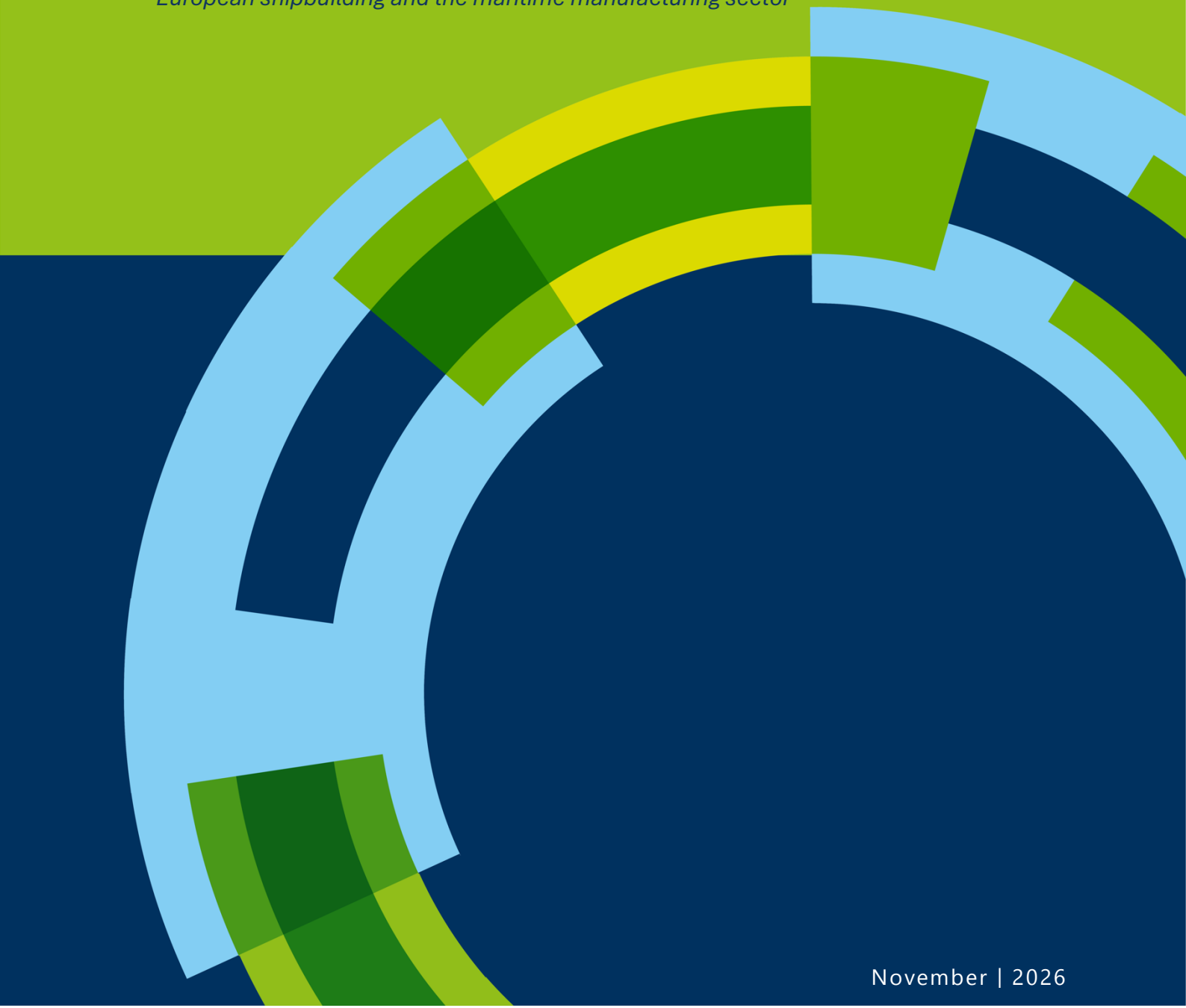
Circles of Life

Booklet

Strengthening EU Shipyards Competitiveness through Enhanced Sustainability

How CirclesOfLife advances Circularity and Competitiveness in European shipbuilding and the maritime manufacturing sector



November | 2026

The project has received funding from the European Union's Horizon Europe Research and Innovation Programme under grant agreement No 101138013

1. The Challenge

Current EU maritime decarbonisation policies focus on reducing ships' operational emissions. As these decline toward 2050 targets, emissions from shipyards and material use – driven by resource intensity and lack of circularity – become increasingly significant. This shift demands urgent attention to maintain the long-term competitiveness, resilience, and strategic autonomy of Europe's shipbuilding and maritime manufacturing sector. The industry spans ship production, maintenance, repair, retrofit, and conversion, alongside a vast supply chain of maritime systems, technologies, and services. It supports[1]:

- Total 52,000+ number of enterprises in the EU maritime manufacturing industry
  - 5,000+ in ship- and boatbuilding
  - 10,000+ in repair of ships and boats
  - 37.000+ in equipment and technology suppliers
- Total 533,000 direct jobs
- Total €153 billion annual production value

However, growing reliance on third countries threatens Europe's industrial sovereignty. The sector's complexity, high-tech nature, and investment intensity make lost capabilities hard to recover. Strengthening this ecosystem is vital for Europe's green transition, defence, and economic security.

2. The Issue

EU shipyards face increasing pressure to reduce emissions and material footprints while competing with regions operating under lower environmental and labour standards. The following key challenges hinder the adoption of circular practices and limit the sector's ability to meet sustainability goals:

- Fragmented data and inconsistent reporting
- Lack of transparency on environmental impacts
- Absence of clear, actionable guidance for decision-makers

3. CirclesOfLife: A strategic response

The Horizon Europe CirclesOfLife project (Grant No. 101138013) delivers practical tools to help the EU maritime sector advance circularity, reduce emissions, and align with evolving policy frameworks. Developed in collaboration with shipyards and stakeholders across Europe, CirclesOfLife's solutions include, on one hand, the Shipyard Environmental Performance Index (SEPI), and on the other hand, the Ship Lifecycle Passport (SLP) and Ship Circular Materials Passport (SCMP).

1 In the EU, the shipbuilding and ship repair sector and the 1st and 2nd tier suppliers represent a €153 billion annual production value. The shipbuilding and ship repair sector and the 1st tier suppliers represent 533,000 direct jobs. The 1st tier suppliers includes nearly 37,000 companies. Source: SEA Europe (2025)

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4. Environmental footprint of shipyards

4.1. Shipyard Environmental Performance Index (SEPI)

The **Shipyard Environmental Performance Index (SEPI)** will evaluate the environmental footprint of shipyard processes. This unique standardised software tool will support assessing and improving shipyard sustainability and circularity across newbuilds, repairs, and end-of-life operations.

As a building block of the SLP, SEPI enables:

- Benchmarking and hotspot identification to target environmental improvements,
- Adoption of cleaner and more circular technologies,
- Environmental, social, and governance (ESG)-driven branding and access to green finance,
- Information about the environmental footprint of the shipbuilding process,
- Incentivisation of Best Available Techniques (BATs).

However, there is currently no single standardised methodology for calculating environmental performance. To ensure consistency and a reliable digital passport for the maritime sector, alignment or clear guidelines on environmental and circular assessment methodologies will be critical. SEPI's proposition and tools are positioned to meet this challenge. In this case, the CirclesOfLife project is working with several European shipyards on specific case studies. These "living labs" aim to create digital tools and modelling systems, which could provide useful ideas and examples for putting the Circular Economy Act (CEA) regulation into practice and help with an initial learning phase.

The results of the SEPI are a needed building block for developing and setting up the passports which are described in the next section.

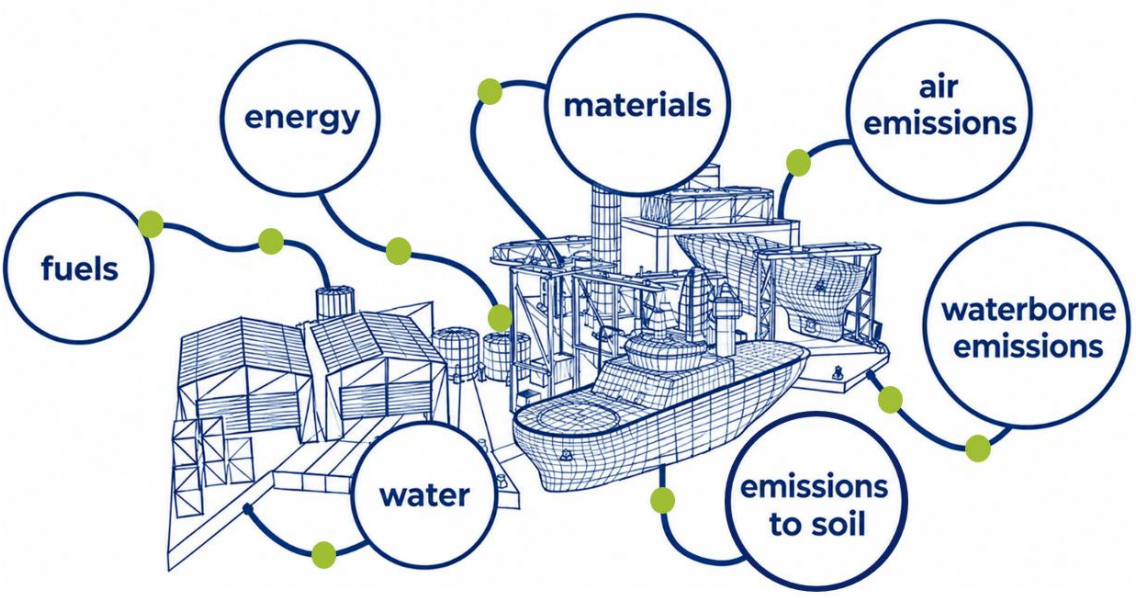


Figure 1: Shipyard's in- and outflows relevant for Shipyard Environmental Performance index

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4.2. SEPI software tool

Based on the experiences and best practices contributed by the industry partners within the consortium, industry standards are developed and regulatory requirements are translated into the context of shipbuilding processes. This exercise highlighted the need for a digital solution that could turn these **standards and best practices into practical guidance.** This resulted in the development of the SEPI software tool.

The aim of developing this tool SEPI digital solution is to **enable accurate assessments of environmental performance, facilitate compliance, and alignment with industry standards.** The diversity of organisations realising the tools, creates added value by combining scientific methods with operational experience and societal validation. The software is developed and validated by the industry partners, see Figure 2 for an illustrative example of the SEPI dashboard.



Figure 2: Shipyard Environmental Performance Index Dashboard (BALance Technology Consulting GmbH)

4.3. Case studies

Within CirclesOfLife, case studies are carried out together with industry partners to investigate into new and more sustainable technologies in real shipyard environments. They cover different stages of the ship lifecycle, including newbuild, repair, and end-of-life, as well as a range of shipyard processes. The case studies have **two main objectives**: **to demonstrate and assess innovative technologies in practice, and to analyse their environmental impact at shipyard level including through the application of the SEPI software tool.** The case studies have now been completed, and the final reporting is being prepared. This booklet provides a sneak preview of two case studies, highlighting the technologies that are investigated and the results and experiences from their practical application. It also presents the experience gained from using the SEPI software tool to assess their environmental impact.

The first case study, from DAMEN, focuses on the repair phase and the application of a new paint repair robot. The second case study, from FSG S+O GmbH, focuses on the newbuild phase and the application of a new welding technology.

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Case Study | DAMEN

Company Description

DAMEN, global shipyard group, is committed to environmental sustainability and aims to become the most sustainable maritime solution provider in the world. The main focus of the case study was on **Damen Shiprepair Dunkerque**. Other Damen yards were also consulted as part of the benchmarking process.

Ship Lifecycle Scope Technology Impact

The case study focuses primarily on the repairing phase of the ship lifecycle. The main focus of Damen Shiprepair Dunkerque yard is on the repairing oceangoing vessels.



Improving Environmental Performance During Paint Repair



Scope Definition

Ship repair yards, particularly those near urban areas, aim to reduce the environmental and health impacts of surface treatment activities. The **Paint Repair sub-study compares the environmental performance of manual and robotic paint application** per square metre of hull surface, covering the full surface-treatment process from hull washing and paint removal to the application of new protective coatings.

Key Objectives

- **Surface treatment (paint repair):** Reduce Volatile Organic Compound (VOC) emissions and paint overspray.
- **Waste management:** Reduce waste streams and optimise water usage.
- **Innovative energy management:** Assess the availability and use of yard energy data for identifying and evaluating energy-improvement measures.

Key Technology

As-Is

The as-is process relies on manual hull washing, hull cleaning, paint removal and spray application.

To-Be

The to-be process introduces robotic and enclosed systems to improve transfer efficiency and reduce paint overspray and VOC emissions.

"Shipyard prioritises energy efficiency, pollution reduction, and waste reduction"

Results

1. **Hull washing:** The robotic system combines hull washing with surface treatment, capturing removed biofouling and.
2. **Paint removal:** Closed-loop robotic high-pressure water blasting removes paint while capturing and filtering paint residues, with proven purified reusable water and only 1.4% water spill reported.
3. **Paint application:** Robotic painting can reduce paint consumption by at least 20% and limit overspray, although the required speed, coating consistency, and quality were not yet achieved.

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Case Study | DAMEN

Key Insight

Robotic surface treatment offers **clear environmental benefits through integrated hull washing, reduced paint consumption and overspray, and significantly lower water losses during paint removal.** This leads to more energy efficient shipyard operations and reduction of waste and pollution. Further research and technological refinement can help achieve the required quality, productivity, and economic viability for wider industry adoption.



Lesson Learned

Data availability remains a challenge for environmental impact assessments. SEPI drives repair yards to take greater control of data collection and assessment and providing better insights for improvement.

Recommendation & Next Step

Continue investing in the development of robotic surface treatment, focusing on overcoming current performance limitations and demonstrating that the technology can deliver the promised environmental, health, operational and economic benefits in practice.

"Without the SEPI software the sector cannot do the calculations that enhance sustainability and business decisions"



Case Study & SEPI Tool

CirclesOfLife showed how **SEPI, reliable data and industry collaboration** can help shipyards consistently measure environmental performance, build on each other's knowledge and ideas, and translate these insights into practical improvements and better-informed decisions. Software tool is needed to do the calculations, analysis (hotspot, re-use existing data, enhancing data) and support business decisions.

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Case Study | FSG S+O Design GmbH

FLENSBURGER SHIPYARD

Company Description

The case study focuses on FSG S+O Design GmbH with approximately 350 people working at the yard. The yard combines bespoke in-house design, engineering, streamline steel production, pre-outfitting, coating, assembly and final outfitting activities.

Ship Lifecycle Scope Technology Impact

The case study focuses primarily on the newbuilding phase of the ship lifecycle. The main focus of the yard is on the newbuilding of Roll-on/Roll-off (RoRo), Roll-on/Roll-off Passenger (RoPax) ferries and other tailor-made vessels and steel structures including offshore purposes.



Reducing Electricity Consumption During Welding



Scope Definition

FSG S+O follows a streamlined RoRo production process, progressing from steel processing and module construction through pre-outfitting, surface preparation and coating to assembly, launching and final outfitting. This case study focuses on the **welding activities** within the yard. Welding machines stand idle for most of the operating time, both welding and idle consumption are addressed, by comparing older welding machines with modern ones. The improvement is measured as the electricity used per meter of weld.

Key Objective

Reduce the electricity consumption of gas metal arc welding (GMAW) in the production of steel structures for RoRo vessels.

Key Technology

As-Is

An older gas metal arc welding machine with manually set controls (voltage, current, wire speed).

To-Be

A modern welding machine that meets the EU Ecodesign requirements for welding equipment (Regulation (EU) 2019/1784), with digital controls, a pulse arc function, automatic shutdown when not in use and built-in cloud monitoring of welding jobs and energy use.



Source: ESAB website

Results

Replacing the older welding machine with the modern model **reduced energy consumption per meter of weld by 6% during welding, and 16% including idle time at assumed 30% arc-on time** and **added monitoring capabilities for weld quality** and **staff awareness**, although further optimisation is needed to achieve its full efficiency potential.



"Welding machines stand idle for most of the operating time, both welding and idle consumption are addressed, by comparing older welding machines with modern ones"

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Case Study | FSG S+O Design GmbH

Key Insight

Monitor and reduce welding-machine energy consumption during idle periods, as manual and semi-mechanised welding machines are idle for much of their operating time; modern machines with automatic shutdown functions can significantly reduce this unnecessary energy use.



Lessons Learned

1. **Increasing process detail** makes it more difficult to allocate energy consumption accurately, particularly when equipment is shared across multiple processes or production areas.
2. **Direct comparison** between the as-is and to-be situations is challenging when identical machine settings and specifications are not available, making longer-term assessment valuable.
3. **Welding methods, parameters and materials** strongly influence energy use, emissions and weld quality, while the chosen assessment focus can also affect the results.

Case Study & SEPI Tool

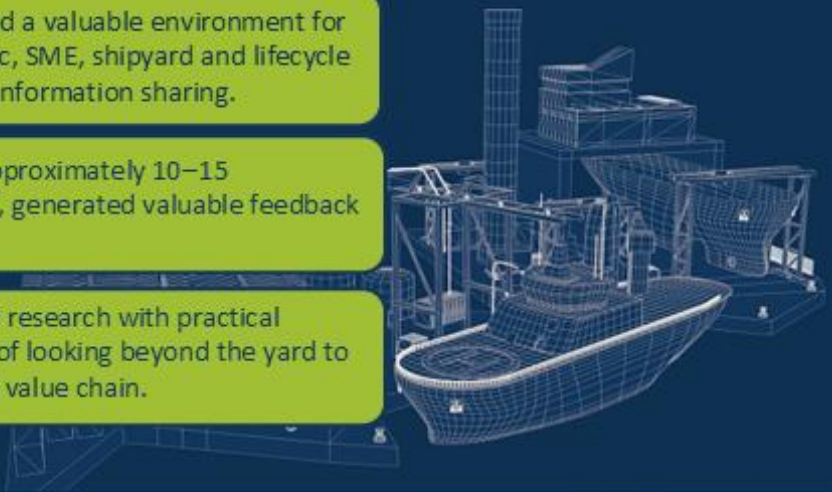
The layout view within SEPI was particularly useful for **bridging the gap between high-level process analysis and detailed yard-level assessment**. By linking processes to physical areas, equipment and meter readings, it provides a more practical understanding of yard operations from process management, efficiency and HSEQ perspectives. This is especially valuable where equipment serves multiple processes or areas, which becomes increasingly difficult to capture as the analysis becomes more detailed.

Recommendation & Next Step

Continue participating in collaborative R&D projects, further develop and test the SEPI tool, and transfer the knowledge gained to other projects. This is particularly valuable for FSG S+O, as project participation provides the time and opportunity to apply innovative solutions that might otherwise not be explored due to uncertain outcomes and restricted resources.

CirclesOfLife Experiences

1. **Collaboration and expertise:** CirclesOfLife provided a valuable environment for exchanging knowledge and learning from academic, SME, shipyard and lifecycle perspectives while respecting boundaries around information sharing.
2. **Internal engagement and awareness:** Involving approximately 10–15 colleagues, from management to operational staff, generated valuable feedback and strengthened internal awareness.
3. **Learning through research:** The project combined research with practical shipyard knowledge and demonstrated the value of looking beyond the yard to understand impacts across the wider lifecycle and value chain.



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5. Anchoring circularity in the European maritime sector

5.1. Ship Lifecycle Passport (SLP) & Ship Circular Materials Passport (SCMP)

Based on the **Digital Product Passport[2] (DPP)** guidelines outlined in the **Ecodesign for Sustainable Products Regulation[3] (ESPR)** and adapted for the maritime sector, CirclesOfLife is developing a blueprint for a **Ship Lifecycle Passport (SLP)** and a **Ship Circular Materials Passport (SCMP).** As part of this process, the DPP and ESPR guidelines are being analysed and translated for application within the maritime manufacturing industry. The SCMP functions as a material passport at the component level of a ship, while the SLP covers the vessel as a whole, aggregating data from all SCMPs. Together, these digital passports will enable traceability of materials and environmental impacts throughout a ship's entire lifecycle.

The SLP and SCMP contribute directly to the objectives of the **EU Circular Economy Act**[4] by:

- Bridging data gaps across the value chain for transparent, informed decision-making;
- Easing compliance with EU design, repair and maintenance, and waste legislation;
- Translating DPP and ESPR guidance into standardised digital tracking for shipping;
- Embedding 9R circular strategies, such as reuse, repair, refurbishment, to maximise circular value retention recovery of high-value materials.



Figure 3: CirclesOfLife's Ship Circular Materials passport (SCMP) and Ship Lifecycle Passport (SLP)

[2] The Digital Product Passport (DPP) is a digital container for products, components, and materials, which will store relevant information to support products' sustainability, promote their circularity and strengthen and facilitate legal compliance. Sources: Digital Product Passport - European Commission

[3] The ESPR is a piece of framework legislation that lays the foundation for the subsequent adoption of concrete rules, either on a product-by-product basis or horizontally, based on groups of products with similar characteristics. Source: Implementing the Ecodesign for Sustainable Products Regulation - Green Forum

[4] Ellen Macarthur Foundation (March, 2026) Circular Economy ACT: Key policy levers for Europe's Industrial Strategy

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5.2. Building the blueprint: what the project has designed

CirclesOfLife's blueprint establishes a common structure for organising ship and component information. It combines a widely used **five-level product breakdown structure**[5] with the yard's own **Manufacturing Bill of Materials**[6] **(MBOM),** geographical location data, and key circularity attributes such as detachability, recycled content, and recyclability. By connecting these elements, the blueprint provides shipyards and digital systems with a common and repeatable way of organising information, rather than requiring each yard to develop its own incompatible structure.

Building on this common structure, the **Ship Lifecycle Passport (SLP)** brings together information that is already generated and reported by shipyards. It is designed to include the complete Bill of Materials, environmental performance data (LCA[7], LCPA[8] and SEPI-based yard impact), operational performance data (EEDI/EEXI[9], CII[10]), and hazardous materials information aligned with the existing Inventory of Hazardous Materials (IHM) under the EU Ship Recycling Regulation (SRR). The passports therefore build on existing reporting practices rather than creating a parallel system.

The **Ship Component Materials Passport (SCMP)** complements the SLP by providing more detailed information at material and component level. This includes composition, mass, origin, recycled content, detachability/separability, and end-of-life options. Together, the SLP and SCMP create a structured information base that supports the assessment and improvement of circularity throughout the ship lifecycle.

The blueprint further incorporates specific methodologies to assess circularity performance. Two indices form the basis of this assessment:

1. the **Material Circularity Index (MCI),** which combines material inflow and outflow with the hierarchy of circular strategies 'R-ladder', usage intensity, and design for life.
2. **Disassembly Potential**, which considers connection type, accessibility, and the efforts required for disassembly. Both indices are adapted from methods already validated in other sectors.

In addition, a **hotspot analysis** helps decision-makers identify where circularity improvements can have the greatest impact, for example through alternative material choices or improved disassembly design. Finally, a **maturity model** provides a roadmap for the progressive adoption of the passport framework. The model consists of three levels: (1) what is currently feasible and available, (2) what is expected to be feasible within 3 to 5 years, and (3) what is expected to be feasible within 10 years. This phased approach provides a clear pathway towards future capabilities and supports adoption by allowing shipyards and other stakeholders to progressively build on existing capabilities.

[5] Ship Function Identification (SFI) or Expanded Ship Work Breakdown Structure (ESWBS), referring to five levels: product, system, sub-system, assembly, and part.
[6] Manufacturing Bill of Materials (MBOM) is the structured list of all the parts, components, materials, and assemblies required to manufacture and assemble a product.
[7] Lifecycle Assessment (LCA)
[8] Lifecycle Performance Assessment (LCPA)
[9] Energy Efficiency Design Index (EEDI) and Energy Efficiency Existing Ship Index (EEXI)
[10] Carbon Intensity Indicator (CII)

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5.3. From research to reality: Damen's Circular Crew Cabin

Damen Shipyards has developed a circular crew cabin concept built around circular materials, modularity, repairability, and material recovery. Components are designed to be disassembled and replaced individually rather than discarded as a whole unit. Materials are selected and documented with reuse in mind, and the cabin is being used as a live pilot for a Digital Product Passport at component level, precisely the kind of data the SCMP is designed to hold.



Figure 4: Circular Crew Cabin outside

The cabin provides a concrete illustration of a broader shift that CirclesOfLife is promoting: moving circularity thinking beyond individual materials towards entire modules and sections of a ship. This approach could enable shipyards to reuse not only recycled steel plates, but also entire pre-fitted cabin subcomponents.

The SCMP and updated **Bill of Materials** developed for the Circular Crew Cabin project were validated in collaboration with Meyer Werft to assess improvements in the circularity of their interior wall system. The validation included calculating optimised **the Material Circularity Index (MCI)** and assessing the system's **Disassembly Potential** with the developed Circularity Assessment Tool (CAT)**.** An important aspect of the validation was also the collection and verification of reliable material and product data from suppliers.


Figure 5: Circular Crew Cabin inside – DAMEN Shipyards

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6. Value chain approach & best practices

Strengthening the maritime value chain requires a dedicated working group bringing together shipyards, suppliers, owners, recyclers and classification societies around the passports. This collaboration can support sharing costs and benefits while building the trust needed for widespread adoption.

Learning from other sectors

- **Construction:** Madaster and the DGNB Building Resource Passport already implement material passports for buildings, while the DeConstruct project assesses circularity before demolition. These provide direct analogues for the SLP and SCMP.
- **Batteries:** The EU Battery Regulation and Battery Pass project demonstrate how mandatory traceability and social due-diligence data can be structured, informing the future development of social indicators for the passports.
- **Composites:** The DigiPass project demonstrates how data on hard-to-recycle materials, such as fibre, resin and foam type, batch, and connection method, can be structured for components such as those used in ships.

CirclesOfLife also interacts with sister EU initiatives, including CIRPASS, CIRPASS-2 and EcoShipYard (ESY), to keep data models interoperable and avoid duplicating effort.

7. Major roadblocks to circularity and how to overcome them

Even with this momentum, three roadblocks still stand between today's pilots and sector-wide adoption: Regulatory clarity, Governance & Assurance, and Economic misalignment.



The results are designed to meet current and **emerging EU frameworks**, including Corporate Sustainability Reporting Directive (CSRD), Industrial Emissions Directive (IED), Circular Economy Act (CEA), EU Ship Recycling Regulation (SRR), Ecodesign for Sustainable Product Regulation (ESPR) and the Digital Product Passport (DPP), and **voluntary standards** such as the Green Passport and Global Reporting Initiative (GRI). Turning that alignment into a working, sector-wide standard takes coordinated action on two fronts: Industry and Policymakers.

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7.1. What it takes from industry

A **sector-wide agreement** is needed on a common minimum dataset and harmonised breakdown structure to ensure that passports are comparable across shipyards. At the same time, **commercial-sensitivity concerns** around sharing Bills of Materials and process data need to be addressed, alongside clear responsibilities for who creates, maintains, and remains accountable for the data as a ship changes hands. For **existing vessels** without digital records, support should also be provided to develop passports through reverse-engineering based on available documentation.

7.2. What it takes from policymakers

Regulatory clarity: ESPR's current silence on ships leaves timelines and minimum requirements uncertain. An explicit maritime scope would give shipyards and other value-chain actors a clear target to work towards, supported by a coherent legal framework for ship lifecycle management under the CEA, SRR, ESPR/DPP.

Governance & assurance: DPP data need clear ownership and governance, including responsibility for an EU-level repository and a credible mechanism for data verification and assurance. Classification societies, for example, could play a role in verifying the reliability and integrity of passport data, ensuring that the DPP becomes a trusted tool across the value chain. A dedicated working group on the DPP within the EU Industrial Maritime Value Chains Alliance could support coordination and implementation.

Economic alignment: The shipyard that bears the upfront cost of creating a passport may not capture its value later in the vessel's lifecycle, therefore policy should better align costs and benefits across the value chain. Dedicated financial instruments and tax incentives, public procurement that rewards circularity, Horizon Europe-backed innovation and scaling support, and a gradual, impact-assessed use of Carbon Border Adjustment Mechanism (CBAM) could help reduce lifecycle costs, incentivise circular practices and support the uptake of DPP and other circular solutions.

8. How does the results contribute to strengthening the maritime value chain and the competitiveness of the industry?

- **Bridges the value chain's data gaps**, connecting shipyards, suppliers, owners, repairers and recyclers around one shared, standardised dataset instead of fragmented, incompatible records - reducing duplication of effort and rework across the supply chain.
- **Opens access to green finance markets**, letting yards and owners demonstrate sustainability and traceability credentials that support green procurement criteria, sustainability-linked lending and access to EU funding instruments.
- **Unlocks the value of secondary raw materials**, particularly high-value steel: better material data at end-of-life increases the quality, verifiability and resale value of recovered materials, feeding the competitive single market for secondary raw materials the Circular Economy Act aims to build.

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- **De-risks investment decisions**, giving owners and yards the lifecycle data needed to plan retrofits, maintenance and modular, zero-emission technology upgrades with more confidence, and better access to financing as a result.
- **Positions EU shipbuilding as a transparency, traceability and sustainability leader**, turning compliance with tightening EU legislation (ESPR, DPP, EU SRR) into a source of differentiation rather than a cost, and strengthening the sector's long-term resilience and strategic autonomy against external competition.

9. Embedding Digital Product Passports in the EU Industrial Maritime Value Chains Alliance

The **EU Industrial Maritime Value Chains Alliance (EMA)**, launched by the European Commission in September 2026 as part of the EU Industrial Maritime Strategy (EIMS), has the opportunity to provide a highly relevant forum for the further uptake of the CirclesOfLife results: it brings together maritime manufacturers, upstream suppliers, downstream users, EU countries, investors, social partners, academia and civil society around a shared general assembly, a steering board and thematic working groups of field experts, with a mandate to map supply and demand barriers, build pipelines of strategic projects, and strengthen European maritime value chains' competitiveness.

CirclesOfLife recommends establishing a **dedicated workstream on Digital Product Passports within the EMA**, giving the SLP and SCMP a permanent, cross-industry home to agree the common minimum dataset, harmonised breakdown structure, governance and verification roles the passports depend on, and turning what is today a project-level blueprint into an industry-wide standard backed by the same alliance tasked with scaling up Europe's maritime manufacturing capacity.

10. Conclusion

CirclesOfLife offers actionable, policy-aligned solutions to decarbonise and future-proof Europe's maritime sector. By delivering Shipyard Environmental Performance Index (SEPI), the Ship Lifecycle Passport (SLP) and the Ship Circular Materials Passport (SCMP), the project strengthens transparency across the value chain and turns circularity into a competitive advantage. Continued EU support is essential to scale these tools and secure Europe's leadership in sustainable shipbuilding.

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Partners

Contact

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