Circles of Life

Deliverable D1.1 -

SEPI concept - Shipyard Environmental Performance measurement system

June | 2025

Project acronym:	Circles of Life
Project full title:	Enhancing material CIRCularity and Lower Emissions of Shipbuilding processes in all phases OF the LIFE cycle
Grant agreement No.	101138013
Coordinator:	Damen Research Development & Innovation BV

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

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

1. Deliverable data

Deliverable No	1.1		
Deliverable Title	D1.1 - SEPI Concept - Shipyard Environmental Performance measurement system		
Work Package no: title	WP1 Concept and methodology definition		
Task(s)	T1.1 Concept and specification for SEPI T1.3 Initial concept for evaluation and reporting of environmental footprint		
Dissemination level	PU – Public	**Deliverable type**	R – Document, report
Lead beneficiary	FSG, DRDI		
Responsible author	Theresa Wilson (FSG), Martin Verboom (DRDI), Mark Lansiaux (DRDI)		
Co-authors	BAL, BV, CMT, DRDI, ERIKS, FSGNK, SBP, GME, TUD, UNIG, VTT		
Date of delivery	30-06-2025		
Approved	**Name (partner)**		**Date [DD-MM-YYYY]**
Peer reviewer 1	Theresa Wilson (FSG)		26-06-2025
Peer reviewer 2	Thulasi Vattekkatte (BAL)		27-06-2025
Peer reviewer 3	Rosanne van Houwelingen (NMTF)		26-06-2025
Quality check	Jeroen Pruyn (TUD)		29-06-2025

Document history

Version	Date	Description
1.0	14-05-2025	First draft created
2.0	24-06-2025	First complete version ready for peer review
3.0	27-06-2025	Peer review conducted, ready for final quality check
4.0	30-06-2025	Final version

The research leading to these results has received funding from the European Union Horizons 2020 Programme under grant agreement n° 101138013.
Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor the granting authority can be held responsible for them.

The information contained in this report is subject to change without notice and should not be construed as a commitment by any members of the CirclesOfLife Consortium. In the event of any software or algorithms being described in this report, the CirclesOfLife Consortium assumes no responsibility for the use or inability to use any of its software or algorithms. The information is provided without any warranty of any kind and the CirclesOfLife Consortium expressly disclaims all implied warranties, including but not limited to the implied warranties of merchantability and fitness for a particular use.

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

2. List of symbols and abbreviations

2.1. Partners and projects

BAL	Balance Technology Consulting GmbH
BV	Bureau Veritas Marine and Offshore
CET	Cetena SPA Centro Per Gli Studi di Tecnica Navale, Fincantieri Group
CMT	Center of Maritime Technologies GmbH
DRDI	Damen Research Development & Innovation BV
ERIKS	Eriks BV
EU	European Union
FSG	Flensburger Schiffbau-Gesellschaft mbH
FSGNK	Flensburger Schiffbau-Gesellschaft mbH, FSG-Nobiskrug Design GmbH
GAL	Galloo
GME	Green Marine Europe
H2020	Horizon 2020
CCA	CirclesOfLife Consortium Agreement
NMTF	Netherlands Maritime Technology Foundation
SBP	NGO Shipbreaking Platform
SEA	Shipyards and Maritime Equipment Association of Europe
TUD	Technische Universiteit Delft
UNIGE	Universita Degli Studi di Genova
VTT	Teknologian Tutkimuskeskus VTT Oy

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

2.2. Terms and abbreviations

AFIR	Alternative Fuel Infrastructure Regulation
ASI	Aluminium Stewardship Initiative
BAT	Best Available Technique
BPM	Business Process Model
C2C	Cradle-to-Cradle (registered trademark)
CBAM	Carbon Border Adjustment Mechanism
CEAP	Circular Economy Action Plan
CE	Circular Economy
CMP	Circular Material Passport
CN	Combined Nomenclature
CoL	CirclesOfLife
CSR	Corporate Sustainability Reporting
CSRD	Corporate Sustainability Reporting Directive
DFSS	Design for Six Sigma
DMA	Double Materiality Assessment
DPP	Digital Product Passport
EED	Energy Efficiency Directive
EGD	European Green Deal
ESG	Environmental Social Governance
ESPR	Ecodesign for Sustainable products regulation
ESRS	European Sustainability Reporting Standards
EU	European Union
FU	Functional Unit
GA	General Assembly
HS	Harmonised System (for international trade)
IDDOVD	Identify, Define, Design, Optimize, Verify, Document
ILCD	International Reference Life Cycle Data System
IMO	International Maritime Organisation
ISO	International Organization for Standardization
KPI	Key Performance Indicator
LCA	Life Cycle Assessment

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

LCCA	Life Cycle Costing Assessment
LCIA	Life Cycle Inventory Assessment
LCPA	Life Cycle Performance Assessment
MARPOL	International Convention for the Prevention of Pollution from Ships
Proposal	CirclesOfLife Proposal (CirclesOfLife, 2023)
R&L	Rules and Legislation
SBTi	Science Based Targets initiative
SCMP	Ship Circular Materials Passport
SDG	Sustainable Development Goals
SEPI	Shipyard Environmental Performance Index
SLP	Ship Lifecycle Passport
SME	Small and Medium-sized Enterprises
T	Task
WP	Work Package

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

3. Contents

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

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

4. EXECUTIVE SUMMARY

The CirclesOfLife (CoL) project, funded under the EU Horizon 2020 programme, aims to enhance material circularity and reduce emissions across all non-operational phases of the shipbuilding lifecycle. Central to this initiative is the development of the Shipyard Environmental Performance Index (SEPI), the Ship Lifecycle Passport (SLP), and the Ship Circular Materials Passport (SCMP). The methodology, framework and support tools are designed to enable shipyards in transitioning toward a zero-emission future while aligning with the European Union's Corporate Sustainability Reporting Directive (CSRD) and the European Sustainability Reporting Standards (ESRS).

Deliverable 1.1 consists of the execution of Task 1.1 (T1.1) and Task 1.3 (T1.3). T1.1 involves defining the concept and specifications of a SEPI measurement system, including the breakdown and calculation of relevant Key Performance Indicators (KPIs), as well as the functional units to be investigated. T1.3 focuses on providing a concept for evaluating the environmental footprint and reporting, in alignment with existing and upcoming standards.

4.1. Comparative analysis of environmental regulations and standards (T1.1a)

A comprehensive comparative analysis of current and emerging environmental regulations and standards was conducted to establish a regulatory foundation for SEPI, SCMP, and SLP. This analysis identified and categorized over 60 relevant frameworks, including ISO standards (e.g., ISO 14001, ISO 50001), EU directives (e.g., CSRD, ESPR, EED), and voluntary initiatives (e.g., Green Marine Europe, GRI, SBTi). These were mapped against ESG domains, ship lifecycle phases (based on a adjusted version of EN15978:2011, see APPENDIX 3: Ship lifecycle phases based on EN15978:2011), and shipyard types (Newbuild, Repair & Conversion, End-of-life), and aligned with ESRS topics E1–E5. This mapping ensures that SEPI is both forward-looking and grounded in current compliance obligations.

4.2. Initial concept for SEPI (T1.1b)

The SEPI framework is designed to measure, assess, report and improve the environmental performance of shipyard processes. It integrates stakeholder requirements gathered through user stories and workshops, ensuring relevance across the maritime value chain—from shipowners and shipyards to equipment suppliers and classification societies. The SEPI methodology includes:

- A digital twin-based generic shipyard model
- Process-based environmental footprint assessment
- Integration with Life Cycle Assessment (LCA) tools and CSRD reporting
- A scoring system based on measurement maturity levels and Environmental, Social and Governance (ESG) performance KPIs relevant to the yards in scope

The SEPI tool will enable shipyards to identify environmental hotspots, simulate improvements, and report transparently using standardized metrics and Key Performance Indicators (KPIs).

4.3. Concept and methodology of evaluating and reporting environmental footprint (T1.3)

The developed concept of the SEPI scoring system is structured around a two-dimensional matrix: ESG performance (aligned with ESRS) and data maturity (from estimated and calculated, to real-time measured data). Scores range from 1 (baseline) to 100 (lowest environmental impact for available technology identified in the case study investigations), with maturity levels from D to A+. This approach encourages continuous improvement and supports strategic investment planning.

Key methodological pillars include:

- Alignment with CSRD and ESRS for seamless sustainability reporting
- Integration with ISO 50001 for energy management

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

- Compatibility with Green Marine Europe certification
- Use of functional units and emission factors for process-level impact assessment
- Support for small and medium sized enterprises/shipyards SMEs through scalable data requirements and generic yard models

The SEPI tool is not only a compliance mechanism but also a strategic enabler for decarbonization, circularity, and sustainable competitiveness in the European shipbuilding sector.

The next steps in WP2 (Implementation and means for assessment) and WP3 (Validation and assessment of emissions) will ensure that these concepts are implemented, tested, and refined for practical application across the industry. WP2 focuses on developing the software tool for the SEPI, which supports shipyards in applying the SEPI to their own processes. WP3 develops case studies and a best practice guide to support industry stakeholders in putting the results into practice.

5. Introduction

T1.1 has involved the concept and specifications of a SEPI measurement system definition, including the breakdown and calculation of relevant Key Performance Indicators (KPIs) and the functional units to be investigated. T1.3 focused on providing a concept for evaluation of the environmental footprint, linked to reporting against existing and upcoming standards and EU legislation, specifically CSRD and ISO 50001. First, Chapter 6 outlines the objectives and targets of Deliverable 1.1, derived from the implementation of Task 1.1 and Task 1.3. Chapter 7 provides a detailed explanation of the methodology applied in the execution of these tasks. Chapter 8 describes the execution plan and Chapter 9 presents the results and progress achieved. Finally, Chapter 10 offers concluding remarks, summarizing key findings and insights.

6. Objective and targets

In this Deliverable 1.1 (D1.1) the execution of Task 1.1 (T1.1) and Task 1.3 (T1.3) is covered based on the objective and task description in the CirclesOfLife Proposal B (CoL Proposal (CirclesOfLife, 2023)). This is analysed, and an approach and sub-tasks are presented.

The tasks and objectives that T1.1, T1.3 and this deliverable, D1.1 is solving are based on different sources in the CirclesOfLife Proposal B document:

- WP1 general objectives
- Task 1.1 and Task 1.3 task description
- Contribution to the CirclesOfLife overall project objectives

In the following sub-chapters, the specific sections of the report, as mentioned in the bullet points above, will be reviewed.

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

6.1. WP1 objectives

The main objective of T1.1 and T1.3 are stated in the overview of the objectives on page 32 in the CirclesOfLife proposal. This can be seen in Figure 1.

Work package number	1 (Lead: FSGNK)
Work package title	Concept and methodology definition

Objectives

WP1 addresses the development of concepts and methodologies required for the development, implementation and reporting of the Shipyard Environmental Performance Index (SEPI) and C2C Ship Passport. It also defines the requirements for the generic digital shipyard model, data collection standards, specification of the tools and concept for the shipyards' case studies. This comprises:

- Define the concept and specification of a SEPI measurement system with a breakdown and calculation of relevant Key Performance Indicators (KPIs) as well as the functional units to be investigated. **T1.1**
- Describe the generic digital shipyard model covering a common understanding of shipyard floor processes, logistics and utilities with clear boundaries between process, organisation, and product.
- Provide a concept for evaluation of environmental footprint and reporting in line with the existing and upcoming standards. **T1.3**
- Develop the initial concept for a material circularity passport.
- Describe the details of implementation and integration, including the selection criteria for case studies.

Figure 1 WP1 Objective from CoL Proposal (CirclesOfLife, 2023)

The following main objectives are specified in the subchapters below.

6.1.1. Objective T1.1

"Define the concept and specification of a SEPI measurement system with a breakdown and calculation of relevant Key Performance Indicators (KPIs) as well as the functional units to be investigated." (CirclesOfLife, 2023)

This will be the main task to be fulfilled in T1.1 and will be labelled **T1.1**.

6.1.2. Objective T1.3

"Provide a concept for evaluation of environmental footprint and reporting in line with the existing and upcoming standards." (CirclesOfLife, 2023)

This will be the main task to be fulfilled in T1.3 and will be labelled **T1.3**.

6.2. Task description

6.2.1. Task description T1.1

The specified description of Task 1.1 states:

"*T1.1 Concept and specification for SEPI (lead: FSGNK)*

This task aims to develop the SEPI covering energy use and emissions to air, water, and soil. The concept and specification of a SEPI measurement system are to be given with a breakdown and calculation of relevant KPIs. Data input specifications will be aligned with the existing state-of-the-art at yards and potential improvement measures. The measurement system will cover a method to identify the contributable energy use and emissions incurred by the whole of the shipyard and organisation to specific ships. Existing standards will be comparatively analysed to define a transparent and traceable reporting standard that is suitable to be used at the EU level. Assessment, implementation, and training requirements to cover a wide variety of shipyards." (CirclesOfLife, 2023)

"IR (Internal Report) 1.1 Comparative analysis of environmental regulations and standards (input to D1.1 and WP2, WP5); due Month 6" (CirclesOfLife, 2023)

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

From this task description, requirements for the main task are derived. These can be found in chapter 7.1.3.

6.2.2. Task description T1.3

The specified description of Task 1.3 states:

"T1.3 Initial concept for evaluation and reporting of environmental footprint (lead: DAMEN)

The task will define the concepts for evaluating the environmental footprint on the level of shipyard processes, the ship as a product and the organisation's influence with regard to materials, energy and waste that are spent throughout the ship's lifecycle. It will also consider the impact of the SEPI concept in T1.1 and utilise existing methodologies such as the production blueprint developed by DAMEN and Building Information Modelling (BIM) from the construction industry. Based on these findings, a reporting methodology will be defined and serve as input for implementation and means for assessment (WP2). The defined method will reflect the European Sustainability Reporting Standards (ESRS), the requirements towards the supply chain and other reporting requirements to be fulfilled to receive a sustainability certificate. In that respect, the task will also monitor the regulatory developments that might occur between the submission of the proposal and the actual project start." (CirclesOfLife, 2023)

" IR1.3 Concept and methodology for evaluating and reporting environmental footprint (input for D1.1); due Month 12." (CirclesOfLife, 2023)

From this task description, requirements for the main task can be derived. These can be found in chapter 7.1.3.

6.3. Contribution to CoL project objectives

T1.1 and T1.3 will contribute to the following main CoL project objectives that can be seen in Figure 2 and Figure 3.

Objective 3: Develop a unified methodology to measure, determine and benchmark the environmental footprint of non-operational life cycle phases of a ship.
Approach: Close the gap in evaluating ships' complete life cycle by assessing the environmental performance of non-operational life cycle phases; enable shipyards and shipping companies to label the ship´s environmental performance and therewith to strive for rewards from stakeholders in respective market segments. At the same time, the SEPI will allow shipyards to benchmark their processes and encourage them to seek improvement potential, like designing ships for circularity, aiming at a better SEPI rating with its associated benefits in terms of financing conditions and meeting customer demands for green transport. By focusing on processes, the existing shipyard certification program of SFE (focus on organisation level) will be expanded, creating an overarching performance standard and maturity framework that is applicable to all European yards and allows each yard to make specific decisions to improve their environmental performances. In addition, the SEPI will provide valuable support to those shipyards which are required to fulfil the upcoming CSRD regulation. Related tasks and Deliverables: T1.1-1.3 and D 1.2 for the development; T3.2-3.4 and D 3.1 for validation.
Verifiable target: 4 SEPI assessments for each CirclesOfLife shipyards performed and validated
Relation to Expected outcome 6: Development of a shipyard environmental performance index (SEPI), relevant KPIs and benchmarks for shipyards through an inquiry into current shipyard processes and utilities (i.e. energy use and emissions to air, water and soil)

Figure 2 Objective 3 of CirclesOfLife Proposal (CirclesOfLife, 2023)

Objective 9: Reduce and verify the actual reduction of non-operational environmental impacts of shipping
Approach: Based on the SEPI methodology developed in WP 1, assess the non-operational life cycle phases of a ship, including production, repair, maintenance, conversion and end of life in several case studies. The results will enable shipyards to identify and benchmark environmental impact reduction potential and incentivise their implementation. Related tasks and Deliverables: T1.1, D 1.1; T3.2-3.4, D 3.1
Verifiable target: Verification of an actual reduction of the non-operational environmental impact of at least 10%
Relation to Expected outcome 1: Reduce the non-operational environmental impacts from shipping, including construction and end-of-life strategies.

Figure 3 Objective 9 of CirclesOfLife Proposal (CirclesOfLife, 2023)

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

For objective 3: T1.1-T1.3 will develop the concept methodology for measuring, determining and benchmarking the environmental footprint of non-operational life cycle phases of a ship. It is good to note that T1.3 will only cover the development of the methodology and concept, the work will be further executed and validated in the other Work packages.

The relationship with objective 5, conducted in WP2 and T2.1-2.5, is based on development of the requirements for the SEPI tool specification, to ensure that the KPIs metrics and functional units that relate the scoring system, generic yard model and process inventory are aligned and agreed.

The relation to objective 9 is that the SEPI methodology is developed in WP1 (including the concept in T1.3). The verification of the actual reduction will be done in the case studies of WP3.

7. Methodology

7.1. Analysis

7.1.1. Analysis T1.1

To be able to develop an approach consisting of tasks and subtasks for Task 1.1, the objective (see 6.1.1 6.1.1) and task description (see 6.2.1) have been analysed. These are the following topics:

- Main task: Define the concept and specification of a SEPI measurement system with a breakdown and calculation of relevant Key Performance Indicators (KPIs) as well as the functional units to be investigated.
- From task description:
  - SEPI should be covering energy use and emissions to air, water and soil.
  - The SEPI system should include a breakdown and calculation of relevant KPIs, based on the ESG topics that are relevant to the shipyard types.
  - Data input specifications will be aligned with the existing state-of-the-art at yards and potential improvement measures.
  - The measurement system will cover a method to identify the contributable energy use and emissions incurred by the whole of the shipyard and organisation to specific ships.
  - Existing standards will be comparatively analysed to define a transparent and traceable reporting standard that is suitable to be used at the EU level.

In general, WP1 defines the concept to be further developed in the other WPs of the CirclesOfLife project, where T1.1 sets out the requirements for WP1 and SEPI. It analyses the current and future regulations, legislations and standards to extract the reporting requirements. It aligns with the following simplified representation of analysis for WP1.

- What to measure
- Where to measure
- How to measure
- How to report, assess and improve (score)

The question ‘What to measure’ related to the Rules, Legislation and standards (R&Ls) plays a pivotal role, not only for the SEPI, but also for the Ship Lifecycle Passport and Ship Circular Materials Passport. It is laying the regulatory foundation for the requirements for this project. Therefore, it has been decided that the task of identifying the current and future R&Ls is of high importance to multiple tasks of the project, so that this should be a separate task within task T1.1. This task will be named Task 1.1a (T1.1a) and will be covered in a separate report IR1.1a – Comparative Analysis of Environmental regulations and standards. The remaining T1.1 objectives

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

are covered in Task 1.1b (T1.1b) which are reported in the internal report IR1.1b. Task T1.1b concentrates on the requirements and concept specification for the SEPI.

The division of Task 1.1 and the approach for 1.1a and 1.1b are described below.

7.1.1.1. Task 1.1a

The purpose of the analysis conducted in T1.1a, is to define an overview for the potential SEPI metrices and to identify the main KPIs to be used for the SEPI scoring system. These should cover the three main shipyard scopes within the project. This task also defines the relevant rules and legislation that are applicable to the SCMP and the SLP passports.

The goal is to define a baseline of rules and legislation that are currently applied to the shipyards, the ship as a product and the components and materials used for the ship, which can be enriched with the requirements that are due to be applied in the foreseeable future, plus the metrics that are designed to fulfil the projects objectives and outcomes.

7.1.1.2. Task 1.1b

Internal Report IR1.1b sets requirements for the SEPI development and explains the methodology for the SEPI scoring and its infrastructure.

The user story definition (see 7.2.4 for more information on the user stories) identified a high-level of business needs and requirements for the SEPI and the product passports, which will be used to verify the solutions that are designed in the subsequent work packages, i.e. WP2, 3, 4 and 5. The following chapters explain more detailed information about the methodology and procedures of the analysis.

Furthermore, the SEPI infrastructure and its workflows are described to give an overview how the different tools within the CoL project are connected.

7.1.2. Analysis T1.3

To develop a structured approach for Task 1.3, the objective and task description have been analysed. The following topics were identified:

- Main task: Define the initial concept for evaluating and reporting the environmental footprint of shipyard activities and ship lifecycle stages, using a harmonized framework aligned with CSRD and ESRS standards.
- From task description:
  - T1.3 aims to create a SEPI reporting framework.
  - The framework must integrate existing EU-level reporting standards (e.g. ESRS) and shipyard-specific Rules & Legislation (R&L).
  - The methodology should support traceable, transparent, and repeatable reporting across Newbuild, Repair & Conversion, End-of-life yards.
  - The SEPI must be compatible with the lifecycle phases and ESG categories and support double materiality assessment (DMA).

In general, WP1 defines the conceptual foundation for the CirclesOfLife project. T1.3 builds on the regulatory and metric groundwork laid in T1.1 and aligns with the digital reporting structures from benchmarking other industries (e.g. construction sector). It focuses on the “How to report, assess (score) and improve” dimension of the WP1 analysis framework.

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

The following simplified representation applies to T1.3:

- What to report: Environmental KPIs across lifecycle phases (e.g. GHG emissions for Scope 1, 2, 3).
- Where to report: Yard-level and vessel-level (relevant for Ship Lifecycle Passport, WP4), mapped to ESG categories.
- How to report: Using a CSRD-aligned SEPI framework, enriched with sector-specific metrics.
- How to assess and improve: Through benchmarking, traceability, and integration with SCMP and SLP passports.

The purpose of the analysis conducted in T1.3 is to define a SEPI reporting framework that merges:

- Mandatory CSRD/ESRS metrics,
- Shipyard-specific R&Ls,
- CoL-specific KPIs and lifecycle metrics.

The framework will:

- Apply a modular structure to accommodate different yard types and lifecycle stages.
- Use ESRS as a baseline and enrich it with SEPI-specific metrics.
- Deduplicate overlapping indicators and ensure consistency across reporting layers.
- Enable annual reporting by shipyards in a format compatible with EU sustainability disclosures.

The SEPI framework will serve as the foundation for environmental performance reporting in WP2–WP5 and will be validated through stakeholder feedback and pilot applications.

Since the kick-off meeting of WP3, several yards in the consortium will be requested to provide additional information related to the Case Studies. The related metrics / KPIs that are collected to provide evidence of compliance with the R&Ls will be further developed in WP3.

The conclusion of the first analysis and actions undertaken, the structured approach for T1.3 and IR1.3, with dividing the main task and objectives into subtasks, can be found in the Approach chapter 7.2.

7.1.3. Requirements from the task description

From the specific task description of T1.1 (see 6.26.2) the following requirements for the SEPI concept can be derived:

- Define the concept and specification of a SEPI measurement system, including:
  - SEPI should be covering energy use and emissions to air, water and soil.
  - The SEPI system should include a breakdown and calculation of relevant KPIs
  - Data input specifications will be aligned with the existing state-of-the-art at yards and potential improvement measures.
  - The measurement system will cover a method to identify the contributable energy use and emissions incurred by the whole of the shipyard and organisation to specific ships.
  - Existing standards will be comparatively analysed to define a transparent and traceable reporting standard that is suitable to be used at the EU level.

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

From the specific task description of T1.3 (see 6.26.26.2) the following requirements for the SEPI concept can be derived:

- Assess environmental footprint at three levels:
  - Shipyard processes and activities
  - The material inflow and manufacturing impact allocation to a ship, at product level.
  - Organizational influence (materials, energy, waste across the ship's lifecycle)
- Consider the SEPI concept in T1.1
- Utilize existing methodologies:
  - DAMEN's production blueprint business process model
  - Building Information Modelling (BIM) from the construction industry
- Define a reporting method and concept, based on the findings
- Serve as technical and functional requirements input for implementation and assessment in WP2
- Align with:
  - European Sustainability Reporting Standards (ESRS)
  - Supply chain requirements
  - Other reporting obligations necessary for obtaining a sustainability certificate
- Track regulatory developments between proposal submission and project start

The requirement in task T1.3 description relates to the Building Information Modelling (BIM), has been reviewed and deemed not relevant for SEPI, although it has provided input for other deliverables in WP4 (e.g. SCMP and SLP), which will be elaborated in D4.1.

7.2. Approach

During the first meetings of WP1 a general approach was proposed that was translated to the goals of the different Tasks of WP1 (T1.1, T1.2, T1.3) to show the dependencies. First the link between tasks 1.1, 1.2 and 1.3 will be shown, then the methodology that is used will be explained, the subtask will be defined, and the resources, timeline and inputs and outputs are stated.

7.2.1. Linking T1.1, T1.2 and T1.3

The main goal of WP1 is to define *"the concepts and methodologies required for the development, implementation and reporting of the Shipyard Environmental Performance Index (SEPI) and the Ship Passport. It also defines the requirements for the generic digital shipyard model, data collection standards, specification of the tools and concept for the shipyards' case studies."* (CirclesOfLife, 2023)

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

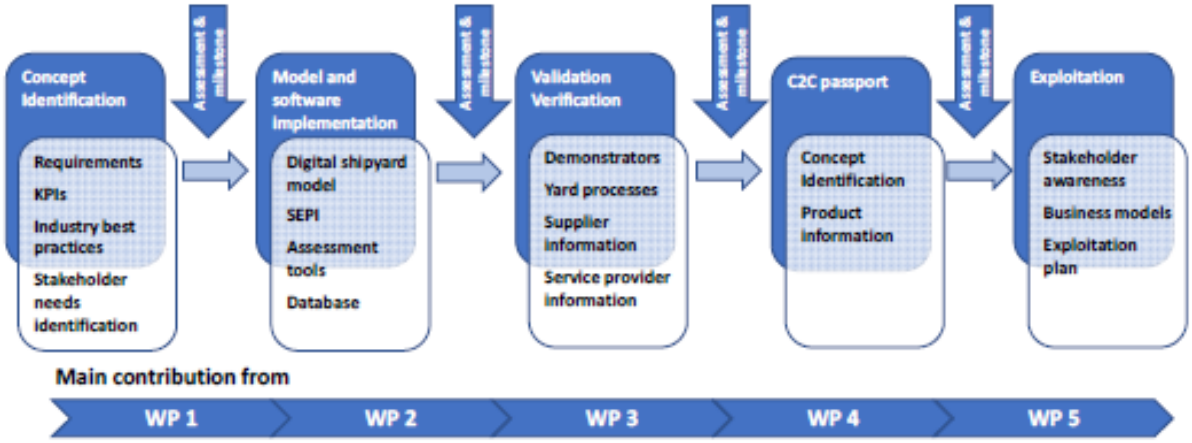

Figure 4 Connection between work packages (CirclesOfLife, 2023)

The tasks T1.1, T1.2 and T1.3 of WP1 have an individual objective, but over the full WP1 scope they are interlinked.

Regarding SEPI development, following overarching aspects were considered:

- **What to measure** (Defined by rules, legislation and standards, current and future) + tool requirements based on stakeholder needs – T1.1
- **Where to measure** (Based on the generic shipyard business process model) – T1.2
- **How to measure** (Based on the additional activity steps, roles and input/output data/metrics) T1.2
- **How to assess, improve, compare** data (score system) and **report** – T1.3

This interconnection of work packages can be seen in the figure below.

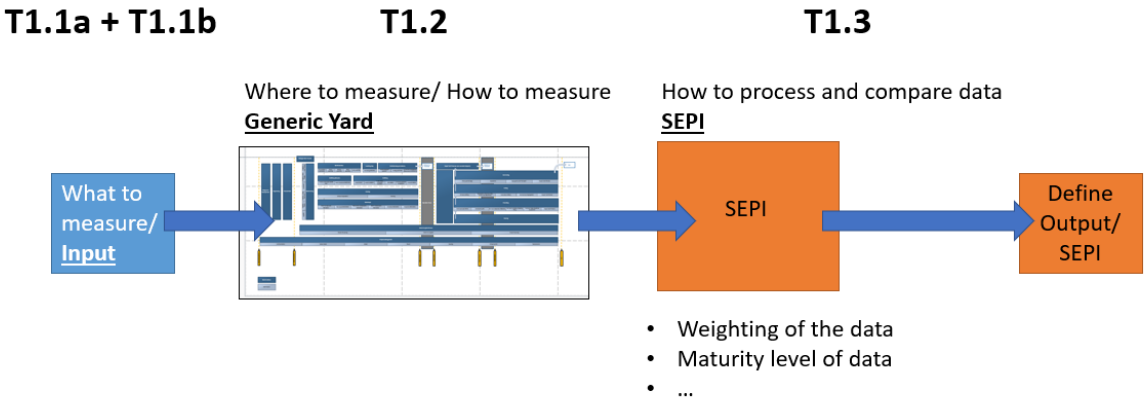

Figure 5 Interconnection of T1.1, T1.2 and T1.3

- **T1.1** focuses on the analysis of rules and legislation (R&L) relevant to shipyards and vessels. It categorizes these by ESG domain, lifecycle phase, and shipyard type (Newbuild, Repair & Conversion, End-of-life). This task lays the legal and regulatory foundation for the rest of the work packages.

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

- **T1.2** builds on T1.1 by developing a generic digital shipyard model. It uses the regulatory insights from T1.1 to define how digital processes and compliance mechanisms can be structured within a shipyard environment.
- **T1.3** then takes the outputs of both T1.1 and T1.2 to define the SEPI (Shipyard Environmental Performance Index) reporting framework. It aligns the regulatory landscape (from T1.1) and digital modelling (from T1.2) with CSRD/ESRS standards to create a measuring, scoring and reporting methodology that is both compliant and operationally feasible, so that the metrics, functional units and calculation algorithms for T2.1 can be defined.

7.2.2. Methods used for T1.1, T1.2 and T1.3

The following methodologies have been used in T1.1, T1.2 and T1.3 to fulfil the various tasks and subtasks:

Table 1 Methods used for T1.1, T1.2 and T1.3

Rules, legislation and standards review table	To create a foundation for the other task of WP1, an overarching Excel table named 'Key Questions list' list is used for T1.1 to capture all the various Rules, Legislations and Standards. These then have been categorized by ESG domain, lifecycle phase, and shipyard type (Newbuild, Repair & Conversion, End-of-life).
User Story Methodology	To capture the various stakeholder's (as identified in WP5) requirements, a User Story methodology has been applied. This will be further described in the next subchapter.
IDDOVD methodology	To achieve structured and innovative product design of the SEPI tool, the Design for Six Sigma (DFSS) adjusted IDDOVD methodology has been applied to the Design phase of WP1, in Task 1.3 and the internal report structure of IR1.3. IDDOVD stands for Identify, Define, Design, Optimize, Verify and Document. Although it appears that the methodology is mainly applied at T1.3, it has been in fact used in various parts of WP1 (e.g. T1.1a and T1.1b), what can be recognized in the names of the subtasks. This process improvement methodology is utilized in T1.3, drawing input from T1.1 and T1.2. The Verification will be conducted in WP2 and WP3, the conceptual Documentation is split between WP1, the assessment implementation in WP2 and the case study implementations in WP3.

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

7.2.3. Subtasks

7.2.3.1. Subtasks T1.1

The following subtasks were derived from the objectives. An overview of methodology that was applied can be found in Figure 6 and Figure 7 below. An optimized version with numbered subtask can be found below the figures.

TASK	STATUS	WHAT	HOW
Existing Regs Benchmark	✓	Identify current and future rules and regs for the lifecycle phases applied to the ship building process	Project stakeholders write rules and regs into the CoL Key Questions excel
Allocate to lifecycle Phase	✓	All R&L must be allocated to lifecycle phases and identify the expert stakeholder	Stakeholders apply the lifecycle phase and their expertise, or knowledge of the standards in the list
Allocate to CoL scope	✓	Allocate to projects scope – SEPI/CMP/C2C	Define which R&L is appropriate for each project deliverable
ESG allocation	✓	Identify which ESG category the R&Ls apply to, including the focus area (e.g. product / production / corporate / material source, etc)	Each R&L must be allocated to Environmental, Social, Governance categories, which can be applicable to more than one category.
R&L Scope	✓	Identify which yard scope the R&R will be applied	Each R&L must be allocated to a yard type New Build, Repair or Recycling Shipyard, plus which main CoL deliverable it relates to (e.g. SEPI, CMP, C2C)
Report Structure and R&L Hierarchy	✓	Allocate R&L to Intermediate report structure (linked to ESG category)	R&Ls are allocated to a specific or multiple report chapters, which are then clustered by main R&L, with a hierarchy to minimize the summary of R&L that are in scope for each topic (e.g SEPI, CMP, C2C).
ESRS framework	✓	Allocate each R&L to a ESRS delegated act (i.e. E1-5,S1-4G1)	WP leads identify which R&L is relevant to a specific, or multiple ESRS category (to-be CSRD reporting framework, based on DMA analysis at Damen and FSG)
Metrics and KPIs	✓	Identify which data points and metrics must be reported according ESRS, plus the additional metrics required to support the R&Ls	Workgroup A defines the metrics from R&L and ESRS, deduplicates the list and identifies the new SEPI metrics – what to measure. Workgroup B creates user stories to allow verification of the business need in the to-be solution, allocates to business function and role, defines the new activities that must be added to the generic shipyard process (SEPI) – where and how to measure.

Figure 6 Preliminary tasks of T1.1a and T1.1b combined

Working Group A **Define c**urrent & future Regs, Legislation and standards that define metrics and KPIs for reporting	**Working Group B** Apply metrics to generic yard processes
Share of existing corporate concepts curently • Benchmark other manufacturing industries • Define all relevant current and future metrics & KPIs….**WHAT to measure**	Define the **generic yard business process overview** for the yard (merge newbuild/repair and Breaking yards) Allocate User stories to the yard business domain and detail to level 3 main process functions - **WHERE to measure at the yard**
Establish a suitable ship lifecycle (phases) which can be aligned with GHG Protocol Scope 1,2,3	Design new activities to support the measuring and reporting of new metrics / KPIs • Including input / output objects for the activity, data format and values for *to-be* process activities ⟹ **input CMP / C2C** according Scope 1,2,3
Allocate R&Ls to lifecycle phase - Input for Work Group B….**WHERE to measure in the lifecycle**	Update the generic yard process for all yard and ship types, **including new activities**, Create a **generic BOP**, showing technologies used at each step • **HOW to measure**
Determine Business domains affected by R&Ls Input for gap analysis Work Group B	Determine the sub processes and activities for managing and reporting KPI's (input WP2) • **How to report** ⟹ **SEPI**
Write User story for the required information by domain stakeholder (business role) based on gap analysis for future needs, (as-is versus to-be situation)	Determine the requirements for managing and reporting KPI's (input WP2) • Define functional / non-functional requirements for application support tool

Figure 7 Working groups approach use to showcase structure to WP1 tasks T1.1, T1.2 and T1.3

For T1.1a and T1.1b, based on the project main objectives, the following sub-tasks have been defined and executed. The tasks were performed in parallel, so the order of the tasks was independent from the execution planning.

Task 1.1a / IR1.1a subtasks:

- **T1.1.a.1 - Benchmark Existing Rules, Legislation and Standards**: Identify a consistent set of all Rules, Legislations & Standards (R&L) applied to Yard and Vessel (current and future)
- **T1.1.a.2 – Allocate to lifecycle phase**: Allocate all R&Ls to lifecycle phase and identify the expert stakeholder
- **T1.1.a.3 – Allocate to CoL scope**: Allocate the R&L to the projects scope – SEPI/SCMP/SLP

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

- **T1.1.a.4 – ESG allocation**: Identify which ESG category the R&L apply to, including the focus area (e.g. product/production/corporate/material source, etc.)
- **T1.1.a.5 – R&L scope**: Identify which yard scope the R&L will be applied (Newbuild, Repair & Conversion, End-of-life)
- **T1.1.a.6 – ESRS Framework**: Allocate each R&L to a ESRS delegated act (i.e. E1-5)
- **T1.1.a.7 – Define metrics and KPIs**: Define relevant current and future metrics and KPIs (What to measure)

Task 1.1b / IR1.1b subtasks:

- **T1.1.b.1 - Identify stakeholders**: Identify all relevant stakeholders over a ship's lifecycle
- **T1.1.b.2 - Stakeholder requirements and user stories**: Capture the stakeholders requirements based on current and future reporting needs (as-is versus to-be-situation) in User stories
- **T1.1.b.3 - Define concept and specification for SEPI**: Define the requirements and elements of the SEPI tool.
- **T1.1.b.4 - Define SEPI methodology**: Define the methodology of SEPI tool in relation to shipyard processes.
- **T1.1.b.5 - Define SEPI interfaces**: Within the shipyard environment in relation to relevant+ processes and tools involved for capturing, processing and exchanging relevant data.

7.2.3.2. Subtasks T1.3

The outline of this report was formed by translating the separate task into the adjusted Design for Six Sigma structure IDDOV(D) which have formed the subtasks. The abbreviation stands for Identify, Define, Design, Optimize, Verify and Document. This approach offers a structure to reach our goal and create a comprehensive storyline. One thing that must be noted is that the Verification (Verify) task will not take place in T1.3, but will be done in WP2 with the tool development and in WP3 in the Case studies. To make sure that all applicable topics are covered this structure has been translated to chapters in the report IR1.3:

- **T1.3.1 - Identify**: Benchmark current best practices for measuring corporate environmental footprint.
- **T1.3.2 - Define**: Define the requirements for the SEPI tool and link the current (as-is) situation of mandatory reporting for (local, regional and European) environmental reporting based on rules and legislation, to the to-be situation of process-based measurements that are mapped to CSRD/ESRS/ESG reporting requirements. The functionalities allow hotspot mapping for improvement planning.
- **T1.3.3 - Design**: Design the SEPI scoring system, maturity levels and reporting requirements.
- **T1.3.4 - Optimize**: Align the designed system with the Green Marine Europe certification for shipyards previously managed by GME.
- **Verify:** The step of verifying the outcomes of T1.3 (and the linked T1.1, T1.2 and T1.5) will be done in WP2 and WP3.
- **T1.3.5 - Document**: This is a continuous task for the project. All results will be documented by extracting the non-functional and functional requirement. This will be captured in this report in chapter 9.3.1. Also, part of the documenting will be extracting the user stories from the findings of this report, so that they can be implemented in WP2 and verified in WP3.

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

7.2.4. Verification of the concept by user stories

The validation of the SEPI concept for "evaluation and reporting the yard environmental footprint" (CirclesOfLife, 2023) will be verified against the user stories, which is a short description of tool requirements told from the perspective of the end user. The objective with the user stories is to capture the business requirements of the stakeholders. The validation will be based on the outcome of WP2, the tool user functionality, data management and exchange feasibility of the solution, into an agreed visualisation and publication format.

User Story Methodology

The tasks of WP1 define the concepts, methods and acceptance criteria. The other WP's (2, 3 and 4) conduct the intended work and match the results against the work done in WP1. The execution of the work is not part of this report but will be completed in the later tasks of WP 2, 3 and 4.

During the early stages of the project , the high-level business needs and requirements of the affected stakeholders in the yard business domains, have been captured in the form of a user stories. These requirements can then be to verify the solution for the SEPI tool and Ship passports, as acceptance criteria for the design.

The user stories were written as role based, business stakeholder needs, related to ship lifecycle phases. The format of the user story is as follows:

As a …….. (business role), **I need** …. (tool agnostic requirement), **so that** …..(rationale), **in order to** …..(SMART metric).

The user stories were generated with the business stakeholders, or business domain process owners' needs in mind, so that they can be related to the SEPI Generic Yard business process model, which covers the 3 main yard types, which specify the main business process functions that the stakeholders are organized within.

These, role based, tool agnostic business and key user requirements, are then prioritized and translated into a tool specific use case, which describes the solution in the support tool. The high-level requirements can then be decomposed into Technical and Functional tool requirements, that supports the design of the solution.

The verification of the user story requirement and the validation of the solution is conducted by the business domain stakeholder, who wrote the user story. The verification score is rated according to the following ISO audit categories:

- Fully met
- Largely met
- Partially met
- Not Covered

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

Template for validation 1

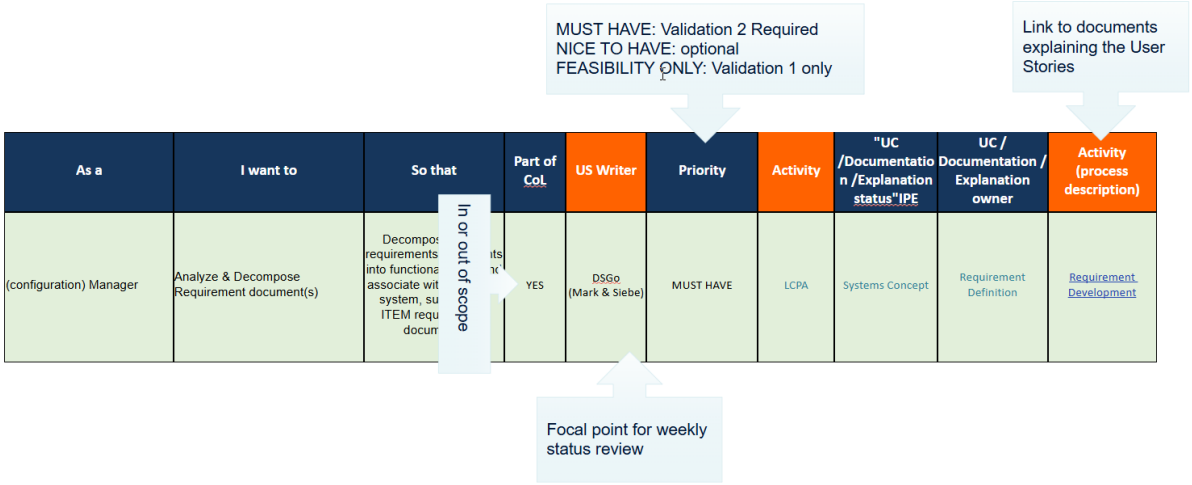

Figure 8 User Story approach proposed template

Template for validation 2

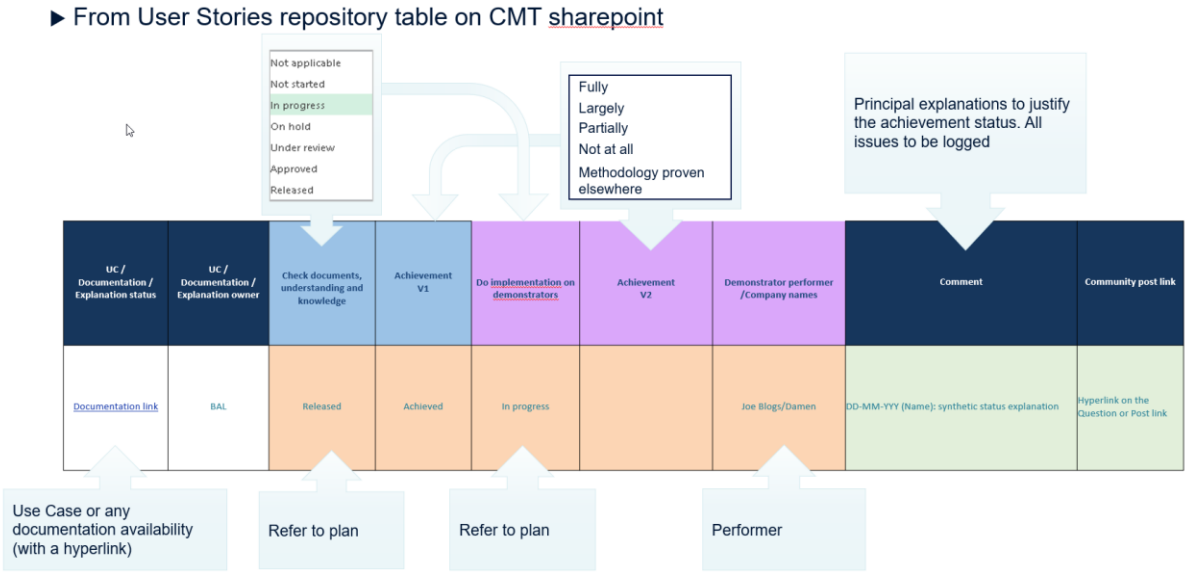

Figure 9 Validation of User Stories with template

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

Work Package 1 - US Approach

User Stories capture WP requirements, based on business domain stake holder needs (process owner / key user perspective with defined 'Measure of Effectiveness'

	What	Who	When	Status
Check 0	Identify User Stories – role based, per business domain	Business stakeholders		Done
Check 1	Check for User Stories – duplication and scope (project or business) priority, key result and WP allocation.	Core Team		Open
Check 2	US Review and understand the main capabilities / functionalities required (reference deliverables / key results)	WP leads / US writer		Open
Validation 1	User / stakeholder verify US requirements and capability have been achieved and a solution is already available, based on an exisitng solution (documentation only)	WP leads / key user / Core team		Open
Validation 2	Case study demonstrator - user story validated, based on tool specific use case documentation, performed by key business users, within proposed solution support tool	BALance / CMT Business users		Open
Feedback loop	Re-align user stories/use cases if gap exist, optimize solution	WP leads / Solution providers		
Result	Internal report with recommendations	Core Team		Open

Figure 10 User Stories approach

The User Story methodology and approach has several benefits:

- User stories capture requirements in a SMART way – End-to-End.
- Each WP capture requirements – role based, to ensure process owner / key user perspective.
- Supports alignment with guiding principles, methodology and ways of working, to facilitate collaboration.
- Ensures application design & configuration is synchronized to optimize implementation (roles& responsibilities, process steps, information flow, work products, applications & associated tools).
- Project reporting can be done, based on the requirement verification (test criteria) per WP task.
- Master a consistent and traceable set of project user stories, test cases and validation results.

The end GOAL is to establish an End-to-End user story overview, linking new capabilities to best practice and guiding principles, to the user stories and use cases, to enable aligned implementation capability and maturity steps (process and support tool).

Please refer to the user story overview in APPENDIX 2: User Stories . The business requirements will be verified according to the achievement levels; 'Fully Achieved', 'Partially Achieved' or 'Not Achieved'. This work will be done in WP1, WP2 and WP3.

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

7.3. Resources and involved partners

7.3.1. T1.1

Based on the CoL proposal the following partners have been involved in T1.1:

"FSGNK will contribute through shipyard expertise, complemented by CET, who contributes expertise of the Fincantieri Group, DAMEN contributing the view of the repair business, and GAL with their insight into the end-of-life activities. SFE will bring and share its experience with existing SEPI and KPIs. VTT will focus on emissions to the environment and exposure routes for human health. CMT will support the development of the SEPI system with a focus on energy use by shipyard processes. TUD and UNIGE will bring Index development knowledge (Yacht Environmental Transparent Index (YETI), Compensated Gross tonnage (CGT), and intensity of emissions). SBP will cover societal aspects and working conditions in ship recycling. BAL will collect the requirements for the generic shipyard model. NMTF will collect information for developing training materials. BV will review and contribute to the requirements from the regulatory perspective." (CirclesOfLife, 2023)

This task was led by Work package leader FSGNK.

Per sub-task as identified in chapter 7.2.3 the involved parties can be seen in the table below.

Table 2 CoL partner contribution

Partner	DRDI	FSGNK	CET	BAL	CMT	ERIKS	TUD	VTT	BV	GAL	UNIGE	GME	NMTF	SBP
T1.1.a.1	X	X	X	X	X	X	X	X	X	X	X	X	X	X
T1.1.a.2	X	X	X	X	X	X	X	X	X	X	X	X	X	X
T1.1.a.3	X	X	X	X	X	X	X	X	X	X	X	X	X	X
T1.1.a.4	X	X	X	X	X	X	X	X	X	X	X	X	X	X
T1.1.a.5	X	X	X	X	X	X	X	X	X	X	X	X	X	X
T1.1.a.6	X	X	X	X	X	X	X	X	X	X	X	X	X	X
T1.1.a.7	X	X		X	X		X	X						
T1.1.b.1	X	X	X	X	X	X	X	X	X	X	X	X	X	X
T1.1.b.2	X	X	X	X	X	X	X	X	X	X	X	X	X	X
T1.1.b.3	X	X		X	X		X	X						
T1.1.b.4	X	X		X	X		X	X						
T1.1.b.5	X	X		X	X		X	X						

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

7.3.2. T1.3

Based on the CoL proposal the following partners have been involved in T1.3:

"DAMEN will define the requirements for the reporting standards from the shipyard point of view and identify the standards to be considered together with the boundaries of the modelling. FSGNK will define the requirements towards software support. CET will support the task with its own reporting experience. BAL will support the definition by providing advice concerning the subsequent implementation in WP2. CMT will address the allocation and attribution of environmental footprint to ships. ERIKS will support the definition of supply chain reporting requirements. TUD will consider the aspects of clarity, reliability, and validity of the input data for reporting. VTT will work on concepts and identify the hot spots of emissions within the shipyard processes. BV will review and contribute with a focus on composite materials' footprint." (CirclesOfLife, 2023)

This task was led by Damen under the supervision of Work package leader FSGNK.

Per sub-task as identified in chapter 7.2.3 the involved parties can be seen in the table below.

Table 3 CoL partner contribution

Partner	DRDI	FSGNK	CET	BAL	CMT	ERIKS	TUD	VTT	BV
T1.3.1	X	X	X	X	X	X	X	X	X
T1.3.2	X	X		X	X	X	X	X	
T1.3.3	X	X		X	X		X	X	
T1.3.4	X	X		X	X		X	X	
T1.3.5	X	X		X	X		X	X	

7.4. Timeline

Task T1.1 started in month 1 (M1) of the project and is due to be completed in month 33 (M33) of the project and Task T1.3 started in month 4 (M4) of the project and is due to be completed in month 18 (M18) of the project with the delivery of this report D1.1.

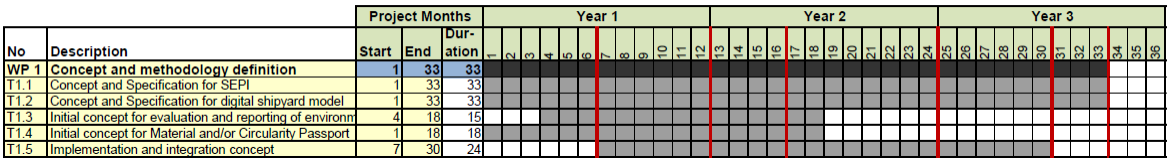

Figure 11 Timeline for WP1 as part of the CoL Proposal B. (CirclesOfLife, 2023)

7.5. Inputs and Outputs

Task T1.1 is the first task of CirclesOfLife project, and it does not have any inputs from other Work packages or Tasks. The created outputs of T1.1 are used as input for T1.3, T1.5, T2.1, T2.3 and deliverable D1.1. Figure 12 shows the direct relation of Task T1.1 to other tasks (marked yellow) of the CoL project and their Work Packages (WP).

Task T1.3 used inputs from T1.1 and T1.2 and created outputs to D1.1. The outputs were also used as input to T1.5 and multiple tasks of WP2 and WP3. Figure 12 shows the relation of Task T1.3 to other tasks (marked yellow) of the CoL project and their Work Packages (WP).

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

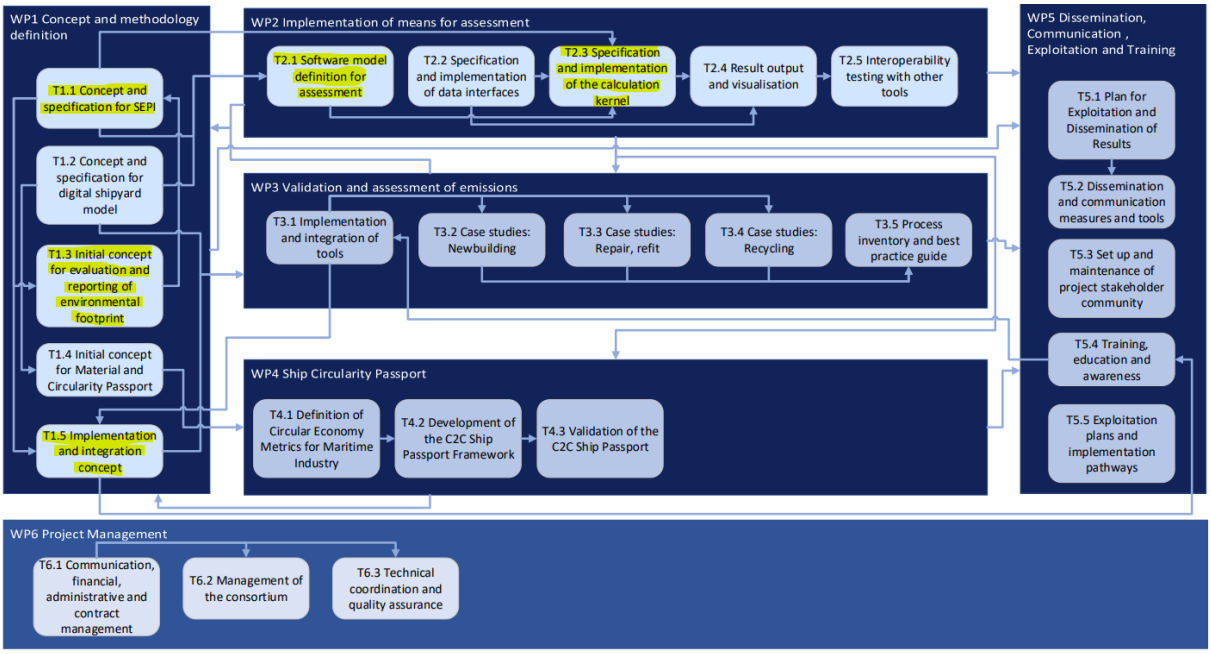

Figure 12 Direct relation of Task T1.1 to other tasks (CirclesOfLife, 2023)

8. PLAN EXECUTION

In this chapter information regarding the plan execution is provided.

A structure has been set up to ensure this alignment, and multiple workshops have been held to ensure progress of the content with the right expertise available.

8.1. Performed activities

The performed activities that have been set in the previous chapters are stated in the table below.

Table 4 Performed activities

Task	Activity	Description
T1.1.a.1	Benchmark Existing Rules, Legislation and Standards	Identify a consistent set of all Rules, Legislations and standards (R&L) applied to Yard and Vessel (current and future). Project stakeholders write rules and legislation into the CoL Key Questions Excel file.
T1.1.a.2	Allocate to lifecycle phase	Allocate all R&L to lifecycle phase and identify the expert stakeholder. Stakeholders apply the lifecycle phase and their expertise, or knowledge of the standards in the list.

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

T1.1.a.3	Allocate to CoL scope	Allocate the R&L to the projects scope – SEPI/SCMP/SLP. Define which R&L is appropriate for each project deliverable.
T1.1.a.4	ESG allocation	Identify which ESG category the R&L apply to, including the focus area (e.g. product/production/corporate/material source, etc.). Each R&L must be allocated to Environmental, Social, Governance categories, which can be applicable to more than one category.
T1.1.a.5	R&L scope	Identify which yard scope the R&L will be applied (Newbuild, Repair & Conversion, End-of-life). Each R&L must be allocated to a yard type New Build, Repair or Recycling Shipyard, plus which main CoL deliverable it relates to (e.g. SEPI, SCMP, SLP).
T1.1.a.6	ESRS Framework	Allocate each R&L to a ESRS delegated act (i.e. E1-5). WP leads identify which R&L is relevant to a specific, or multiple ESRS category (to-be CSRD reporting framework, based on DMA).
T1.1.a.7	Define metrics and KPIs	Define relevant current and future metrics and KPIs (What to measure).
T1.1.b.1	Identify stakeholders	Identify all relevant stakeholders over a ship lifecycle
T1.1.b.2	Stakeholder requirements and user stories	Capture the stakeholders' requirements based on current and future reporting needs (as-is versus to-be-situation) in User stories. This work was conducted by two Workgroups. Workgroup A defines the metrics from R&L and ESRS, deduplicates the list and identifies the new SEPI metrics – what to measure. Workgroup B creates user stories to allow verification of the business need in the to-be solution, allocates to business function and role, defines the new activities that must be added to the

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

		generic shipyard process (SEPI) – where and how to measure.
T1.1.b.3	Define concept and specification for SEPI	Define the requirements and elements of the SEPI tool.
T1.1.b.4	Define SEPI methodology	Define the methodology of SEPI tool in relation to shipyard processes.
T1.1.b.5	Define SEPI interfaces	Within the shipyard environment in relation to relevant processes and tools involved for capturing, processing and exchanging relevant data.
T1.3.1	Identify current rules and legislation (as-is)	Identify the current rules and legislation applicable to the yards in the CoL project based on input from T1.1.
T1.3.2	Define future to-be SEPI scoring requirements	Define the requirements for the SEPI tool and link the current (as-is) situation of mandatory reporting for (local, regional and European) environmental reporting based on rules and legislation, to the to-be situation of process-based measurements that are mapped to CSRD/ESRS/ESG reporting requirements.
T1.3.3	Design the SEPI scoring analysis and methodology	Design SEPI scoring analysis and methodology, maturity levels and reporting requirements.
T1.3.4	Optimize by aligning SEPI system with Green Marine Europe certification	Align the designed system with the Green Marine Europe certification for shipyard previously managed by GME.
T1.3.5	Document the results in User Stories	Document the results by extracting the user stories from the findings of this report and CoL member's input. Disseminate the results of T1.3 with WP2.

For most of the tasks all partners have contributed. For some of the tasks a core group for WP1 have performed the activities of T1.1: DRDI, FSGNK, CMT, BAL, TUD and VTT. This was supported by other members as stated in chapter 0. Bi-weekly meetings were organized to track progress and assign tasks. Several face-to-face workshops have been organized during the various General Assembly meetings and an additional meeting in Bremen. This has been supported by ad-hoc online meetings.

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

8.2. Deviations from the plan

There have been no deviations from the tasks and sub-tasks and these have been executed according to plan.

The deviations for tasks of WP1 (including T1.1 and T1.3) have been on the group of consortium partners linked to the risk as stated in the project proposal: *"Withdrawal of partner(s) from consortium (l/)"* (CirclesOfLife, 2023) The WP1 and T1.1 lead FSGNK went into insolvency and bankruptcy, which has led to the contribution of FSGNK to stop after February 2025. This has been mitigated by DRDI taking over this role and progression WP1 and the related report D1.1. It is foreseen that in Summer 2025 FSG (without Nobiskrug (NK)) will return to the CoL project. Until that moment is officially declared, DRDI will take over these responsibilities, in close cooperation with other project partners. This might result in a change to the allocation of hourly spend on WP1.

CET were also unable to support the project and decided to leave the consortium. This has not led to any deviations, or mitigations for the execution of WP1. For WP3 a replacement partner is being actively sought for the New Build – Cruise Vessel implementation case study.

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

9. RESULTS

9.1. Comparative analysis of environmental regulations and standards (T1.1.a)

9.1.1. Executive summary

Task 1.1a, titled "Comparative Analysis of Environmental Regulations and Standards", is a foundational deliverable within the CirclesOfLife (CoL) project, and provides a comprehensive mapping and analysis of environmental, social, and governance (ESG) regulations and standards relevant to shipyards and ship products.

The analysis identifies and benchmarks over 100 international, European, and voluntary standards, including CSRD, ESRS, ISO 14000 family, ISO 50001, GHG Protocol, Green Marine Europe, and the EU Digital Product Passport. These are categorized by lifecycle phase (Newbuild, Repair & Conversion, End-of-life), ESG domain, and relevance to CoL deliverables such as the Shipyard Environmental Performance Index (SEPI), Ship Circular Materials Passport (SCMP), and Ship Lifecycle Passport (SLP).

The report emphasizes the importance of aligning SEPI with the CSRD and ESRS frameworks to ensure regulatory compliance, reduce reporting burdens, and promote stakeholder acceptance. It also introduces a Double Materiality Assessment (DMA) approach to filter and prioritize KPIs, and outlines the integration of these standards into the broader CoL methodology.

9.1.2. Task results

Table 5 Task results T1.1a

Task	Activity	Result
T1.1.a.1	Benchmark Existing Rules, Legislation and Standards	A consistent set of all Rules, Legislations & Standards (R&Ls) applied to Yard and Vessel (current and future) has been Identified, supported by the project stakeholder. See APPENDIX 1: Rules, Legislation and Standards matrix
T1.1.a.2	Allocate to lifecycle phase	All the R&Ls have been allocated to the relevant lifecycle phase by the expert stakeholders to support identification of the stakeholder domains and user stories. See APPENDIX 1: Rules, Legislation and Standards matrix
T1.1.a.3	Allocate to CoL scope	The R&Ls have been allocated to the relevant project scope and the appropriate project deliverable – SEPI/SCMP/SLP. To define the must have requirements. See APPENDIX 1: Rules, Legislation and Standards matrix
T1.1.a.4	ESG allocation	ESG category have been applied to the R&Ls, including the focus area (e.g. product/production/corporate/material source, etc.) to support material topics identification for the yards. See

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

		APPENDIX 1: Rules, Legislation and Standards matrix
T1.1.a.5	R&L scope	The R&Ls have been applied to the yard scope (Newbuild, Repair & Conversion, End-of-life) to support WP3. See APPENDIX 1: Rules, Legislation and Standards matrix
T1.1.a.6	ESRS Framework	All R&Ls have been related to an ESRS topic/delegated act (i.e. E1-5). WP leads have identified which R&L is relevant to a specific, or multiple ESRS category. See APPENDIX 1: Rules, Legislation and Standards matrix
T1.1.a.7	Define metrics and KPIs	Relevant current and future metrics and KPIs (What to measure) have been identified, to support definition of the yard main function functional units.

9.1.3. Task conclusion

The following key insights are part of the outcome of T1.1:

- The CSRD and ESRS are the basis of the SEPI framework, to align of reporting topics and reuse the collected data, framework and reporting structure.
- Voluntary standards like GRI, ISO 14000 series, and ISO 59000 provide valuable methodologies and metrics.
- The integration of environmental, social, and governance aspects is essential for a holistic sustainability assessment.
- Stakeholder engagement and user stories (Appendix II) are critical for ensuring practical applicability and acceptance of SEPI.

Task 1.1a has established a regulatory and methodological foundation for the CoL project by:

- Mapping a wide array of environmental regulations and standards to shipyard processes and lifecycle phases.
- Aligning SEPI, SCMP, and SLP with current and future mandatory yard reporting, to ensure future-proof compliance an acceptance of the SEPI scoring system.
- Highlighting the need for stakeholder engagement and user story development to guide tool design and solution implementation.
- Identifying key metrics and KPIs that will form the scoring system for SEPI and the data structure for the support tool and data repositories.
- Recommending the use of voluntary standards (e.g., ISO 14001, ISO 59000, Green Marine Europe) to enhance credibility and comparability.

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

Integrating these standards into a unified framework will not only support regulatory compliance but also drive innovation, transparency, and sustainability in the maritime sector. It sets the stage for subsequent tasks in WP1 and other work packages, particularly the development of the Generic Yard Model (T1.2), SEPI methodology (T1.3), and digital infrastructure (WP2, WP4).

9.2. Initial concept for SEPI (T1.1b)

9.2.1. Executive summary

Task 1.1b outlines the initial concept and specification for the Shipyard Environmental Performance Index (SEPI), a core deliverable of the CirclesofLife (CoL) project. SEPI is designed to assess and improve the environmental footprint of shipyards across all lifecycle phases—new build, repair, maintenance, and end-of-life—by providing a standardized, transparent, and traceable measurement system.

Task T1.1b, builds upon the regulatory groundwork laid in T1.1a and focuses on defining the SEPI methodology, stakeholder requirements, and system interfaces. It introduces a process-based approach that integrates stakeholder input, user stories, and ESG-aligned metrics to support compliance with the Corporate Sustainability Reporting Directive (CSRD) and European Sustainability Reporting Standards (ESRS).

Key components include:

- A generic shipyard model (digital twin) to simulate and assess environmental performance. Input for T1.2
- A workflow architecture connecting SEPI with tools like the Ship Lifecycle Passport (SLP) and Ship Circular Materials Passport (SCMP).
- A scoring system based on KPIs, functional units, and maturity levels of data collection. Input for T1.3
- Stakeholder analysis and user story methodology to ensure relevance and usability.
- Alignment with ISO 50001, LCA frameworks, and CSRD reporting requirements.

9.2.2. Task results

Table 6 Task results T1.1b

Task	Activity	Result
T1.1.b.1	Identify stakeholders	Stakeholders across the ship's lifecycle were identified to ensure comprehensive coverage of interests and responsibilities in the SEPI framework.
T1.1.b.2	Stakeholder requirements and user stories	Stakeholder requirements were captured and translated into user stories, forming the basis for SEPI tool validation and future development. See APPENDIX 2: User StoriesAPPENDIX 1: Rules, Legislation and Standards matrix
T1.1.b.3	Define concept and specification for SEPI	The concept and specification for the SEPI tool were defined, including its structure, scoring logic, and integration with other CoL tools.

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

T1.1.b.4	Define SEPI methodology	A methodology was developed for how SEPI will assess shipyard processes, including environmental impact metrics and performance indicators.
T1.1.b.5	Define SEPI interfaces	Interfaces between SEPI and other systems (e.g. digital shipyard model, SLP and SCMP, reporting tools) were defined, ensuring data flow and tool interoperability.

Task 1.1b also outlined:

- Requirements for secure data exchange (e.g., protecting IP).
- Use of open-source standards and compatibility with existing IT infrastructure.
- A scoring system based on maturity levels and environmental performance

9.2.3. Task conclusion

T1.1b defined the conceptual and methodological framework for SEPI, setting the stage for its implementation and integration into broader sustainability reporting systems. The report emphasizes the importance of:

- Standardization: Aligning SEPI with EU and international standards (e.g., ISO, ESRS, CSRD) ensures regulatory compliance and comparability.
- Stakeholder engagement: Incorporating diverse perspectives through user stories and stakeholder mapping enhances the tool's relevance and adoption.
- Process-based assessment: Using a digital twin model allows for granular analysis, hotspot identification, and continuous improvement.
- Scalability: The SEPI framework is designed to accommodate shipyards of varying sizes and digital maturity, including SMEs.

Between important lessons above and next steps below, there should be an actual conclusion in line with the task steps (What is the final SEPI based on, how does it work and how does it fit within the other legislation and CoL solutions?)

The next steps involve refining the digital shipyard model (T1.2), developing the scoring and reporting methodology (T1.3), and validating the system through case studies (WP3). Ultimately, SEPI aims to empower shipyards to transition toward a low-emission, circular economy by providing actionable insights and a foundation for sustainability reporting.

9.3. Concept and methodology of evaluating and reporting environmental footprint (T1.3)

9.3.1. Executive summary

The CirclesofLife (CoL) project aims to support shipyards in transitioning toward a zero-emission future by developing the Shipyard Environmental Performance Index (SEPI). This index is designed to align with the Corporate Sustainability Reporting Directive (CSRD) and the European Sustainability Reporting Standards (ESRS), enabling shipyards to measure, report, and improve their environmental performance across all lifecycle phases of shipbuilding.

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

Task 1.3 outlined the methodology for evaluating and reporting environmental footprints through five subtasks (T1.3.1–T1.3.5). It begins by benchmarking current rules and legislation (T1.3.1), then defines future requirements and scoring logic (T1.3.2), followed by the design of a scoring system and maturity model (T1.3.3). It also ensures alignment with the Green Marine Europe (GME) certification framework (T1.3.4), and documents functional and non-functional requirements for tool development (T1.3.5).

SEPI introduces a dual-axis scoring system: one for ESG performance (1–100 scale) and another for data maturity (D to A+). It leverages a generic shipyard model to map environmental impacts to specific processes and technologies, enabling hotspot analysis, improvement planning, and traceable reporting. The framework supports both large and small shipyards and is designed to be interoperable with CSRD reporting tools and LCA systems.

9.3.2. Task results

Table 7 Task results T1.3

Task	Activity	Result
T1.3.1	Identify current rules and Legislation (as-is)	Benchmarked current best practices and identified “as-is” yard-specific rules and legislation, including ISO 14001 compliance and Green Marine Europe alignment. Based on input from T1.1.
T1.3.2	Define future to-be SEPI scoring requirements	Defined future “to-be” SEPI scoring requirements, aligned with CSRD/ESRS, and developed hotspot analysis and maturity levels. Addressed SME applicability and ensured scalability across yard sizes and scopes.
T1.3.3	Design the SEPI scoring analysis and methodology	Designed the SEPI scoring system, maturity matrix, and reporting structure, including visualizations and auditability features.
T1.3.4	Optimize by aligning SEPI system with Green Marine Europe certification	Aligned SEPI with Green Marine Europe certification and ensured compatibility with ISO 50001 and LCA reporting.
T1.3.5	Document the results in User Stories	Captured functional and non-functional requirements, user stories, and verification criteria for WP2 and WP3 implementation. See APPENDIX 2: User Stories

9.3.3. Task conclusion

The SEPI framework provides a scalable, and forward-looking methodology for shipyards to evaluate and report their environmental footprint. By aligning with CSRD and ESRS, it ensures regulatory compliance while promoting continuous improvement through data-driven insights.

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

Key achievements of T1.3 include:

- A structured scoring system that integrates ESG performance with data maturity.
- A methodology that supports both compliance and strategic environmental planning.
- Compatibility with ISO 50001, GME, and LCA reporting frameworks.
- Support for ISO 14044 input, based on measured manufacturing data
- A flexible design that accommodates shipyards of varying sizes and digital maturity.

The next steps involve refining functional units, validating scoring logic through WP2 and WP3, and finalizing the SEPI tool for implementation. This will empower shipyards to not only meet regulatory demands but also lead in sustainable maritime innovation.

9.3.3.1. Functional and non-functional requirements / Input WP2

The approach to define user stories, which relate to the business needs associated with Yard environmental performance have been written, so that use cases can be created that explain the SEPI tool functionality to potential key users, but also to ensure that the criteria for acceptance can be validated in the case studies.

An overview of the user stories can be found in APPENDIX 1: Rules, Legislation and Standards matrix, categorised according to domain stakeholder, Work Package, key objectives and lifecycle phase.

A questionnaire will be written together with WP1, 2, 3 and 5 teams, so that the stakeholder groups have the opportunity to write more detailed key user functional and technical requirements. The intention is that this questionnaire can be used to verify the requirements and solution with internal and external stakeholders.

The technical requirements for the SEPI tool will be developed further in within WP2, based on the scoring methodology described in the previous chapters and the peer review with BALance and CMT, related to the calculation logic and methodology, which was agreed and sufficient to develop the SEPI tool software.

Conclusions:

- SEPI Framework – ESG / CSRD topics are applied to the SEPI the reporting framework, E1 to E5, S3, which are aligned with the GME certification framework, so that SEPI metrics & KPIs are consistent with ESRS topics, sub-topics and associated data points in listed in the EFRAG list (what to measure).
- Maturity levels, for the measurement of the environmental data, are broken into 5 levels. The lowest measurement equates to SEPI maturity 1 by default, based on annual purchased energy and materials at the yard The highest equates to process activity measurement, linked to technology type, based on a digital representation of the yard .
- The scoring bandwidth 1-100, will be defined by benchmarking yards historical CSR data from 2008, which will set the lowest baseline performance level, linked to the technology used in 2008. The highest performance level will be a combination of CO2 emissions reduction transition to achieve a reduction of 55% by 2030, plus meet all ESG criteria for E2 to E5, including producing no waste, avoiding pollution, and having a robust social and governance framework. These yards will receive a green label A+, indicating they are on target for net zero by 2050.
- Improvement planning for reduction of impact will also relate to the Best Available Techniques (BAT), which is the current best practice for manufacturing. This is not a guarantee of achieving a reduction the highest score, but will provide guidance for hot-spot reduction plans and investment planning at the yard, linked to technologies used to conduct the main functions at the yard.
- The functional units applied to the main activities at the yard, that are used to calculate the SEPI score, must be hull material agnostic. Therefore, we use WORK (man hours) as the common factor for calculation of the impact.
- ESRS sub-topics will be allocated to yard main function, sub process and activity to enable technologies to be applied to the processes in the generic yard process. This allows the impact for technology

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

improvement to be calculated and scored. Total yard performance can then be aggregated up from activity, to sub process, to main function and finally up to yard level (process level L4 up to L1)

- Detailed METRICS for the ESRS subtopics will be taken from the EFRAG list and the Rules & Legislation and used by WP2 to create the algorithms for the SEPI tool.
- The SEPI Generic Yard Business Process Model (BPM) can be adopted by all yard types and is suitable for commonly used business process modelling applications. The SEPI generic yard model will be mapped to the calculation method designed in the SEPI tool. It shall be possible to evaluate potential improvements in yard impact, by selecting alternative technology in the SEPI generic yard model. This analysis functionality will be available at main function, sub process and activity level, to support all yard measurement maturity levels. Some BPM applications allow for reporting out to business intelligence tools, so that the SEPI tool mapping can also connect to a reporting tool that is currently used by the yard e.g. Power BI.
- Hotspot analysis in the process model will enable improvement planning based on environmental impact and technology investment.

9.4. Further work to be conducted in WP1

- Define the functional units for the main functions and sub-processes at the yard, based on the generic yard model. Define the specific impact categories and functional unit that differentiate the hull material environmental footprint - especially composite hull construction, - units could relate to WORK to avoid hull material type.
- Define the E1-5 data points related to the ESRS sub-topics, that are identified during the case studies, the relevant production technology used in each activity step and the potential improvements, so that a process can be created for the AS-IS and TO-BE, which will be added to the SEPI generic yard model.
- Further develop the Best Available Techniques (BAT), for the generic yard main functions and sub-processes, so that the improvement planning can be related to an accepted set of EU performance levels.
- Define Supply chain reporting requirements and process steps, to support corporate and product reporting - reference the LCA data layer part attributes.
- Graphic Design the SEPI scorecard (from the 3 framework proposals) and translate into a label for publication (e.g. energy label) for the yard, aligned with existing labels e.g. GME, for Sales & Marketing purposes - for review at Hamburg GA 2024.
- Design the SEPI report structure, for the detailed report that supports the SEPI scorecard, with trend lines for specific KPIs, with the previous 3 years performance as a reference (e.g. CO2eq , Water, Circular content).
- Review and agree the aspects of clarity, reliability, and validity of the input data for reporting with the internal stakeholders.
- Define technical requirements towards software support, as input for WP2, related to the logic at data exchange with the SEPI tool, based on a high-level information model that shows the application architecture.
- Validate the scorecard against each yard type and scope, according to the user stories, as input for the use cases for verification.

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

10. CONCLUSION

10.1. Achievements

The CirclesOfLife project has delivered a concept for evaluating and reporting the environmental footprint of shipyards through the development of the Shipyard Environmental Performance Index (SEPI). The combined efforts of Tasks T1.1a, T1.1b, and T1.3 have resulted in the following key achievements:

- **Comprehensive Regulatory Mapping:** Over 100 environmental, social, and governance (ESG) regulations and standards were benchmarked and categorized by lifecycle phase, ESG domain, and yard type. This mapping supports SEPI, the Ship Circular Materials Passport (SCMP), and the Ship Lifecycle Passport (SLP), and will serve as a regulatory baseline for future development in WP2 and WP4.
- **SEPI Concept and Specification:** A concept for SEPI was defined, including its scoring methodology, stakeholder requirements, and alignment with the Corporate Sustainability Reporting Directive (CSRD) and European Sustainability Reporting Standards (ESRS). This concept will be implemented and tested in WP2 (tool development) and WP3 (case studies).
- **Methodological Integration:** The SEPI methodology integrates process-based and project-based objective data, enabling both yard-level and product-level environmental footprint assessments. This dual approach will be further refined in WP3 and WP4, particularly in the development of the SCMP and SLP.
- **Scoring and Maturity Framework:** A two-dimensional scoring matrix was introduced, combining ESG performance (D-A+) with data maturity levels (M1–M5). This framework will be operationalized in WP2 and validated through real-world application in WP3.
- **Stakeholder Engagement and User Stories:** Stakeholder needs were captured through a structured user story methodology. These user stories will guide tool design in WP2 and be verified through implementation and feedback loops in WP3 and WP5.

10.2. Verification of the objectives

The objectives of Work Package 1 and Task 1.1 have been met and verified through the following:

- **Objective 3 Verification:** The concept and methodology for measuring, determining, and benchmarking the environmental footprint of non-operational ship lifecycle phases have been defined. This includes the identification of relevant KPIs, functional units, and scoring logic for SEPI. These elements will be further developed and validated in WP2 and WP3.
- **Objective 5 Verification:** Requirements for the SEPI tool have been defined for WP2 and agreement on the functionality confirmed by peer review.
- **Objective 9 Verification:** The SEPI concept provides the foundation for future verification of environmental impact reduction in WP3 case studies. The scoring system and benchmarking logic will be applied to real shipyard scenarios to assess effectiveness and usability.
- **Alignment with CSRD/ESRS:** The SEPI framework is fully aligned with CSRD and ESRS requirements. This alignment ensures that shipyards can reuse ESG data for both regulatory compliance and internal performance improvement. The integration with CSRD reporting tools and traceability mechanisms will be implemented in WP2.
- **Tool Readiness and Interoperability:** The SEPI concept is designed to interface with digital yard models, LCA tools (although an LCA is not necessary), and reporting platforms. These interfaces will be further developed in WP2 and tested in WP3. The SEPI scoring system will also be aligned with the Green Marine Europe (GME) certification.
- **No Deviations from Scope:** All subtasks under T1.1 and T1.3 were executed as planned. Mitigation measures were successfully implemented to address partner withdrawal, and DRDI has taken over leadership responsibilities to ensure continuity.

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

In summary, the work conducted under Task 1.1 and T1.3 has delivered a coherent, future-proof foundation for environmental performance evaluation in shipbuilding. The SEPI framework not only meets current regulatory demands but also anticipates future needs. The next steps in WP2, WP3, and WP5 will ensure that these concepts are implemented, tested, and refined for practical application across the industry.

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

11. List of tables

12. List of figures

13. References

CirclesOfLife. (2023). *Circles Of Life Part B 2023_04_20final2.pdf.*

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

14. APPENDIX 1: Rules, Legislation and Standards matrix

The matrix with Rules, Regulations and Standards can be found on the next page. Use zoom for more detail.

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

15. APPENDIX 2: User Stories

The User Stories overview can be found on the next page. Use zoom for more detail.

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

16. APPENDIX 3: Ship lifecycle phases based on EN15978:2011

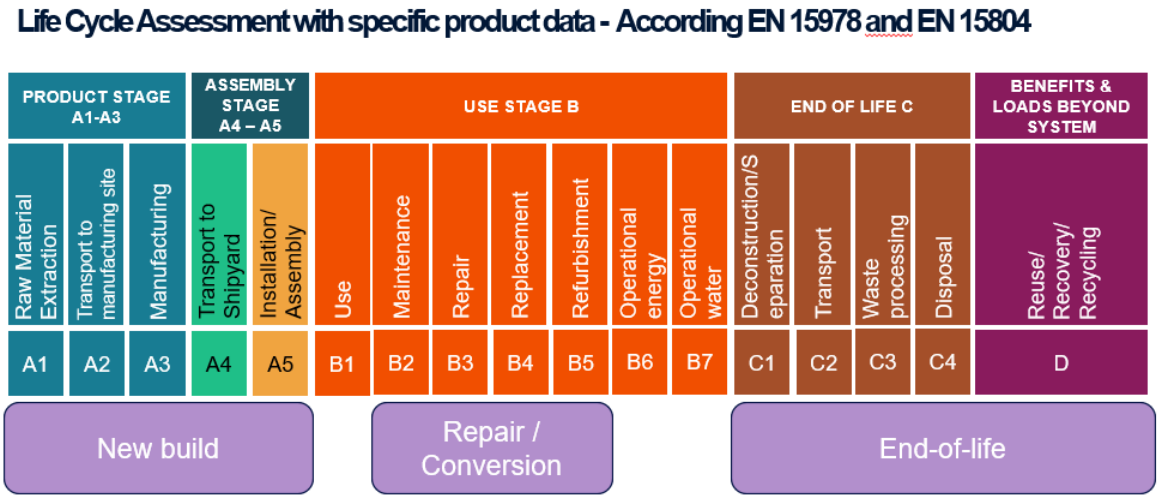

Figure 13 Lifecycle Assessment (LCA) phases and relation to CoL yard types.

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