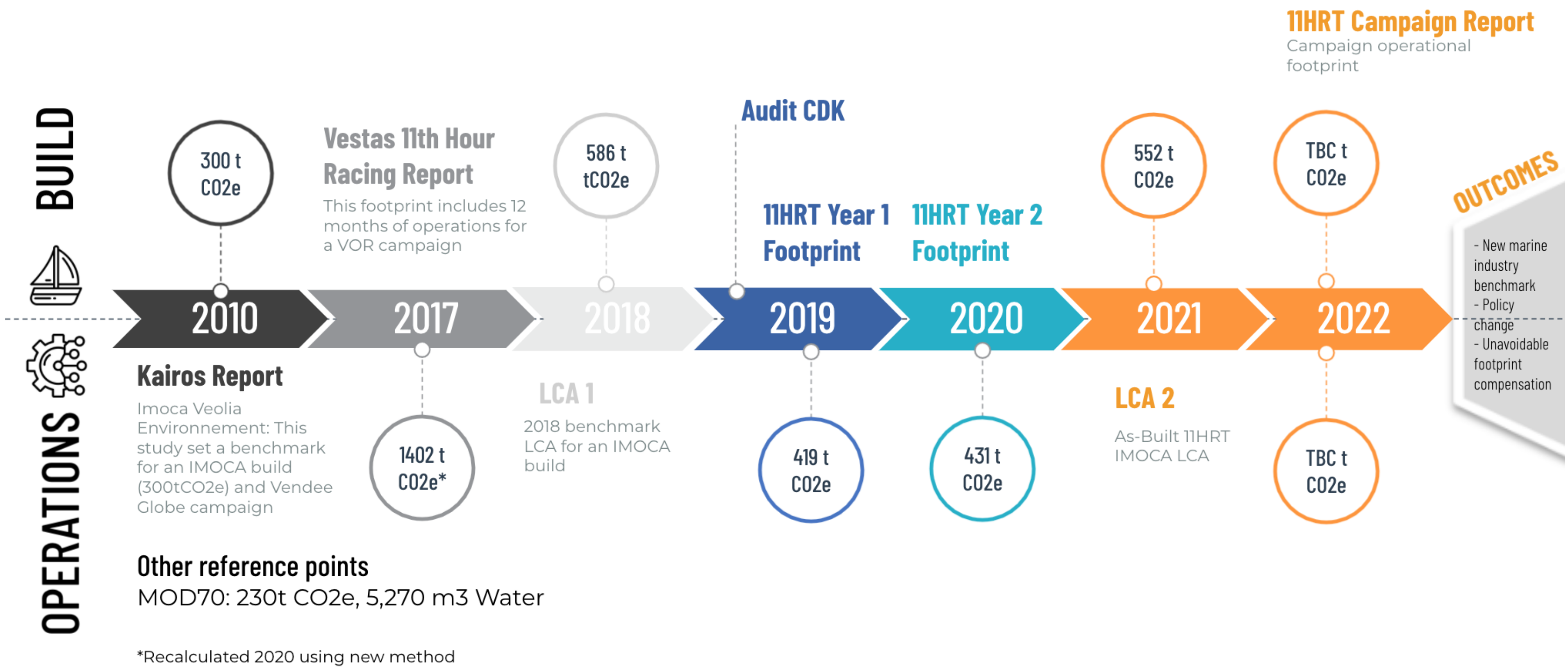


Figure: Benchmarks and greenhouse gas emission totals, 11th Hour Racing Team

MANUFACTURE VS. USE PHASE

While this report focuses on the environmental footprint of the design and build of an IMOCA launched and ready to sail (cradle to user), the design and build footprint is only 10-20% of a typical ten-year use phase. It is out of the scope of this report to discuss the measures needed to address the operational footprint of teams, Classes, and events. 11th Hour Racing Team publishes annual sustainability reports addressing the Team's operational footprint.

KAIROS 2010

The 2010 Kairos life cycle assessment report of an IMOCA build, was completed by Quantis. The ten-year gap to the Team's own LCA 2 study of the 11.2 build in 2020 provides a very relevant reference point and outlines how the IMOCA Class and the design and build impacts have changed over this period. The Kairos LCA document will be referenced throughout this report, and comparison of results can be found in Chapter: FINAL RESULTS

STANDARDS

NET ZERO

Calling for marine industry-wide action to align with the Paris Agreement, the Team committed to a *net positive – regenerative* campaign. The Paris Agreement calls for organizations to achieve 45% reduction in emissions by 2030 and to reach net zero by 2050. A key part of this report is understanding what boat building and performance sailing might look like in a net zero world, and what are the steps to get there.

A United Nations resolution at the COP 24 climate summit in Katowice in 2018 recognized the importance of sport as an enabler of sustainable development[2] and the International Olympic Committee has launched a sport climate change framework and carbon guide with UNFCCC and are calling for sports to take action[3]..

The Team's own net zero climate action strategy is to measure, understand, reduce and compensate for the build and operational carbon, water and waste footprints plus 10% by the end of the campaign, to achieve a net positive impact.

GOVERNMENT AND INDUSTRY STANDARDS

In the context of the performance offshore yacht design and build sector, there is an imperative to embed sustainability within the Design and Build Working Group strategy and operations, a powerful platform from which to catalyze change.

With market forces such as resource scarcity and the implications of policy, there are clear operational benefits to be realized. By investing resources in developing innovations to improve manufacturing efficiencies, the Team can challenge the prevailing economic growth model that seems to suggest there can be infinite growth with finite resources.

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[2] *United Nations General Assembly (2018), Sport for Development and Peace. Retrieved here*
[3] *IOC (2018). Sport as an enabler of sustainable development.*

ISO 14044

ISO 14044 is an international standard that specifies requirements and provides guidelines for life cycle assessment[4]

The Team is developing its own LCA to this standard for reasons of credibility, comparability, for a recognizable process and methodology, and for transparency.

APER

APER is a non-profit organization established in 2009 by the French Nautical Industries Federation, and the first boat-dismantling network in Europe.

With more than two million leisure craft constructed across North America and Europe annually, one of the main challenges for the development of the sector is the recovery of materials, in particular composite waste which makes up the larger part of the deconstruction process.

By placing extended user responsibility on marine manufacturers at the point of construction, and facilitating the development of networks for recycled materials, APER builds key elements of the circular economy into the marine industry.

LOCAL WASTE REGULATIONS

Local and European standards[5] of waste management and resource recovery

UNFCCC

The United Nations Sport for Climate Action framework (UNFCCC) invites sports organizations and their stakeholders to join a new climate action for sport movement towards the net zero emission economy of 2050, agreed by global leaders in Paris.

The UNFCCC guiding principles for sports are:

1: Undertake systematic efforts to promote greater environmental responsibility

2: Reduce overall climate impact

3: Educate for climate action

4: Promote sustainable and responsible consumption

5: Advocate for climate action through communication.

[4] https://www.iso.org/standard/38498.html
[5] Waste & resource management is described further in the circularity section

WORLD SAILING

The sport's governing body, World Sailing, published the Sustainability Agenda 2030 as a guideline for the industry. Two of the high-level objectives that relate to the Team's design and build of 11.2 are:

- Set technical standards by 2030 to reduce the environmental impact of the sailing industry, focusing on the end of life of composites and engine, and energy technology.
- Take a science based approach, underpinned by research to understand our impact and identify solutions.

IMOCA

On April 26, 2021, IMOCA announced their new Class rules for 2022-25. Described as 'a technical evolution rather than a revolution', the rules champion sustainability, safety, performance and accessibility – values shared by everyone here at 11th Hour Racing Team. Aside from the sporting elements, for us, the real highlight is the renewed emphasis on sustainability, encouraging engineers and athletes alike to take bigger steps in reducing their carbon footprint'. - ***Mark Towill, CEO, 11th Hour Racing Team***

Here is a non-exhaustive list outlining some of the current and future Class rules and initiatives that relate either directly or indirectly to sustainability:

IMOCA Class Rules 2021-2022

Materials:
- A specific list of authorised materials
- A minimum laminate cloth weight of 150g/m2.
- High modulus carbon fibers are expressly prohibited except for boom, spars and foils where a short list of permitted HM carbon is allowed.
- Nano materials are prohibited, with the exception of sails.

Manufacturing process:
- Maximum temperature 135°C for hull manufacturing process.
- Limitations on autoclave use, and maximum pressure for vacuum assisted construction is 1.1 bars.

One-design and designated suppliers:
- The Class defines the following as designated supplier and/or one-design components: mast, mast spreaders, lateral standing rigging, engine, keel canting system, keel fin.

Measurement:
- Renewable energy charging systems shall be removed for lightweight measurement.

Class Rules 2022-2025 (**Draft proposals and/or changes in bold**)

In addition to the existing IMOCA environmental code, the following ***Approach*** is added:
- **To contribute to the preservation of the environment and the protection of marine biodiversity.**
- **To put in place all the necessary resources to satisfy the annual goals set out by the IMOCA Teams' Charter.**
- **To optimize the use of renewable energies with the aim of being self-sufficient in energy by 2024.**

- **To adhere to World Sailing Environmental Code**
- **To gauge and understand one's carbon footprint in order to meet the objectives set by the Paris Agreement in 2030.**

General
- **Implement a life cycle analysis to appraise the carbon footprint by using the 'MarineShift360' tool for the construction of any new boat.**
- **Teams can put forward an alternative solution for motorization, with a view to obtaining exemption from the measurement.**

Life onboard, mandatory requirements for:
- **Drinking water and freshwater tanks.**
- **Plumbed toilet.**

Sails
- **Limitations of sails per year.**
- **Carbon fiber not to be used in sails.**
- **By 2023, every competitor shall have aboard one 'green sail' among the eight permitted on IMOCA Globe Series Championship races. The 'green sail' definition is yet to be specified but the sail could be made from alternative materials and/or be fully recyclable.**

Equipment
- **The boom will be one-design.**
- **Cost limitation on bespoke electronic equipment.**

Grandfather rule
- Promotes use of boats older than **2013.**

Materials
- Definition of **alternative materials.**
- A new minimum weight for laminate ply - **200g/m2.**
- Nomex® (Aramid Honeycomb Paper) or foam (PVC and SAN) or **alternative material** shall be the only core materials used.

Construction method
- Maximum of four nomex and two foam core types allowed.

Lightweight measurement
- Renewable energy charging systems**, and non-structural parts made from Alternative material shall be removed for lightweight measurement, within a limit of 100kg (tbc).**

Some topics still under consideration:
- Molds - Foil construction without molds.
- Materials - remove Nomex from materials list and to be replaced with more sustainable honeycomb alternatives.
- Materials - add PET, recycled PET and bio-based cores to permitted materials. For the moment they remain in the non-structural rule as to test them for their mechanical properties before adding them to structural parts.
- Finishing and painting - banning certain types of paints with high levels of volatile organic compounds (VOCs).

The IMOCA Class is a membership organization. The Technical and Sustainability Committees both play an important role in exploring and defining the solutions that will be most relevant to achieving world class performance within a sustainable transition.

A recent article on the new IMOCA Class rules can be read in full here.

OUTCOMES

- By discussing policy and sharing its intentions, the Team had the opportunity to support the work shaping the IMOCA policy, and to test materials to help define the rules.
- The Team was able to build its new boat to the rules, optimizing not only for performance but for sustainability as well.
- By understanding and aligning with the UNFCCC Sports for Climate Action Framework, the Team gained access to a number of useful tracking tools and strategies to support its net zero climate action plan.

RECOMMENDATIONS

- Aligning with existing regulations, rules and guidelines allows stakeholders to showcase best practice and push for bold new steps and the policies to support them.
- By taking a proactive stance, the marine industry can provide direction and stay ahead of new policy requirements.
- Looking to other industry sectors for examples of legislative approaches to innovation and progress will aid and expedite progress.

WORKING GROUPS

CONTEXT

The objective of the Design and Build Working Group was to contribute to the boat building industry's uptake of circular economy principles. The key stakeholders include the Team, MerConcept, Guillaume Verdier Design Studio, CDK Technologies, and Kairos. The Team also identified industry groups such as Composites UK, Sport and Sustainability International and The Ocean Race Sustainable Design and Build Workshop, in order to learn more about industry challenges and solutions, available technologies, materials, and collaborative opportunities.

ACTION

The first Working Group meeting in 2019 included stakeholder discovery and an exercise to understand the needs and expectations of interested parties, followed by a review of the existing benchmarks including the life cycle assessment of the Kairos 2010 IMOCA project, which helped to define further strategies focusing on areas of high impact.

The Group also reviewed lessons learned in other racing circuits such as MOD 70, Class 40 America's cup, as well as utilizing and developing tools to support the sustainable design and build plan, such as the MarineShift360 Life Cycle Assessment Tool. The Working Group looked into the current market for alternative sustainable materials and as a result commissioned a report into bio composites by Kairos, to further understand the materials that could become candidates for onboard and shore-based components. Further Working Group meetings reviewed the bio-composites report and defined an environmental audit outline which was undertaken in collaboration with the build facility at CDK Technologies.

The Working Group also attended and actively contributed to the Sustainable Design and Build Workshop at the Ocean Summit in Genoa in September which addressed the state of the industry, the latest best practices in waste management, a roadmap for sustainable rules development, and a discussion around the benefits and challenges of an industry-led accreditation standard.

In 2020, the Team held two remote meetings with the working group to present research and continue development of the plan. The first was held in May 2020, and focused on the boat build facility environmental audit recommendations, supply chain optimization and life cycle assessment data capture processes, as well as the presentation of the power-rib test results, and the use of recycled carbon. The second was held in November 2020, and had a focus on alternative materials, learning about recent developments in re-use, recycling, recovery, re-purposing of fiber reinforced polymer composite parts, fibers and resins through Composite UK’s RECOMP conference. In addition, the meeting received an update on the proposed IMOCA alternative materials rules, a review of the Team’s bio-composite test hatch, and the intention to map out a selection of further components to be built from materials with a lower embodied carbon.

OUTCOMES

- A group aligned on finding sustainable solutions.
- Contributions of knowledge and ideas on a collaborative industry platform.
- Group accountability through regular meetings and updates.
- The joint development and support of the new sustainability led IMOCA Class rules.
- The implementation of a biomimicry approach to components such as engine box and deck panels.
- The trialing and use of bio-based fibers and resin.
- The sharing of R&D with future teams to reduce the price point of components made from alternative, more sustainable materials.
- The opportunity to learn and share our challenges and successes with Composites UK, Sport and Sustainability International and The Ocean Race.

RECOMMENDATIONS

- Establishing a working group at the earliest stage ensures that the existing resources and time frame is used to best effect.
- Placing sustainability clearly on the agenda up front ensures that stakeholders assign the relevant importance and resources, and prioritizes them accordingly.
- Defining a set of sustainability objectives provides a common goal, and a new way of looking at success, and a source of motivation beyond business as usual.

SUPPLY CHAIN

"The scale of impact in the supply chain is increasingly being recognized by suppliers. Supply chain emissions are on average 11.4 times higher than operational emissions, more than double previous estimates, due to suppliers improving their emissions accounting."
Carbon Disclosure Project 2020 Supply Chain Report

OBJECTIVE

Supply Chain	1. Put together component inventory, define quantities and suppliers.
	2. Go through a stakeholder discovery and sustainable sourcing code process with higher impact suppliers.
	3. Request bill of materials for life cycle assessment.
	4. Work together on sustainability improvement plans and initiatives.

ACTION

The Team engaged with suppliers through a stakeholder discovery process, which ensured a broad discussion around the issues, impacts and opportunities associated with key products or services supplied to the Team. With the build of 11.2, significant effort was applied to keeping up with the inventory of spend going out and materials coming in to the campaign.

The Team's spend in 2020 was spread across over 515 different vendors who supplied the Team with boat-related products and services, personnel, transportation, accommodation, and other products and services (such as insurance, legal and accounting). 90% of the Team's total spend in 2020 went to 53 vendors; 55% of that spend went towards boat-related products and services.

OUTCOMES

The Team engaged with 50 suppliers in its sustainability discovery and engagement plan. 100% of these suppliers expressed a willingness to collaborate on the sustainability agenda, and are working with the Team to co-create and deliver goals and initiatives. These suppliers include: Ecoworks, Caraboni, C3, AMPM, Karver, Harken, Lorima, Diverse, Persico, Pixel sur Mer, Southern Spars, Marlow, MerConcept, CDK Technologies, Guillaume Verdier Design Studio, Multiplast, and North Sails.

TOP 10 SUPPLIER ANALYSIS

When looking at external vendors (excluding Team personnel), 52% of the Team's total spend was paid to 10 vendors:

Top 10 supplier analysis

Supplier	Percentage Total spend	Supplier type	Geographical location	Engagement level
Supplier 1	22%	Boat-related Service	Brittany, France	Level 1
Supplier 2	8%	Boat-related Service	Brittany, France	Level 1
Supplier 3	5%	Boat-related Service	Brittany, France	Level 1
Supplier 4	5%	Boat-related Product	Italy	Level 2
Supplier 5	4%	Boat-related Service	Brittany, France	Level 1
Supplier 6	3%	Boat-related Product	Brittany, France	Level 1
Supplier 7	3%	Other Service	USA	Level 3
Supplier 8	1%	Boat-related Product	France	Level 1
Supplier 9	1%	Boat-related Service	UK	Level 3
Supplier 10	1%	Boat-related Product	Brittany, France	Level 2

- Level 1 - stakeholder sustainability discovery completed, stakeholder engagement plan in place, with regular communications
- Level 2 - stakeholder sustainability discovery completed
- Level 3 - stakeholder yet to be engaged

81% of the Team's top ten supplier spend in 2020 was invested within the Brittany region where the Team has a temporary base.

RECOMMENDATIONS

- As a client or consumer, the most important influence one can have is to apply sustainable sourcing to the supply chain: create a protocol for engaging your suppliers and partners..
- Build the sustainable sourcing process into your organization's procurement and accounting system.
- Consider each conversation as unique, and solutions to challenges you might have will certainly exist within other organizations.
- Consider how to work with motivated suppliers to explore deeper into their own supply chain, with the ultimate goal to have clarity from raw material to end product.

ENVIRONMENTAL AUDIT

OBJECTIVE

The boatbuilding facility CDK Technologies had already started putting in place a range of sustainable practices before the Team arrived and this positive approach has enabled both parties to openly discuss the sustainability challenges and associated solutions with the build of a new race boat.

The Team undertook an audit of the boatbuilding facilities, allowing both parties to better understand and anticipate the different impacts associated with the design and build process. Particular attention was paid to materials, production methods, waste, energy, water, and travel.

Objectives of the audit:

1. To understand and map the boat build infrastructure.
2. To understand the material and utility flows in and out of the facility.
3. To make recommendations to inform the future build.
4. To create templates to efficiently track the information generated for the purposes of life cycle assessment.

ACTION

A key decision for the Team was to base its operations in Brittany, France, placing themselves at the center of the marine industry hub. This decision can be defined simply as efficiency. In detail it has improved the team's performance by:

- Creating new partnerships.
- Giving access to specialist skills and knowledge base.
- Improving allocation of resources.
- Optimizing timelines and improved deadlines.
- Reducing supply chain transport distances.
- Providing access to skilled local labor.
- Generating an overall reduction in all associated environmental impacts.

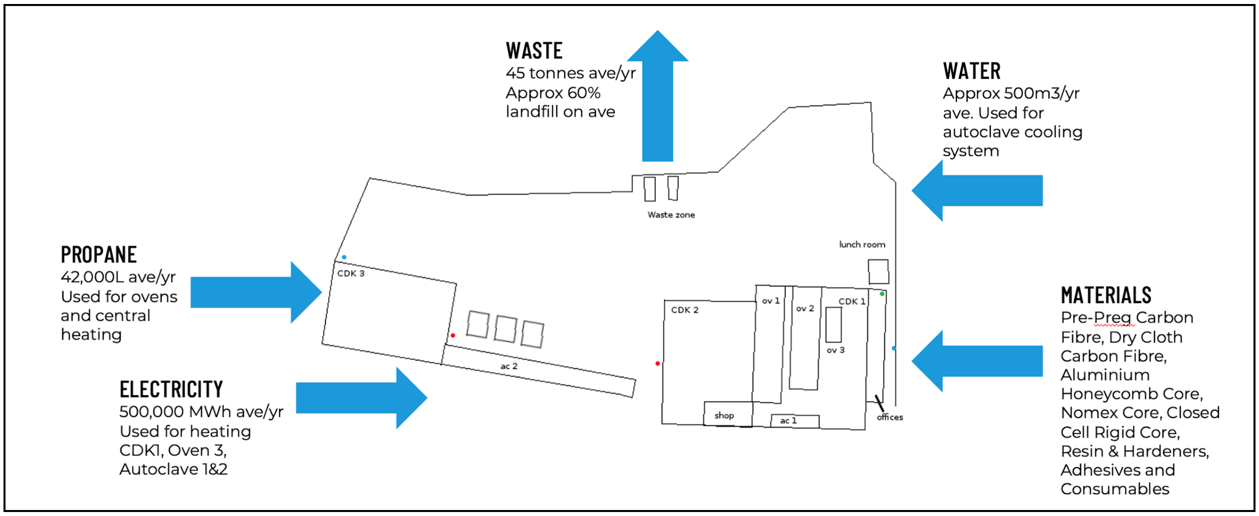
This simple, yet vital decision placing the Team at the center of the marine community provided the Team with the best opportunity to promote sustainable change.

TRACKING

Through the audit process, the Team tracked a year of commuter and site travel, energy use, autoclave and office facility water use, waste production, while exploring trends and opportunities for improvement. Some examples of the positive steps taken follow.

CDK INFRASTRUCTURE

The audit team started by reviewing the activities, facilities and infrastructure at CDK Technologies to understand the material management process and energy flows in and out of the site.



RENEWABLE ENERGY

CDK Technologies is on a renewable energy tariff, which has a great impact on the overall build footprint (see Chapter ENERGY). Through their electricity supplier contract, CDK contributes to the development of several compensation projects including reforestation, renewable energy development, improvement of buildings' energy efficiency, and others, with the goal to achieve net zero CO2 emissions (carbon-free electricity production). Natural gas is sourced locally from a bio-methane provider.

MATERIAL MANAGEMENT

A key element to management of materials throughout construction at CDK Technologies is an integrated material management system that tracks in detail resources from order through the system to either end product or waste treatment. This material management system was adapted to incorporate the nomenclature of the life cycle assessment inventory.

WASTE

CDK Technologies implemented a waste management course for internal team leaders in 2017 after a new waste service was put into place which increased their recycling rates from 10% to 55% of their annual breakdown. They continue to look for waste reduction opportunities through inventory management software, through manufacturing waste redirection to other industries, through packaging return initiatives with suppliers, and by researching local, alternative routes than landfill for the remainder of their waste.

OUTCOMES

The audit resulted in a list of findings and recommendations for the boatyard and the build process highlighting the key inputs to be taken into account during the life cycle assessment of a new race boat build.

In 2020, the build facility at CDK Technologies started to implement some of the actions from the 2019 environmental audit commissioned by the Team. Examples achieved by CDK Technologies include:

- Insulation of the main manufacturing building roof at Port La Forêt.
- Energy sourced on a 100% renewable tariff.
- Manufacturing efficiencies including a 30% reuse of steel materials in the plug component resulting in an energy reduction of ~30k MJ.
- New partnership set up with local window manufacturers who will take CDK Technologies dry cloth carbon offcut waste for processing into new products.
- By the end of 2021, CDK switched to LED lighting for the entire site that typically lasts five times as long as the fluorescent equivalent and has been shown to generate energy savings of 20-30% which will bring annual cost savings that will pay back the installation costs.
- A new route for recycling prepreg backing (PE and PP, at a volume of approximately 2 metric tons per year), through a local waste contractor who collects and processes it for remanufacturing. Saving: 528 kg CO_2e per year.

RECOMMENDATIONS

- Integrating sustainability with contractual agreements, and reporting systems, highlights opportunities for value added rather than onerous obligations.
- Accept that challenges and barriers exist; these are the opportunities to create real change.
- Every process requires energy, this is a starting point for sustainable manufacturing. Requesting that your builders and suppliers switch to a 100% renewable energy tariff is potentially a big win up front.
- Consider how responsibility for environmental impacts is assigned, examples might include:
    - Material management systems.
    - Extended manufacturer responsibility.
    - Waste management.
    - Life cycle assessment.
- Infrastructure and system improvements not only provide direct impact reductions for your contractor and project, but can be considered:
    - Through the lens of insetting[6].
    - As a net positive legacy to benefit others.

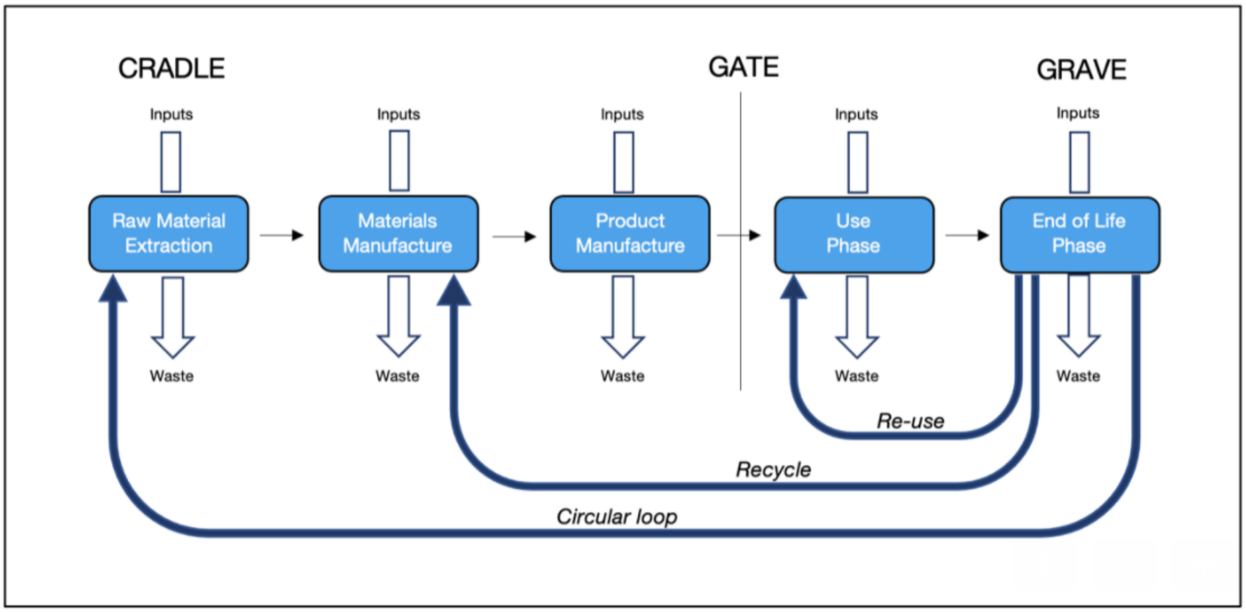
[6] Following best efforts to optimize and reduce negative climate impacts associated with an organization's operations, carbon insetting is an investment by the organization in emissions reduction projects within their value chain. In contrast to emissions reduction in external climate protection projects (carbon offset projects), climate protection money remains within the organization's value creation cycle.

LIFE CYCLE ASSESSMENT

INTRODUCTION

Life cycle assessment (LCA) is a methodology for assessing environmental impacts associated with all stages of the life cycle of a product, process or service.

LCA aims to scientifically quantify the environmental impacts that arise from material inputs and outputs, energy use, transport emissions and waste management.



Source: Michel Marie The Ocean Race Workshop Presentation, 2020

Eco-design is an approach that allows us to take the environment into consideration by reconciling our production methods with Earth's limited resources. It therefore consists of integrating the environmental factor from the design phase of a product or service with the aim of reducing and anticipating the impacts linked to the various stages of the life cycle.

In addition to the environmental benefits, eco-design also brings economic and strategic benefits for the company. The environmental analysis tools make it possible to identify the weak points of a product or service and to define improvement levers that can have an impact on the reduction of material and process costs, and the optimization of the supply chain. From a strategic and moral point of view, this innovative approach also enables the company to position itself in relation to the competition thanks to a better knowledge of its products and compliance with environmental standards.

LCA OBJECTIVES

IMOCA, a complex development Class, represents a real-world testbed for addressing the range of environmental impacts of the marine leisure industry. In line with this approach, the IMOCA Class has established new rules for 2021 and has defined objectives such as the obligation to carry out a life cycle analysis for any new boat construction.

CDK Technologies, builder of the team's new IMOCA, 11.2, is a committed pilot partner in the development of the MarineShift360 LCA tool. CDK Technologies is supporting the IMOCA Class to define achievable goals to reduce the environmental footprints.

The Team's goal for the LCA process is to quantify the environmental impact of the boat manufacturing process in order to identify, apply and share best practices in sustainable development. This overall objective is broken down into three operational objectives:

1. To develop and sustain a data collection procedure adapted to the maritime industry and the field of high-performance carbon composite construction by carrying out a complete inventory of materials, processes, transport, etc.
2. Determine realistic, feasible and technically viable developments of all kinds (materials, processes, methods, etc.) in order to reduce the environmental footprint of future boats.
3. To establish a new benchmark for the design and build of an IMOCA.

MARINESHIFT360

MarineShift360, is an international partnership-based collaboration backed by 11th Hour Racing as Founding Sponsor, which has developed a life cycle assessment tool specifically for the marine industry to evaluate and compare materials and processes, explore alternatives, and stimulate innovation to enable informed, environmentally and economically sustainable choices.

The MarineShift360 model is a bespoke customized marine industry tool that provides a cradle to grave assessment of the materials and processes involved in yacht construction. The methodology used in the model has been reviewed by LCA experts at Anthesis to ensure it conforms with best practice and is suitable for producing ISO14044 compliant reports. The database behind the tool is made up of primary research conducted in a number of marine products and processes, as well as data points from a wide range of third-party sources including, for example, the European LCI database.

The MarineShift360 life cycle assessment tool is certified in accordance with the standards for life cycle assessment: ISO 14040:2006 and ISO 14044:2006. MarineShift360's calculation models, approach, and reporting template are compliant with standards for life cycle assessment: ISO 14040:2006 and ISO 14044:2006. MarineShift360 is an ISO 14040:2006 / ISO 14044:2006 compliant and certified life cycle assessment tool.

Individual outputs and reports generated through the use of MarineShift360 must be separately reviewed to confirm compliance to ISO 14040:2006 and ISO 14044:2006, if compliance to these standards is required by the tool user.

The database behind the tool is supplied by a licensed provider who calculated the primary data points using Ecoinvent 3.6 library and SimaPro9.1. For a series of manufacturing processes and materials specific to the marine industry, MarineShift360 derived the primary data points using information provided by pilot partners and specialists from the marine industry.

The MarineShift360 LCA tool provided the team with a streamlined approach to calculating the CO_2e, water, waste, toxicity and energy footprints of the design and build of 11.2.

MarineShift360 calculations used in this report are from the MarineShift360 beta tool taken October 2021.

PILOT USER

As a Pilot Partner to MarineShift360, the Team spent a considerable amount of time testing features, providing feedback and contributing to the development of the tool, for the benefit of the broader recreational and performance marine industry. Approximately one third of the time spent working on LCA 1 and LCA 2 were spent providing feedback, streamlining and contributing to the usability of the web application for the benefit of future users.

RESOURCES

Rather than paying an external consultant to produce a life cycle assessment for the Team, it was important to develop the skills in-house, create opportunities for internships, and to support the production of MarineShift360, an open access streamlined tool being developed by 11th Hour Racing for the industry.

The team assigned a full time Life Cycle Assessment intern for 14 months, with specialist support from the Team's Sustainability Officer. Suppliers and subcontractors provided significant time, information and data on the boat components. Based on the team's work, the following is a breakdown of time it took to complete the LCA study and report.

Tasks		Days		
		Staff	**Intern**	**Suppliers**
LCA 1	Benchmark assessment	20	1	
LCA 2	Inventory development	1	1	
	Stakeholder engagement	10	15	10
	Data collection	10	20	16
	Data processing	20	40	
	Results analysis	5	10	
	ISO Report	2	3	
D&B report	Creation and compilation	30	2	
Total human resource		98	92	26

The team has provided this high-resolution life cycle assessment of an IMOCA built in 2021 for the benefit of the IMOCA Class, teams and the wider marine industry as a new reference point.

Future builds, new manufacturing processes and better materials will require new updated studies. While build and process remain comparable to 11.2, a simple update of this study is suggested here:

Tasks		Days	
		Staff	Suppliers
LCA	Inventory development	2	
	Stakeholder engagement	10	5
	Data collection	10	5
	Data processing	10	
	Results analysis	2	
	Reporting	5	
Total human resource		37	10

LCA 1

The team undertook an LCA using beta software provided by MarineShift360 to determine the footprint of a theoretical build of an IMOCA with the purpose of identifying impact hotspots, and creating case studies for the comparison of business as usual with alternative sustainable initiatives.

The study provided information on the main environmental concerns of the build, highlighting material and process 'hotspots'. This information was used to help identify best practices and areas for improvement. The study was also compared with a 2010 scenario and a 2020 scenario to highlight change in impact hotspots over time and validate data collection and processing.

Key findings:

- The total estimated footprint calculated was 586 metric tons CO2e.
- The construction (hull, deck, molds, assembly, and structure) components accounted for 50% of the overall build.
- The next largest GHG emissions impact was the appendages at 27% (includes keel, rudders, foils, and cases).
- Fit out was at 13% (includes hydraulics, electronics, deck fittings, and machinery).
- Rig was 6% (includes standing rigging, running rigging and mast).
- Sails at 4% (includes seven sails).

Focusing on the hull and deck construction only, for which detailed input data was available, the impact of the plug and molds became evident. Combined they represent **50%** of the hull and deck assembly, or **25%** of the boat launched and ready to sail. See graph below.

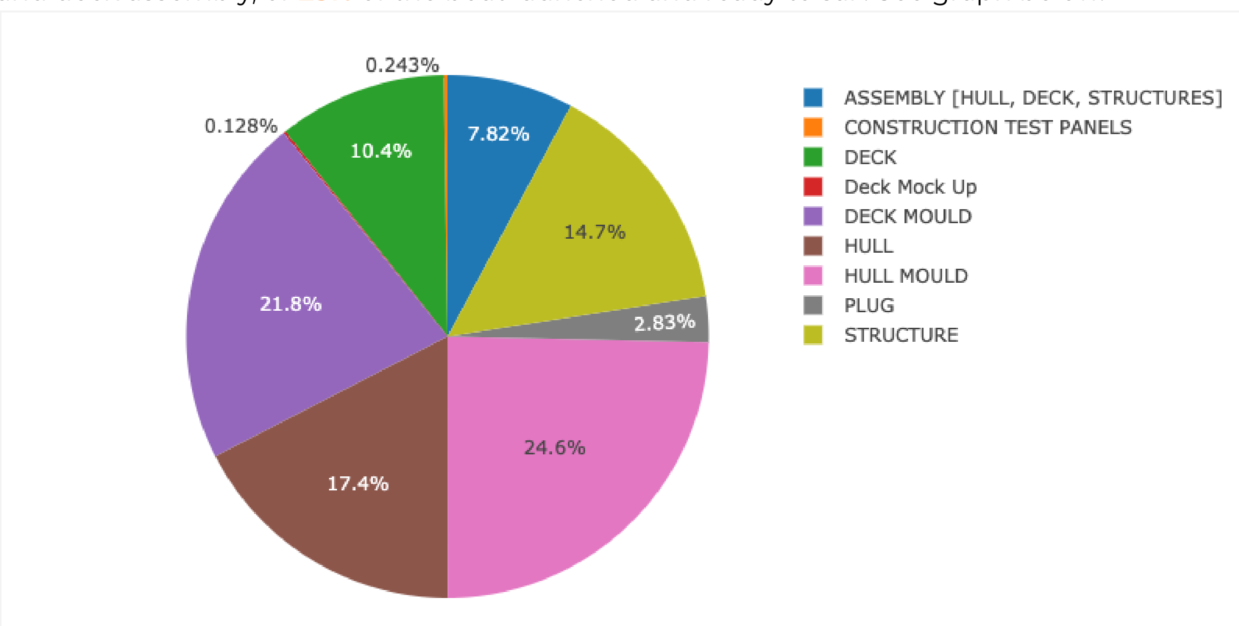


Figure: LCA1 composite construction greenhouse gas emissions impact breakdown by component from MarineShift360 beta software

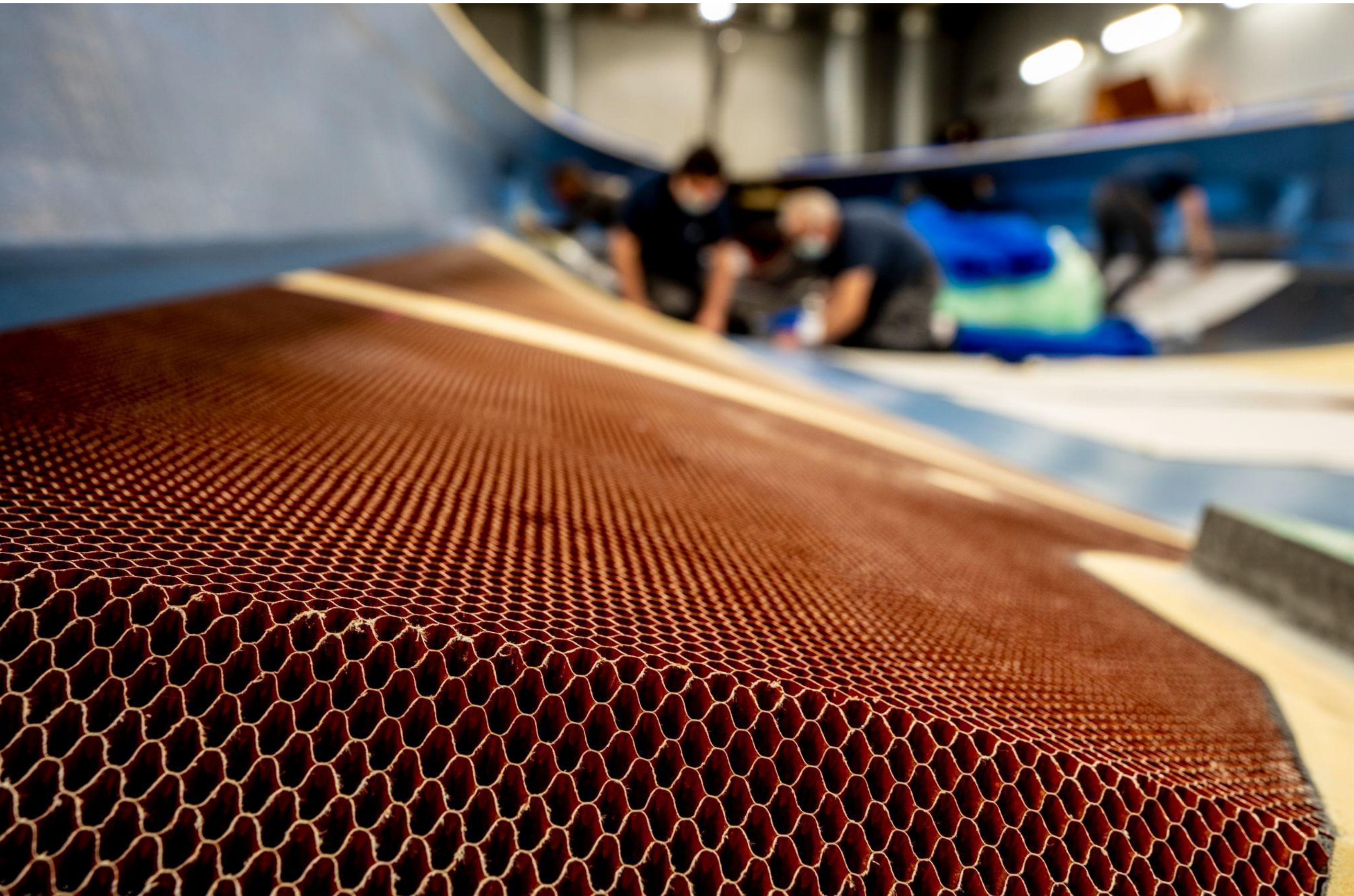
RECOMMENDATIONS

Key recommendations from the report include:

- Study: further study is needed to capture the exact energy usage for computer numerical control (CNC) machining processes.
- Source PEFC certified wood: the use of PEFC certified wood in the deck mock-up reduced the impact from 375 kg CO2e to 330 kg CO2e. All wood should be PEFC or FSC certified due to the benefits of sourcing from sustainably managed forests.
- Use renewable energy: build facilities powered by 100% renewable energy have significantly lower footprints.
- Test alternative composites with a lower embodied carbon than carbon fiber for nonstructural parts.

General recommendations for future builds include:

- Building using a female mold only and no plug would reduce the footprint of future builds by 1.6% or 8.3 metric tons, equivalent to 33,500 kilometers driven by an average passenger vehicle.
- Use recycled carbon in mold,
- Switching to a renewable energy provider for manufacturing processes is the single biggest way to reduce the footprint of the construction. The build study took place in France where energy has a low carbon mix; compared with an average European build, the 2018 IMOCA was approximately 30% lower for the build overall.



LCA 2

CONTEXT

The following study was undertaken to determine the footprint of the build of the new IMOCA 11.2, in France from 2019-2021. 11th Hour Racing Team produced this study with their partners in order to develop a new industry benchmark, and to make recommendations for future builds in order to align the industry with the Paris Agreement of a 45% reduction by 2030 and net zero by 2050.

GOAL AND SCOPE

The objectives of the study are as follows :

- Evaluate the environmental impacts of the IMOCA 11.2 build.
- Identify the improvement tracks and evaluate the potential environmental gains.
- Provide a replicable data collection methodology and streamlined process for future IMOCA Class builds.

The impact indicators and consumption flows chosen for this study, and represented by default within MarineShift360, are in the following table:

Table: Impact indicators

MarineShift360 - October 2021		
Impact category	**Unit**	**Impact method**
Global warming	Kg CO_2-eq*	ReCiPe 2016 v. 1.10
Mineral resource scarcity	Kg Cu-eq	ReCiPe 2016 v. 1.10
Marine eutrophication	Kg N-eq	ReCiPe 2016 v. 1.10
Water consumption	m^3	ReCiPe 2016 v. 1.10
Non-renewable energy	MJ	Cumulative Energy Demand
Renewable energy	MJ	Cumulative Energy Demand

***equivalent**

A detailed description of these indicators is presented in the interpretations SUB-CHAPTER: MAIN ANALYSIS RESULTS.

The scope of the study covers the life cycle of 11.2, from the extraction of the raw materials to its launch (cradle to user).

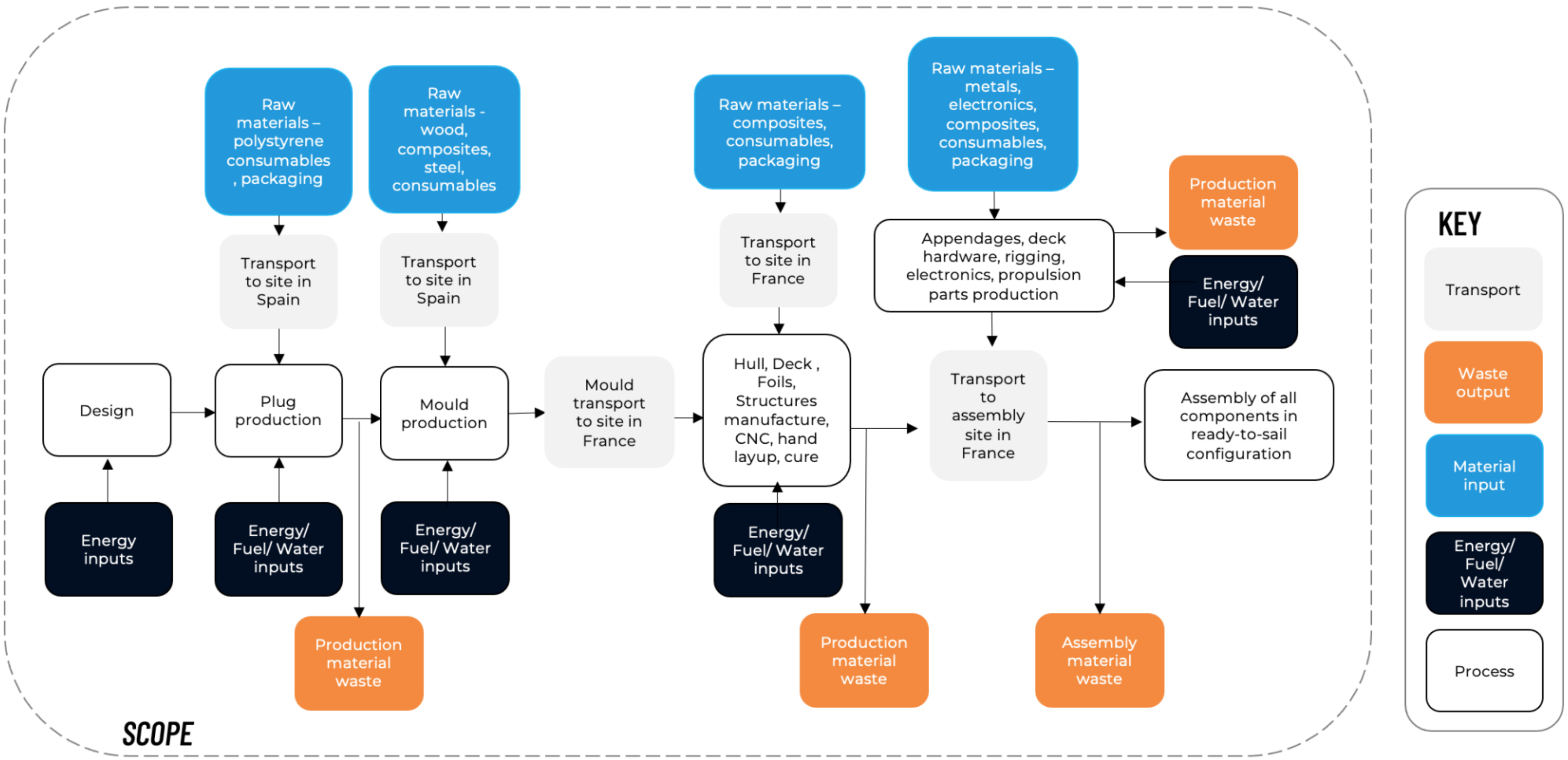


Figure: The scope of life cycle assessment 11.2

The ***functional unit*** describes qualitatively and quantitatively the function(s) or the service(s) provided by an IMOCA.

The main functional unit is as follows: the life cycle of an IMOCA assembled and ready to sail, built in France, excluding[7] the use phase and end of life.

[7] Use and end of life (EOL) phases are addressed in separate chapters of the Design and Build Report

INVENTORY

The production inventory, grouping together all the inputs (quantity of materials and energy consumed), is a decisive step in the analysis. The total weight of 11.2 as built and ready to sail is 8.6 metric tons.

The table below highlights the weight breakdown by group while the production system inventory details all the components included in the scope of the study.
The energy used during the manufacturing process was also taken into account.

Table: Breakdown of the inventory by weight

GROUP	Weight (kg)	%
Appendages	800	10
Equipment	800	10
Hull/Deck/Structure	2,500	29
Keel	3,500	39
Rig	500	6
Sails	500	6

Table: Material and process flows

Transport	Waste	Materials	Energy, fuel, water	Process
90% local road 5% european road 5% international air	25 metric tons	34 metric tons	kWh & Litres	45,000-50,000 man-hours hull and deck

PRODUCTION SYSTEM INVENTORY

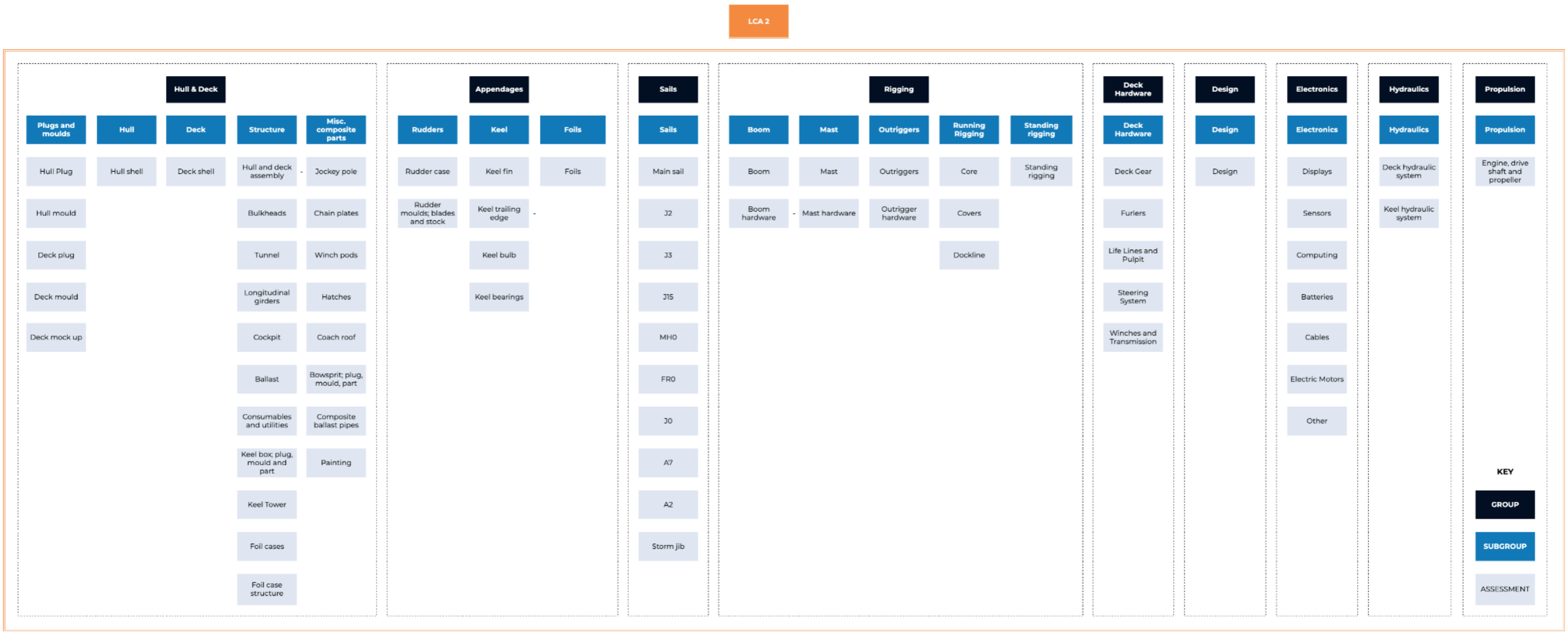


Figure: Outlining the full inventory of the life cycle assessment of IMOCA 11.2

DATA COLLECTION - PROCESS REVIEW

The quality of data directly affects the quality of the LCA results, therefore the Team developed stringent procedures to ensure high and accurate standards were maintained.

The ultimate goal was to establish a common methodology for the collection of data.

- This helps to facilitate consistent data retrieval and analysis from the various stakeholders in the life of a boat (design, manufacture, operation and deconstruction).
- The use of input forms is the method most adopted by LCA practitioners because they bring together all the necessary information (quantity of materials, distance from supplier, manufacturing processes, end-of-life scenario, etc.) and are fairly simple to use by subcontractors.
- To streamline the data collection process the team created several input forms specific to the type of component material used e.g. wood, metal or composite, etc.

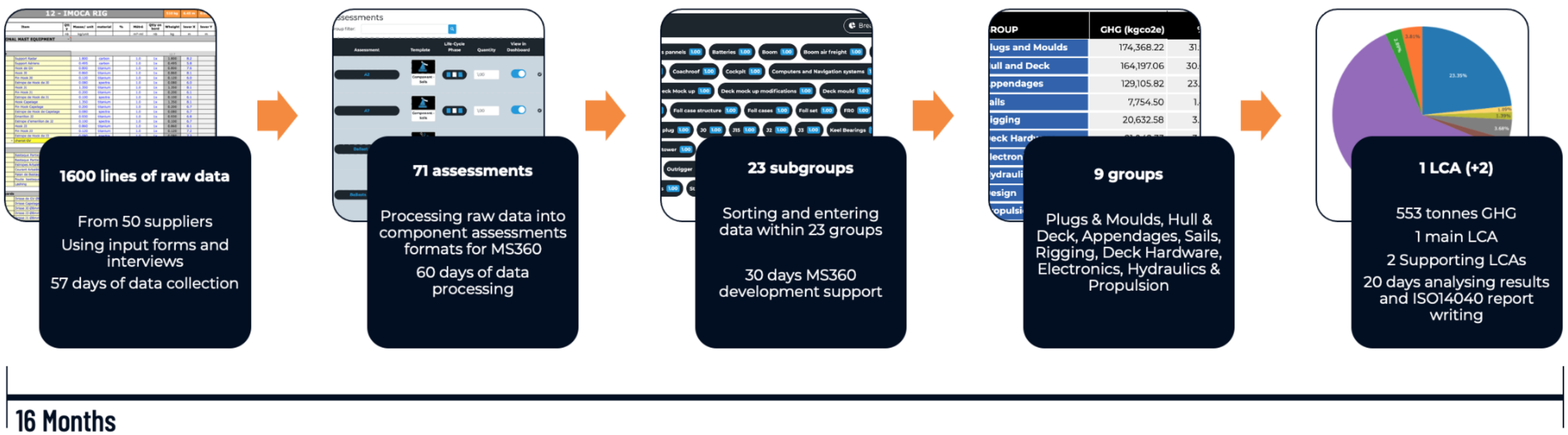


Figure: describing the process of recovering and processing data for the life cycle assessment

	Data Collecting Procedure **LCA 11-2**	Code: **PROICV_11-2** *Version: 1.1* *Created: 10/28/2020* *Page: 1/1*

Goal	This procedure covers the various stages of collecting all types of data (measured, calculated and estimated) in accordance with ISO 14044:2006.

Scope of application	11-2 CDK LCA system boundaries	**Other documents links**	ISO14040/14044 (4.3.2)

Tasks	**Description**	**Resources**	**Person involved**
1- Preparation of the data collection	List each process/product involved in the system and the type of data required.	Nomenclature file 11-2	Primary LCA contact Quality control manager Project manager
2- Collection of raw data	Conduct an inventory of raw materials, supplies, suppliers, transport and energy consumed for each process/product.	4D export files, production manufacturing ranges, autoclave and oven programs, utility reciepts, accounts department	Primary LCA contact
3- Assessment of data quality	Check the measurement units and the level of confidentiality of the data.	Summary file	Primary LCA contact Quality control manager
4- Data aggregation	Convert raw data into process/product specific data categories.	Data forms	Primary LCA contact
5- Data validation	Compare the values with an existing one. Estimations may be necessary if some data are missing or inconsistent.	LCA 1	Primary LCA contact Quality control manager Project manager

MAIN RESULTS ANALYSIS: LCA 11.2

There are three main results[8] from the life cycle assessment of the design and build of 11th Hour Racing Team's IMOCA 11.2:

- The environmental impacts in absolute value for the main functional unit.
- The greenhouse gases (GHG) emissions breakdown by group and sub-group.
- Analysis of the contribution of the life cycle stages to the environmental impacts.

Global Warming	Mineral Resource Scarcity	Energy consumption	Water consumption	Marine Eutrophication
tC02e	kg Cue	MJ	m3	kg Ne
553	**10,300**	**15,900,000**	**7,500**	**231.7**

To put this in context :

- **Global Warming Potential** is the total emission of greenhouse gases was **553 tCO2e** (metric tons of carbon dioxide equivalent C02e). This amount is the equivalent to 2.2 million kilometers driven by an average passenger vehicle, or the annual electricity consumption of 100 US homes, or the manufacture of 100 average Renault cars.
- **Mineral resource scarcity** represents the total extraction of minerals on available reserves (stated as Cue - copper equivalent). The mineral resources needed to build 11.2 were **10,300 kgCue**, or enough to produce 130 electric cars.
- **Energy consumption** is the energy consumed by the production of materials and building process of the IMOCA was **15.9million MJ**, this is equivalent to 370 US homes' energy use for one year.
- **Water consumption** represents the total quantity of water used in production of the goods and services associated with the design and build of the IMOCA. The total, **7,500m3** (7.5 million litres or 2 million US gallons) is the equivalent of three olympic swimming pools, 50,000 baths, or the annual water consumption of 115 people in the US.
- **Marine eutrophication**, stated as nitrogen equivalent, this is the modification and degradation of an aquatic environment due to excessive supply of nutrients, particularly nitrogen and phosphorus associated with materials and/or processes. The impact of the design and build of the IMOCA was **231.7 kgNe**.

[8] The team's life cycle assessment results were calculated using MarineShift360 in October 2021. 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.

GREENHOUSE GAS BREAKDOWN

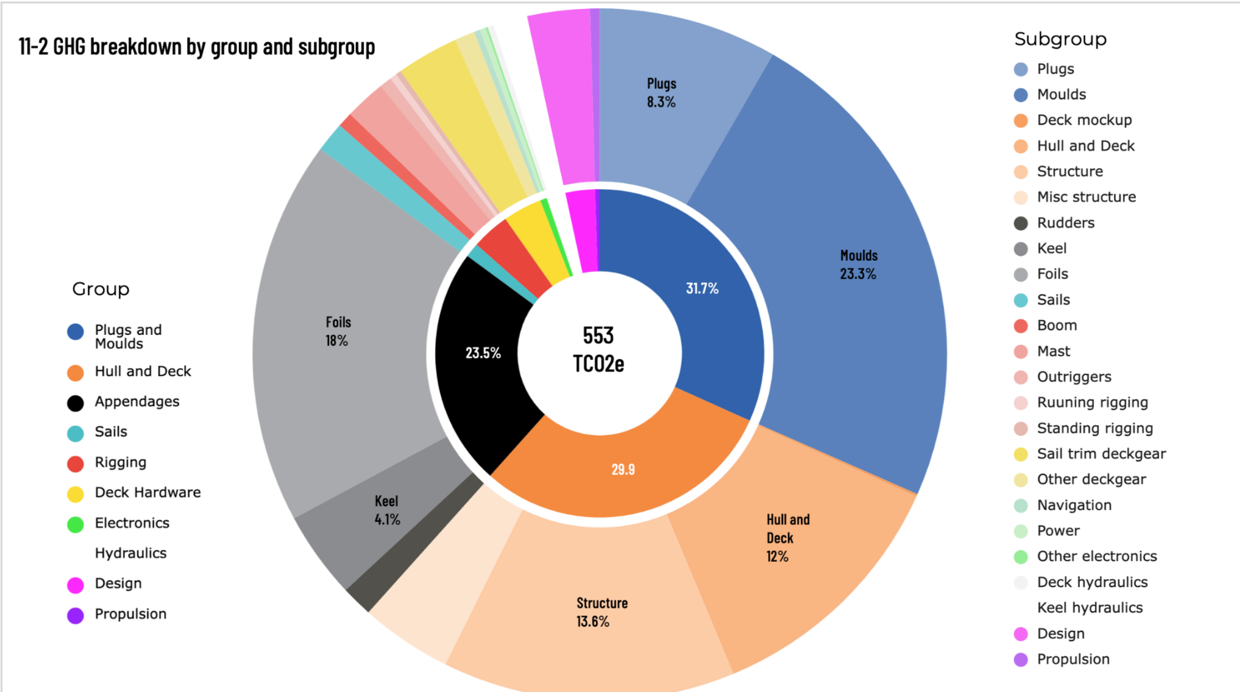


Figure: 11.2 GHG breakdown by group and subgroup
Calculated with MarineShift360 beta software on September 1, 2021

The hull and deck ((342t CO2e) and appendages (129t C02e) contribute to 85% of the GHG emissions and require the largest focus for improvements. Previous studies have also highlighted the important impact of composite parts and the need to rethink the build process by implementing 'greener' materials, or simply reducing their weights and processes (e.g. avoiding plugs and reusing molds).

When reviewed by components, 32% of the GHG emissions come from the plugs and molds. Reusing or removing these components completely will offer significant reductions.

Although the foils are not the heaviest composite parts within the inventory, their related carbon footprint is notable (23 tCO2e vs 20 tC02e for the hull and deck shell). This is mainly due to the high amount of materials used and waste generated (~300% of final component weight).

The remaining emissions are divided evenly across the other subgroups of components of 11.2.

Tables below: GHG breakdown by group and sub-group calculated with MarineShift360 beta software on September 1, 2021

GROUP	GHG (kgco2e)	%
Plugs and Moulds	174,368.22	31.9
Hull and Deck	164,197.06	30.0
Appendages	129,105.82	23.6
Sails	7,754.50	1.4
Rigging	20,632.58	3.8
Deck Hardware	21,042.33	3.8
Electronics	3,632.01	0.7
Hydraulics	10,309.39	1.9
Design	16,000.00	2.9
Propulsion	2,486.75	0.5

Sub-Group	GHG (kgco2e)	%
Plugs	45,649.15	8.3
Moulds	128,082.83	23.3
Deck mockup	636.24	0.1
Hull and Deck	65,833.12	12.0
Structure	74,868.09	13.6
Misc structure	23,495.85	4.3
Rudders	8,029.82	1.5
Keel	22,377.42	4.1
Foils	98,698.58	18.0
Sails	7,754.50	1.4
Boom	3,861.47	0.7
Mast	10,530.16	1.9
Outriggers	3,053.88	0.6
Running rigging	1,770.74	0.3
Standing rigging	1,416.32	0.3
Sail trim deck gear	15,858.82	2.9
Other deck gear	5,183.51	0.9
Navigation	1,554.03	0.3
Power	1,556.38	0.3
Other electronics	521.60	0.1
Deck hydraulics	1,543.53	0.3
Keel hydraulics	8,765.86	1.6
Design	16000	2.9
Propulsion	2,486.75	0.5

The figure below shows the contribution of the life cycle stages to the environmental impacts and flows. They are grouped as follows:

- The extraction of raw materials, production of products and semi-products such as carbon fabrics, resins, and various materials (wood, steel, lead, plastics etc.).
- The transport of raw materials to the different stakeholders.
- The utilities for the sites and the manufacturing processes which integrate the energy consumed from the various composite cures, Computer numerical control (CNC) machining, welding process etc.
- The consumables including the vacuum consumables, prepreg backing and PPE (personal protection equipment).
- End of life and waste management, including all production waste and consumables.

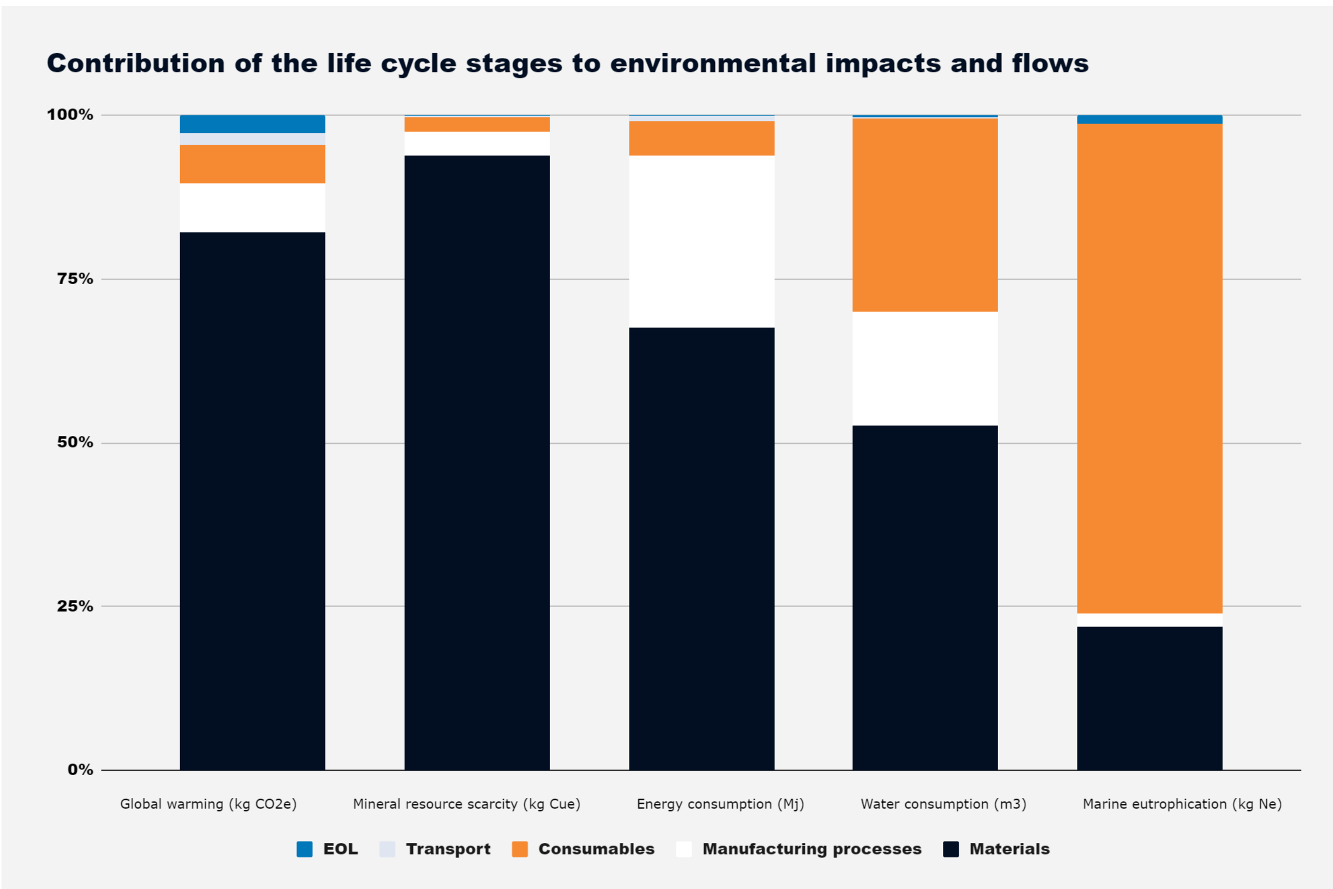


Figure: Contribution of the life cycle stages to environmental impacts and flows

Calculated with MarineShift360 beta software on September 1, 2021

CONCLUSION

The life cycle assessment of the actual build (LCA 11.2) is comparable to the theoretical study (LCA 11.1) completed the previous year with a different inventory source: 553 tC02e actual build vs 586 tC02e theoretical build.

The extraction and production of raw materials contribute more than 50% to the majority of the impact indicators. This is explained by the large amount of material produced from non-renewable resources associated with their energy-intensive manufacturing processes.

The manufacturing site also has an important contribution, particularly on the flow of energy and water consumption.

With 1.2 metric tons of prepreg backing plastic waste generated during the build, the impact of the consumables on marine eutrophication and water consumption is significant and mainly related to the use of plastics. It encourages thinking about the use of composite processes using less plastics.

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SCENARIO ANALYSIS - ENERGY

INTRODUCTION

Transforming raw materials to end products requires energy; this is a key sector in which to look for emission reduction opportunities. Switching to renewable energy from non-renewables is typically a straightforward choice and in terms of feasibility, it is often one of the easiest changes for a business to implement.

The objective of the full scenario analysis - Energy, which is summarized here is to understand the impact of renewable electricity choices. To do this, we studied the design and build of an IMOCA 11.2, launched and 'ready-to-sail' in three scenarios, defined as:

- Base scenario: 100% renewable energy by all component manufacturers.
- Actual build: all electricity inputs selected as per supplier input data.
- 100% EU Grid: 100% average EU grid by all component manufacturers.

RESULT

Compared to the EU average, applying 100% renewable energy across all builders and manufacturers of the boat launched and ready to sail reduces greenhouse gas emissions by 210 tC02e, or 32% of the total footprint of the build.

Table: Comparing GHG impacts of different electricity sources to build an IMOCA, calculated with MarineShift360 beta software on October 1, 2021

	Total tC02e	Improvement from EU average tC02e	% improvement from EU average baseline
100% EU grid scenario	651	n/a	n/a
Actual build	553	-98	-15%
100% renewable scenario	441	-210	-32%

ACTUAL CONSTRUCTION 11.2

Built in France, 11th Hour Racing Team's IMOCA 11.2 benefited from the low energy impact of the French national grid average for most suppliers, and a 100% renewable energy tariff for CDK Technologies. This gave a 98 tC02e - or 15% - reduction compared to the EU average.

RECOMMENDATIONS

- Make renewable energy a key point of discussion across your supply chain, and sourcing contracts.
- Ensure manufacturing energy needs are sourced from 100% renewable energy tariffs

DIGITAL FOOTPRINT

INTRODUCTION

Directly reliant on energy, digital and online services have growing environmental impacts[9]. Recognizing that performance sailing is reliant on a significant amount of research and development, the Team conducted a full assessment of the digital footprint of the design and build of 11.2. which is summarized here.

Table: Digital footprint of designing and building 11.2

11th Hour racing team IMOCA - 11.2	Digital footprint	Digital % of total
Design & Build 2019-2021	16.5 tCo2e	3%

METHODOLOGY

The method for calculating the GHG emissions of the Team's digital services has been through a combination of the UK GHG Reporting Protocol, direct inputs (where number of servers running, energy required, and the carbon intensity of energy sources used are known), online research and estimations (Including online data storage and transfer, office emails, conference calls and communications), and specialist input[10].

INVENTORY

The supplier inventory for the design and build of 11.2 included:

- A detailed calculation of digital use by core design and build group
- An estimate for other suppliers and contractors

The inventory of services used that have been calculated include Google Workspace, email and website traffic, digital asset cloud storage, super-computer, office computer time, web searching, sail design and online server use associated with yacht design and analysis**.**

[9] A recent report from Bristol University highlighted Netflix streaming at 100g C02e per hour
[10] Sylvain Baudouin - The Shift project, provided guidance on calculation of digital impacts. Additional support with regards to the definition of 11th Hour Racing team's digital footprint was provided by Craig Simmons, Anthesis

An example of the inventory used to calculate the digital footprint is described below

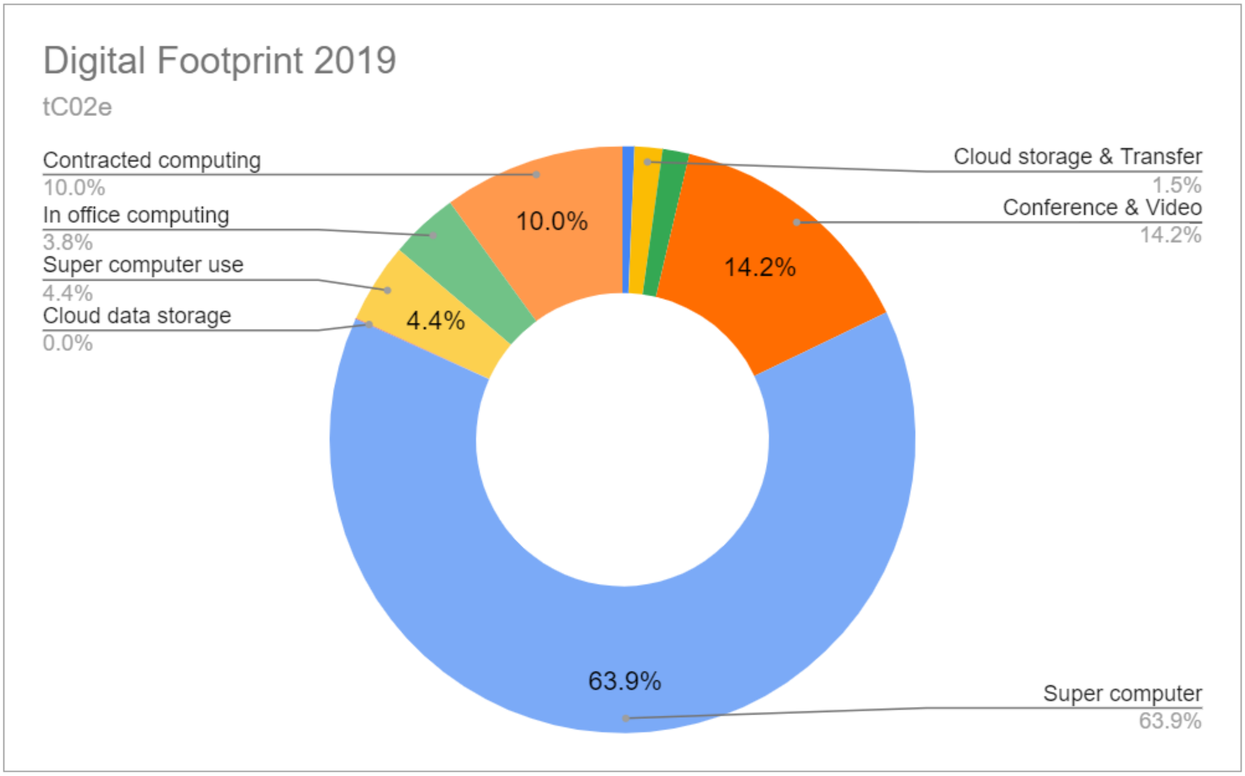


Figure: 11th Hour Racing Team's digital footprint inventory for 2019

The impact of digital use across the design and build process from 2019 - 2021, was 15 tC02e or 3% of the total footprint.

Table: total breakdown digital footprint of the design and build

Digital footprint - 11.2	**Design and build group**	**Other suppliers**
2019 research and development	7.69	
2020 design and build coordination	2.79	0.5
2021 design and Build	2.79	1.0
TOTAL	15 tC02e 3% of total design and build footprint	

DIGITAL SOBRIETY

While the digital services applied to the design and build provide efficiencies in terms of reducing build time, trial and error, designing circularity into products and limiting travel between organizations, the growing capacity and energy needs of digital tools mean they are responsible for an increasing environmental impact of their own.

Best practices the Team put in place include:

1. Use of the Google workspace platform which provides a net zero carbon emissions service through use of renewable energy purchases to offset the emissions from the Google data center. Visit Google's environmental report (pgs. 13, 24-34) for their emissions statement.
2. Working with Kinsta for website hosting, which uses the Google Cloud Platform.
3. Using Image Relay, a certified B-Corp, for its Digital Asset Management. Image Relay uses Amazon Web Services to hold the digital assets which exceeded 50% renewable energy usage for 2018 (latest available data) (n.d., AWS).
4. Using two supercomputers from the Wolfson Unit at the University of Southampton which have been rated in the Top 500 of the world's greenest machines. (Greenlist, 2013, 2017) for the team's aero analysis.

Additional recommendations include:

- Use green web design and hosting services.
- Source digital services that are powered by renewable energy tariffs which can provide significant impact reductions (In certain cases a factor of ten or more).
- Use data compression where possible, which reduces the amount of online and stored data.
- Minimize email content and quantity, and cleaning out inboxes.
- Turning off cameras during video conferencing, which can reduce impacts by 96%.
- Reduce in-person meetings. One study suggests a conference call might produce just 7% of the impact of an in-person meeting. The same study indicated that this is still the case even for car rides for distances less than 20km.
- Select carefully replacement hardware, using sustainable sourcing standards.

CONCLUSION

At 15tC02e, the digital footprint is a relatively small percentage (3%) of the total build impact, and this reflects the impact of the digital sector worldwide estimated at 3.5% of global GHG emissions, or the equivalent of the entire aviation industry. The global impact of digital use is set to increase by up to 14% by 2040, underlining the importance of understanding and taking responsibility for impacts in this sector.

BEYOND BUSINESS AS USUAL

In assessing existing boat building processes and materials, the design and build group focused first on the simple solutions looking for absolute reductions in current resources needs, efficiencies within existing practices, and finally the alternatives which include new materials.

Carbon fiber is the ubiquitous material in the marine industry, it has the highest weight to strength ratio, and provides both the performance, and often the reliability and longevity, not possible with other materials. However, the environmental impacts associated with producing carbon fiber can be 100+ times that of natural fibers.

The production of carbon fiber requires significant energy and heat resulting in 4,000kg C02e for the production of 100kg of standard carbon fiber. For high modulus carbon, the associated GHG emissions increase quickly with the increase in carbon modulus[11], to over 6,000kg C02e per 100kg material due to the duration of process (96hrs+), higher temperatures (1,500°C+) and for certain high modulus fibers Argon gas replacing Nitrogen[12].

The availability of specialized, high modulus materials has both enabled the ongoing gains in performance, whilst also making the design and build of the boats ever more complex.

COMPLEXITY OF NEW BUILDS VERSUS OLDER BENCHMARKS

"Building a new IMOCA has become a significantly more complex process. Construction of the hull requires 40% more man-hours than just a few years ago, while the time we spend on the deck has increased by 60%. This increase in build time is a function of more complex designs and structures, and is also due to the use of more specialized materials." - **Yann Dollo, CDK technologies**

© CDK Technologies

When building a new boat, the Team recommends three main questions are asked, and answered, by the commissioner, the designer and builder:

- How much carbon fiber do we really need?
- What and how many types of different materials are needed?
- How can limiting material types reduce the environmental impacts without impacting performance?

[11] Composite materials are defined using measurements to quantify the amount or ***modulus*** of various mechanical properties such as tensile strength, stiffness, sheer and elasticity.
[12] Lifecycle impact assessment of different manufacturing technologies for automotive CFRP components, Journal of cleaner production (2020)

Due to the time frame of construction for the build of the Team's new IMOCA, carbon fiber was the default material. However, one of the ways the IMOCA Class are addressing the impact of carbon fiber use, including cost, waste and build time, is by setting a new minimum cloth weight at 200g.sqm.

Considering that current builds are frequently using multiple cloth weights from 150g.sqm and above, this will have a significant impact in reducing not only the types of cloth used, simplifying purchase orders, use and reducing offcuts, but will also directly reduce and in many cases half the actual man-hours needed to layup a carbon component, and also the associated consumables/waste. In addition, a common set of materials aligns the industry with higher value waste recovery and recycling at end of life. More on this in the Waste chapter.

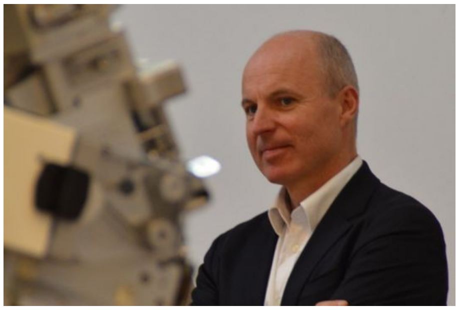
Simplification and standardization of materials is a powerful policy to find reductions within business as usual.

DISCUSSION

Further discussion on improving business as usual can be found in the following scenarios:

- Scenario analysis - metal
- Scenario analysis - 10m2 (prepreg versus infusion)
- Scenario analysis - Design choices vs Impact (minimum cloth weights)

RECOMMENDATIONS



"The increase of greenhouse gas emissions associated with the production of higher modulus carbon fibers can be by a factor of two or more. Defining limits for the use and type of carbon fiber within Class rules can bring significant reductions in greenhouse gas emissions throughout the build process."
– **Luc Talbourdet, Avel Robotics**

© Avel Robotics

Underpinning the discussion on improving business as usual is the importance of simplifying material choices, processes and prioritizing local supply chains.

ALTERNATIVE MATERIALS

Having identified that the materials and consumables used in boat manufacturing would be a considerable part of the footprint, the Team's Sustainable Design and Build Plan (developed in 2019) defined alternative, lower impact materials as a key workstream. The plan outlined the following steps:

Alternative Materials	1. Commission report on sustainable and alternative materials, and conduct targeted research to understand their properties, applications and footprints. Identify one project to tackle using a biomimicry approach to problem solving.
	2. Define a list of onboard components that are good candidates for those materials.
	3. Map the list of component candidates with the materials.
	4. Commission parts and/or build in-house.
	5. Quantify the impact of alternative choices.
	6. Create and share case studies with lessons learned

"One of my key roles is exploring how to utilize and exploit alternative materials. We're constantly asking the question: 'How can we use different composites to build parts, and what are the applications of those? Are they safe? Will they last?' I pick components on the boat that are strong candidates for a sustainable alternative, and from there we explore whether it is a possibility. Sometimes my ideas don't work but often we are able to prove that more sustainable alternatives really can compete with the more common construction methods. We have final parts on the way to use on our new IMOCA. It's a first for the fleet I think, probably any racing fleet. Along with this delivered outcome we have regular workshops to keep the ideas coming in- It's a long road but we are making headway."

Wade Morgan, 11th Hour Racing Team Build Manager

ALTERNATIVE MATERIALS REPORT

In 2019, the Team commissioned Kairos to prepare a report on the current state of play with regards to sustainable alternative materials and build processes. The full report summarized here compared the environmental and structural properties of a number of biobased composite materials, which has allowed the Team to undertake further research in the form of testing panels. The intention was to select a few onboard components to be built from fibers with a lower embodied carbon footprint.

MECHANICAL COMPARISON

The evolution of the mechanical properties of boat building materials has caused a direct increase in their environmental impact. This is due both to the raw material and the production process. The alternative materials report explored the mechanical properties of a number of fibers, resins and core materials, alongside their relative environmental impacts.

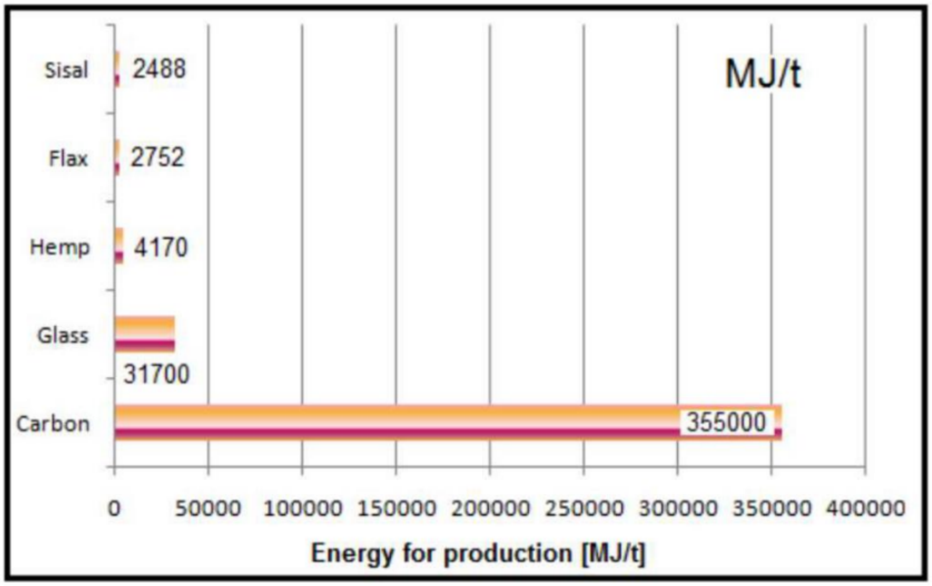
Nature	Type	E_1 (Gpa)	ρ (g/cm3)	σ_{max} tensile (Mpa)
Aramid	Kevlar 49	130	1.45	3500
Carbon HR	HR	230	1.7	4500
Basalt	Filava	100	2.6	2000
Glass E	E	78.7	2.6	2366
Glass R	R	86	2.5	3200
Flax		48	1.38	800
Hemp		45	1.47	700
Bomboo		30-50	0.9	500 - 740
Jute		42	1.23	610

Nature	Type	E (Gpa)	v12 (Gpa)	G12 (Gpa)	ρ (g/cm3)	σmax t (Mpa)	σmax c (Mpa)	τ max (Mpa)	Approx. cost (€/Kg)
Epoxy	SR 1700	3.5	0.4	1.6	1.2	90	90	75	12-18
Biobased Epoxy	SR810	3.2	0.4	n/a	1.2	70	70	47	12-18
Polyester ortho	Orthophthalic	4	0.4	1.4	1.1	80	80	46	2
Biobased Polyester		3.1	0.37	1.13	1.2	62	62	35	4.5
Polyamide	PA6.6	3.3	n/a	n/a	1.15	80	n/a	n/a	n/a
Polyamide	PA11	1.55	n/a	n/a	1.03	44	n/a	n/a	n/a
PLA	Polylactic acide	3.3	0.3	1.23	1.24	60	60	45	3.5
Elium	Methacrylate	3.3	0.3	1.27	1.19	76	130	45	14.5
Polypropylene		2	0.3	0.8	0.9	20	20	15	1

Figure: Mechanical properties of renewable and non-renewable fibers, resins and core materials.
Source: Kairos alternative materials report

ENVIRONMENTAL IMPACTS

The figure below shows the energy needed for the production of various fibers, in megaJoules per metric ton of fiber.. The production of carbon fiber needs 10 times more energy than glass; the manufacturing process of glass fiber needs 10 times more energy than natural fibers.



Source: Kairos Alternative materials report [SachsenLeinen; Daimler 1999; BAFA; NOVA; AVB; REO]

Comparing the environmental impact and global warming potential of composite fibers, it is important to note that the graph below is based on weight and not on comparable strength.

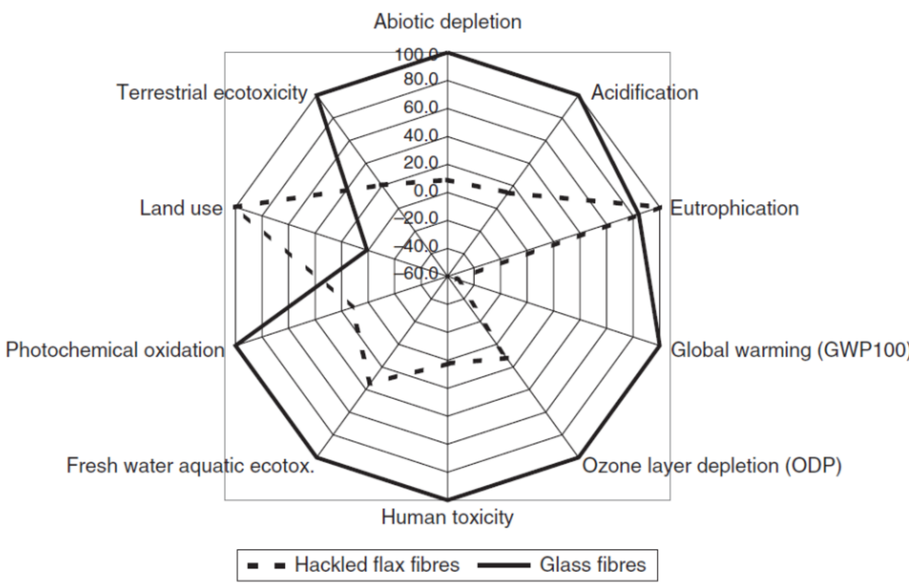


Figure: Environmental impacts during the production of hackled flax fibers compared to those for glass fibers. Source: Kairos alternative materials report.

COMPOSITE COMPARISONS

Assessing the environmental impacts of composite materials and processes.

FIBERS

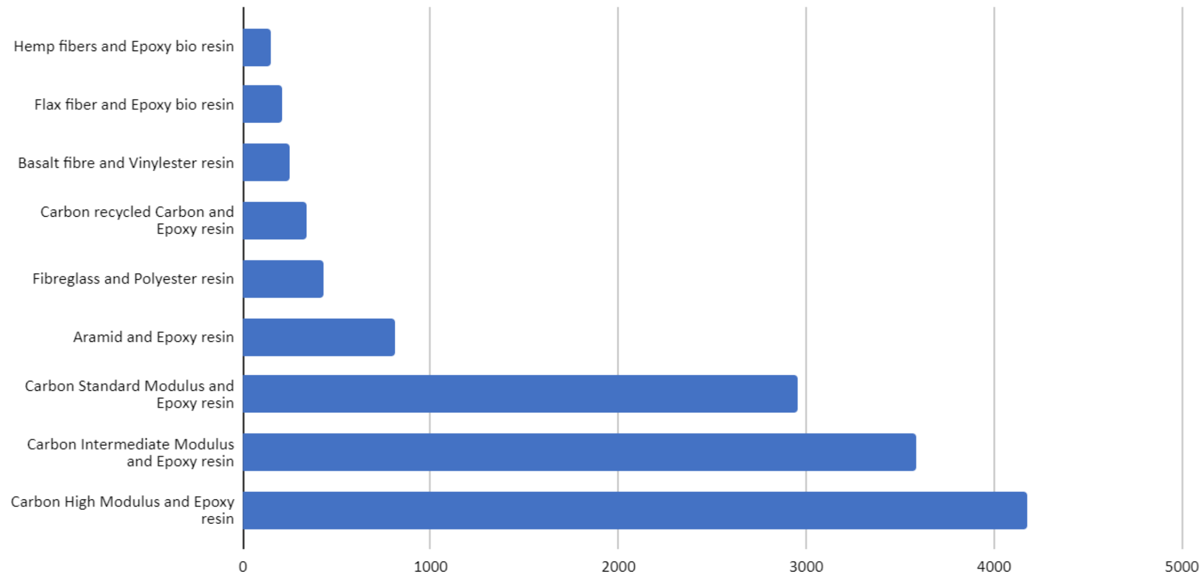


Figure: Comparing relative greenhouse gas impacts of different fibers
Source Michel Marie
Calculated with MarineShift360 beta software on October 14, 2021

While the need to look beyond carbon fiber is evident, the primary challenge for the team with regards to fiber choice was primarily finding non-structural areas that could receive alternatives, such as recycled carbon and flax. The approach and applications are outlined in the following chapters.

RESINS

Safe bio-based alternatives for resins improve the protection of human health and the environment. The bio-based resins the Team tested and used in various components included Sicomin Greenpoxy (35% bio-based), and Gurit's AMPRO bio (40-60% bio-based).

Bio-based resins have an 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.

The Team used bio-based resins for the splashes, engine box, deck fairing, and hatches.
For more discussion on improvement tracks related to bio resins see the scenario analysis:

- Molds
- 10m2 - Bio resin

CORE

The Team used recycled PET core for some components, which has a 56% lower global warming potential than virgin PET core. The boat builders and engineers found it good to work with, and used it for cradles, engine boxes and deck fairings.

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

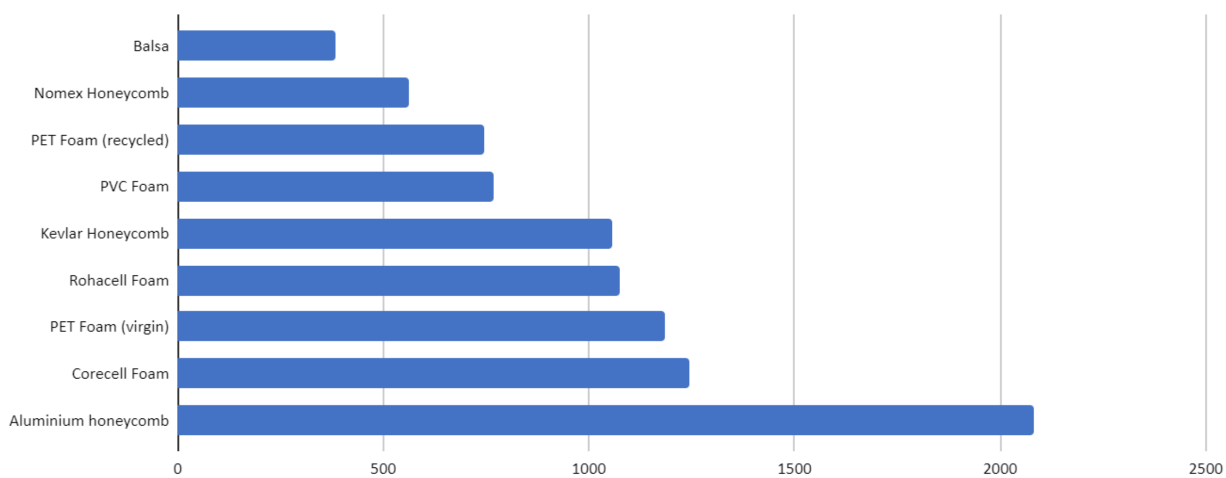


Figure: Comparing relative greenhouse gas impacts of different core materials, source Michel Marie Calculated with MarineShift360 beta software on October 14, 2021

RECYCLED MATERIALS

RECYCLED CARBON - IN

Changing from business as usual can be a complex and long-haul process, however, in some areas big gains can be made. Recycled carbon fiber (rCF) has just 5-20% of the greenhouse gas emissions of virgin carbon fiber and in many cases provides a valid alternative. Prominent examples include nonstructural parts and molds.

Through better recycling processes, the value of carbon fiber increases. This will enable the wider use of rCF in semi-structural and, in certain cases, structural components.

Example: See HiPerDif in the table below.

RECYCLING CARBON - OUT

Carbon fiber represents a significant proportion (30%) of the waste generated during a typical build. Early on, the Team conducted research to find out more about the different options for composite recycling that are available in Europe. The following table describes some of those processors, and the materials and methods they use.

Processor	**Location**	**Materials and Methods**
Apply Carbon (Procotex)	France	Dry cloth fiber ground into a milled material which can be used as an additive in adhesives, chopped granulates and cut carbon. In 2021 Procotex acquired ELG pyrolysis technology, and will set up a new facility in Auray, Brittany.
Alpha Recyclage	France	Composite waste is treated by vapor-thermolysis technology. Semi-finished products are then manufactured in small series from recycled fiber (e.g. granules, mats, yarns, braids, co-blends, knits).
V-Carbon	Switzerland	Recycling of end-of-life components and carbon fiber scraps.
ELG Carbon Fibre	UK / France	Pyrolysis (resin is burned off the fiber at high temperature). Processed into chopped strand mat (carbiso) that can be used as a high-quality additive.
Fairmat	France	Non-pyrolysis. Fibers are aligned by robotic technology.
Gen2Carbon	UK	Following a management buyout of ELG Carbon Fibre, Gen2Carbon was set up to deliver the next generation in carbon fiber recycling technologies, crucial to underpin the growth of the carbon fiber industry.
Light Black	UK	A sail recycling initiative to recycle carbon fiber in sails.

Design		
RYMYC	Italy	Focused on the removal of epoxy resins, binders, sizing and coating from carbon fiber composite waste. Have installed a textile plant of 500 t/year capacity suitable to transform the recycled carbon fiber into nonwoven mat, to be used again in the carbon fiber composite market. Especially useful for any parts/molds made at Persico who have an existing relationship.
Prodrive	UK	Prodrive Composites has developed a process for manufacturing recyclable composite components that can satisfy future end-of-life requirements without any compromise in the performance of the original parts. Called P2T (Primary to Tertiary).

As a result of the build, the Team has approximately five metric tons of carbon composite waste to process, including molds and broken parts. The Team is working in partnership with processors to assure the recycling of these components at their end of life. (See chapter: circularity)

ELG CARBON FIBER

The Team chose to use Carbiso's recycled chopped strand mat for a few applications. The ELG material is manufactured in a pyrolysis process, recovering fiber from waste composites in the automotive, marine and aerospace industries, to produce a recycled chopped strand mat product. In the knowledge that the recycled product is resin thirsty, the Team paired it with PowerRibs between layers to increase strength and to allow resin to flow through. As a result, the Team was able to achieve a 50:50 resin to fiber ratio.
Source: BComp

HiPerDif

HiPerDiF (high performance discontinuous fiber) technology, invented at the University of Bristol, produces highly aligned discontinuous fiber composites with the goal of addressing recycling challenges in the composite industry[13]. HiPerDif technology processes the recycled chopped strand fiber (from facilities such as ELG), using a water jet technology to align fibers and produce a prepreg tape with properties comparable to virgin fiber.

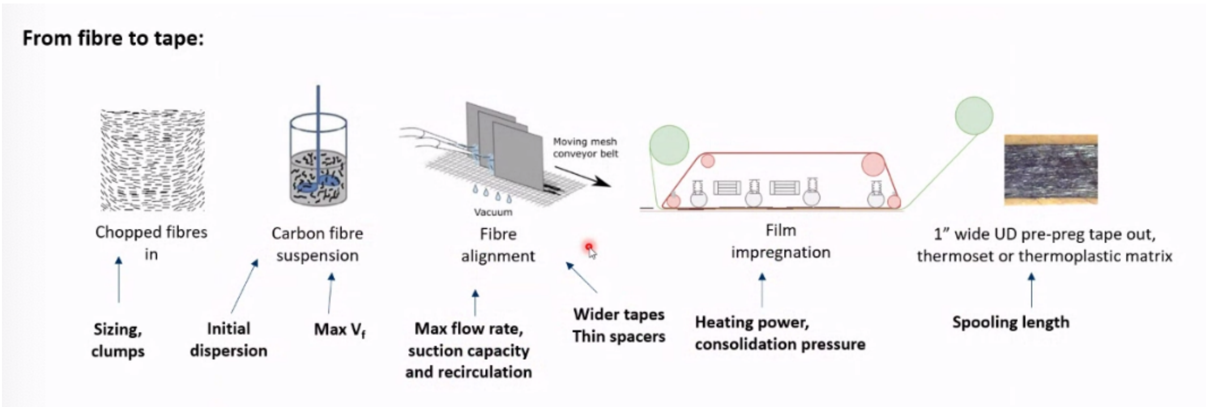


Figure: HiPerDif process.
Source: Lourens Blok, HiPerDif, RECOMP November 2020

HiPerDif is processing parts of the Team's broken foil, which will be returned in the form of carbon tape, for use onboard in future components.

RECOMMENDATIONS

rCF IN

- Defining rCF use as a required alternative to virgin carbon within IMOCA Class rules will create innovation and demand.

rCF OUT

One of the main barriers to recycling materials (especially carbon fiber) is knowing the exact material composition, without this data recyclers typically have to downgrade (downcycle) the output material.

- Maintaining 'material passports' using technology such as digital twin[14] is an important step to retaining both financial and performance value of recycled products. This would be best mandated by a Class policy for key high value components (such as foils and masts).

Beyond creating value for rCF is the need to centralize/coordinate the material flow.

- A central organization, or body would link manufacturers and teams, creating bulk of material at a scale that is relevant to regional/national recyclers.

Class rules

- Define maximum waste/minimum recycling standards.

[14] A digital twin is a virtual model designed to accurately reflect a physical object.

FLAX

Flax has a number of properties that make it a good choice for testing and building components.

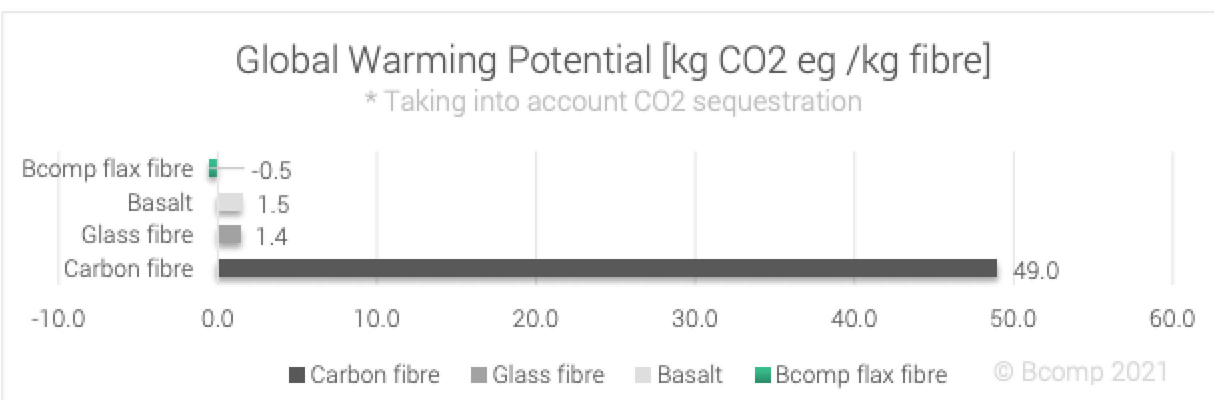
MATERIAL PROPERTIES

- Tubular structure with low density and high stiffness.
- Strong resistance to breakage when under tension or compression.
- Viscoelastic = strong ability to dampen vibrations.
- Very good mechanical properties among natural fibers.
- Intrinsic affinity with epoxy for a good fiber-matrix adhesion.

Source: BCOMP

ENVIRONMENTAL ADVANTAGES

- Flax is an indigenous plant which acts as a rotational crop and grows naturally in Europe. Europe produces 85% of the world's Flax, and much of this is in Normandy, France.
- The Team used ampliTex™ flax fibers which are CO_2 neutral over their life cycle, and the fibers themselves are biologically decomposable.



Source: BComp

PowerRibs

“The ‘biomimicry’ circular economy school of thought is an important one for the Team. In nature, there is neither waste that it cannot recycle, nor pollution that it does not know how to regulate.” Guillaume Masse, Station de la Marine, Concarneau.

In 2019, the Team engaged internal team members on how to apply biomimicry at the design stage, through an #OceanHour Session - an internal learning opportunity attended by the team. In collaboration with a cohort of Masters students from the French National Institute for Advanced Studies in Industrial Design, and the Marine Station in Concarneau, the group explored innovative bio-inspired solutions that reflected on all the possibilities of a future robust, fast, sustainable and bio-inspired racing yacht.

Building on this, the Team commissioned the testing of a leaf vein inspired bio-based material called PowerRibs, to better understand the mechanical properties, applications, and comparisons to standard boat build materials. This testing reviewed the properties from both an environmental and life cycle assessment perspective, as well as strength, stiffness deflection and fracture properties.

Key outcomes included the discovery that the use of PowerRibs increases the flexural strength and stiffness. The Team matched these properties with applications such as deck fairings, and engine boxes, with more detail found on these specific components in the next chapter - Built Components.

RIGGING

Standing and running rigging represents just 0.6% (3 metric tons C02e) of the total greenhouse gas emissions for the boat's design and build. Being primarily carbon or PBO[15] with titanium fittings, standing rigging represents 0.3% (1.4 tC02e) of the greenhouse gas emissions, with the remaining 0.3% (1.8 tC02e) being lines and ropes (running rigging).[16]

The Team's running rigging from Marlow Ropes Blue Ocean range includes:

- Bio-based[17] dyneema for all performance lines.
- Marlow/DSM's recycled-based dyneema.

Rigging Works provided the in-house services to the team, including specific attention to sustainable best practices:

- Rigging ordered and woven to spec at Marlow, ensuring minimum offcuts/waste.
- Optimized transport and packaging.
- Stockpiling used ropes and offcuts for recycling.

Jon Mitchell, Managing Director at Marlow Ropes: "We're proud to be one of the first manufacturers to integrate recycled-based Dyneema® within our products and demonstrate the material's feasibility. Our products are trialed and tested by professional offshore sailing teams including 11th Hour Racing Team, a proud partner of ours at Marlow, with whom we share a progressive approach to seeking sustainable solutions: no more business as usual."

Recommendations

- The calculation for running rigging was made using 'business-as-usual' coefficients for Dyneema. More up to date data is needed to include the bio-based and recycled-based numbers within the MarineShift360 in order to understand the impact reduction these material choices have had.
- Work needs to be continued on putting in place reverse cycle logistics in order to fully close the loop on these materials.

© Marlow Ropes

[15] Polybenzoxazole
[16] Calculated using MarineShift360 beta software, October 1, 2021
[17] Certified by ISCC, DSM bio-base, and recycled Dyneema is produced with bio-based ethylene and the mass balance approach. As stated by Marlow bio-base Dyneema emits 29 tC02 less per ton of HMPE produced.

OPTIONS NOT EXPLORED, OR NOT ACHIEVABLE IN THE TIMELINE

This report primarily focuses on the actual experiences, processes and materials used by the design and build team. The composite industry holds many existing and future solutions which will help the marine industry to transition to a sustainable future.

Topics that have potential but the Team did not explore or implement include:

- Testing and building confidence with bio resin to enable systematic use across the build.
- Innovation vacuum consumables for reduction of single use plastic.
- Light black design - sail recycling.
- Female only molds (no plug).
- rCF and alternative materials in molds.
- Thermoset and recyclable or thermoplastic resins.
- Bio-plastics and alternatives to single use plastic consumables.
- AltMat materials such as: bamboo, basalt, alternative to Nomex for honeycomb core.
- Automated robotic based systems.

MAKING IT HAPPEN

"The challenge is not supplying the recycled materials; the current barrier is lack of demand from the marine industry. Better policies and rules are needed to create the demand at scale." - **Yannick le Morvan, Gurit**

Using the Team's research to select and source alternative materials which fulfill the technical requirements of the various components of the boat build was the focus for the build team. Key early actions included:

- The commissioning hatches from flax, bio resin and eco-friendly core.
- Purchasing 50 linear meters of recycled, non-woven carbon fiber mat, for use within other components.
- Assigning one of the Team's inhouse boat builders to work with the alternative materials and build components for 11.2.
- Collaborating with the IMOCA Class on the definition of alternative materials within the Class rule.
- Advancing discussions around scaled recovery and reuse of recycled carbon by the marine industry.

RECOMMENDATIONS

Prepare an alternative material and process testing program as early as possible to validate, build confidence and ensure that alternatives are relevant to build timelines

TELLING THE STORY

‘THE MAKING OF’ SERIES

To help share the design and build story of the new IMOCA 60 with a wider audience the Team produced in-house a three part video series.

THE DESIGN STORY

Two years in the making and tens of thousands of hours spent on the design and build process resulted in a new era of IMOCA 60 race boats.

In Episode 1 of ‘The Making Of...' web series, Skipper Charlie Enright, naval architect Guillaume Verdier and Mer Concept project manager Armand de Jacquelot reflect on the unique challenge of designing and building an IMOCA 60 for fully crewed racing.

ART GOES OFFSHORE

'What's below the surface connects us all' is 11th Hour Racing Team's core message in its mission to drive positive change in the marine industry and beyond.

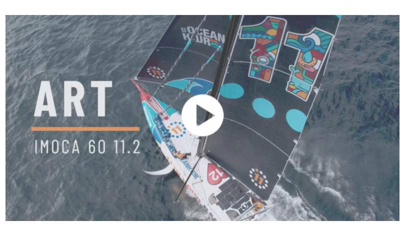
The colorful livery on 11.2's hull and sails are a visual translation of the Team’s mission, brought to life by a collaboration with Italian artist duo Van Orton Design and French yacht design specialist Jean-Baptiste Epron.

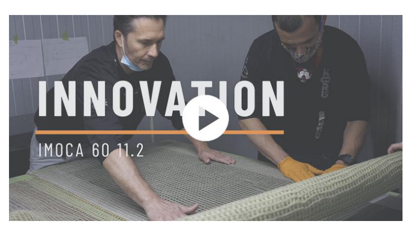
In part two of the three-part 'Making Of...' series, the creative heads involved shared their experience and inspirations in bringing this vision to a physical reality.

INNOVATION STORY

Intense energy and material usage on one side and an urgent need to drive change within the marine industry on the other - how did the Team tackle this complex issue when building the new boat?

In Episode 3 of the 'Making Of...' web series the key areas of innovative success and how the build of the new IMOCA 60 was pushing the boundaries to establish new benchmarks for the Class and the wider marine industry.





MARK CHISNELL ON '11.2'

Sailing specialist Mark Chisnell is a British novelist and non-fiction author.

The former professional sportsman took a deep-dive behind the scenes of the design and build of the Team's new IMOCA 60, with a three-part feature series, shedding light on:

1. The design challenge
2. The design solutions
3. The build story

BUILT COMPONENTS

HATCHES

In 2020 the Team commissioned the build of a test transom hatch, constructed from alternative materials with a lower carbon footprint than the 'business-as-usual' carbon composite approach. The intention was to investigate the feasibility that bio-based materials could provide the strength and weight qualities required from this component. The part underwent non-destructive testing with the same engineering parameters as a carbon composite part and satisfied the design and build team to the extent that five further hatches were commissioned for build in 2021. The materials used were flax fiber, a 35% biobased resin and a 100% recycled PET core.

Challenges *"The biggest challenge with the hatch builds was to develop a component from alternative materials within the same target weight of a carbon hatch withstanding the same load case. We approached it by several iterations of optimization covering the specific load case but also cases of daily use. This led to challenging laminate schedules and a more complex manufacturing route."*

Successes *"The biggest success was definitely to build the components with the given targets of business as usual in mind and to achieve such an immaculate finish. Also, the experience of working with a team at the pinnacle of high-performance offshore sailing was rewarding and a great chance to showcase the potential of the materials and technology we use."*

Legacy and scalability *"We definitely gained experience in optimizing the laminate schedule for a specific load case. The developed manufacturing route further improved the fiber volume ratio leading to stronger and lighter components, which will be used for future application in our serial production boats and components."*

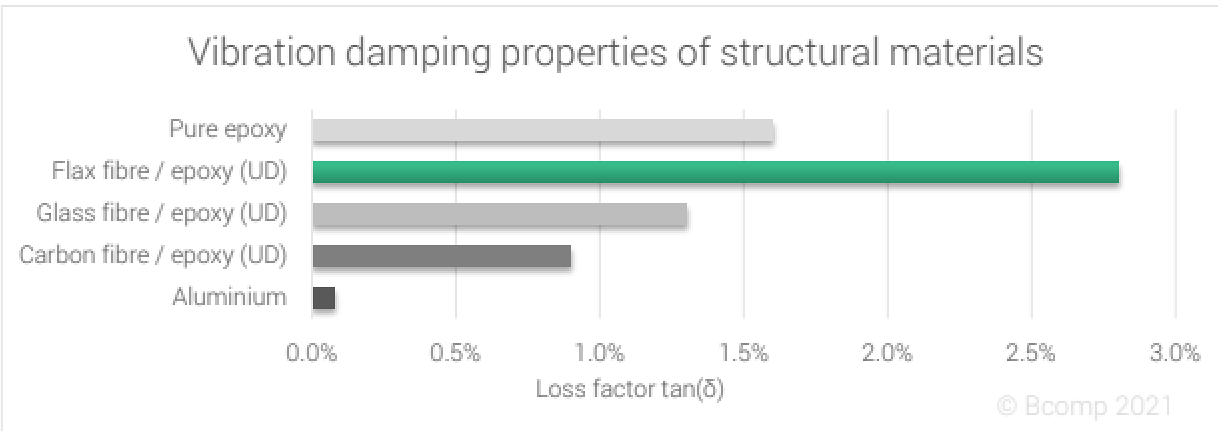
Hendrik Plate, *Head of Product Development, Greenboats*

© Greenboats

ENGINE AND BATTERY BOXES

"Engine and battery boxes were a good application for alternative materials such as flax because of their vibration and sound damping properties. We built a few parts with the normal flax which we found hard to wet out fully and the use of peel ply ensures a clean finish on the edges as powerRibs doesn't easily sand to a nice finish."

- ***Lucien Moore, Boatbuilder - 11th Hour Racing Team***



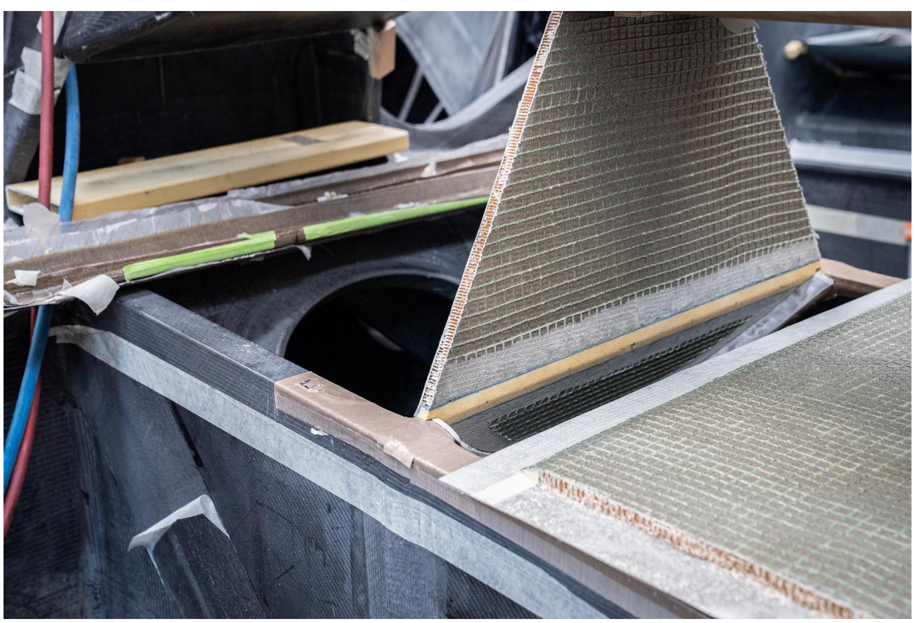


Image: The Biocomposite engine box being put together below deck. Credit: Amory Ross / 11th Hour Racing

CRADLES

The cradles were built onsite using a second-hand container which forms the base, aluminum structure for the frames and one of the splashes was made from recycled carbon, biobased resin, recycled PET core and powerRibs.

During the construction, the build team reported that the Carbiso recycled carbon fiber was better to handle than fiberglass mat, and easy to achieve thickness without needing to build up multiple layers. The first product test resulted in challenges with resin flowing evenly through the material, so the team tried a layer of PowerRibs between each layer of Carbiso, and a second test with every other layer.This resulted in the PowerRibs working successfully as a resin transfer medium during the infusion process. The core used was recycled PET which was quite porous, good to work with, but did require drilled holes to make sure resin went through. This process resulted in an approximate and satisfactory ratio of 50:50 fiber to resin, plus some resin wastage from the infusion process.

3 layers of Carbiso with PowerRibs in between Recycled PET Foam 2 layers of Carbiso with PowerRibs in between AMPRO Bio-based resin system

OBSERVATIONS

The PowerRibs showed some voids at each corner where they intersect. Using an autoclave process would improve that. One of the limitations with the powerRibs in this type of application, is that the ribs print through, so used on a molded surface, it would need a few layers of finishing carbon, or require post preparation (fairing and filling).

Image: Cradle in use on the launch day of 11.2.

Other observations from the yard include:

- There were improvements in technique and products as each part was built.
- The bio-based infusion resin system has a high exotherm spike and the part needed water cooling.
- Once prepped for secondary bonding, the Carbiso was still quite porous but still worked for bonding.
- Future rCF products for testing include Lineat recycled aligned fiber carbon tape with reduced fiber volume fraction and strength properties closer to virgin fiber.

PAD EYES

A small part on the boat, pad eyes were a good showcase of alternative materials, made by Carbon Instinct, from flax, biobased resin and using the Marlow bio-based dyneema.

©: Kristi Wilson / 11th Hour Racing

FORE DECK FAIRING

Similarly to the engine box and battery boxes, the foredeck fairing was built with flax, bio resin, recycled PET and powerRibs. The benefit of experience building previous components helped with this process, as the Team trialed the use of a thin strip of peel ply along the part edges underneath the powerRibs. This meant that they could be easily stripped back for secondary bonding, rather than needed to grind them down which can damage the skin.

Images: Biocomposite foredeck fairing painted in red © Ben Bireau / 11th Hour Racing

CIRCULARITY

The three key principles of the circular economy are:

- Designing out waste and pollution.
- Keep products and materials in use.
- Regenerate natural systems.

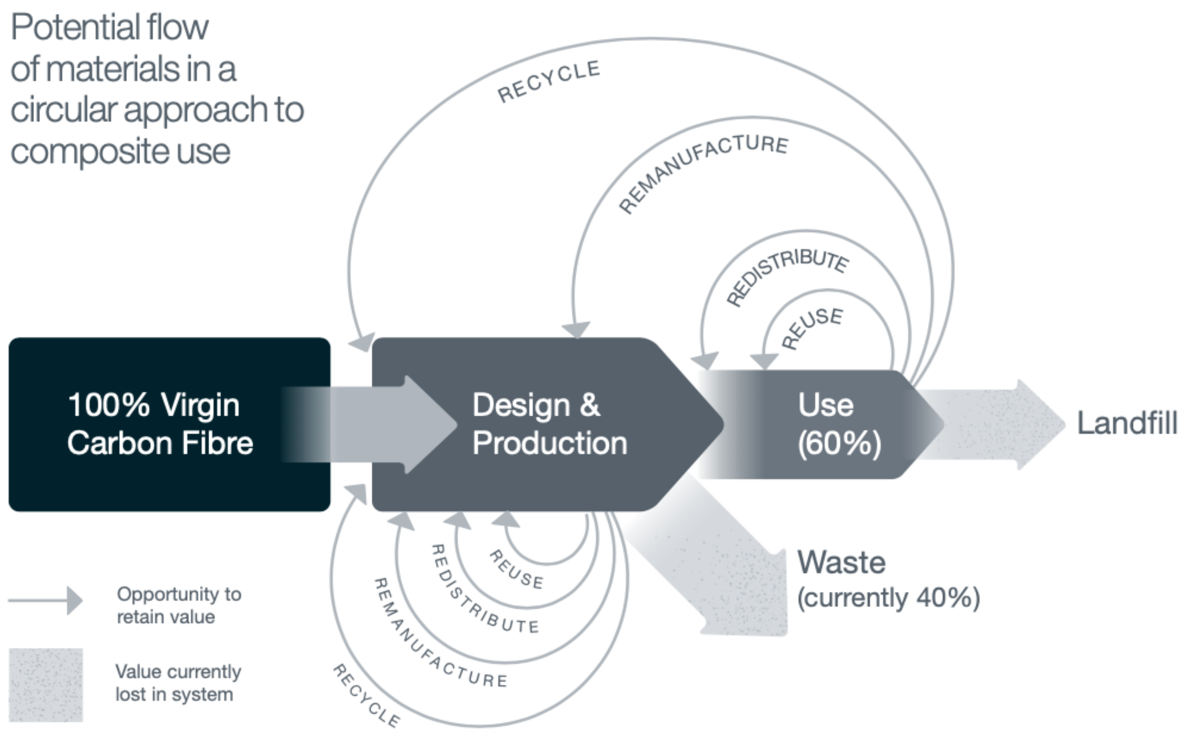


Figure: Circular economy approach for carbon fiber
Source: Dr Susie Tomson, Earth2Ocean

OBJECTIVES

Linear resource use, and the resulting externality - waste, is ubiquitous to the marine industry. By re-thinking the circularity of materials and components within the system, 'waste' becomes a resource.

The Team set a goal of 90% diversion from landfill across the project. Fundamental to this approach was understanding the waste and resource management system at the CDK Technologies yard, as well as engaging suppliers across the supply chain on the issues of design, packaging and end of life solutions.

This chapter details the materials and resource and waste breakdown across the design and build inventory and outlines several case studies, with lessons learned.

CIRCULYTICS

Circulytics is a measurement tool that enables the user to quantify circularity of material resources within a system. Using a set of indicators such as material use or recovery, the tool provides an indexed measurement where 0 is linear, and 1 is circular.

An important element when considering circularity are the elements of longevity and number of cycles or recycles.

Given the complexity of the resources inventory used for the build of 11.2, the Team did not run a full analysis, but this will be considered in the future. A detailed breakdown of resource recovery or waste by kilos and % weight can be found in the following section.

RESOURCE RECOVERY AND WASTE ANALYSIS

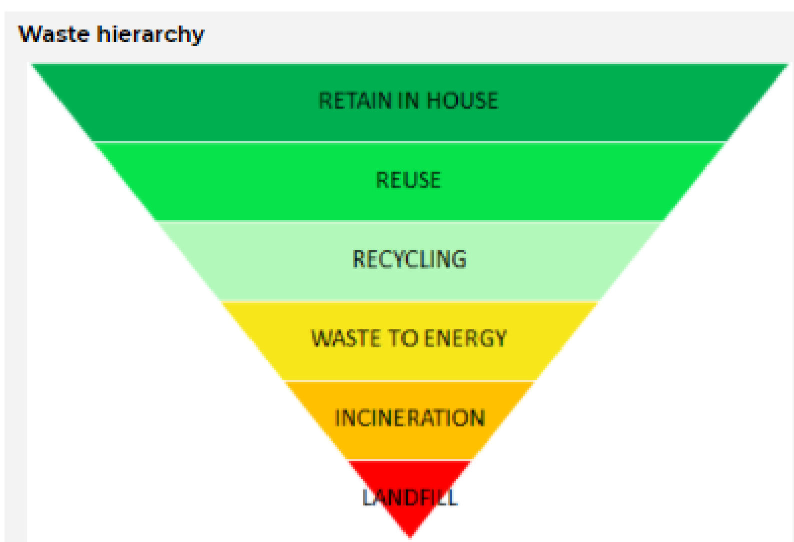
In parallel with the LCA study, the Team undertook a detailed resource recovery and waste assessment which compiled detailed waste measurements onsite during the various build processes. Where no specific data was provided by suppliers, assumptions were made for percentage waste during the LCA data input process.

The following analysis is based on the full system (boat launched and ready to sail).

A total of 34.5 metric tons of various materials were used to build the boat and components comprised of:

- Material resources, including plugs, molds, templates, offcuts and waste - 25.9 metric tons
- The end product IMOCA (11.2) – 8.6 metric tons

The team used the following resource management hierarchy with the objective of retaining materials and components for reuse in-house. Where reuse in-house or externally was not possible alternative solutions were explored, with a central standard to avoid landfill.



The detailed manufacturing resource recovery and waste analysis is summarized here.

Table: Manufacturing resource recovery/waste analysis – Material types to next use or destination

BREAKDOWN OF TOTAL MATERIAL/RESOURCE MANAGEMENT BOAT LAUNCHED READY TO SAIL							
Kg	Composites***	Plastics**	Consumables*	Wood	Metal	Electrical****	Total
Retain in house	94.00						94.00
Reuse	3258.00				4250.00		7508.00
Recycling	4899.00			42.00	2747.74		7688.74
Waste to energy	1112.25		4645.54	0.50			5758.29
Incineration							0.00
Landfill	2720.59	77.03	2087.83			10.89	4896.34
Total	12083.84	77.03	6733.37	42.50	6997.74	10.89	25945.36

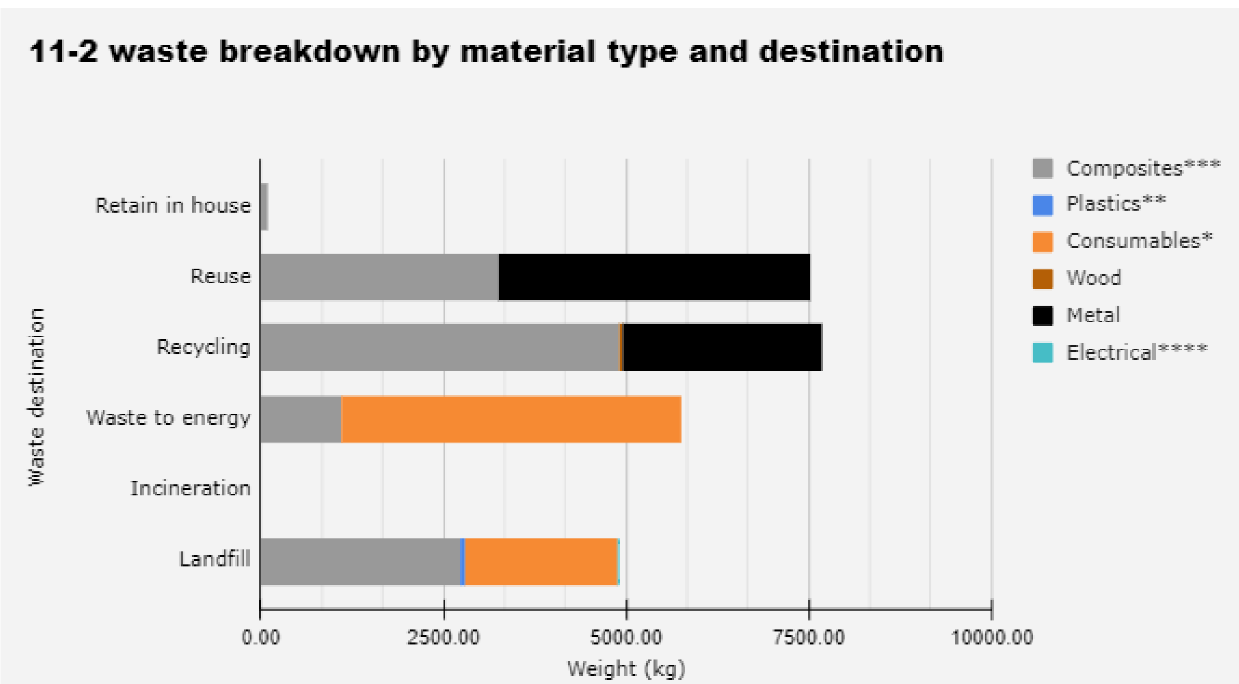


Figure: Manufacturing resource recovery/waste analysis – Material types to Next use/Destination

The total resource recovery and waste across the system was 25.9 metric tons, of which 7.6t (30%) was retained or reused; 7.6t (30%) was recycled; 5.7t (22%) went to generate energy; and 4.9t (19%) went to landfill.

A detailed review of the manufacturing inventory as it was structured for the life cycle assessment provides a better understanding of which components generated the most resources to recover and waste.

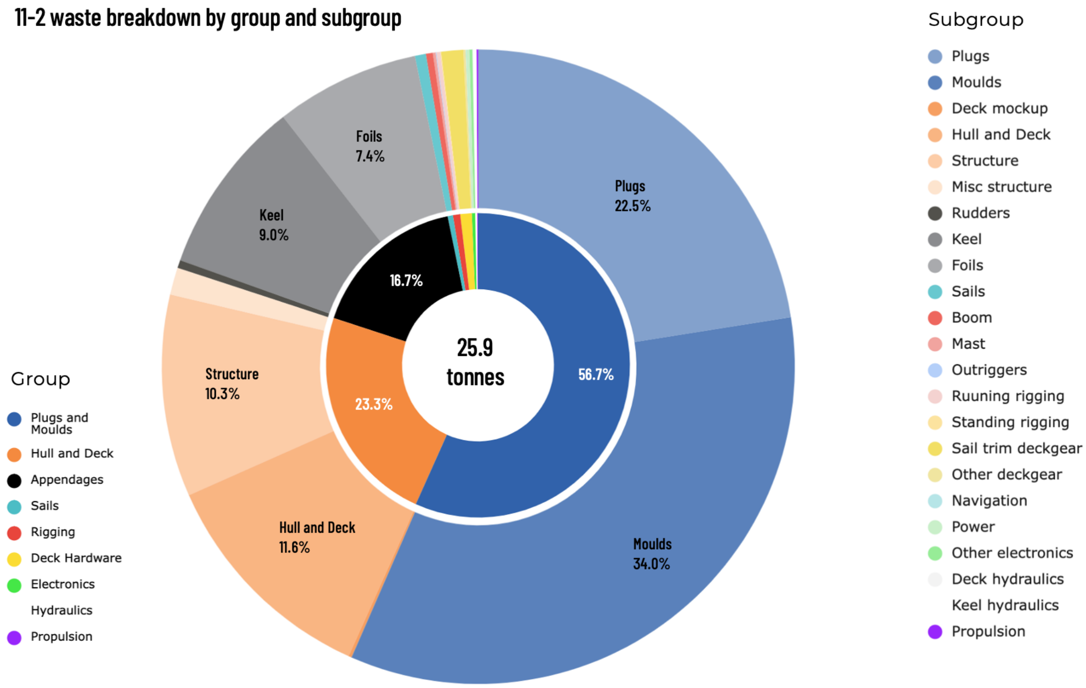


Figure: 11.2 waste breakdown by group and subgroup

The boatbuild's plugs, molds, hull and deck assembled represents a total of 80% of the resource, if we add the composite parts from appendages almost 87% of an IMOCA's material resource and waste relates to composite manufacturing. The remaining is divided between keel (9%), and everything else (3%).

Looking at composite material resource and waste, 57% of the total build footprint relates to construction and end of life of plug and molds. The male plugs resulted in 5.8 metric tons (t) of waste of which 3.3t of EPS foam was mechanically recycled by the supplier, while the remaining 2.5t was landfilled.

The male plug is certainly a topic for further exploration and optimization (see policy recommendations):

- Success: the recycling 3.3t of EPS foam, a non-typical practice
- Area of improvement: 2.5t of landfilled EPS foam waste represents more than half of the total 4.9t of landfill associated with the whole project, with the majority of the remaining 2.4t of landfill also applied by the same supplier to waste generated by the construction of the molds.
- Future consideration: plugs represent a significant percentage of a build's waste and GHG emissions; are they really necessary for future builds?

Table: Breakdown of waste by component groups and subgroups

GROUP	Kg WASTE	%
Plugs and Moulds	14714	56.7
Hull and Deck	6052	23.3
Appendages	4344	16.7
Sails	147	0.6
Rigging	201	0.8
Deck Hardware	320	1.2
Electronics	91	0.3
Hydraulics	54	0.2
Propulsion	23	0.1

Sub-Group	Kg WASTE	%
Plugs	5,839.00	22.5
Moulds	8,833.00	34.0
Deck mockup	42.00	0.2
Hull and Deck	3,021.50	11.6
Structure	2,670.00	10.3
Misc structure	361.00	1.4
Rudders	104.74	0.4
Keel	2,330.00	9.0
Foils	1,908.00	7.4
Sails	147.00	0.6
Boom	92.00	0.4
Mast	36.00	0.1
Outriggers	11.00	0.0
Running rigging	50.00	0.2
Standing rigging	11.00	0.0
Sail trim deckgear	292.00	1.1
Other deckgear	28.00	0.1
Navigation	7.00	0.0
Power	45.00	0.2
Other electronics	38.00	0.1
Deck hydraulics	8.00	0.0
Keel hydraulics	46.00	0.2
Propulsion	23.00	0.1

KEEPING PRODUCTS IN USE

Reuse, refurbish, repair are all core actions to keeping materials and products in use.

Be it reuse as a function of longevity, or repairability, all are reliant on the end of life being considered at the moment of design. From small to large impact reduction potential, a few key examples that the Team worked on are listed in the table below. In addition, the Team supported the Givebox initiative by consolidating a large inventory of unused products to be passed on to new owners

KEEPING MATERIALS IN USE

Reuse, recycling, downcycling materials again requires consideration for a component's material during design and manufacture, and it also often requires some sort of sectoral or cross sector collaboration to find and coordinate ways to reuse and the exchange of material and resources. Recycling carbon fiber was the primary focus for the Team and is outlined In the table below, and the chapter Alternative Materials.

DESIGN OUT WASTE

During the environmental audit at CDK Technologies, the Team discovered an already well-developed resource, material and waste management process in place. This resulted in zero waste sent to landfill from the actual boat yards.

Various case studies found in this report outline some of the other challenges and success, including:

- SCENARIO - PACKAGING
- SCENARIO - FOILS
- SCENARIO - MOLDS
- Key observations table below

KEY OBSERVATIONS FROM RESOURCE RECOVERY/WASTE MANAGEMENT			
EOL	Item	Kg	Plan
Retain in house	Bowsprit mold	94	Bowsprit mold is currently retained at CDK Technologies, for reuse or recycling
Reuse	Hull/Deck/Keel box molds	3278	Hull and deck molds were reused immediately by IMOCA team MC5, saving a total of 7,528 Kilos and 171t C02e.
	Molds, metallic structure	4250	
Recycling	EPS plugs	3367	EPS foam from male plugs was mechanically recycled by contractor.
	Foils offcuts	1550	11.2 foils were built using the 'out of plan' method which means no tooling was needed. However, 1.5 metric tons of composite waste was generated from this construction process, notably after the water jet cutting process. The type of waste is a cured CF/epoxy composite which will be recycled through partnership with Gen2 Carbon.
	Deck mock up	42	Built for deconstruction using PEFC certified wood, reused onsite, remainder recycled.
	Keel fin	2278	Recycled by contractor.
	Keel bulb	110	The manufacturer of the keel bulb reuses a 'generic' mold or cast, reused for each IMOCA contract. It is optimized to within +/- 10mm of the final shape, thereby generating significantly less lead metal waste which is then recycled by the manufacturer.
	Rig, electronics and hydraulics hardware	294	Hydraulic manufacturer data confirmed very low wastage due to optimized initial material use, reuse and recycle inhouse.
Waste to energy	CF prepreg offcuts	841	Uncured CF prepreg offcuts generated by CDK Technologies during the layout process were sent to energy recovery. Few recycling options exist in France for carbon fiber or epoxy prepreg. Since the build of 11.2, CDK Technologies has taken the lead to collaborate with a local company from the building sector for a reuse alternative. The rate of prepreg offcuts is estimated to be 30% of the total prepreg layup creating 700kg of waste for an IMOCA build. The potential environmental gain associated with the reuse scenario was evaluated using MarineShift360 and shows a saving of 1.7 tons of CO2.
	Prepreg backing	1210	During the build of 11.2, 1.2 metric tons of pre-preg PE plastic backing were generated (every square meter of prepreg cloth generates twice as backing plastic). Without a better solution, this plastic went to waste-energy. The Team has subsequently made contact with local specialist recyclers who can recycle this material with potential savings of 2.85 tC02e.
	Vacuum bags	2200	CDK Technologies systematically reuse vacuum consumables debulking bags, economising between 25% plastic.
	Tenting plastic – Painting process	350	120 linear meters of single use poly tenting used during the painting process.
Landfill	Plugs and molds CF/GF offcuts	4892	19% or 4.9t of all waste went to landfill, all of which was associated with the plug and mold manufacturing.
Total		25939	Total resource recovery/waste was 26 metric tons of mixed waste, 7.6t (30%) retained/Reused, 7.6t (30%) Recycled, 5.7t (19%) waste-energy, 4.9t (22%) to landfill.

RECOMMENDATIONS

- Design material end-of-life into the process and system from the start.
- Keep materials in the system for as long as possible.
- Create a demand for recycled materials ‘in & out’.
- Use waste to energy as a last resort.
- Strict zero waste to landfill policy.
- Areas for significant improvement include:
    - Prepreg backing to recycle.
    - Prepreg and other carbon offcuts to recycle.
    - Alternatives to general composite consumables: Peel ply, vacuum bags, transfer mediums.
    - Painting consumables, especially tenting plastic.

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ONBOARD RENEWABLES

OBJECTIVE

The objective was to make the onboard system as energy efficient as possible and surpass renewable targets set by The Ocean Race. The Team seeks to gain performance advantage with the installed renewable energy sources onboard through measurement incentives in the IMOCA rule and the need to carry less diesel onboard.

Onboard renewables	1. Understand and get clarification on race rules.
	2. Research and consider renewables options and feasibility.
	3. Make recommendations to achieve minimum 30% renewables on board.
	4. Implement plan.

ACTION

The primary renewable energy source onboard is from a custom solar array mounted on deck which in good weather conditions will meet the majority of the daily energy demands. A hydro generator will be used as a backup.

For safety reasons the boat will have a diesel engine installed as per Class rules. The Team worked hard to ensure this is as efficient as possible, further driving down our use of fossil fuels.

Instead of a conventional alternator charging system the boat is fitted with an electric motor generator which will improve charging efficiency from around 60% to over 90%. The work achieved in this space together with Diverse Performance Systems is intended to pave the way for the development of a suitable hybrid system which will further reduce dependence on fossil fuels while not compromising on safety.

OUTCOMES

The main innovation is the 48v main battery and the solar power coming in at the same and higher than typical voltage for improved efficiency. This is becoming more common in the IMOCA Class.

We are also monitoring and logging various sources of power input and output to feedback into design refinement in the future.

RECOMMENDATIONS

A significant factor holding back overall system efficiency is the Class mandated one design keel system being at 24v. If the keel system were allowed to run at 48v it would remove the need for step down converters and the resultant losses involved for one of the main consumers of power.

SCENARIO ANALYSIS

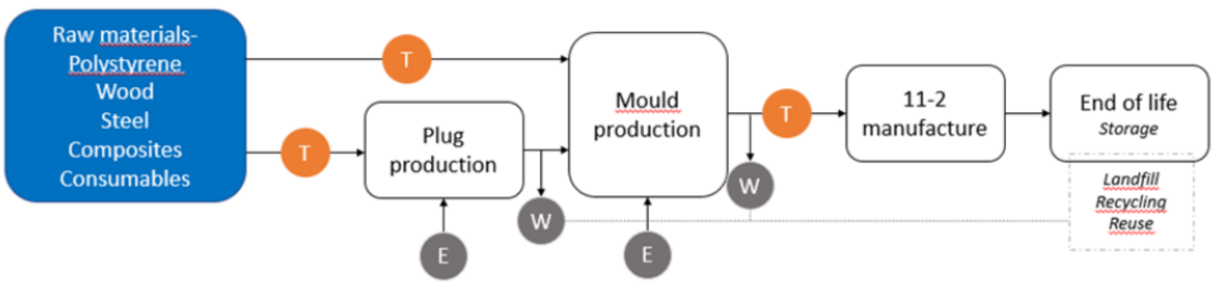
SCENARIO ANALYSIS - MOLDS

OBJECTIVES

The following study concerns the assessment of the environmental impacts of 11.2's hull and deck molds built in 2019 in Spain using the Life Cycle Assessment (LCA) approach.
The objectives of this study are:

- Evaluate the potential environmental impacts of an IMOCA hull and deck molds.
- Identify the improvement tracks and evaluate the potential environmental gains.

The scope of the assessment is outlined here:
Includes the raw materials, manufacture process and the transport of the plugs and molds, it does not include the manufacture and assembly of 11.2 which is compiled in the LCA-2 (11.2).



RESULTS

Global Warming	Mineral Resource Scarcity	Energy consumption	Water consumption	Marine Eutrophication
tC02e	kg Cue	MJ	m3	kg Ne
171	**1,050**	**4,200,000**	**2,440**	**79**

IMPROVEMENT TRACKS

Table: Hull and deck molds, impact reduction potential, compared to the full system (IMOCA launched and ready to sail - 553 tC02e)
Calculated with MarineShift360 beta software, June 2021

	FEASIBILITY	tC02e	Global Warming (%)	Mineral Resource Scarcity (%)	Energy consumption (%)	Water consumption (%)	Marine Eutrophication (%)
1. Reuse of steel structure at 50%	GOOD	-6.6	-1.2	-2.9	-0.4	-1	-0.2
2. Recycling of production waste (EPS,foams,CF/GF)	POSSIBLE	-2.2	-0.4	-0.1	-0.3	-0.5	-0.1
3. Integrate recycled carbon fibre	POSSIBLE	-23.8	-4.3	-0.3	-4.1	-2.6	-1.6
4. 100% Bioresin	GOOD	-2.7	-0.5	-0.1	-0.3	-0.5	0
5. Local supplier	GOOD	-5.6	-1	-0.1	-0.6	-0.1	0
6. No Plugs	POSSIBLE	-46	-8.3	-4.6	-6.3	-13.5	-13
All improvements tracks		-87	-15.7	-8.1	-12	-18.2	-14.9
Best improvement track Reuse of the molds	EASY	-171	-31	-10	-26	-32	-34

RECOMMENDATIONS

At 50% of an IMOCA as built, or 25% of the total impact of a boat launched and ready to sail, the Team identified the build and use of molds as an important area for improvement.

Removing male plugs from the build process would reduce waste by 3 tons and greenhouse gas emissions by 46tC02e (8% of the total greenhouse gas emissions).

Alternative materials: certain sectors of the composite industry are already using recycled carbon fiber and/or flax as an alternative to virgin carbon fiber in molds.

Reusing molds is one of the most significant ways to reduce impacts. The actual mold for 11.2 was already being used by another IMOCA team, before 11.2 had even left the build shed. By reusing the Team's mold, this new team removed 171 tC02e from their build footprint

Prioritizing local suppliers: The impacts of transporting the molds from Spain to the build site in France are discussed in SCENARIO - TRANSPORT.

SCENARIO ANALYSIS - PACKAGING RETURN

SUMMARY

Showcasing that incorporating sustainability actions makes good business sense, a key manufacturing efficiency initiative from the Team's boat builders, CDK Technologies, was the collection and bulk return of carbon fiber product packaging to the supplier for reuse.

When taking into account the cost and impacts of packaging and transport, the reverse logistics of returning product packaging to the supplier for reuse resulted in:

- The approximate reduction of 1 metric tCO2e per year
- Annual financial savings on new packaging and waste management of between €4,000-€4,500.

OBJECTIVES

The aim of the following study is to estimate the carbon footprint of the reuse of prepreg cardboards which consists in sending back the cardboards to CDK Technologies' main prepreg supplier Gurit, located in Spain, in order to reuse them for the next shipments.

Two different scenarios on transport options were chosen and their associated carbon emissions were calculated according to the ADEME greenhouse gas transport calculation method*.

- **Scenario 1:** Reuse of prepreg cardboards with shipment by van type vehicle (1t payload, diesel, 12l/100km average consumption) of which CDK Technologies would be the sole beneficiary.
- **Scenario 2:** Reuse of prepreg cardboards with shipment by lorry type vehicle (18t payload, diesel, 35l/100km average consumption) concerning several beneficiaries.

Functional unit: comparison of the carbon footprint on the lifecycle of a ton of cardboard in relation to the end-of-life scenarios.

Assumptions:

- Road transport of a ton of cardboard over a distance of 1,500km.
- Transport between cardboard's supplier to Gurit and Gurit to CDK Technologies first shipment is excluded.

OUTCOMES

- Transport related emissions: (Calculated using MarineShift360 beta software, October 2021)
  - Scenario 1 GHG = 550kg CO_2e
  - Scenario 2 GHG = 90kg CO_2e
- Avoided emissions: (source Ademe)
  - Cardboard production related emissions = 1,064kg CO_2e/t
  - Cardboard mechanical recycling emissions = 33kg CO_2e/t

Total emissions = Transport related emissions – avoided emissions

Scenario 1 GHG_{Total} = - 547kg CO_2e/t
Scenario 2 GHG_{Total} = -1000kg CO_2e/t

Conclusions:
In both scenarios the carbon emission reductions are significant, a function of the reuse of cardboard providing CO_2 storage. Ongoing benefits can be realized for each subsequent cycle of reuse and shipment by avoiding the production of new cardboard.

Cost:
Positive financial economies were achieved and anecdotally from Gurit, the cost of the prepreg packaging for a 12 month period of sales to CDK Technologies is €7,314 (including 25% scrap). Taking into account the transportation cost to Spain (€3000) and the avoided waste management cost (€100), the total savings are approximately €4,000-€4,500.

RECOMMENDATIONS

Engaging suppliers on the topic of transportation, packaging, waste and products' end of life may introduce financial savings for suppliers and end-consumers.

SCENARIO ANALYSIS - TRANSPORT

OBJECTIVES

The main objective of the full scenario analysis - Transport, which is summarized here is to identify and quantify the largest greenhouse gas impact linked to international transport stages in order to evaluate the potential environmental gain of using local suppliers.

The differences of greenhouse gas impacts between transport types are very significant, with airfreight being almost 10 times more than road, and 100 times more than sea or rail.

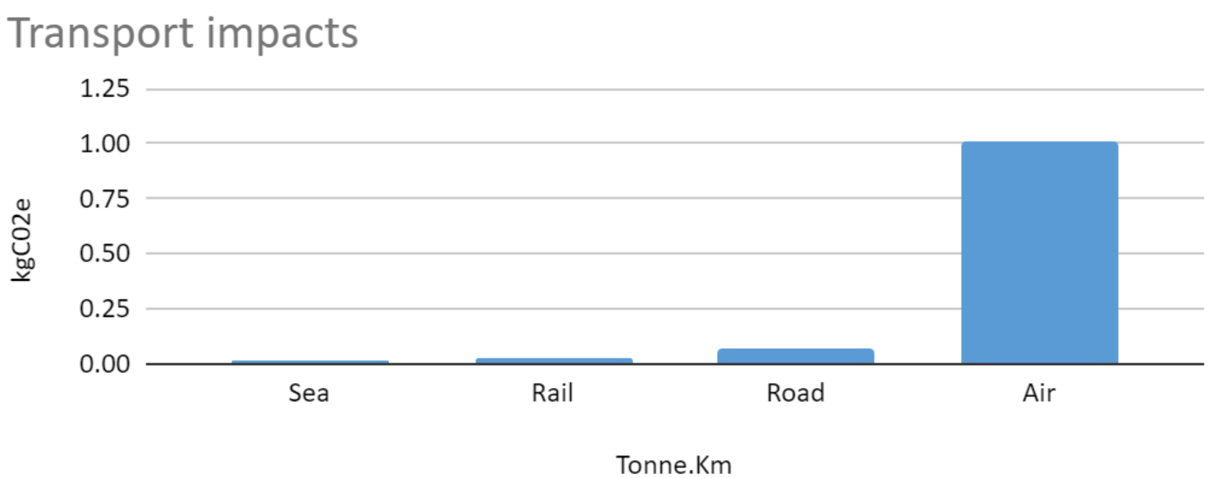


Figure: Source greenhouse gas protocol, greenhouse gas emissions by Tonne.km

OUTCOMES

Although the contribution of the transport stage of all materials is less than 2% (9t C02e) of the total C02e emissions of the full design and build (553 tC02e), some notable parts of the boat were built in other countries resulting in airfreight or long road distances:

- The hull and deck molds : from Spain to Lorient, France.
- One boom: from Auckland, New Zealand to Lorient, France.

Table: Assessing the greenhouse gas impacts of international freight choices, Calculated using greenhouse gas protocol, 2021

INTERNATIONAL FREIGHT	Quantity	Mode	km	Weight	Factor	Factor	kgC02e	% Total GHG (553 tC02e)
Boom	1	Air	18500	0.13	ton.km	1.01	2,429	0.44%
Hull and deck molds	3	Road	1500	8	Truck.km	1	4,500	0.81%
Total							6,929	1.25%

The transport of the hull and deck molds represents a major part of transport greenhouse gas emissions (4.5tC02e). This can be explained by the weight and dimension of the final parts which directly influences the greenhouse gas emissions.

The boom air freight from New Zealand, represents a significant distance by airfreight, and almost 2.4tC02e.

RECOMMENDATIONS

- A total of 7 tC02e can be saved by using closer supply chain solutions and builders from the same country of construction site.
- Where long distance transport is required forward planning enables the use of lower impact transport methods such as sea freight which has a 100 times lower impact than airfreight

SCENARIO ANALYSIS - METAL

OBJECTIVES

- Understand the impact of different metal materials.
- Review where the high impact metal materials are located in the build.
- Quantify any reductions that can be made by switching to lower impact metals.
- Highlight the importance of material selection and processes and assumptions in LCA building.

ACTION

The full ***Scenario analysis - metal***l is summarized here.
The Team calculated the impact per 100kg of each metal material type used in the boat build. Initial observations show that titanium alloy is around 10 times the impact of stainless steel.

To take into account the different performance factors of these metals the Team asked one of its suppliers for a generic comparison of performance adjusted for weight.

Based on this feedback the Team calculated a performance factor compared to titanium for each material: kg alternative material/kg titanium = Performance factor. Then applied this performance factor to greenhouse gas emissions.

Table: Comparing greenhouse gas emission impacts of different metals (adjusted for weight and structural performance), calculated with MarineShift360 beta software on October 1, 2021

Material	kgC02e Replacing all titanium kg - kg assessed during LCA 11.2	Perf. factor	kgC02e - Replacing all titanium	kgC02e Delta - vs Titanium
			Performance corrected	
Titanium	26,521	1	26,521	-
Aluminium	20,293	1.5	30,439	+ 3,918
Stainless steel	14,507	1.57	22,776	- 3,744

RECOMMENDATIONS

At 3.7 tC02e, the potential reduction is only 0.7% across the full system (IMOCA launched and ready to sail). Some of this benefit quantified above may be lost by the partial use of aluminium as a replacement (a metal with comparable greenhouse gas emissions to titanium).

Closer investigation into applying more precise mechanical properties adjustments for weight and material grades may validate removing titanium from use within the IMOCA Class.

SCENARIO ANALYSIS - FOILS

Between 2019-2021, 11th Hour Racing Team purchased new foils for the development and optimization of 11.1 as well as a set (two foils) for11.2.

OBJECTIVES

To understand the greenhouse gas emissions and waste impacts of two different foil construction methods used by two separate suppliers which represent the key methods currently used:

- Without mold
- In mold

The full Scenario Analysis - Foils is summarized here.

OUTCOMES

Comparing both foils methods we note that using both waste and greenhouse gas emissions' environmental indicators, the larger impacts are associated with foils made in molds.

Table: Comparing greenhouse gas emissions and waste impacts of foil construction methods adjusted for weight
Calculated with MarineShift360 beta software on October 1, 2021

Set of foils (600 kilos)	Without mold	From mold
GHG impact (kgco2e)	90	96
Percentage waste	371%	524%

RECOMMENDATIONS

The integration of foils in the IMOCA Class has transformed performance in certain conditions, however at **+/- 100t C02e** a set of foils represent almost **20%** of the total greenhouse gas emissions of the design and build.

The Team undertook one relatively simple study. Further investigation is needed for validation of results, ideally by comparing two identical sets of foils using the two different methods.

The Team recommends comparing a third construction method using 3D printed spars is undertaken to understand the relevant greenhouse gas and waste implications.

It is important to highlight the opportunities for improvement that come with types of composite construction, as it relates to consumables, energy sources, waste management processes and materials sourcing.

SCENARIO ANALYSIS - DESIGN CHOICES VERSUS IMPACT

OBJECTIVES

Completing a life cycle assessment of an IMOCA 60 built in 2020 confirmed that more than 80% of greenhouse gas emissions are associated with the use of composite materials. The full scenario analysis - 10m2 which is summarized here, uses various scenarios to analyse business as usual versus alternatives (actual and hypothetical) to better understand the potential of the following improvement paths:

- Replacing kg for kg carbon fiber with recycled carbon fiber (rCF) or flax in non-structural components e.g. 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

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 60 and/or its component.

The scenarios used were:

- Prepreg carbon cloth weights : 150 gsm vs 300 gsm.
- Substitute epoxy resin with bio epoxy resin.
- Infusion versus prepreg versus hand layup.
- Comparing weight for weight impacts of fiber : carbon fiber versus flax versus recycled carbon fiber.

SCENARIO: 150 vs 300gsm

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

Table: Comparison 150 versus 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
Backing plastic (kg)	20.64	10.32
GHG (kgC02e)	1295	1249
Prepreg cure	12h at 95°C	

Observations:

The key aspects that were impacted by the use of different cloth weights were:

- Number of layers of cloth doubles.
- Total cloth area doubles.
- Backing plastic doubles.
- Labor and 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 VERSUS 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, 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 greenhouse gas 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 VERSUS INFUSION VERSUS HAND LAYUP

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

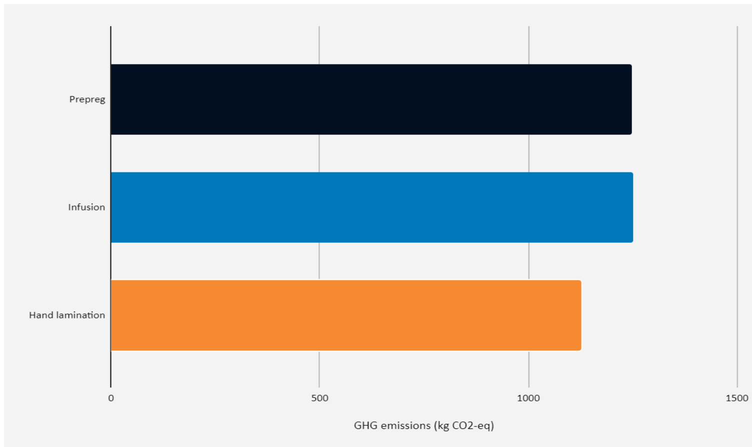


Figure: Comparative greenhouse gas emissions of prepreg, infusion and hand lamination, calculated with MarineShift360 beta software on October 1, 2021

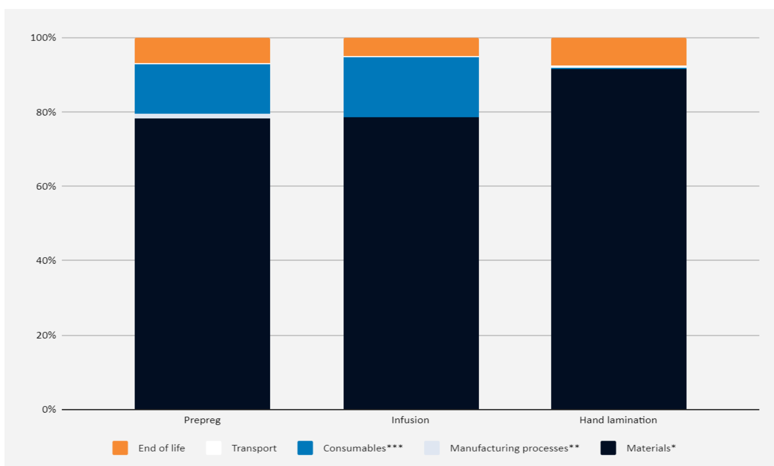


Figure: Breakdown of source of greenhouse gas emissions from prepreg, infusion and hand lamination processes, calculated with MarineShift360 beta software on October 1, 2021

Observations

Both the prepreg and infusion processes show a similar or higher impact, 1,250kg versus 1,130kgCO2-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. It also encourages forward-thinking about the use of consumables with less impacts (biosourced plastics) or then in smaller quantities (e.g. powerRibs). The curing process of the prepreg only contributes to 1.2% of the greenhouse gas emissions.

SCENARIO: VIRGIN CARBON FIBER VERSUS 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.

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

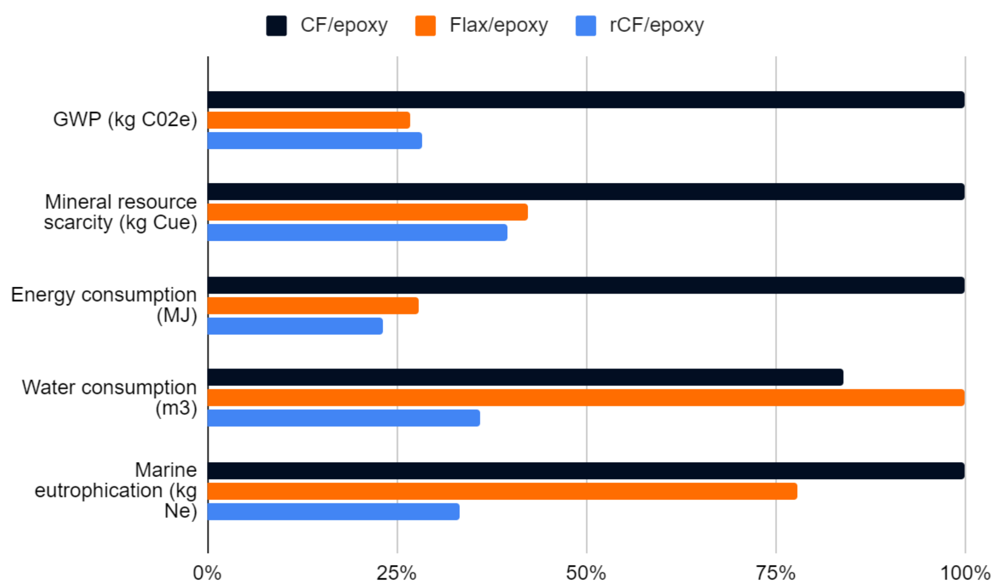


Figure: Environmental impacts of three different fibers used to build 10m2 composite

Observations :

The significantly greater environmental impacts of virgin carbon fiber compared to recycled carbon fiber 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.

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 less when manufacturing larger components and 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.

Assessment of materials without the context of the manufacturing process and the structural requirements of final components is very limited, and at best is just a guide for defining more targeted life cycle assessments. Further component specific work is needed.

FINAL RESULTS

Throughout this report the Team followed the three year process to prepare for and implement the design and build of a competitive IMOCA capable of winning The Ocean Race. The Team has described the challenges this represents, outlined the actions undertaken by the design and build group, and explored the resultant impacts associated with the process.

To follow is The Team's key observations and learnings.

2010 KAIROS REPORT COMPARISONS

The Team used the Kairos 2010 report as a benchmark to indicate key initial research topics, and a reference for potential improvements for the actual build process.

In comparing results between the two reports, it is worth noting the similarities and limitations to such a comparison.

Teams
Both reports focus on the build of an IMOCA for a round the world race, over a similar time period, but the Kairos report included the use phase associated with the operations of the team participating in the Vendée Globe, a three year project. Comparisons have taken this into account by extracting the use phase.

Molds
Both reports took into account the hull and deck molds, and the fact that both teams passed the molds onto another team to be used again. However, the method of allocating the mold's impact was approached differently by each team:

- Kairos split the impact of the molds, allocating only 50% of the impact to life cycle analysis total (300 tC02e).
- 11th Hour Racing Team allocated 100% of the impact of the molds (171 tC02e), to the total calculation of greenhouse gas emissions (**553 tC02e**[18]) and passed the mold on to the next team as zero impact[19].

By adding 12.5% (40 metric tons) to include the remaining 50% of the mold, an adjusted assessment for the Kairos IMOCA built in 2010 is estimated to be **343 tC02e.**

Database
While only 11th Hour racing used the MarineShift360 software, the data used by both studies were sourced from the Ecoinvent database, ten years apart. Certain factors will have changed because of better data or impact assessment methods to process the data. Without a more detailed comparison of these changes, or re-calculation of one of the studies, the Team has assumes an error factor of +/- 10%

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[18] Calculated using MarineShift360 beta software, October 1, 2021.
[19] This is in line with life cycle assessment allocation where the initial owner/manufacturer is 100% responsible for impacts, and reuse has a 0% footprint.

Electricity
One factor that has changed over time is that greenhouse gas emissions associated with electricity have significantly reduced. Using the UK as an example, it represents a 50% reduction per kWh.

- 2010: 0.496 kgC02e/kWh
- 2021: 0.212 kgC02e/kWh

As energy is used in transforming raw materials, throughout the supply chain and in the design and build process, impacts in 2021 are lower than in 2010.

Inventory
In comparing both studies inventory is the most significant difference. Construction processes, materials, and components have changed over the ten year period.

IMOCA boats in 2021 have replaced relatively simple daggerboards for complex foils, with the foils today represent +/- 100 tC02e (20% total).

The overall design and build process has created more complicated deck, hull, mold, and components; this has had an impact on material choices, energy used, and build time which has more than doubled:

2010: 20,000-man hours
2021: 40-45,000-man hours.

It is in these last points that the Team has found the main reasons for such an increase in greenhouse gas emissions for an IMOCA build, and one of the key reasons for doing the comparison in the first place.

Summary
The limitations of comparing the two different reports and systems does not devalue the importance of this opportunity - to have two LCA studies from similar teams ten years apart. Conclusions made with care to context can therefore provide valuable information.

Regarding the relevance of the Kairos 2010 report, not only are their recommendations and improvement tracks still useful today, but maybe most importantly that the Kairos 2010 report establishes the first benchmark for the IMOCA Class net zero targets, which are analyzed in the next chapter.

IMPROVEMENTS

The Kairos report identified a core list of well researched improvements that combined would provide **20% reduction** in greenhouse gas emissions over the period of a Vendée Globe campaign over three years. The report also provided a long term assessment beyond three years suggesting a potential **long-term reduction of 40%** greenhouse gas emissions. We have seen that while some of these recommendations have indeed been implemented by IMOCA Class and teams the net result is still a doubling of greenhouse gas emissions from 2010 to 2021.

Having now completed the design and build of 11.2, we combined our own learnings and recommendations with the major improvement tracks from the Kairos report to offer an updated version.

These comprise:

- A comprehensive list of including both quantitative and qualitative recommendation in the list over the following pages
- A shortlist of Improvement tracks that can be quantified as reductions using tC02e or metric tons waste, described in the following graph
- A table describing four different scenarios for Future builds and the IMOCA Class
- The Pathway to Net Zero

It is important to note that while one may tend to be drawn to focus on the measurable reductions described in the graph, many are reliant on the more often important and priority recommendations that are more qualitative in nature. An example would be the importance of establishing sustainable policy and Class rules, on which more measurable actions would rely.

QUANTITATIVE IMPROVEMENT TRACKS

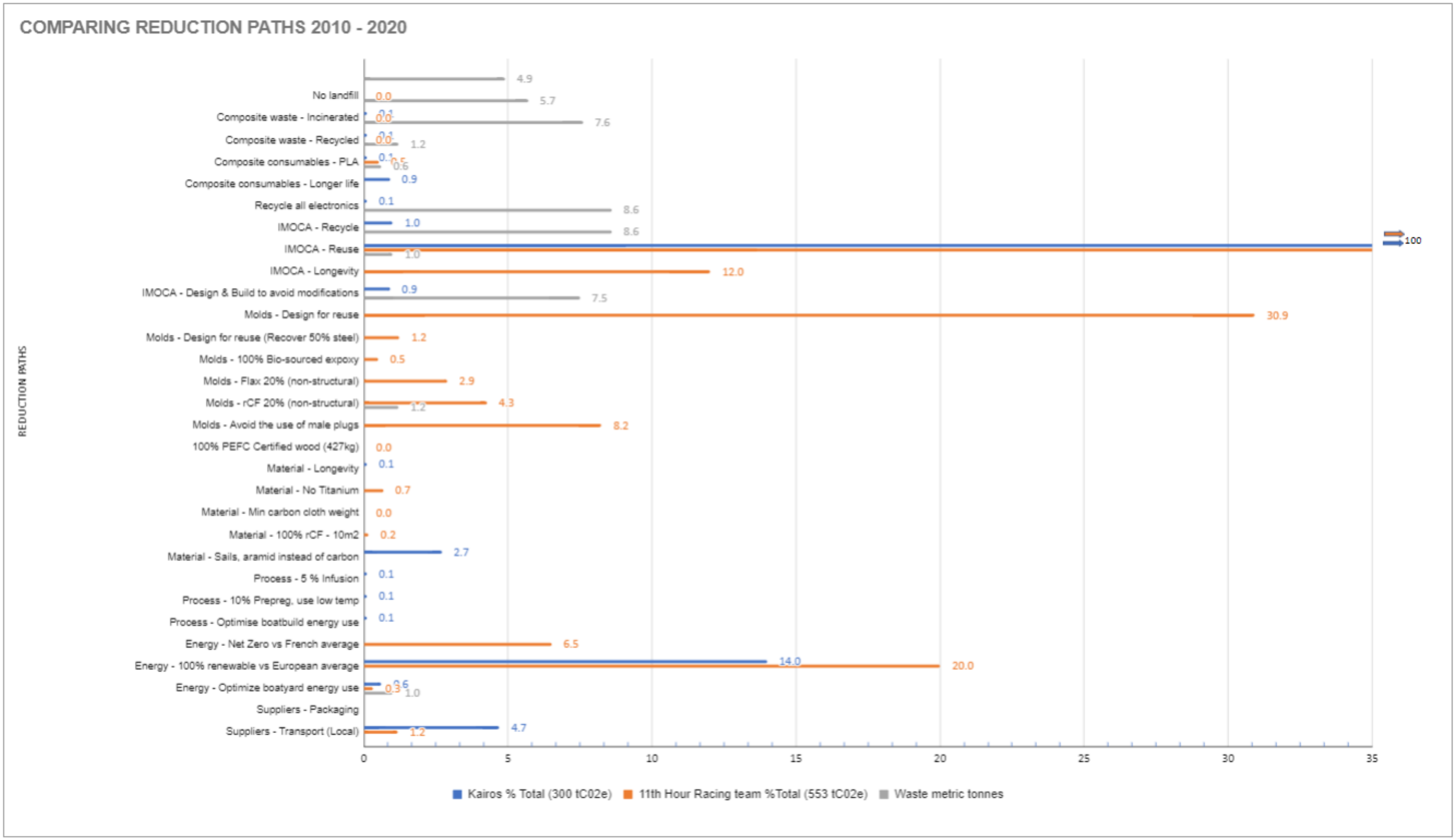


Figure: Comparing improvement tracks 2010 - 2021
[Download 'Worksheet - Improvement path' to zoom]

Table: Comparing future improvement tracks, calculated using the MarineShift360 beta software October, 2021

FUTURE BUILD AND IMOCA CLASS CHOICES AND NET ZERO TARGETS	FEASIBILTY	DESCRIPTION
	EASY	No barriers
	GOOD	Requires basic planning
	POSSIBLE	Technically possible, certain barriers to be overcome

IMPROVEMENT TRACKS		FEASIBILITY	REDUCTION tC02E	NEW BUILD	NEW BUILD SECONDHAND MOLD	SECONDHAND BOAT ONLY	IMOCA RULES
TEAMS	100% local suppliers, no international transport or airfreight	EASY	7	☑	☑	☐	☐
	Reuse of the moulds (Once)	EASY	171	☐	☑	☐	☐
	Reuse of boat	EASY	553	☐	☐	☑	☐
SUPPLIERS	Reduce packing through reverse logistics	GOOD	1	☑	☑	☐	☐
	Improve insulation of main build facility	GOOD	1.8	☐	☑	☐	☐
	Net zero energy supplier (Boatyard only)	GOOD	36	☑	☑	☐	☐
IMOCA	Define minimum cloth weight (300 gsqm)	GOOD	0.046	☐	☐	☐	☑
	Prohibit plugs (Female mold only)	GOOD	45.6	☐	☐	☐	☑
	Replace all titanium with stainless steel	GOOD	3.7	☐	☐	☐	☑
ALL	Molds - Integrate rCF (+/- 20%)	POSSIBLE	23.6	☑	☐	☐	☑
	Molds - Integrate Flax (+/-20%)	POSSIBLE	16	☐	☐	☐	☐
	Molds - Substitute all epoxy resin by bioresin	GOOD	2.7	☑	☐	☐	☑
	Use only PEFC certified wood	EASY	0.1	☑	☐	☐	☑
	Built for reuse and longevity (steel structure of moulds	GOOD	6.8	☑	☐	☐	☑
	Collect and mutualise the PE prepreg backing for recycling	EASY	2.9	☑	☑	☐	☑
	Design & Build for four RTW races	GOOD	66.5	☐	☐	☐	☑
TOTAL: Calculated with MarineShift360 beta software on October 1, 2021			tC02e	**80**	**219**	**553**	**152**
			% TOTAL BUILD	**14%**	**40%**	**100%**	**27%**

RECOMMENDATIONS

These are the recommendations highlighted by the Team throughout this report:

1. Benchmarks & Standards
    a. Aligning with existing regulations, rules and guidelines allows stakeholders to showcase best practice and push for bold new steps and the policies to support them.
    b. By taking a proactive stance, the marine industry can provide direction and stay ahead of new policy requirements.
    c. Looking to other industry sectors for examples of legislative approaches to innovation and progress will aid and expedite progress.

2. Planning & Coordination
    a. Establishing a working group at the earliest stage ensures that the existing resources and time frame is used to best effect.
    b. Placing sustainability clearly on the agenda up front ensures that stakeholders assign the relevant importance and resources, and prioritizes them accordingly.
    c. Defining a set of sustainability objectives provides a common goal, and a new way of looking at success, and a source of motivation beyond business as usual.

3. Supply Chain
    a. As a client/consumer the single most important influence one can have is to apply sustainable sourcing to the supply chain, create a protocol for engaging your suppliers and partners
    b. Build the sustainable sourcing process into your organization's procurement and accounting system
    c. Each conversation is unique, and solutions to challenges you might have will certainly exist within other organizations
    d. Consider how one can work with motivated suppliers to explore deeper into their own supply chain, the ultimate goal would be to have clarity from raw material to end product

4. Environmental audit
    a. Integrating sustainability with contractual agreements, and reporting systems, highlights opportunities for value added rather than onerous obligations.
    b. Accept that challenges and barriers exist; these are the opportunities to create real change.
    c. Every process requires energy, this is a starting point for sustainable manufacturing. Requesting that your builders and suppliers switch to a 100% renewable energy tariff is potentially a big win up front.
    d. Consider how responsibility for environmental impacts is assigned, examples might include:
        i. Material management systems.
        ii. Extended manufacturer responsibility.
        iii. Waste management.
        iv. Life cycle assessment.

    e. Infrastructure and system improvements not only provide direct impact reductions for your contractor and project, but can be considered:
        i. Through the lens of insetting[20].
        ii. As a net positive legacy to benefit others.

5. Energy
    a. Make renewable energy a key point of discussion across your supply chain, and sourcing contracts.
    b. Ensure manufacturing energy needs are sourced from 100% renewable energy tariffs

6. Digital
    a. Use green web design and hosting services.
    b. Source digital services that are powered by renewable energy tariffs which can provide significant impact reductions (In certain cases a factor of ten or more).
    c. Use data compression where possible, which reduces the amount of online and stored data.
    d. Minimize email content and quantity, and cleaning out inboxes.
    e. Turning off cameras during video conferencing, which can reduce impacts by 96%.
    f. Reduce in-person meetings. One study suggests a conference call might produce just 7% of the impact of an in-person meeting. The same study indicated that this is still the case even for car rides for distances less than 20km.
    g. Select carefully replacement hardware, using sustainable sourcing standards.

7. Carbon Fiber

    rCF IN
    a. Defining rCF use as a required alternative to virgin carbon within Class rules will create innovation and demand

    rCF OUT
    b. Maintaining 'material passports' using technology such as Digital twin is an important step to retaining both financial and performance value of recycled products. This would be best mandated by a Class policy for key high value components (such as foils and masts)
    c. Beyond creating value for rCF is the need to centralize/coordinate the material flow, a central organization, or body would link manufacturers and teams, creating bulk of material at a scale that is relevant to regional/national recyclers.

    Class rules
    d. Define maximum waste/ minimum recycling standards

    Virgin Carbon fiber
    e. The increase of GHG emissions in higher carbon fiber modulus can be by a factor of 2 or more. Defining limits for the use and type of high-modulus carbon within Class rules can bring significant reductions in GHG emissions.

[20] Following best efforts to optimize and reduce negative climate impacts associated with an organization's operations, carbon insetting is an investment by the organization in emissions reduction projects within their value chain. In contrast to emissions reduction in external climate protection projects (carbon offset projects), climate protection money remains within the organization's value creation cycle.

8. Alternative materials
    a. Source PEFC or FSC certified wood products due to the benefits of sourcing from sustainably managed forests.
    b. Prepare an alternative material & process testing program early in the design and build process to validate, build confidence and ensure that alternatives are relevant to build timelines

9. Plugs and molds represent 50% of the build process.
    a. Avoid the use of male plugs
    b. Design & build for reuse

10. Design for longevity and end of life
    a. Longevity, simply put, a component that lasts twice as long and doesn't need replacing, has half the impact
    b. Reuse has even bigger potential, under LCA protocol, the original purchaser retains the 100% responsibility of the impact of a new component or boat, therefore an impact <u>free</u> benefit is passed on to <u>each</u> subsequent user

11. Rigging
    a. The calculation for running rigging was made using 'business-as-usual' coefficients for Dyneema. More up to date data is needed to include the bio-based and recycled-based numbers within the MarineShift360 in order to understand the impact reduction these material choices have had.
    b. Work needs to be continued on putting in place reverse cycle logistics in order to fully close the loop on these materials.

12. Resource/waste
    a. Design material end-of-life into the process and system from the start
    b. Keep materials in the system for as long as possible
    c. Create a demand for recycled materials 'in & out'
    d. Use waste to energy as a last resort
    e. Strict Zero waste to landfill policy

13. Onboard energy
    a. A significant factor holding back overall system efficiency is the Class mandated one design keel system being at 24v. If the keel system were allowed to run at 48v it would remove the need for step down converters and the resultant losses involved for one of the main consumers of power.

14. Molds
    a. At 50% of an IMOCA as built, or 25% of the total impact of a boat launched and ready to sail, the Team identified the build and use of molds as an important area for improvement.
    b. Removing male plugs from the build process would reduce waste by 3 tons and greenhouse gas emissions by 46tC02e (8% of the total greenhouse gas emissions).
    c. Alternative materials: certain sectors of the composite industry are already using recycled carbon fiber and/or flax as an alternative to virgin carbon fiber in molds.
    d. Reusing molds is one of the most significant ways to reduce impacts. The actual mold for 11.2 was already being used by another IMOCA team, before 11.2

had even left the build shed. By reusing the Team's mold, this new team removed 171 tC02e from their build footprint

e. Prioritizing local suppliers: The impacts of transporting the molds from Spain to the build site in France are discussed in SCENARIO - TRANSPORT.

15. Transport
    a. A total of 7 tC02e can be saved by using closer supply chain solutions and builders from the same country of construction site.
    b. Where long distance transport is required forward planning enables the use of lower impact transport methods such as sea freight which has a 100 times lower impact than airfreight

16. Packaging
    a. Use Case Study – Packaging to engage your suppliers on the topic of transport, packaging, waste and products end of life.

17. Policy
    a. Place sustainability as a key criterion within Class, and race rules and define how boats are designed and built
    b. Establish minimum standards on sourcing, energy, waste, and resource circularity
    c. Define a threshold for carbon emissions, based on LCA data
    d. Incentivize the marine industry to use its inherent capacity for innovation to focus on sustainability
    e. Set an internal price for carbon emissions

The Improvement tracks, Recommendations, Pathway to Net Zero, and Future build and Class choices provide a clear roadmap for reduction of future impacts for teams and the IMOCA Class.

THE END OF LIFE OF AN IMOCA

The lifecycle assessment has described the impacts of the manufacturing phase - cradle to user - from the extraction of raw materials, through the manufacturing stage, to the boat assembled, launched and ready to sail. 11th Hour Racing Team publishes annual reports which provide detail on the use phase of the campaign.

Assigning various options for end of life to a component during lifecycle analysis can offer various challenges and different impacts depending on allocation method. The Team chose to address end of life outside of the main lifecycle assessment, ensuring that potential differences of interpretation are avoided with past and future studies, and allowing consistent comparisons of the cradle to user phase.

End of life options can be categorized by: reuse, recycle, waste to energy, incineration, landfill. It is important to avoid the negative impacts of landfill and prioritize retaining components for use.

The end of life for material resource or waste applied and calculated during the lifecycle assessment process, and a detailed breakdown is provided in the chapter on circularity.

The boat builder CDK Technologies aligns with APER standards which places extended user responsibility on marine manufacturers at the point of construction, and facilitates the development of networks for recycled materials. APER builds key elements of the circular economy into the marine industry.

EOL IMOCA COMPONENTS			
End of life plans for IMOCA components and their respective reductions or impacts			
SUB - GROUP	**Component**	**Short term - First cycle**	**Final cycle**
		Actual	**Actual**
		Planned	Planned
PLUGS AND MOULDS	HULL & DECK PLUG		**Partial recycle - Most to landfill**
	HULL MOULD	**Reused**	Recycle or waste to energy
	DECK MOULD	**Reused**	Recycle or waste to energy
	DECK MOCK UP		**Recycled**
HULL & DECK	HULL SHELL	Reuse	Recycle or waste to energy
RUDDERS	RUDDER CASE	Reuse	Recycle or waste to energy
	RUDDERS	Reuse	Recycle or waste to energy
KEEL	KEEL FIN	Reuse	Recycle
	KEEL TRAILING EDGE	Reuse	Recycle or waste to energy
	KEEL BULB	Reuse	Recycle
	KEEL BEARINGS	Reuse	Recycle
FOILS	FOIL SET	Reuse	Recycle or waste to energy
	FOIL BEARINGS	Reuse	Recycle or waste to energy
SAILS	ALL SAILS	Reuse	Waste to energy
BOOM	BOOM	Reuse	Recycle or waste to energy
	BOOM HARDWARE	Reuse	Recycle
MAST	MAST	Reuse	Waste to energy
	MAST HARDWARE	Reuse	Recycle
OUTRIGGERS	OUTRIGGERS	Reuse	Waste to energy
RUNNING RIGGING	ROPE	Reuse	Recycle
STANDING RIGGING	STANDING RIGGING		Waste to energy
	STANDING RIGGING HARDWARE		Waste to energy
SAIL TRIM DECKGEAR	FURLERS	Reuse	Recycle
	DECK GEAR	Reuse	Recycle
	WINCHES AND TRANSMISSION	Reuse	Recycle
OTHER DECKGEAR	STEERING SYSTEM	Reuse	Recycle
	LIFE LINES AND PULPIT	Reuse	Recycle
NAVIGATION	INSTRUMENTATION	Reuse	Recycle
POWER	BATTERIES	Reuse	Recycle
	CABLES	Reuse	Recycle
	ELECTRIC MOTORS	Reuse	Recycle
DECK HYDRAULICS	DECK HYDRAULIC SYSTEM	Reuse	Recycle
KEEL HYDRAULICS	KEEL HYDRAULIC SYSTEM	Reuse	Recycle
PROPULSION	ENGINE, DRIVE SHAFT AND PROP	Reuse	Recycle

Table: End of life plans for IMOCA 11.2 and components

AN IMOCA TEAM IN THE OCEAN RACE

The last three editions of The Ocean Race have been strictly one-design. The absence of the need for bespoke research and development for teams has resulted in significantly reduced expenditures, boats and equipment being reused, and associated environmental impacts being the lowest in recent history of The Ocean Race.

The inclusion of the IMOCA Class in The Ocean Race has brought back the emphasis on innovation and development, and this report quantifies some of the direct impacts on teams.

It is worth noting that while an IMOCA built specifically for The Ocean Race is certainly more design and development intensive given the fully-crewed format, there is an inherent economization in combining events for classes, whether new boats are built or not.

The following table demonstrates the annual operational footprint for 11th Hour Racing Team's IMOCA campaign for The Ocean Race.

Table: Full campaign greenhouse gas emissions
Calculated using MarineShift360 beta software, October 1, 2021

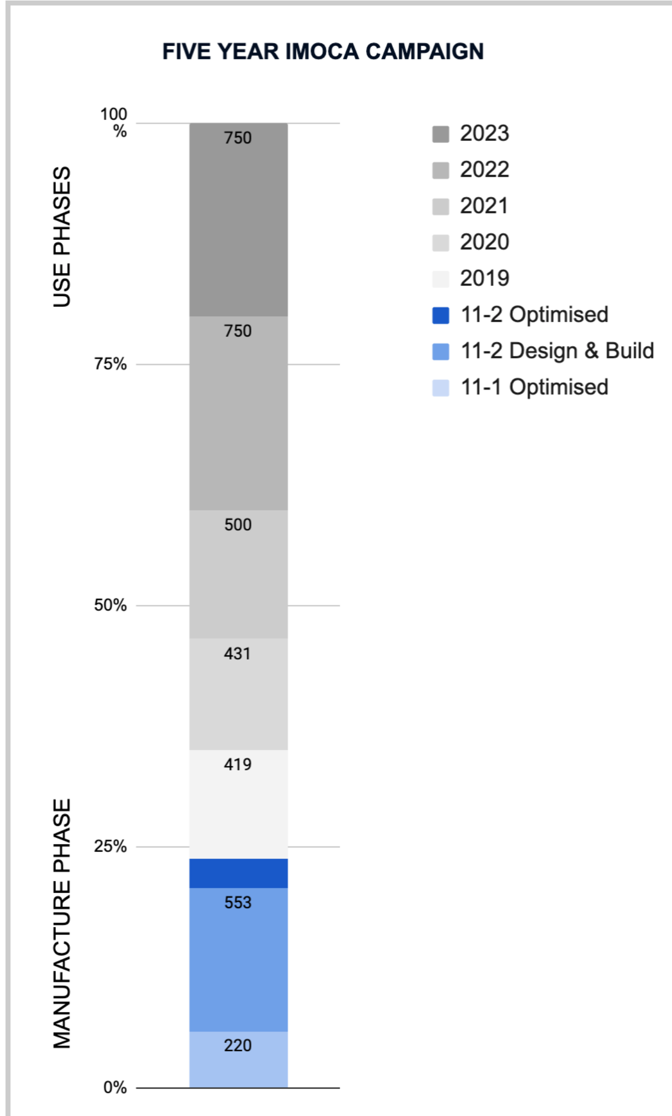
<table>
<tr><th>Design & Build</th><th>11.1
Optimized</th><th colspan="2">11.2
Launched and ready to sail</th><th colspan="2">11.2
Optimised for The Ocean Race</th></tr>
<tr><td>Inventory</td><td>Ex-Hugo Boss plus 4 foils (1 set plus 2 others)
1 set sails + 3
1 set rigging</td><td colspan="2">Launched and ready to sail with IMOCA Class inventory
1 set foils
1 set sails
1 set rigging</td><td colspan="2">1 spare rudder
1 set foils
1 set sails
1 set rigging</td></tr>
<tr><td>tC02e</td><td>220</td><td colspan="2">553</td><td colspan="2">116</td></tr>
<tr><th>Operations</th><th>2019</th><th>2020</th><th>2021</th><th>2022</th><th>2023</th></tr>
<tr><td>tC02e</td><td>419</td><td>431</td><td>500 +/-</td><td>750 +/-</td><td>750 +/-</td></tr>
</table>

Time and good planning allows a team to maximize the opportunity for technical development and testing of components which can have a large impact on performance e.g. as sails and foils. The bottom line is that more activity and expenditure typically generates more impacts.

While this report focuses on the design and build of an IMOCA, it is important to note that even taking into account; the development of 11.1, the build of 11.2 and optimization for The Ocean Race, this only represents approximately 25% of the total greenhouse gas emissions of the full five year campaign. The majority of a boat's impacts are in the use phase, including all of 11th Hour Racing Team's activities. This underlines the importance of sustainable event guidelines, race rules and team operations.

The impact of 11th Hour Racing Team's operations are outlined in the annual sustainability reports which describe the importance of the efforts applied, alongside detailing the support of partners and event organizations to address these issues.

Figure: Breakdown of the campaign's greenhouse gas emissions by year and build phase
Calculated using MarineShift360 beta software - October 1, 2021



ACKNOWLEDGEMENTS

11th Hour Racing Team would like to thank the group of designers, builders and over 50 of our suppliers, as well as our own in-house team, for exploring with us in such depth the opportunities for integrating sustainability within the performance sailing industry today. Collectively we see the need for an immediate change of direction, supported by strong policies, which will bring into play multiple solutions at scale.

“Only by working together was all of this possible.”
Mark Towill, 11th Hour Racing Team, Concarneau 2021

Photos by Amory Ross / 11th Hour Racing, unless otherwise credited.

RESOURCES

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Critical review by:
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ANNEXE

REVIEW

About the reviewers
Craig Simmons is the Chief Technology and Metrics Officer at Anthesis . He has been closely involved in the development of MarineShift360 working with pilot partners to understand their lifecycle assessment needs. He has more than 25 years experience in lifecycle assessment, material flow accounting, ecological footprinting and greenhouse gas assessment. He has previously worked on the carbon strategy for the America's Cup.

Michel Marie is a technical consultant with more than 30 years experience in composites manufacturing. As lifecycle assessment technical advisor and database consultant, he has been involved with the development of MarineShift360 since its inception in 2016. In the last ten years, in complement to the high-performance environment of America's Cup yachting, he has developed an interest for the sustainability issues raised by the manufacturing of composites components.

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Worksheet - GHG processing
Worksheet - Manufacturing waste analysis
Worksheet - Improvement paths
Worksheet - 11.2 LCA 2 results
Worksheet - End of Life
State of the art (Kairos bio-composite report)
Pathway to Net Zero
Internal price of carbon
Annual sustainability report 2019
Annual sustainability report 2020
Vestas 11th Hour Racing sustainability report 2017-18
Scenario analysis - Molds
Scenario analysis - Foils
Scenario analysis - Energy
Scenario analysis - Metal
Scenario Analysis - Transport
Scenario analysis - 10m2 Composite panel

OTHER

- Kairos 2010 LCA of an IMOCA report
- Roadmap for the decarbonization of the European maritime leisure craft sector
- Lifecycle impact assessment of different manufacturing technologies for automotive CFRP components, Journal of Cleaner Production (2020)
- The Ocean Race - Sustainable boatbuilding report
- Earth Overshoot

STAKEHOLDER INVENTORY

Suppliers	Service Component	Sustainable Sourcing	LCA Data Provided	Data input Type	Data Quality
Guillaume Verdier Design	Optimization 11.1 design 11.2	☑	☑	Complete	Very Good
CDK Technologies & sub-contractors	Build 11.2 and Foils	☑	☑	Complete	Very Good
Mer Concept	Design and Build coordination	☑	☑	Complete	Very Good
Kairos	Specialist services	☑		NA	NA
Lorima	Mast & Outriggers		☑	Complete	Very Good
Southern Spars	Boom	☑	☑	Complete	Very Good
Running rigging	Marlow ropes	☑	☑	Complete	Very Good
Future Fibers	Standing rigging			Estimated	Missing
North sails	Sails and Race course analysis	☑	☑	Partial/Extrapolated	Very Good
AMPM	Keel fin		☑	Complete	Very Good
Guelt	Keel Bulb and cage, Foil bearings		☑	Partial	Average
Hydroem	Keel hydraulic system			Missing	Missing
C3	Rudders, Keel fin trailing edge		☑	Complete	Very Good
JP3	Rudder bearings and steering system			Missing	Missing
Prot Design 3D	Keel bearings and various hardware			Missing	Missing
Caraboni	Deck hydraulics	☑	☑	Partial/Extrapolated	Very Good
Persico	Foils 11.1	☑	☑	Complete	Very Good
Greenboats	Hatches	☑	☑	Complete	Very Good
Harken	Deck gear & hardware	☑	☑	Partial/Extrapolated	Very Good
Karver	Furler	☑		Estimated	Low
Nanni Diesel	Engine			Estimated	Good
Diverse	Electrical system and installation	☑	☑	Partial	Average
Navico	Instrumentation	☑	☑	Partial/Extrapolated	Very Good
Pixel sur mer	Fiber optic system	☑		Estimated	Low
NDT	Nautiscan			NA	NA

The Ocean Race	Ocean Pack	☑		NA	NA
Blackfibre	Boat painting			Missing	Missing
Pesch Alu	Cradle & containers			NA	NA
Mast trolleys	Celtinox			NA	NA
Gen2	Carbon recycling	☑		NA	NA
IMOCA	IMOCA Class	☑		NA	NA
MarineShift360	LCA Tool	☑		NA	NA

11TH HOUR RACING TEAM

2021 SUSTAINABLE DESIGN AND BUILD REPORT

IMAGINING NET ZERO

IMAGINING NET ZERO

Damian Foxall, Sustainability Program Manager, describes the opportunity:

"'Innovation and pushing beyond business as usual have been inherent to sailing throughout its history. In every aspect of the sport, the focus has been on performance, developing new designs, and using new technologies which allows us today to 'foil and fly' far beyond what Archimedes could ever have dreamt of.

"What we need to do now, is to take some of that amazing capacity we have for innovation, and to focus it on making our industry sustainable. The knowledge, material, and resources exist, all that is needed is for us to take responsibility and to make the right choices, right now."'

WHAT IS NET ZERO?

The Paris Agreement outlines the need for a reduction of greenhouse gas emissions of 45%[21] by 2030, and Net Zero by 2050.

Net Zero is the balancing of anthropogenic[22] greenhouse gas emissions that is achieved by emitting no more than we remove from the atmosphere.

In the broader sense, it is crucial to include a more complete understanding of all impacts. Taking other natural resources such as; water, land and energy that all require a Net Zero approach as minimum.

At 11th Hour Racing Team, we believe that in reality, given the degraded state of the earth's resources, impacts should be considered through a Net Positive lens, how can our presence leave things better than we found them?

Only through this approach can we expect to achieve the social values we globally aspire to, and healthy equitable economies to support them.

[21] To stay below the 1.5 degree threshold for global warming, UNFCCC Sports for climate action, and the Race to Zero define the interim target as **50% by 2030**, and Net Zero by 2040 (July 2021), as signatories of this initiative 11th Hour Racing team align with this definition.
[22] Anthropogenic - Caused or produced by humans

TARGETS BASED ON SCIENCE

Over the last ten years, the IMOCA Class has made impressive progress in performance. However, locked into the status quo of this ‘arms race’ there has been an important side effect: since 2010 the environmental impacts of building an IMOCA have almost doubled from 343 tC02e to +/- 553 tC02e (tons of carbon dioxide equivalent).

Using the Kairos report of 2010 as the base year to reference the Paris Agreement targets, the requirement over the same period is that the Class should be working towards **45% reduction of impacts by 2030, or 190 tC02e.**

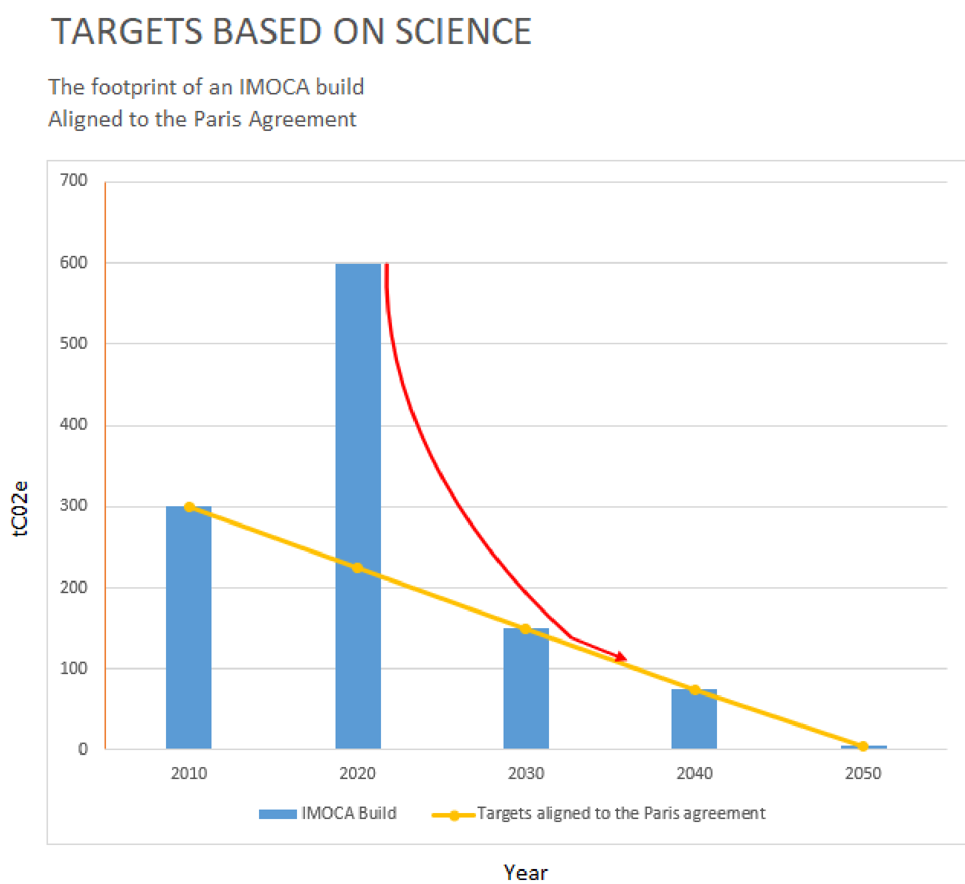


Figure: Comparing two IMOCA builds ten years apart and the path to Net Zero

he yellow line aligns the base year 2010 to the Paris Agreement:

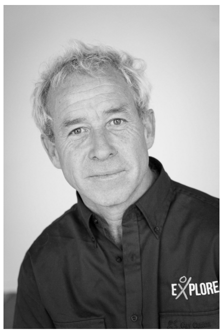
- ***45% reduction by 2030 - 190 tC02e** (absolute reductions)*
- ***Net Zero by 2050[23] - 0 tC02e** (ongoing reductions and sequestration of remaining C02e)*

The red line represents this new, steeper and now more urgent pathway to Net Zero.

[23] UNFCCC require Net Zero by 2040

It is worth noting that both 2010 and 2020 data points were from two IMOCA teams with strong sustainability and performance standards. Although both teams used different lifecycle analysis tools, we can consider this high-quality data, and a consistent representation of both past, present, and to the extent that is possible, future data points.

While we use the IMOCA Class here as an example, this is representative of the wider economy, as we all have accelerated fast in the wrong direction, and are only now waking up to reality.



"The planet is a boat with a growing crew but diminishing resources. We must change direction before there is a mutiny."

Roland Jourdain, Skipper IMOCA - Véolia Environnement

THE RISK OF DOING NOTHING

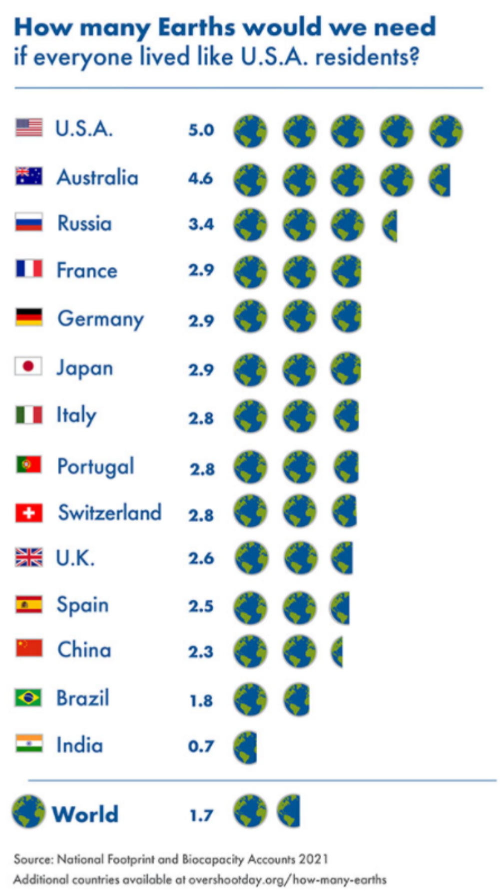
Business as usual is no longer an option. While the performance sailing sector and much of the leisure marine industry is geographically centered in the global North and a few other well-off regions, we live in a fragile bubble of prosperity.

This alternative reality does not reflect either the reality for most of the world's citizens, or the availability of the earth's resources. Inherently tied to the ongoing growth of global economies, we would need 1.7 Earths each year just to maintain the situation for the average global citizen. Scaled to the typical lifestyles associated with the marine industry this is more like 5+ Earths each year: a growing annual debt.

The direct impacts of this annual shortfall are typically transferred to many underdeveloped countries and natural environments which provide the large percentage of our material, energy and supply chain needs.

At the level of our sport, recognition of the importance of increasing diverse participation and a balanced representative participation across disciplines means the sport must grow by 100%, with the requirement therefore to double our material needs, while at the same time reduce our impacts by 50% by 2030.

The ongoing quest for performance at all cost has taken us into a dead end. The challenge the sport faces is existential.



VISION

'Believe me, my young friend, there is nothing - absolutely nothing - half so much worth doing as simply messing about in boats.' **Kenneth Grahame, The Wind in the Willows**

As we look for inspiration for the future, we could start by looking back into the origins of our sport.

Sustainability is about using the resources that are available within our reasonable proximity and being responsible for the impacts that the extraction of these resources has.

Our capacity for innovation holds the key for lasting, positive solution., How we will integrate new sources of renewable energy ashore and afloat, new materials locally sourced, better circular manufacturing processes, and products with longer life spans. These all provide opportunities for new sustainable business models and social benefits for a healthy marine economy.

The performance sailing sector is well positioned to both benefit from, and provide services to, other, larger industry sectors. This places the performance marine industry in a position to have a positive impact far beyond its immediate and traditional scope of operations.

Around us, governments and other industries are taking stock and implementing increasingly rigorous new policies and standards. The marine industry has the opportunity to stay ahead of the curve, but the path to the scale of reductions we need by 2030 is steep. We need 7%+ annual reductions, starting now (2021).

The vision for the future of performance sailing and the marine industry must encompass a whole new *raison d'etre*, and a Net Positive approach to doing better across all sectors of operation, rather than just trying to be less bad.

By embracing a Net Positive approach, we can continue to build the scale of our fleets, events and sport, because the increase in activity will generate economic, social and environmental value.

WHAT IS NEEDED

POLICY

'What are individual ethical obligations regarding unregulated externalities?
... Our primary ethical obligation is as a citizen to promote laws that correct the spillovers.'
The Spirit of Green, William D Nordhaus

The 11th Hour Racing Team Design & Build Report has explored the impacts and influence of the Team as a marine sector client, the manufacturers products along the value chain, and the policymakers both Classes and events. The reality of build timelines and performance objectives, means all parties are locked into the status quo of business as usual.

The most important factors that influence the decisions on overall design and build processes are:

- Builder and client confidence in material properties.
- Timelines.
- Class & Race rules.

But it is only rules and policy that will break the status quo.

A telling example is that despite the collective best efforts of all concerned, only 100 kilos of the new boat 11.2, or less than 2% by weight, represent alternatives to 'business as usual' of composites. As it is, this was made possible by the IMOCA Alternative Material rule. Without good policy, even gains like this will not happen.

Once policy has placed sustainability as a key criterion, the industry will do what it does best, which is to innovate and find the optimum solutions.

Our recommendation is to set a carbon emissions threshold, and to implement an internal price for carbon emissions, thereby linking financial budgets to responsible decision making and sustainable performance.

THE CARBON EMISSIONS POLICY

Threshold

A threshold for carbon emissions for each team, component, boat build or similar unit, is a direct method to define limits for the transformation of raw materials to finished boats, as well as boundaries for the use phase. Based on the most recent lifecycle assessment or use emissions data, thresholds should be set at a level that is achievable, but also incentivizes innovation. It should be updated periodically to reflect new innovations and regularly revised targets.

Internal price for carbon emissions

There is a growing recognition that pricing carbon emissions provides a mechanism at the global, national and company or organization level, to support the pathway to Net Zero. Here is a conceptual model of what it might look like for the sailing sector and the IMOCA Class

By linking a threshold for carbon emissions to an internal price for carbon emissions, a mechanism is created that places reductions at the heart of decision making and innovation.

It promotes an internal market incentivizing longevity, reuse and best practice both within the system, and its external supply chain, whilst also putting a cost on negative impacts.

The internal price could be:

- Fee based, with an actual financial transaction for participants based on calculated, estimated or actual activity emissions, thereby creating an internal carbon emission reduction fund.
- Virtual, with no monetary transaction (shadow price), but designed to guide decision making.

The price set needs to be affordable, yet to be high enough to influence the change required, and can be established internally or indexed to an external cost such as a national carbon tariff, or an evaluation on the social cost of carbon. The price should be reviewed periodically to keep momentum along the pathway to Net Zero.

As described by Nodhaus below, implementing this mechanism, along with a robust approach to reducing impacts, will help sailing organizations and marine industry to achieve Net Zero well ahead of the Paris Agreement targets.

"The country may have the best climate scientists developing the most skilful projections of climate change; it might have the best materials scientists working on high-efficiency CO2 pipelines; it may have the best financial investments. But if the carbon price is zero, then the projects to develop promising but costly low-carbon technologies will die before they get to the boardroom of a profit-oriented company."
The Spirit of Green, William D Nordhaus

SUSTAINABILITY FUND

Various revenue streams can be developed to support a Class sustainability fund. Rather than relying on external funds and sponsorships, a sustainability fund should primarily be sourced from the stakeholders within the Class and industry, who will take responsibility for the costs associated with the externalities of their collective activities.

This can be supported by other examples such as:

"Down-scaling and simplifying materials within rules would have interesting cost savings which could then be re-injected to support the sustainability development of the Class and marine industry" ***Yannick Le Morvan, Gurit***

Other funding sources exist such as those associated with green development funds.

'"To encourage the roll-out of low carbon recreational vessel propulsion technologies, it is likely that taxation or financial incentives will be required .... the European Green Deal has unlocked significant funding for the development and demonstration of low/net zero carbon technologies within the maritime sector...'
Roadmap for Decarbonization of the European recreational marine craft sector, Carbon Trust[24]

[24] Roadmap for the Decarbonization of the European recreational marine craft sector - Carbon Trust

RECOMMENDATIONS

- Place sustainability as a key criterion within Class and race rules to define how boats are designed and built.
- Establish minimum standards on sourcing, energy, waste, and resource circularity.
- Define a threshold for carbon emissions based on LCA data.
- Incentivize the marine industry to use its inherent capacity for innovation to focus on sustainability.
- Set an internal price for carbon emissions.

HOW TO CHANGE

The approaches to sustainable change on the scale that is needed can be described as follows:

- Efficiency reduction
- Absolute reduction
- Modal shift

Otherwise stated as: Better, Less and Alternative.

Using transport as a theme, the graphic below describes these examples of change

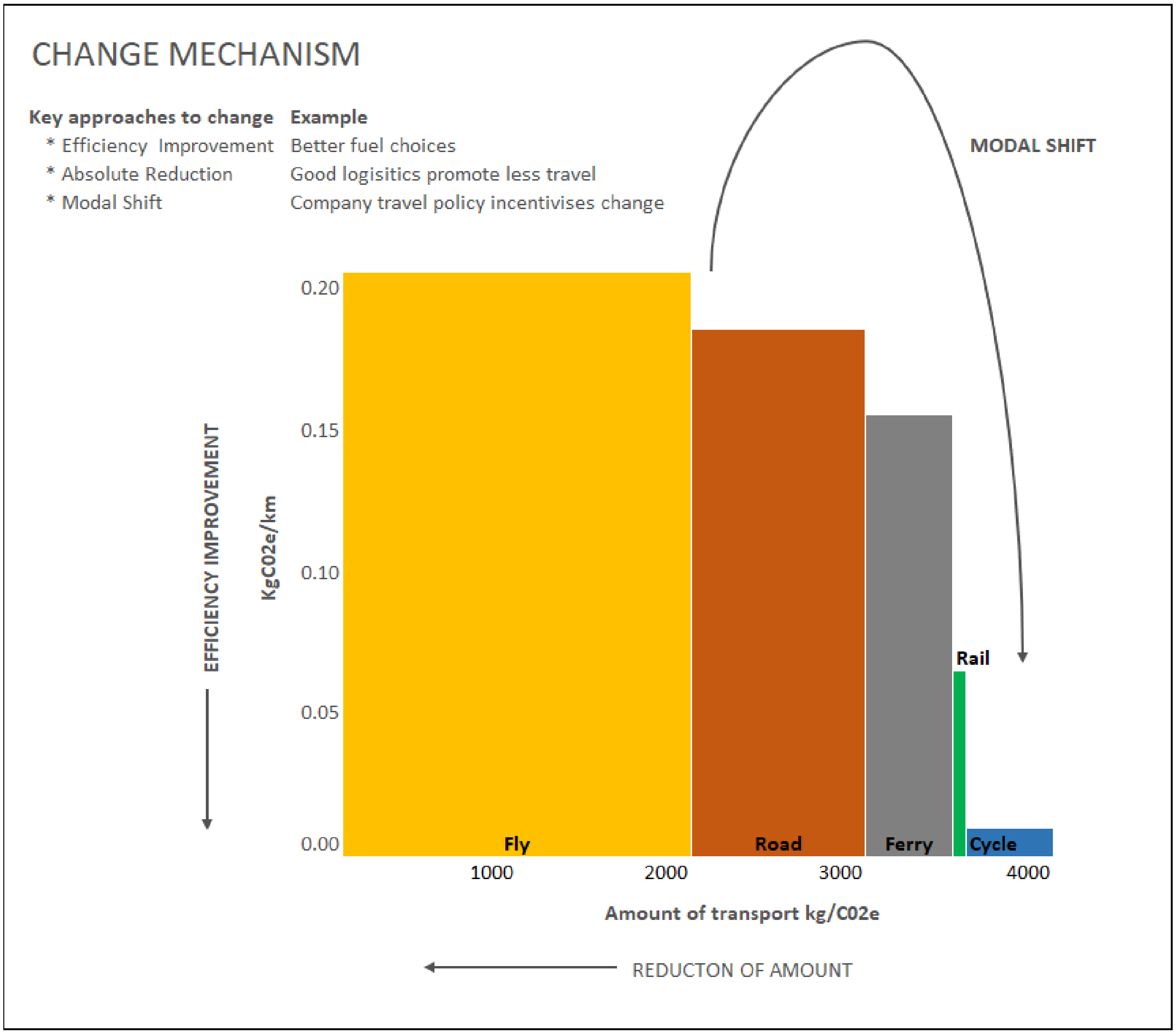


Figure: Looking at options for change

Looking at this from the marine industry perspective suggests that change will be a function of multiple actions:

- More energy and resource efficient manufacturing
- Sobriety with regards to consumer choices
- A systemic shift to a different model of construction, use and end of life

PATHWAY TO NET ZERO

Adapted from work undertaken for The Ocean Race by Kellie Covington, this interpretation of the Pathway to Net Zero maps the observations in this report out to 2050, describing a broad strategy for a sustainable future.

DECOUPLE GROWTH FROM IMPACT

The capacity for innovation within our sport can provide sustainable solutions for both the sector and the wider marine industry, and a balanced approach must be taken to achieve the desired outcomes of reduced global impacts. Without this approach, sustainable solutions will only create new problems elsewhere.

There is a growing recognition that the **reductions**, **efficiencies** and **innovations** we have highlighted in this report will only get us part of the way to decoupling impacts from economic activity. We will also need direct action methods such as carbon capture and storage at source to avoid greenhouse gas emissions. We need impact compensation and carbon offsetting strategies to sequester and neutralise the unavoidable impacts.

But most importantly, underlining all of this, the marine economy needs a new definition of success that decouples economic growth and performance from environmental impacts.

"Pour ce qui est de l'avenir, il ne s'agit pas de le prévoir, mais de le rendre possible. "

Antoine de Saint Exupéry, Citadelle, 1948

"With regards to the future, it is not about predicting it, but about making it possible."

For questions about this report, please contact sustainability@1degree.us