International Ship and Offshore Structures Congress (ISSC) 2025
Committee IV 2 – Materials and Fabrication Technology
Committee Chair: Agnes Marie Horn

Documentation of an expert workshop

Topics:	Low emission shipyard processes and circularity ready products – opportunities and challenges on the way towards a sustainable maritime industry
Format:	Face-to-face meeting
Date:	September 17th, 2024
Place and Venue:	DNV | Brooktorkai 18 | 20457 Hamburg, Germany

Background

The 'Material and Fabrication Technology' Committee of ISSC

The **International Ship and Offshore Structures Congress** (ISSC) is an international group of experts in the field of shipbuilding and offshore which is working with own resources and commitment to analyse the state of the art and latest developments in certain fields of technology, collects the findings in a public report and discusses it every three years on a congress. Usually, the reports also cover benchmark studies e.g. on certain methods and tools, and include recommendations for further developments in research, education, rulemaking or industry. Since 2022, issues around decarbonisation, sustainability and circular economy receive increased attention by ISSC. Further information can be found on websites of the up-coming and the last congresses at www.issc2025.com and www.issc2022.org.

The ISSC2025 **Committee IV.2 focuses on 'Materials and fabrication Technology'**. It is led by Agnes Marie Horn of DNV in Høvik, Norway. The list of committee members as well as its mandate is available here: http://www.issc2025.com/news/detail/217.html.

Focus topic 'Materials and Processes in a lifecycle perspective'

In recent years, dedicated meetings between committee members and external stakeholders were successfully held to enhance discussion on subjects of specific interest between experts. Several chapters of the report currently being prepared by the committee IV.2 will address numerous subjects related to the topic of more environmentally friendly materials and processes in the maritime industry, including:

1. Methodologies to assess and compare transparently the environmental friendliness of life cycle processes other than ships' operation (newbuilding, repair/conversion, end-of-life)
2. Methodologies to assess the circularity readiness of materials and components used in ships
3. Novel and eco-friendly manufacturing, joining and repair technologies,
4. Development of new materials, especially fibre reinforced plastics for lightweight construction,
5. Approval processes for new materials and technologies.

There are currently various initiatives on international and national level that cover the abovementioned aspects, for instance:

- R&D&I: In the EU funded project CirclesOfLife (start in January 2024), industry, research organisations and NGOs will develop concepts for a *Shipyard Environmental Performance Index* (SEPI) and a digital *Cradle to Cradle (C2C) Ship Circularity Passport*. The goals include overcoming the fact that the non-operational footprint of the ship, i.e. shipyard processes as well as materials and components integrated into the ship, remain a black box, and paving the way for a greener and more circular shipbuilding and shipping industry. [1]
- Regulation: The use of materials other than steel in ship structures is governed by IMO regulations. For the use of composites in SOLAS vessels, a dedicated Interim Guideline (IG) is in place [2][…]. Recently, the IMO Sub Committee Ship design and construction (SDC) installed a Correspondence Group to formalise the dialogue between IMO and industry stakeholders about a possible review of the IG, up to the potential expansion of its scope to load bearing structures made of composite materials.
- Networks of stakeholders: Industry associations and policy makers have the greening of transport and the enhancement of material circularity on their agenda and pursue these goals actively in their responsible bodies. Actors in Germany include MariLight (the network for lightweight design in the German maritime industry) and the Federal Ministry for Economic Affairs and Climate Action (*Bundesministerium für Wirtschaft und Klimaschutz* – BMWK). [3]

Since the activities are interrelated in many ways and demand to be considered in their entirety, an expert meeting with representatives from the abovementioned groups was suggested.

Participants

ISSC – Committee IV.2 Material and Fabrication Technology

Name	Country, Organisation, comments
Agnes Marie Horn	Norway – DNV AS; Committee chair
Matthias Krause	Germany – Center of Maritime Technologies gGmbH; Link to CirclesOfLife
Iraklis Lazakis	UK – Department of Naval Architecture, Ocean & Marine Engineering | University of Strathclyde
Stéphane Paboeuf	France – Bureau Veritas; Link to IACS and to the CirclesOfLife and RAMSSES projects

Consortium members of the EU project CirclesOfLife

The workshop was attended by various representatives of the project consortium:

Name	Organisation, role in the project
Jorinus Kalis	Damen Research Development & Innovation BV; project coordinator
Conrad Plange	Flensburger Schiffbau-Gesellschaft mbH; leading the concept and methodology definition
Stephan Wurst	BALance Technology Consulting GmbH; leading the implementation of means for assessment
Michael Hübler	Center of Maritime Technologies gGmbH; leading the validation and assessment of actual emissions, and best practice guide to reduce them
Rosanne van Houwelingen	Leading the dissemination, communication, exploitation and training activities

Name	Organisation, role in the project
Romain Benoit	Surfrider Foundation Europe; Representing the Green Marine Europe initiative for environmental self-assessment of shipyards
Benedetta Mantoan	NGO Shipbreaking Platform; Representation of/liaison with the stakeholder group of the ship recycling industry
Theresa Wilson	Flensburger Schiffbau-Gesellschaft mbH; contributing to the concept and methodology definition and to a case study 'new build'

Further experts

Further experts who participated in the workshop are representing the following organisations and initiatives:

Name	Organisation, relevance
Jon Steinlein	Center of Maritime Technologies gGmbH, Germany; Coordinator of the network for maritime lightweight construction MariLight.Net
Bastian Brenken	Composites United; Managing director of one of the world's largest network for fiber-based multi-material lightweight design
Paul Riesen	Greenboats GmbH; Supplier of components and products made of lightweight and sustainable materials
Katharina Koschek	Fraunhofer Institute for Manufacturing Technology and Advanced Materials (IFAM), Department Adhesive Bonding and Polymeric Materials
Frank Roland	German Aerospace Center (DLR), Institute of Maritime Energy Systems; partner in the EU project EcoShipYard
Jens Bottke	Abeking & Rasmussen Schiffs- und Yachtwerft SE; Vice Chair of the German Shipbuilding and Ocean industries association (VSM e. V.) ESG committee
Philippe Noury	DNV AS; classification society with a considerable track record on R&D in shipbuilding and in composites materials application
Abhiram Kakkollilrajan	German Aerospace Center (DLR), Institute of Maritime Energy Systems; partner in the EU project EcoShipYard
Frank Roland	DLR, Institute of Maritime Energy Systems; long track record on maritime R&D, former member of the ISSC Committee on materials and fabrication
Agnieszka Dzielendziek	DLR, Institute of Maritime Energy Systems; PhD in sustainable composites

Organisation of the workshop

The workshop's agenda is shown in Table 1.

Table 1: Workshop agenda

Time	Subject	Speaker(s)
10:00	**Welcome, organisational issues, tour de table**	Agnes Horn, all
10:15	**Introduction, aim of ISSC Committee, purpose of the meeting**	Matthias Krause
10:30	**Session I: Greening of shipyard processes** Focus on novel production, repair and recycling processes with a potential to reduce emissions in non-operational processes of ship's lives. The processing of any kind of materials can be covered.	Chair: Matthias Krause

Time	Subject	Speaker(s)
10:30	Pitch presentation I: SEPI – Concept to measure, determine and bench-mark the footprint of shipyard processes	Jorinus Kalis
10:40	Pitch presentation II: Presentation with practical examples on process im-provement	Ernest Kyei
10:50	Discussion, e.g.: • In an industry as heterogeneous as shipbuilding, is it possible to find a method that allows companies to be compared fairly and transpar-ently with reasonable effort? • Can the necessary data be obtained at all, and what should be done if not?	All
11:30	**Coffee break**	
12:00	**Session II: Material in a life-cycle perspective** Focus on 'new' materials	Chair: Stéphane Paboeuf
12:00	Pitch presentation I: Recycling technologies for FRP	Bastian Brenken
12:10	Pitch presentation II: Material and business model innovation in the boat building industry	Paul Riesen
12:20	Discussion, e.g.: • What are the benefits (e.g. lightweight), challenges (e.g. safety, recy-cling), and requirements (e.g. design for circularity) that come with new materials? • What are the solutions so far, and what are the remaining issues?	All
13:00	**Lunch break**	
14:00	**Session III: 'Composite Structures nowadays and in the years to come'**	Chair: Agnes Horn
14:00	Presentation: 'Advancing Composite Structures: DNV's Current and Future Role in Technology Qualification and R&D'	Philippe Noury
14:30	Discussion	All
15:00	**Session IV – creating incentives, overcoming/removing barriers** Focus on activities and needs regarding qualification, approval pro-cesses/regulations, and acceptance	Matthias Krause
15:00	Pitch presentation I: Concepts for Digital Product Passports	Bastian Brenken
15:10	Pitch presentation II: Environmental certification of shipyards	Romain Benoit
15:20	Discussion, e.g.: • How can a market pull be created for more eco-friendly ships and shipyards? • What incentives could convince stakeholders to accept instruments such as a SEPI and a C2C digital ship circularity passport, and to share data?	All
16:00	**Conclusions, future outlook**	
16:15	**End**	

Workshop report

Session I *Greening of shipyard processes*

Focus on novel production, repair and recycling processes with a potential to reduce emissions in non-operational processes of ship's lives. The processing of any kind of materials can be covered.

The session commenced with a pitch presentation, 'SEPI – Concept to measure, determine and benchmark the footprint of shipyard processes', about the mission and approach of the ongoing European R&D project CirclesOfLife. The project aims to contribute to enhanced sustainability of the maritime sector by addressing lifecycle processes other than the ship's operation. The scope covers two major fields: (a) shipbuilding processes in newbuild, repair/conversion and end-of-life. The aim is to provide a blueprint for a Shipyard Environmental Performance Index (SEPI), a scheme which allows to rate the environmental performance of shipyards and to assess the potential to achieve an improved SEPI score through technical innovation. (b) circularity in shipbuilding. It is envisaged to deliver a concept for a cradle to cradle digital ship passport (C2C DPP) which informs about the materials and components a ship actually consists of, and whether and how they can be recycled, reused, repurposed etc. Both the SEPI and the C2C DPP concept will be assessed and demonstrated by means of dedicated case studies. The project's storyline is represented in Figure 1.

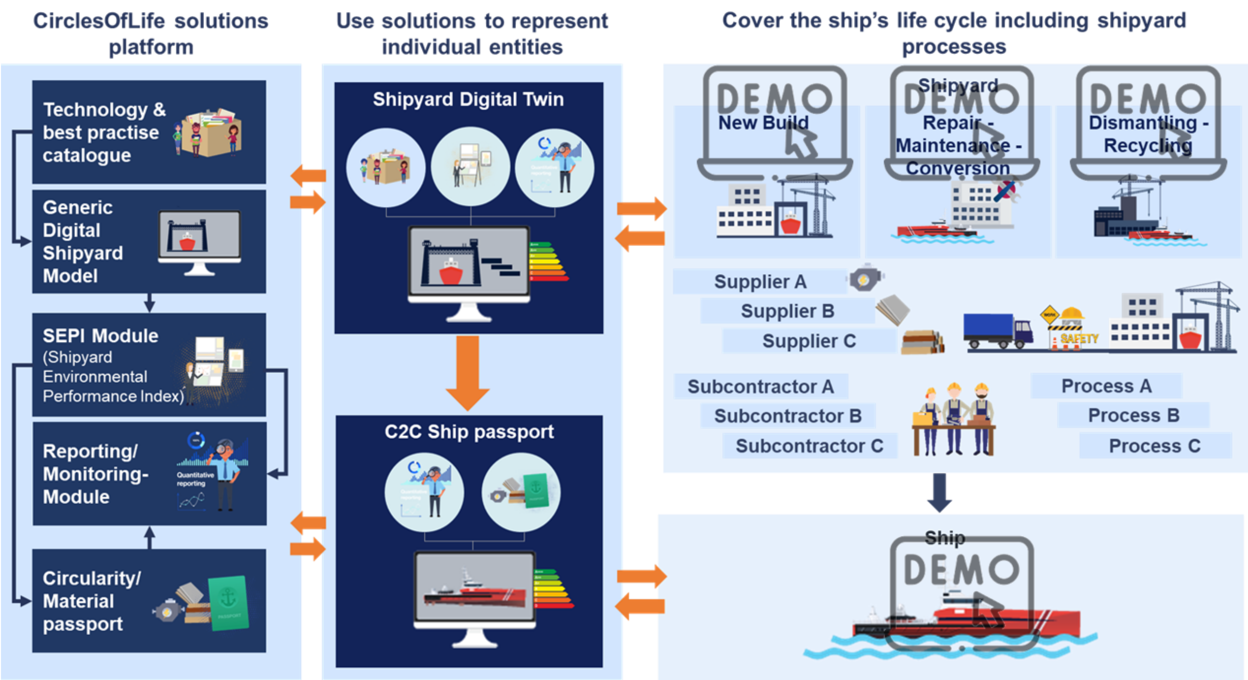


Figure 1: CirclesOfLife Deliverables and Implementation

It should be noted that EcoShipYard, a second EU funded project, dedicated to exactly the same subject, is running in parallel with and independently from CirclesOfLife [4]. The two projects are collaborating on several fields, including the organisation of joint public conferences.

The second pitch presentation came from Eriks BV in the Netherlands, a supplier of shipyard equipment and member of the CirclesOfLife consortium. Being aware of the public demand for climate action, the company is currently reorganising its business strategy with a focus on emissions. A quite comprehensive as-is assessment is ongoing, including a detailed LCA for all products (the portfolio comprises some five thousand different products). While it is challenging to exactly quantify the emissions, it has become obvious that the so-called scope 3 emissions stemming from upstream processes (particularly obtaining raw materials, semi-finished products, and transport) are representing the most critical hot spots. Therefore, Eriks is focusing on material-related approaches (alternative sources of supply or substitution of materials). Regarding alternative materials, each option has to be checked carefully for potential negative side effects, be it deterioration of product properties or additional emissions elsewhere in the process chain. Alternative manufacturing technologies within the manufacturing process can be considered as well, but again the impact on product properties needs to be considered.

In the following discussion, it was widely agreed that an isolated assessment of production processes' footprints without considering materials' and products' life cycle properties makes limited sense. However, sufficiently accurate knowledge about the emissions and the consumed resources along the process chain is considered necessary as well as insight into the potential levers for improvement.

Processes and technologies for improved sustainability

It is agreed that various low-emission technologies for shipbuilding are around. To narrow down where the greatest effect can be achieved, it was suggested to look at what contributes most to the overall lifecycle footprint of the ship first and then to derive the subjects to concentrate on. Following this premise, two fields of action were identified, and possible solutions were suggested:

(a) A long lifetime of a ship is a highly desirable and sustainable choice, as it means a longer time till the ship is going to be scrapped and needs to be replaced. Suitable processes, technologies and concepts contributing to a long life of a ship include additive manufacturing of spare parts, structural health monitoring, design for easy repair, conversion and disassembly, modularity of the design, easy access to maintenance and repair (e.g. on-board kits), reusability of materials, structures and components, and dedicated crew training.

(b) Alternative fuels and propulsion techniques are the main keys to reduce the footprint of ships in operation. Following this line of thinking, the focus should be on materials and processes which support efficient and safe application of such concepts (e.g. lightweight construction to maintain stability when using towering wind assisted propulsion facilities or to increase the range of battery powered ships).

One concern regarding this suggestion was the question whether it is desirable to create a long-living ship while at the same time sacrificing opportunities for design optimisation. In consequence, a newbuilt ship would consume some percentages of fuel more than technically possible. Over time, witnessing more innovation cycles than a short-living ship, the gap between possible and actual consumption would become even worse. This illustrates the scope of the issue, which is clearly an optimisation problem. Furthermore, it should be noted that design for easy conversion is probably the most important aspect among the suggested measures under (a). Refurbishing or changing the engine during the ship's life can help, and the probable need for such modifications should be anticipated by retrofit-ready, modular design.

Further discussion dealt with specific technologies, material groups and industry sectors. An increasing interest in lifetime extension of composite ships is being observed, and the required technologies are available. As an example, typically only the first layer of composite parts suffer from the typical wear and tear in maritime environments. Under the first layer, the material is usually still in excellent condition. By simply grinding the affected zone and then remaking the uppermost layer, parts can virtually be restored to new condition. As well, oil & gas companies want to extend the lifetime of their steel platforms. Here, composite patch repair is a solution which is gaining attention.

Means to measure, document and improve the performance

While the CirclesOfLife project which was briefly introduced in the pitch presentation is aiming to elaborate consistent and viable SEPI and C2C DPP concepts, various maritime stakeholders have already been active systematically assessing environmental footprints. Some examples for current practices:

- Life Cycle Assessment (LCA) is gaining importance in the ship design process, for instance at GREENBOATS. However, the decisive factor is the purpose of the vessel and its performance requirements; the optimisation of LCA properties is subordinate, and even more so the selection of low-emission technologies. Transparency is an issue; industry stakeholders are usually only willing to issue the results of their assessment, but not the details they are based on.
- Certain shipyards have implemented strategies to reduce their footprint and to – at least qualitatively – document the progress. For instance, LISNAVE in Portugal adopted the assessment scheme of Green Marine Europe (see session IV). Local factors such as neighbourhood to a nature reserve were part of the motivation here.
- In the course of investment planning, many European shipyards are obliged to assess the ecological impact. There is a lack of suitable tools which take into consideration both the economic and ecological aspects when undergoing an investment planning process.

The list above includes some of the observed shortcomings and challenges. It was agreed that assessing entire shipyards in terms of their footprint is even harder. It begins with the general question to determine what an eco-friendly shipyard actually is, due to the complexity and heterogeneity of the matter (very different shipyard types, sizes, maturity levels, very different types of ships, complexity of the structures and components…). The complexity and heterogeneity also make it challenging to compare shipyards against each other. Even more difficult is the idea to compare shipyards which are specialising into different lifecycle processes, e.g. newbuild vs. repair. Several studies and approaches were discussed:

- A recent PhD Thesis at Strathclyde University [5] proposes a shipyard assessment framework, looking at the performance not only in terms of efficiency, but also environmental and human aspects. The concept is based on a value engineering approach.
- A study in South Korea [6] analysed and compared the development status of shipyards there in terms of 'smartness' (e.g. maturity of digitalisation and application of Industry 4.0); the level of a shipyard's smartness can be considered as an important indicator for the ability to assess its ecological footprint and to identify the potential for improvement.
- An existing ABS guideline [7] addresses smartness as well; however it is questioned whether it is applicable to all shipyards. It was suggested to look at the different approaches for comparing shipyards. However, it should be avoided to compare yards that are completely unlike each other.
- The yachting industry did some studies [8], facing many issues with stakeholders unwilling to share information. However, there is a need to create transparency, which again requires collaboration between the stakeholders along the supply chain.
- The question was raised whether the classification societies should come up with rules that enforce such a collaboration.
  - BV approves designs regarding compliance with IMO and own rules.
  - DNV operates a platform where related properties can be shared without disclosing the detailed data.

Finally, the discussion touched some of the business-inherent aspects which currently prevent a further uptake of sustainability and circularity in maritime, and which were to be discussed in session IV:

- Limited control – Even though a shipyard might be willing to take comprehensive measures towards low-footprint processes, it is usually not entirely responsible for the situation, since the customer's specification often prohibits eco-friendly designs, material choices or processes and technologies.
- The classical (linear economy based) mindset of shipyards is not to be too much interested in long-living products, but to offer a replacement once a used ship is outdated.
- A clear need is seen to develop viable, circularity-based business concepts. Future business models could include leasing models, or the idea of shipyards purchasing back used products.

Survey

After session I, the attendees were asked to answer a survey:

- Question: 'What is the biggest lever for reducing emissions in shipyard processes?'
- Mode: Multiple choice; each participant was given three votes which could be accumulated to a single option or distribute over several of those.
- Possible answers: Eleven possible answers were suggested which had been created spontaneously by the moderator of the session, summarising the contributions to the discussion. It appears that some of the answers received few votes because of unclear formulation. Example: 'Assignment of measurements to meaningful references' should read 'Choosing suitable reference units to make measurements comparable'.
- Outcome: However, the answers allow some conclusions, especially if categorised as shown in Figure 2 (the categorisation took place after the voting). The workshop participants were most likely to agree that improved knowledge and transparency (cluster 2) regarding actual emissions can contribute to their reduction. Creating an acknowledged assessment framework (cluster 3) and extending the ships' lifetime (cluster 4) are also considered relevant levers. On the other hand, there was only little support for cluster 1 – shipyard equipment and technology.

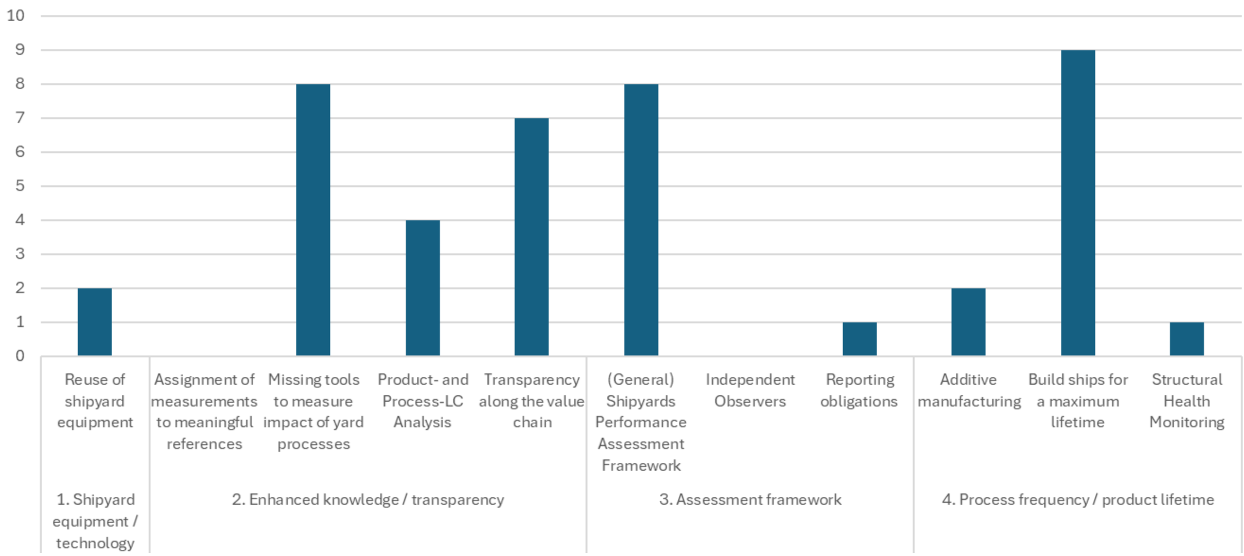


Figure 2: Survey session 1 – clustered results

Session II: Material in a life-cycle perspective

Focus on 'new' materials

Two pitch presentations were given in the beginning of this session. The first was titled 'Recycling technologies for FRP' and was delivered by Composites United. It began with a quick look into legislation in Germany (Circular Economy Act – Kreislaufwirtschaftsgesetz KrWG). Its underlying principle is the so-called waste hierarchy (Figure 3), which suggests decreasing levels of desirability for different end-of-life approaches to products, ranging from *reduce* over *reuse*, *recycling* and *recovery* to *disposal* [9]. After that, several technologies for fibre composites were addressed, including economic aspects. In the second pitch, 'Material and business model innovation in the boat building industry', Greenboats gave an understanding of the company's philosophy and multiannual strategy. Sustainability is considered as one of its 'horizons' for success. The ambition is to offer products which come with a lower ecological footprint than conventional ones, but which are also on a par in terms of operational performance and price (Figure 4). Current products include different boat hatches made of nature based materials, and circular structures which can be found in recreation vehicles.

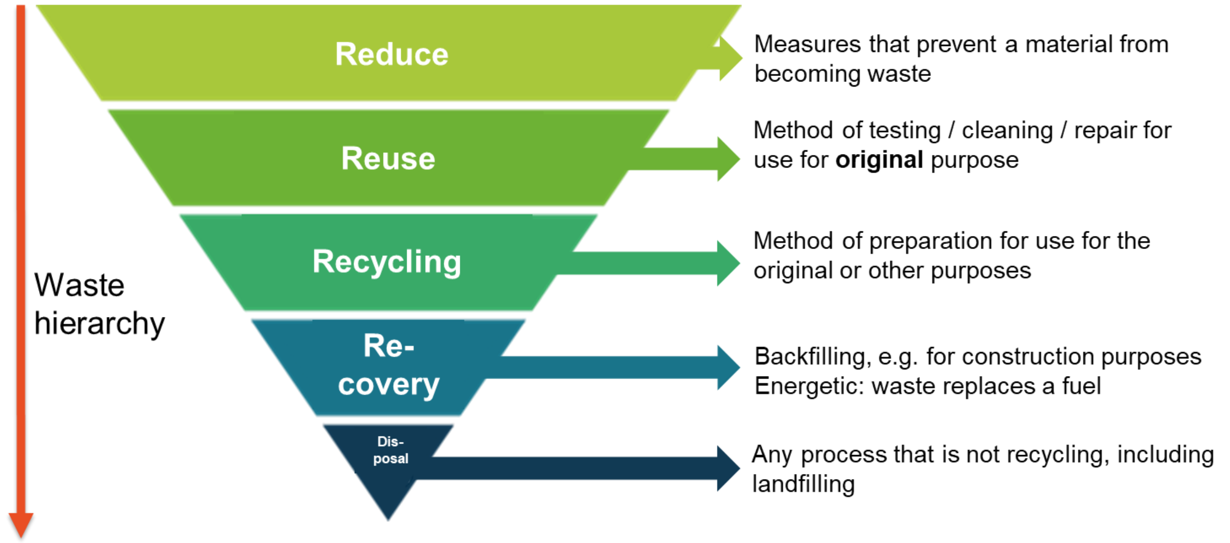
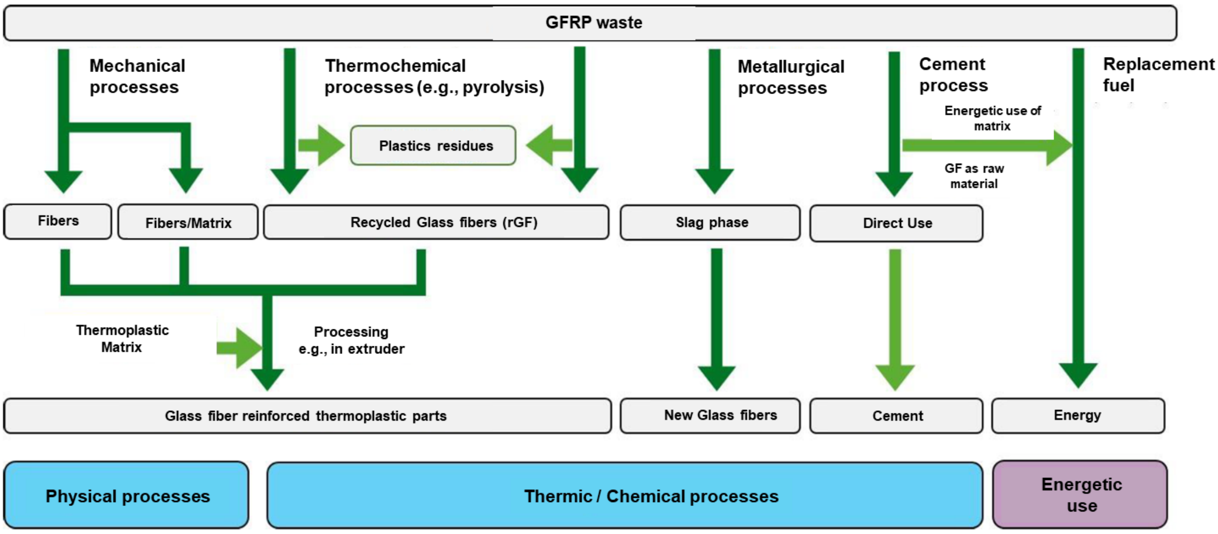


Figure 3: The waste hierarchy

Figure 4: Greenboat's roadmap

Technologies for used materials

The following discussion of end-of-life technologies for composites focused on GFRP, as this type of material is considered more likely to be used in shipbuilding than others. It was generally agreed that suitable technologies are already in place, while the main challenges were seen on the economical area. Figure 5 gives an overview of available technologies, classifying different types of processes which lead to different results (glass fiber reinforced thermoplastic parts, new glass fibers, cement, energy), which correspond with different levels on the waste hierarchy pyramid [10]. Currently, the most widespread end-of-life principles in the transport industry are recycling and recovery, whereas reuse is rarely observed. Particularly the application of mechanical processes is gaining momentum in the wind energy industry. New solutions include shredding and recycling of GFRP from wind turbine blades (EURECUM GmbH) [11], recyclable decking boards with GFRP remnants (Novo-Tech), and recyclate compounds from GFRP residues (iwas-concepts AG) [12].



Source: KIT-ITC, from Development of dismantling and recycling standards for rotor blades, final report, research code 3720 31 301 0, publisher: Federal Environment Agency, TEXTE 92/2022, Dessau-Roslau, August 2022

Figure 5: Overview of GRP recycling / recovery

In principle, thermochemical processes are suitable for utilising both the fibers and the resins of used FRP. However, technical development and existing applications are focusing on recycling the fibers, as they are more valuable. From used resins, oil and gas could be extracted and new polymers could be generated from those, but the costs would not be competitive. Thermochemical processes are currently applied on CFRP materials, but not on GFRP, since the price for GFRP recycled by means of e.g. pyrolysis technology cannot compete with juvenile GFRP.

Several R&D projects have looked into the subject with a view on technology uptake in the wind energy sector. Basically, two paths have been addressed:

- Recycling used materials from existing assets – The Danish funded project CETEC [13] looked into the recycling of rotor blades based on conventional thermoset resin systems. According to reports by project partner Vestas, a technology has been invented that allows extracting new raw materials from used epoxy-based blades, thus avoiding landfill storage which has long been considered unavoidable [14].
- Provide new materials and products which are ready for reuse, recycling etc. – In the ZEBRA project, new recyclable resin systems with intrinsic recyclability have been developed. Process development and the production of 77 m rotor blades has been done which are currently being tested [15].

Pathways and obstacles towards practical circularity

Business cases – For any business that involves recycling, economy of scale is a key criterion for viability of business models. It takes a reliable minimum material volume both on the supply and the demand side – if either of both occurs only sporadically and scattered over the world, it will be hard to create a business. In this respect it is assumed that markets like China will benefit from more favourable framework conditions than e.g. Europe. Looking at industry branches, recycling is gaining momentum in the wind energy sector, as there is a rising volume of GFRP waste. This is not only demonstrated by the numerous R&D activities mentioned above. A cement producer near Hannover is ready to accept 40.000 tonnes of GFRP per year, which corresponds with the annual waste of German wind turbines, representing a reasonable material demand and supply.

There are quite some popular examples for repurposing of used GFRP, including in the general press, e.g. benches or bicycle shelters made of used wind rotor blades. Projects like this are considered reasonable pilot or niche applications, but they cannot be the ultimate solution to the problem, for instance because of the inability of the garden furniture industry to absorb large amounts of GFRP waste from the wind sector in the long run. Also, new windmills would still require juvenile GFRP. Therefore, and in line with the waste hierarchy idea discussed above, reuse should be preferred to recycling.

Long life cycles – Once more, the typically high life expectancy of ships and the complex interrelationships within the maritime industry were highlighted, now with their implications and challenges on creating a circular economy.

The ownership and liability issue – Any novel business model needs to be attractive for the owner of the asset. Nowadays, a ship's owner changes several times over its lifetime, and quite often there is not one single owner at a time but a rather fragmented ownership structure, which adds to the complexity of the endeavour to create attractive incentives for circularity and sustainable recycling. In view of this problem, new business models could become interesting which turn the liability of the manufacturer into an asset. The shipyard and/or the system suppliers remain the owner of the vessel and merely hand it over to the ship operator, offering lifecycle services and finally take care of its scrapping or recycling. In times of increasingly scarce resources, there is a chance that the materials a ship is made of will be seen as an investment with rising value over a vessel's lifetime, and stakeholders in the manufacturing industry could see their role more as a material bank rather than a vendor.

Lacking availability of knowledge and data – There is a widespread lack of knowledge among ship owners on where and how ship recycling could be done, and there are no sufficient means to make such knowledge available on international level. Standardised and agreed methods to characterise materials in terms of their recyclability could help. For the designers of new ships, it would both be important to have access to such material data, but also to have knowledge and methods at hand for creating circularity-ready ships, e.g. standardisation and modularisation in design or easy to disassemble structures.

Regulatory aspects – It is considered that regulations can generally be a useful instrument to enhance recycling. For instance, by making it mandatory to collect waste, the volume of material which is available for recycling can be increased. On the other hand, regulations can also act as an obstacle, e.g. when penalties discourage the introduction of innovative materials.

More specifically with respect to the use of FRP in SOLAS ships, current developments in the International Maritime Organisation (IMO) were discussed, e.g. the International Maritime Organization's (IMO) Interim Guidelines which govern the use of FRP elements within ship structures [2]. A Correspondence Group at IMO's Sub Committee on Ship Design and Construction (SDC) is currently discussing a possible revision of the Interim Guideline. On one side there are considerable concerns against opening the regulations to a wider use of composite materials, arguing that such kind of material should not be used in ships at all because the relatively high difficulty of recycling, let aside fire safety aspects. On the other hand, proponents are pointing out that the issues of FRP regarding recycling are clearly neglectable given their clear and proven advantages such as lightweight or better performance in corrosive environments. The impression is that discussions are often driven by different interests rather than technical facts, which does not really help to speed up the already time-consuming rule making process.

Situations like this have not been observed in the maritime sector only. In the automotive industry for instance, it took a long time until the insight that 98 percent of the lifetime CO_2 equivalent of a car is attributed to its operational phase ensured that a certain break-even point in the discussion was achieved, ensuring a friendlier attitude towards FRP.

Note: Incentives and regulatory instruments as a possible means to enhance circular economy were raised, see documentation to session IV.

Session III: 'Composite Structures nowadays and in the years to come'

Focus on applications of composites in the maritime industry

A presentation by DNV titled 'Advancing Composite Structures: DNV's Current and Future Role in Technology Qualification and R&D' served as introduction to this session. Featuring nine examples from the company's involvement in various research fields, the range of activities and application areas was outlined, along with an assessment of their advantages and challenges as well as the contributions from DNV and other classification societies and regulatory bodies, see Table 2.

Table 2: Summary of Technology areas presented by DNV

Subject	Main benefits ('+') and challenges ('!')	Rules, R&D
1. Composite Superstructure for Large Naval Vessels	+ payload, speed, stability, signature ! blast/ballistic resistance, streamlining the engineering process	DNV Naval rules EU project MaJoR
2. Composite Pressure Vessels for H_2 and CO_2 Maritime Transport – for fuel & cargo tanks	+ enhancing decarbonisation (alternative fuels) ! exotic concepts not fitting in existing standards	New upcoming DNV rules
3. Composite Patch Repair – for Pipes, structures (FRP and steel) in FPSOs etc.	+ cold repairs ! general technical misunderstandings wrt bonded connections	More efficient qualification framework needed, starting with less critical cases
4. Composite Propeller – for Research and naval vessels	+ efficiency, cavitation, noise & vibration, avoid scarce materials (Cu)	rules by BV, Class NK no DNV rules
5. Composite Hatch Cover and Tween Decks – for newbuild and refit of used ships; also hoistable decks	+ simple and scalable design, cheap, non-corrosive, easy repair, stability	DNV rules flag state approval
6. Fire Safety of Composite Structures for Large Ships – for Commercial and naval ships	+ long R&D track at DNV and BV ! Wartime of Naval ships	IMO regulations (SOLAS) DNV drafting MSC.1/Circ.1574
7. Composite Wind Propulsion Systems – for Bulk carrier, Tanker, Roro, Car carrier, MPV, PAX	+ enhancing decarbonisation (alternative propulsion) ! deck space required	DNV Rules […] and Standard […]

Subject	Main benefits ('+') and challenges ('!')	Rules, R&D
8. 3D Printing of Composite Structures – for propellers, impellers, composite repairs, gangway, passerelle	+ New geometric design options, lifetime extension ! trust between stakeholders to be built	DNV-ST-B203 rules for AM of metals and additional RPs and CP; DNV JIP to extend scope to polymers and composites
9. Thermoplastic Composites – for subsea transport of water, gas, HC, H_2 and CO_2	+ Recyclability and reversibility (melting, reshaping retaining material properties), easy, fast and low-cost processing (injection moulding, extrusion, blow moulding, winding), impact resistance	DNV-ST-F119 Future R&D&I on pressure vessels, piping systems for ballast, scrubber systems, wind turbine blades

The examples reminded that much has been done in the past years, and a variety of application areas for composite materials in the maritime industry were created. Besides the obvious benefits of reduced weight (less fuel consumption and/or better payload/deadweight ratio), further advantages are offered by innovative composite materials and related processes. Many of the innovative solutions listed in the presentation have already been implemented. The composite tween deck had to be stopped during the Covid-19 pandemic in the middle of the construction of its first commercial application. It was added that a similar solution for hoistable decks is also conceivable, and Uljanik shipyard in Croatia built a car carrier with removable composite panels on the upper decks, allowing for adding one more deck thanks to reduced weight and a lowered center of gravity [16].

The question was raised whether it can be showcased that those applications which are stemming from naval shipbuilding or the yacht industry could be transferred to the commercial shipbuilding sector. Here, it was pointed out that innovative solutions are easier to be realised in naval applications thanks to the absence of prescriptive rules in this field. Also, the market pull for composites is often missing in the civil sector. Ship owners and also some shipyards shy away from the material for several reasons, including:

- unawareness of shipowners regarding repair methods and other life cycle processes,
- lacking knowledge about R&D results and application possibilities for composites (this can be observed at all stakeholders in the maritime industry),
- lack of ability to to demonstrate overall lifecycle benefits (both economically and ecologically),
- alternative design approval process involving extensive risk assessment, instead of accepting risk based design,
- uncertainty whether unconventional solutions would eventually be approved,
- physical limitations of composites which make their application in very large ships difficult, and require multimaterial designs with suitable joining technologies,
- issues ensuring the prefinancing of newbuild contracts when technical details are unknown at the time of signing the contract.

Notwithstanding these obstacles, there was a great confidence that technology transfer is possible. Again, it is key to identify the suitable business cases. Those should come with low cost, low risk and high potential for scaling. The discussion was concluded with the view that despite some stagnation or backlashes, there should be no reason for being discouraged about a wider use of composites in the maritime field – technologies will find their way, provided that there are people who see viable business cases for them.

Once those are clearly demonstrated, even the creation of more composite-friendly IMO regulations would become possible.

Session IV – creating incentives, overcoming/removing barriers

Focus on activities and needs regarding qualification, approval processes/regulations, and acceptance

The first pitch presentation to this session, 'Thoughts on Digital Product Passports' by Composites United, addressed the issue of lacking data on materials and their recyclability of actual ships. One approach to overcome this is the development of Digital Product Passports (DPPs). In the European funded Project DigiPass [17], DPP concepts are currently being developed, with one of the foci being Composite Materials and their particular properties.

The second pitch presentation focused on the process chain in the maritime industry. 'Environmental certification of shipyards' by Green Marine Europe (GME) introduced an initiative which stems from Canada, in the first place creating a sector-specific label for ship operators and ports, allowing to get certified for their efforts for ecological transition. In a joint effort with the CirclesOfLife project, the initiative is currently rolled out to Europe, at the same time also involving the stakeholders of the ship production, repair/conversion and end-of-life processes. Interested stakeholders need to undergo a certification process (Figure 6) in which several performance indicators are assessed (Figure 7).

Figure 6: Certification process by GME

As already mentioned in the sessions before, the transition from linear to circular economy requires that those who dismantle a ship at the end of its life need to have all relevant information about the materials and the components used, and it should not be their task to find those out. All stakeholders need to be involved in the creation and maintenance of such a data base, including the production supply chain and the lifecycle phases during the ship's service life as well. Sharing data is an issue which is difficult to overcome. Identified requirements include IT (create a neutral unit which can centrally save and provide the relevant data), IPR (sharing material information without disclosing trade secrets), and again viable business models.

With respect to both pitch presentations, it was welcomed that two European Projects (CirclesOfLife and EcoShipYard) are currently addressing the problems, at the same time raising the issue that the projects could come up with different, in the worst case contradicting conclusions and competing solutions. Such a scenario should be avoided by collaboration and exchange in an early phase. Moreover, with respect to sustainability reporting, it would be of utmost importance to create solutions which help stakeholders fulfil their obligations rather than creating new burdens.

GME replied that the idea is to enable stakeholders to demonstrate that they are doing more than what is asked for by existing regulations, and that the certification scheme is not intended to compete with classification societies (GME collaborates with BV, DNV and others). Damen added that they even nowadays get cheaper loans when the fulfilment of green standards is demonstrated. Hence, a business case is already given.

Figure 7: Performance indicators by GME and their applicability to different sectors in the maritime industry

Survey

After session IV, the attendees were asked to answer a survey:

- Question: 'Which of the discussed measures could create the biggest market pull?'
- Mode: Same as survey after session 1
- Possible answers: Eleven possible answers were suggested which had been created spontaneously by the moderator of the session, summarising the contributions to the discussion.
- Outcome: As Figure 8 shows, the answer 'Digital Product Passport' clearly won the most votes. Hence, again the cluster 'enhanced knowledge/transparency' was considered most relevant, together with 'assessment framework' (Cluster 3), while the cluster 'business models' scored slightly worse.

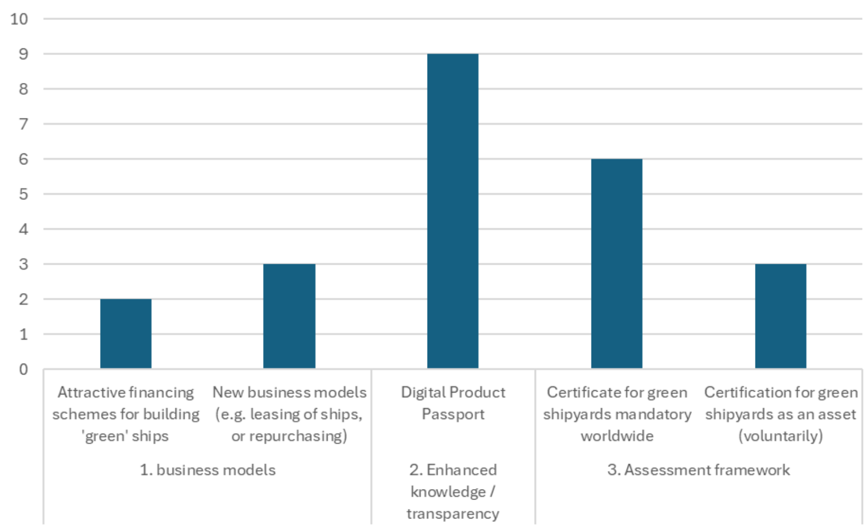


Figure 8: Survey session IV – clustered results

Conclusions

- A workshop report will be drafted and made available to the workshop participants for approval.
- The final report will be included and published in the ISSC 2025 report of Committee IV.2.
- The current members of the Committee are interested in further collaboration on sustainability and circularity in shipping as well as composites and other new materials.
- The CirclesOfLife project and the MariLight network are open for continued dialogue on the said topics.

Appendix

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Glossary