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Circles of Life

D2.1 – System specification

01 | 2025

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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 gGmbH
DRDI	Damen Research Development & Innovation BV
ERIKS	Eriks BV
EU	European Union
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

2.2. Terms and abbreviations

API	Application Programming Interface
BAT	Best available technology
BPM	Business Process Modelling
C2C	Cradle-to-Cradle
CoL	CirclesOfLife
CSRD	Corporate Sustainability Reporting Directive
DPP	Digital Product Passport
ERP	Enterprise Resource Planning
ESPR	Ecodesign for Sustainable Products Regulation
ESG	Environmental Social Governance
ESRS	European Sustainability Reporting Standards

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ISO	International Organization for Standardization
KPI	Key Performance Indicator
LCA	Life Cycle Assessment
LCPA	Life Cycle Performance Assessment
Proposal	CirclesOfLife Proposal (CirclesOfLife, 2023)
SCMP	Ship Circular Materials Passport
SDT	Shipyard Digital Twin
SEPI	Shipyard Environmental Performance Index
SLP	Ship Lifecycle Passport
T	Task
WP	Work Package

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2.3. Table of Content

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3. Preamble

To be able to assess and improve the environmental footprint of shipyards, the Shipyard Environmental Performance Index (SEPI), Ship Circular Materials Passport (SCMP) and Ship Lifecycle Passport (SLP) will come into place.

Funded by the EU under the Horizon Europe research and innovation programme, the European project CirclesOfLife (CoL) and its partners will develop methodologies and concepts for the Shipyard Environmental Performance Index (SEPI) and Ship Lifecycle Passport (SLP) during the first phase of the project (Work package 1).

Enhancing the shipyard's knowledge and understanding of their processes including the alignment with their environmental footprint, is one of the goals of the CirclesOfLife project. In order to implement, assess, benchmark and improve the shipyard's processes in terms of sustainability, a tool needs to be developed which serves at least one of the purposes of the CirclesOfLife projects ambitions and is part of the Task T1.2:

"Development of a generic digital shipyard model encompassing shipyard processes with the associated energy use and emissions, enabling to assess and benchmarking the environmental performance and cost-efficiency of shipyards and their contribution to the environmental impact assessment within the ships' Life Cycle (LC)."

Based on the methodology and scope developed in T1.1 and T1.3, requirements for the Generic Shipyard Model have been analysed and documented in IR 1.2. This D 2.1 will continue the documentation by describing the model specification that will be implemented in the SEPI tool as well as the approach to implement the modules that will be implemented based on this model.

Figure 1 shows the direct relation of Task T2.1 to other tasks (marked yellow) of the CoL project and their Work Packages (WP).

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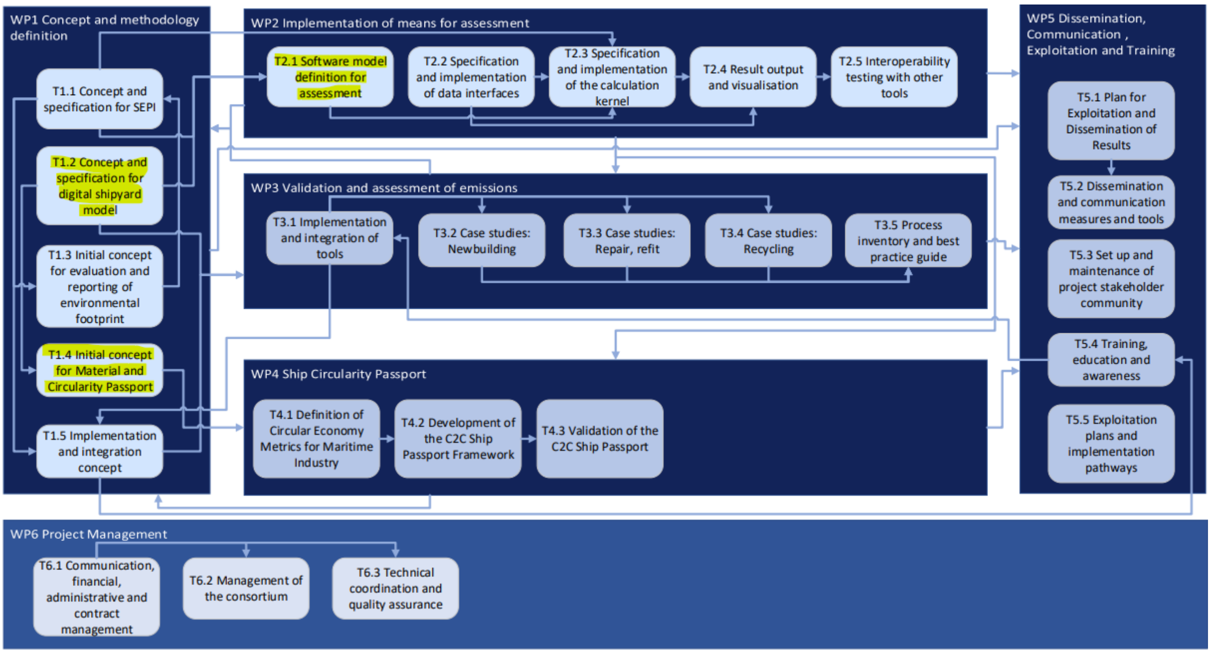

Figure 1: Direct relation of Task T2.1 to other tasks

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4. Purpose of the tasks

4.1. Task descriptions

D2.1 collects information from all tasks active in WP 2 in the first half of the project. It discusses the functionality of the software tool and how it will be implemented during the second half of the project.

T2.1 Software model definition for assessment
Based on the collected requirements and the specification of the digital shipyard model in WP 1, the software models for carrying out the assessment as well as the generic shipyard model will be defined and implemented. These models will contain all input data needed for the assessment and the output data required to forward or visualise the results. It will be capable of storing process as well as product data.

The purpose of the task is to translate the shipyard model defined in WP 1 into a software model that will serve as foundation of the database implementation to be performed later in WP 2.

T2.2 Specification and implementation of data interfaces
Data interfaces will be developed for two major activities: The retrieval of input data from external sources, such as LCA databases and the provision of data to other applications, such as the LCPA tool. Therefore, T 2.2 will cover two major areas, Implementation of data retrieval modules that access software applications and therefore have to comply with their Application Programming Interfaces (APIs), and
Implementation of an API that enables other applications to retrieve output data from the assessment tool for further processing.

The purpose of the task is to specify the data exchange of the SEPI software with the outside world, i.e. other software tools used by the shipyard.

T2.3 Specification and implementation of the calculation kernel
This task will specify and implement the assessment algorithms to calculate the KPIs defined in WP 1. The software will use the model specified in T2.1 and take the input data from the interfaces specified in T2.2. After performing the calculations, the results will be stored in the model. Major activities in T2.3 are:
Specification of the KPI implementation, especially the calculation routines
Implementation of the calculations and the supporting modules, such as retrieval and storage of data

The purpose of the task is to describe the algorithms used for the SEPI calculation and the envisaged implementation in the software tool.

T2.4 Result output and visualisation
T2.4 will ensure that the assessment results will be made available in different ways, suitable for presentation and further processing. Therefore, the following elements will be specified and implemented:

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Visualisation via a customisable user interface (different types of charts and graphs, arrangement of results, postprocessing of results to perform additional analyses)
Output as a report (e.g., in PDF, XLSX or DOCX format)
Output of data for postprocessing
An additional way of forwarding result information will be the information provided by the API implemented in T2.2. The purpose of the task is to define the output of the SEPI tool, on screen as well as in printable format.

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5. Overall concept of the SEPI software tool

5.1. Purpose

Although the main purpose of the SEPI tool is the calculation of a Shipyard Environmental Performance Index, the application is more complex. It actually provides three different functionalities, in particular the collection of energy consumption and additional resource use as well as emission according to ISO 50001 (shipyard layout based), SEPI score calculation (process based) and export to business process modelling tools to support ESG/CSRD. To achieve these goals, additional functionality is available such as data input/output, mapping between the different models and visualisation of results. The following figure provides an overview of the main function areas and the relations between them.

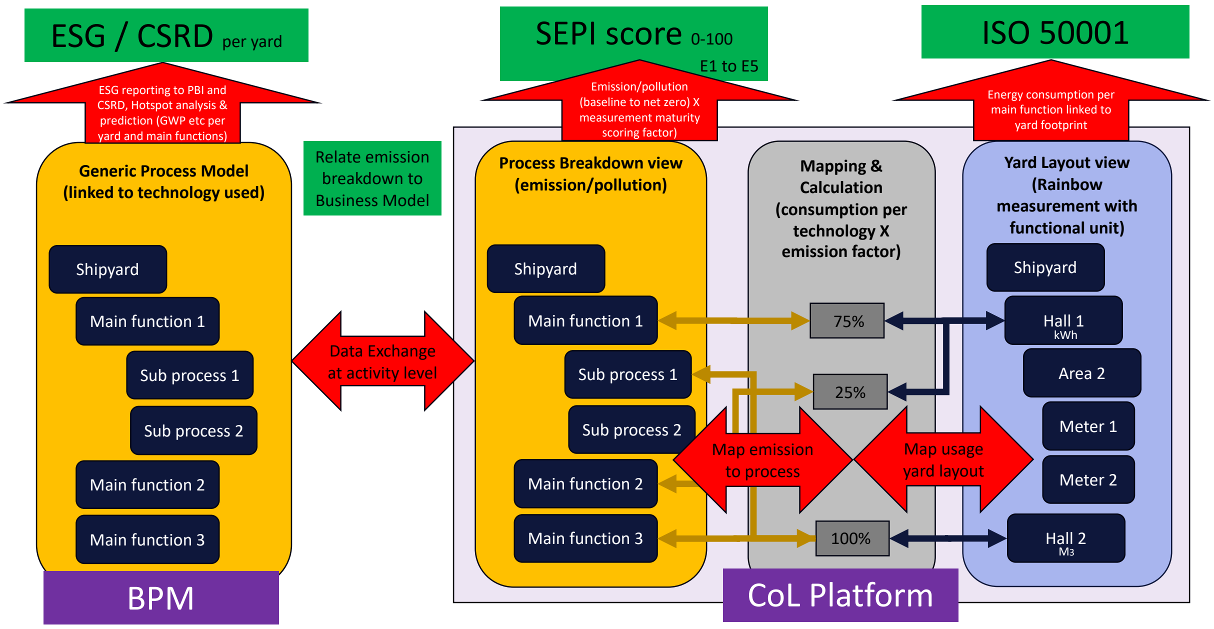

Figure 2: Overview of SEPI tool main functional areas

5.2. Functionality

In the context of shipyard data analysis and environmental performance assessment, several key components must be addressed. One essential aspect is the preparation of a simplified model of the shipyard layout, which serves as a basis for organizing and contextualizing data collection. Complementary to this, a generic shipyard process model will be defined to represent typical operational workflows, providing a flexible framework for various analytical applications.

To perform a specific analysis, a customized shipyard model will be derived to support specific calculations. A crucial element in this modelling effort is the definition of a mapping between measured data from the physical shipyard layout and the corresponding elements within the

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process model. This ensures that data collected in the field can be meaningfully interpreted within the analytical framework.

Data collection itself includes the measurement of emissions and energy consumption at the yard. These data points are vital for evaluating the environmental and operational efficiency of shipyard activities. To support integration and data consistency, interfaces to other software tools are implemented. Where automation is limited, manual input is also supported, enabling users to directly enter relevant information.

Furthermore, it is important to record the maturity level of all input data. This provides insight into the reliability and completeness of the available information, which in turn influences the confidence in subsequent calculations. One of the central outputs of this system is the calculation of SEPI scores, which offer a quantitative view of environmental performance across different shipyard processes.

The results of these analyses can be visualized in a variety of formats, supporting both high-level summaries and detailed process-specific views. These visualizations can also be exported for reporting or further evaluation. Overall, the system provides both a general overview of shipyard performance and the ability to focus on specific operational processes, enabling comprehensive and adaptable analysis.

5.3. User roles

The software system will address different types of users. First of all, a modelling expert will be required to perform the initial setup of the system at the shipyard. This involves activities like modelling the shipyard layout and the data measuring points. It also covers the definition of the shipyard processes. Typically, this will be done by means of a business process modelling software (commercial tools such as MAVIM [MAVIM] or open source tools such as CAMUNDA [CAMUNDA]). The SEPI tool will then read these models and extract the information needed for the SEPI calculation. This part of the import will have to be supported by the modelling expert, e.g. selecting relevant processes. Major task of the modelling expert will be performing the mapping between the shipyard layout and the process model which has to work in both directions.

The actual SEPI calculation will be initiated by a SEPI specialist who will create the SEPI project as the initial step. Here general data will be entered and the purpose of the calculation will be determined (global SEPI analysis, looking into specific processes, performing an analysis to determine the impact of introducing a specific technology). Based on the data available, the actual calculation will be carried out. After this step has been finished, the results will be visualised, reports will be created, data will be exported and the results will be analysed. Although all these activities will be performed by SEPI specialists, different aspects might be covered by different persons.

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Results interpretation will also be carried out by shipyard experts. Their job will also include data collection and import and the performance of predictive analyses. Since all three roles require detailed knowledge of the shipyard, there will be an overlap between them. Especially on the smaller yards, all three roles might even be performed by the same group of persons. Therefore, the role definition mainly exists to structure the modules of the SEPI tool.

5.4. User groups

The actual user groups for the software are currently being determined in the use cases of WP 3. First definitions have been made, but the final list is still under preparation and will be documented in the following deliverable D2.2.

Despite the shipyards as such, ship design offices, energy suppliers, classification societies, suppliers, ship owners, standardization/certification bodies and waste handlers are among the groups that will either provide input data or might be using reports created by the SEPI tool. The results might also be used for standardization and policy making activities. The precise requirements of each user group will be reflected by the ongoing implementation of the SEPI tool.

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6. Architecture of the digital generic shipyard – software view

The overall digital Shipyard Model (which is captured in the business process modelling application) will consist of four different parts.

- The Generic Yard Business Process Model (BPM, including all yard activity scopes) – Library. The generic yard will have the technologies, and the emissions (E1-E5) descripted in it.
- Process Inventory
- Shipyard Digital Model (incorporate the as is processes)
- Improved Digital Model (different environmental footprint solutions to evaluate the improvement roadmap)

In terms of software implementation, two major aspects need to be realised, the model structure and nodes. The structure will be tree-like with exactly one parent node for each process node in the tree. While the parent node will normally be the process node of the next higher level, the root node will be connected to a global object that depicts the current calculation project. As long as the tree is generic, the reference to this “project” object remains empty.

The BPM as well as the project inventory will be realised inside a relational database which will be connected to the application code via a mapper that translated the object oriented queries into SQL code and vice versa. The actual model instances will be set up by the user, interacting with the application. There will be no hard-coded model built into the software tool.

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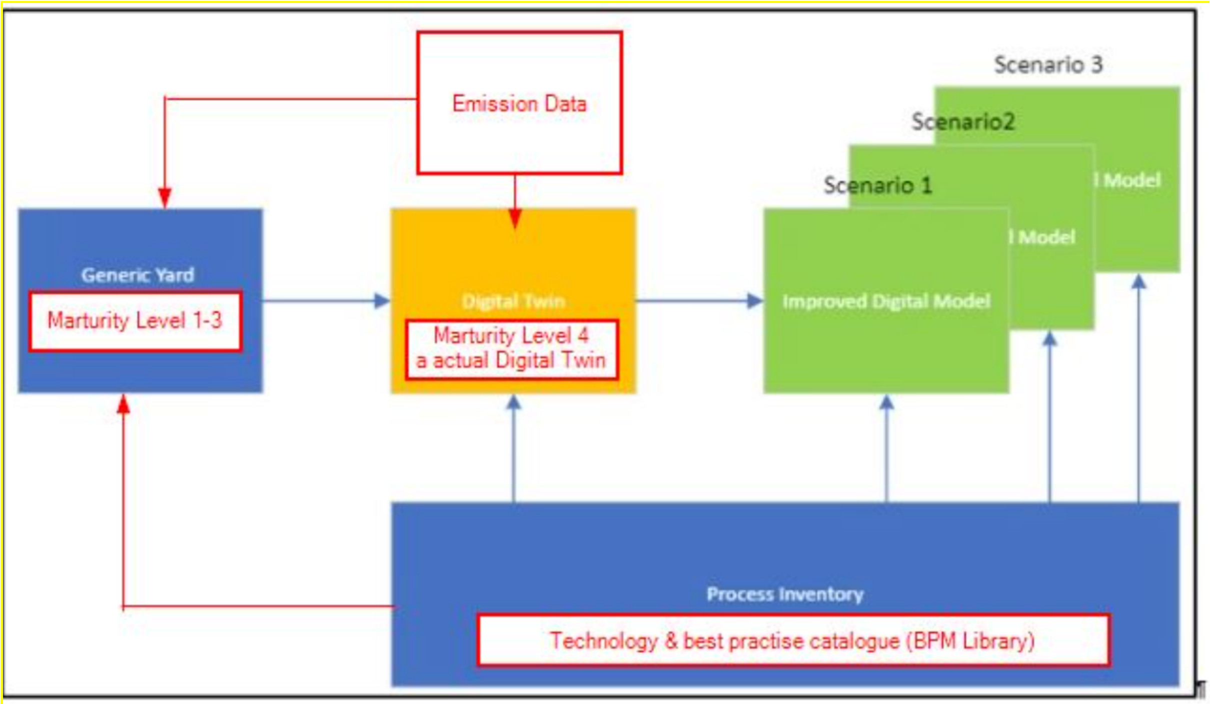

Figure 3: Digital Shipyard Model - components

6.1. Yard scopes and responsibilities of the Digital shipyard model

Yard scopes and responsibilities for the digital twin/generic model need to be defined, related to make or buy material inflow. So based on the environmental footprint of a shipyard, only processes on the actual site need to be assessed. This means, any other processes carried out for the yard but not conducted on site, need to be taken into account as Scope 3 upstream (detailed description in chapter 11). This scope 3 emission will put in the main function to assess the yard with the SEPI. Since the model implementation is generic, this concept will not have an impact on the actual implementation but needs to be taken care of by the BPM creator. Although this approach requires additional effort when setting up the model, it gives the shipyard more flexibility to handle individual process distribution that may change depending on the current order as well as overall in case of site reorganization.

For example, if the hull is manufactured by a subcontractor and shipped to the yard, this would be the Scope 3 upstream information for the main function "hull production" at the assessed yard, including all the environmental emissions. Therefore, the whole life cycle of a ship is included as an environmental footprint on the yard. This still seem a challenging topic, since Scope 3 information is usually not easy to get from subcontractors and due to intellectual right properties. Within the EU, this could change due to transparent CSRD reporting requirements

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which are mandatory for the majority of companies from 2026[EC 2022]. However, the software implementation will consider this challenge by allowing to capture such data manually (even though with a lower maturity level, depending on the quality of the data source).

Any purchased main functions need to be defined against in the generic yard model by the yard. Therefore, if a main function is not conducted by the yard, the baseline emissions will be allocated using either pre-defined values (defined according to maturity level 1) or emission information from the supplier. Again, implementation-wise this fact does not have an impact on the software implementation as the approach will be able to cover both internal and external processes.

6.2. Generic Yard (Library)

Shipyards of the CoL project shall find out which process modelling tool suits best to model processes and define interfaces for WP2. At the moment, the processes of different CoL shipyards are assessed and modelled with MAVIM and CAMUNDA which have the functionality of aggregating all business processes and calculating based on functional units. An interface shall possibly be developed to other modelling tools which is documented in IR 2.3.

The software implementation in WP 2 considers the fact that different shipyards and different purposes of SEPI calculation will require different types of BPM. Therefore, the initial step of setting up a calculation project will be the selection of the model to start with. This could either be the generic model which will then be customised according to the requirements of the envisaged calculation, or it could be a previous model (e.g. from an earlier SEPI calculation) that will be copied and adapted to the current needs. The user (except for dedicated modelling experts) will not be able to create new models from scratch. They can only load a pre-defined model and alter the activity level before starting to collect the data. The shipyard layout model is even more restricted. It cannot be changed at all, except by specific experts in case of physical changes to the yard (who will create this model manually when setting up the software system and adapt it later in case of changes to the yard layout. An important from external systems will be considered but not implemented in the context of CirclesOfLife). The same applies to the mapping between layout model and process model. These restrictions are necessary in order to avoid mistakes in the modelling process and to retain the comparability between models.

Data provided within the generic yard:

- Generic distribution of energy and emission (throughout the main functions sub processes and activities)
- The distribution of the emission is based on purchased data at the yard such as energy bills, water consumption, purchased scope 3 emissions, etc.

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Possible future developments of the tool could be a definition of generic emissions per hour of consumer usage and a generic value for the usage of the technology for a specific process to align the data input with the input values for the digital twin and the improved digital twin.

6.3. Process Inventory

Interface to the process inventory database will be specified. Depending on the shipyard, this database will be integrated into the SEPI tool or remain a separate entity already run by the yard.

To describe the used technology on process level 4, a process inventory will be used. Each technology will be described as a generic input to be able to calculate the SEPI with hardly any yard information (maturity level 1). The data captured will be the same as on higher process levels to allow an easy accumulation of the data up to shipyard level.

The information which is defined in the process inventory (technology library) can be transferred to different process levels, such as activities, sites e.g. buildings, subprocesses, main functions and the yard. This information will contain e.g. material inflow and outflow (including re-use/recyclability), "technology label" information like energy use, etc. A detailed description can be found in D1.1.

The process inventory will contain different kind of filters to find appropriate technologies and processes/activities according to specific requirements. In a later development stage, it will be connected with the best practice guide which would work like an assistant. Therefore, further attributes in respect of e.g. economic and social might be stored for the activities and processes.

	Technologies	Primary Process Surface Preparation				
ID#		Resources	Energie	Waste	Emissions	Co-Product
1	Shotblasting					
2	vacuum blasting					
3	grinding					
4	sand papering					

	Technologies	Sceondery Process Surface Preparation (cleaning)				
ID#		Resources	Energie	Waste	Emissions	Co-Product
21	Vacuum Cleaning					
22	Bucket elevator					

	Technologies	Sceondery Process Surface Preparation (covering)				
ID#		Resources	Energie	Waste	Emissions	Co-Product
31	cloth					
32	protictiv cardbord					

Table 1: Process inventory template

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6.4. Shipyard Digital Model and Digital Twin

As defined in D1.1, the Shipyard Digital Twin (SDT) is a model of a shipyard's site, which consists of at least all relevant main functions which are necessary to produce the product (ship) or execute the relevant service tasks for maintenance, repair, conversion and or end of life (EOL) of the assessed site.

A digital twin can be created from the generic shipyard processes (from Level 1 to 4) and can be adjusted to suit the shipyard's activities. The generic data can be replaced with measured, calculated or estimated (emissions) input data. The SEPI digital shipyard model consists of generic processes (BPM), a process inventory (which contains all technologies, including their assumed emissions based on generic data).

Additionally, the SEPI tool will be able to create a digital twin based on the shipyard layout, capturing the data at the place where the resource use and the emissions take place. While the process model is dedicated to the SEPI calculation and the optimisation of company processes, the layout model is mainly meant to support the data collection. It is still possible to map the process data back to the layout model, especially when trying to investigate the impact of introducing a new technology for a given activity.

The digital representation will be established by the combination of process model, layout model and the intermediate data mapping.

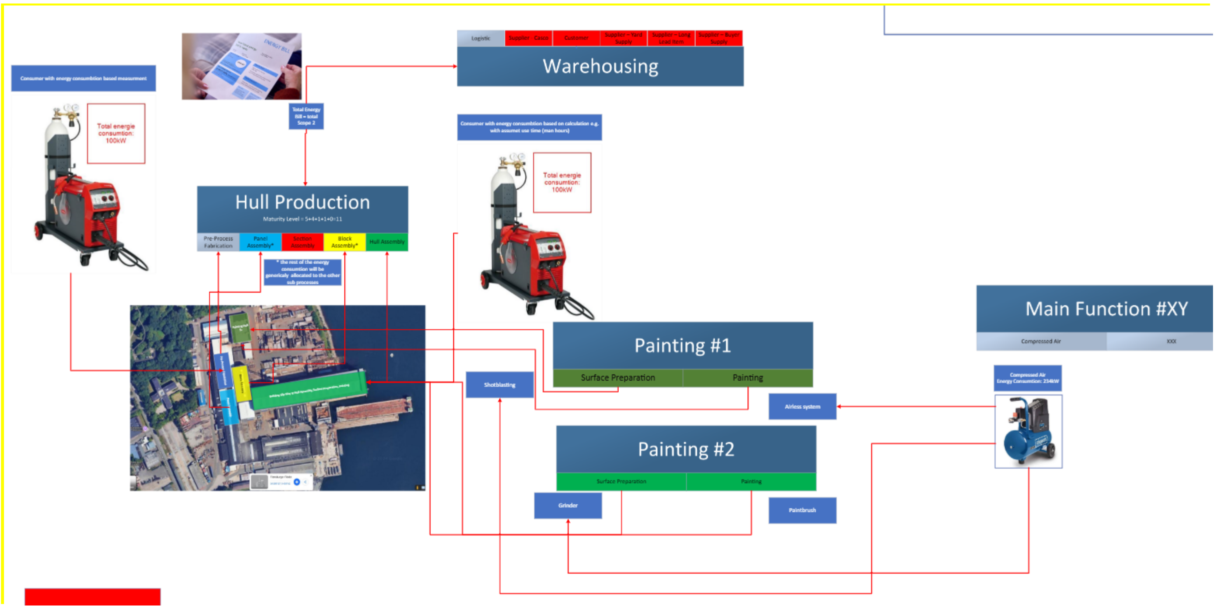

Figure 4: Possible development of the yard model (layout view on the left, process view on the right)

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7. Specification of the process model

Since it has been decided that the SEPI scoring will be based on the environmental performance of different tasks a specific shipyard (main functions) can perform, it is necessary to model at least the main function with the interrelated subprocesses for the shipyard which is to assess. The processes will be modelled only to assess the environmental performance of a shipyard. Therefore, the shipyard model in the CirclesOfLife project will not aim at providing a model that can be used for anything else than the SEPI calculation.

The implementation ensures, that each calculation will always be based upon a full model tree. In case only subtree or single processes will be investigated, they can be selected in the software and any other process will be hidden. This ensures the consistency of the model for partial investigations.

7.1. Overall model structure

Two distinct but interconnected model trees will be developed: one representing the shipyard's process model and the other reflecting the shipyard layout model. These two trees serve different but complementary purposes within the overall framework. The process model is intended to provide the representation of all processes within the shipyard, as required by the SEPI concept. In parallel, the shipyard layout model is designed to facilitate the systematic collection of energy-related and operational data, aligning with the requirements of ISO 50001, which focuses on energy management systems and continuous improvement of energy performance. The latter model reflects the actual method of collection data at the yards which will support this process and consequently lead to higher acceptance of the software system.

Although both models are structured independently, they are aligned in terms of the data they represent. Specifically, the nodes in both the process tree and the layout tree contain the same set of variables. These variables include energy consumption, resource usage, pollution, or other relevant SEPI parameters. Despite this structural symmetry, the actual data collection will take place exclusively within the layout model. This means that the layout tree serves as the central point for capturing real-world data from the shipyard, while the process tree will serve the purpose of determining the SEPI and identifying optimisation potentials.

To establish the connection between the collected data and the underlying shipyard processes, a manual mapping procedure will be implemented between the two trees. This mapping involves assigning specific percentages or weights to different processes, linking the data of the layout model to corresponding elements in the process model. For example, if a particular workshop in the layout model is responsible for several subprocesses, its energy consumption might be distributed proportionally across those subprocesses based on expert judgment and empirical or actual measurements. This manual mapping enables a more accurate attribution of energy and resource usage to individual processes, enhancing the quality of the analysis.

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Furthermore, both the process model and the layout model will include the concept of a maturity level, which will be assessed and recorded on both sides. The maturity level reflects the accuracy of the collected data.

The established mappings between layout and process trees will be optionally stored, allowing them to be reused in future analyses or benchmark studies. This reusability ensures that once a reliable mapping is created, it does not need to be redone for every new evaluation, saving time and ensuring consistency over time. Additionally, at a global project level, functional units will be collected and used to contextualize the data. These units—such as Compensated Gross Tonnage (CGT), tons of steel processed, or total working hours—provide a standardized basis for performance comparison across different projects or shipyards.

Importantly, functional units will differ depending on the type and specialization of the shipyard. For instance, a newbuilding shipyard will emphasize different metrics than repair or recycling yards. Difference might also be determined by the product portfolio. This flexibility in functional unit selection ensures that performance indicators remain relevant and meaningful across a diverse range of shipyard types and production contexts. However, in order to be able to compare different shipyards, use of an identical set of functional units is required. It will therefore be necessary to determine standard functional units (in WP 1 or 3) for this purpose without giving up the possibility to customise this list for specific applications.

7.2. Process Hierarchy (Main Functions and Sub Processes)

The process hierarchy has been defined in WP 1 and is referenced here for better understanding.

A clear and agreed process hierarchy is required to have a uniform way of tracking and optimising the emissions of various shipyards (for each life cycle). Furthermore, this hierarchy must contain the right levels to match and serve the actual processes and process structure of each three shipyards types (yard scopes). The process hierarchy below is designed to be generic for all shipyards and to cover all available process information related to emissions and consumers. This hierarchy consists of five hierarchical levels, which are shown below. Four are relevant for the CirclesOfLife project and will be described in the following.

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Figure 5: Business process levels hierarchy - level 0 to level 4 (DAMEN)

7.2.1. Level 0 - Company Landscape

This level indicates the connection between the various process landscapes (level 1) and can be used if a company has different divisions e.g. DAMEN. This level is not considered further in the analysis of the Generic Yard, since the hotspot and SEPI is analysed at a shipyard's physical site and all incoming external data is integrated as scope 3 (CSRD, further information see D1.1). Since getting the required information for Scope 3 can be difficult, this topic still needs further development.

7.2.2. Level 1 - Process Landscape

The process landscape is a visual representation of all the process groups of a generic yard (see chapter 5).

The level 1 layer will show all level 2 process main functions (represented in dark blue) that are currently identified, or as a structured overview. Beneath the main functions you can find the level 3 Sub Processes (represented in light blue).

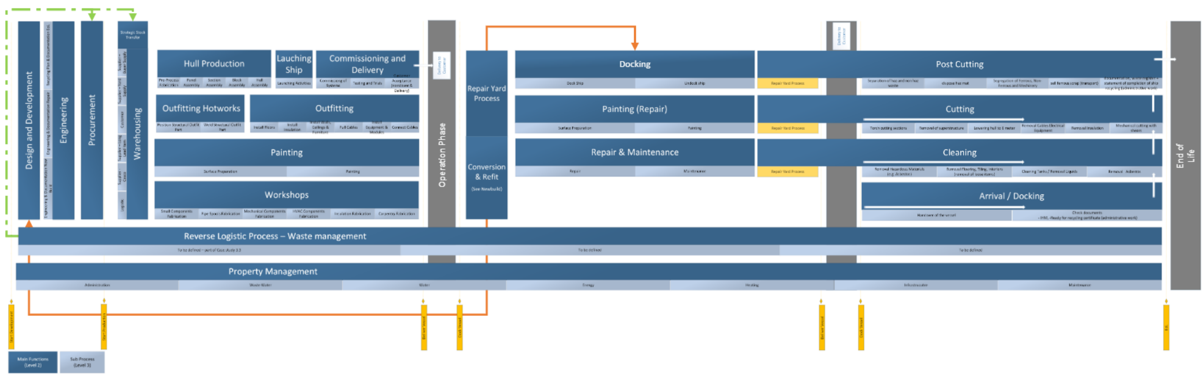

Figure 6: Process level 1 - process landscape overview

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7.2.3. Level 2 - Main Function

Main functions (dark blue) gather and represent a group of sub processes (light blue). For example: The main function "*Painting*" consists of the sub processes *"Surface Preparation"* and *"Painting"* as shown in the picture below.

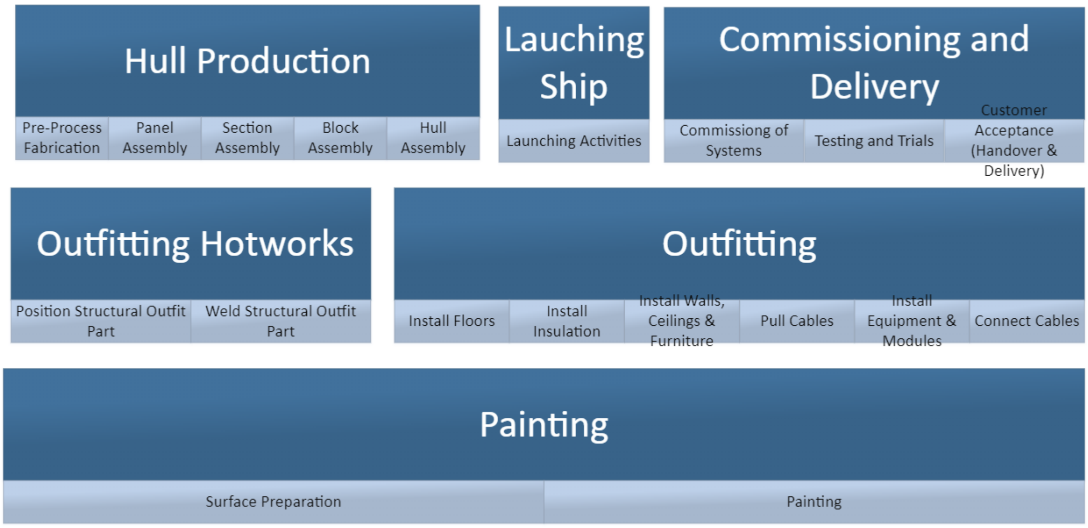

Figure 7: Process level 2 – Main function (dark blue), sub process level 3 (light blue)

7.2.4. Level 3 - Sub Process

A sub process is a set of activities to accomplish a specific organizational goal. A business process is mostly part of an end-to-end flow. A sub process may consist of multiple activities (process level 4).

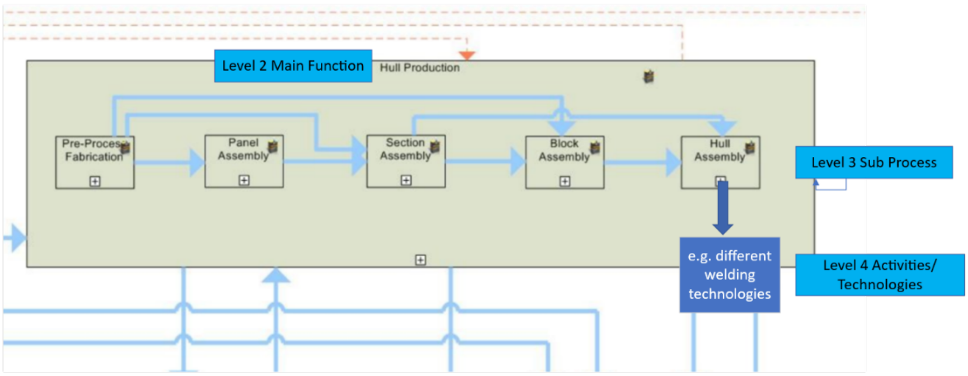

Figure 8: Process level 3 – sub process

7.2.5. Level 4 - activities / technologies (Work Process)

A work process is a series of interrelated activities (with their associated technologies) that lead to a defined outcome.

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For example, the surface preparation had the actives shotblasting/grinding and cleaning with their associated technologies. This information will be gathered as described in the process inventory (see chapter 6.3 "*process inventory*").

ID#	Technologies	Primary Process Surface Preparation				
		Resources	Energie	Waste	Emissions	Co-Product
1	Shotblasting	ice, Sand, steel grit		grit	Dust, noise, CO2 (Scope 3 and 2)	
2	vacuum blasting					
3	grinding		Pneumatic, electrical	fan washer	Dust, noise, CO2 (Scope 3 and 2)	
4	sand papering			sand paper	Dust, CO2 (Scope 3)	

ID#	Technologies	Sceondery Process Surface Preparation (cleaning)				
		Resources	Energie	Waste	Emissions	Co-Product
21	Vacuum Cleaning		electrical		noise, CO2 (Scope 2)	
22	Bucket elevator		electrical		CO2 (Scope 2)	

Figure 9: Process level 4 – activities

With respect to software development, all levels will be treated equally, by defining a single node object that contains information about the connection to the neighbour levels and additionally about all values collected for the given object. This information could either be filled with values (collected on this level) or empty (meaning that no information has been collected on this level and the SEPI tool there needs to generate the information by adding the information from the inherited level). Furthermore, the same model structure will be used by the layout based model which means that the top level object should contain the same value for both trees if all data has been collected and mapped correctly.

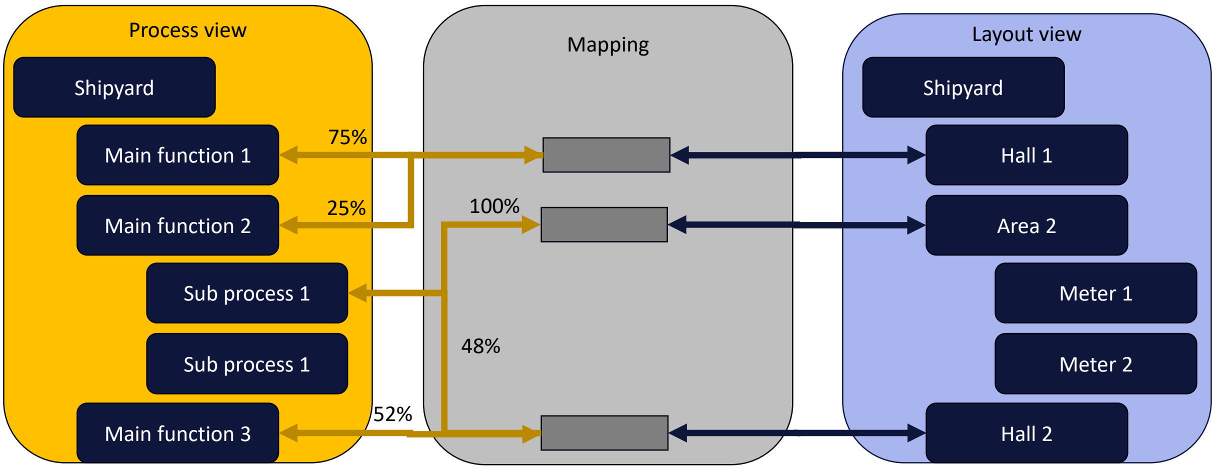

Figure 10: Process based vs. layout based shipyard model

7.2.6. Model architecture

The current data model is able to capture the two trees (process and layout model), the variables and the maturity level. Additionally, the user, organisation and project information can be handled. The only aspect missing is the mapping between the two trees. This functionality will be added once the definition has been finished.

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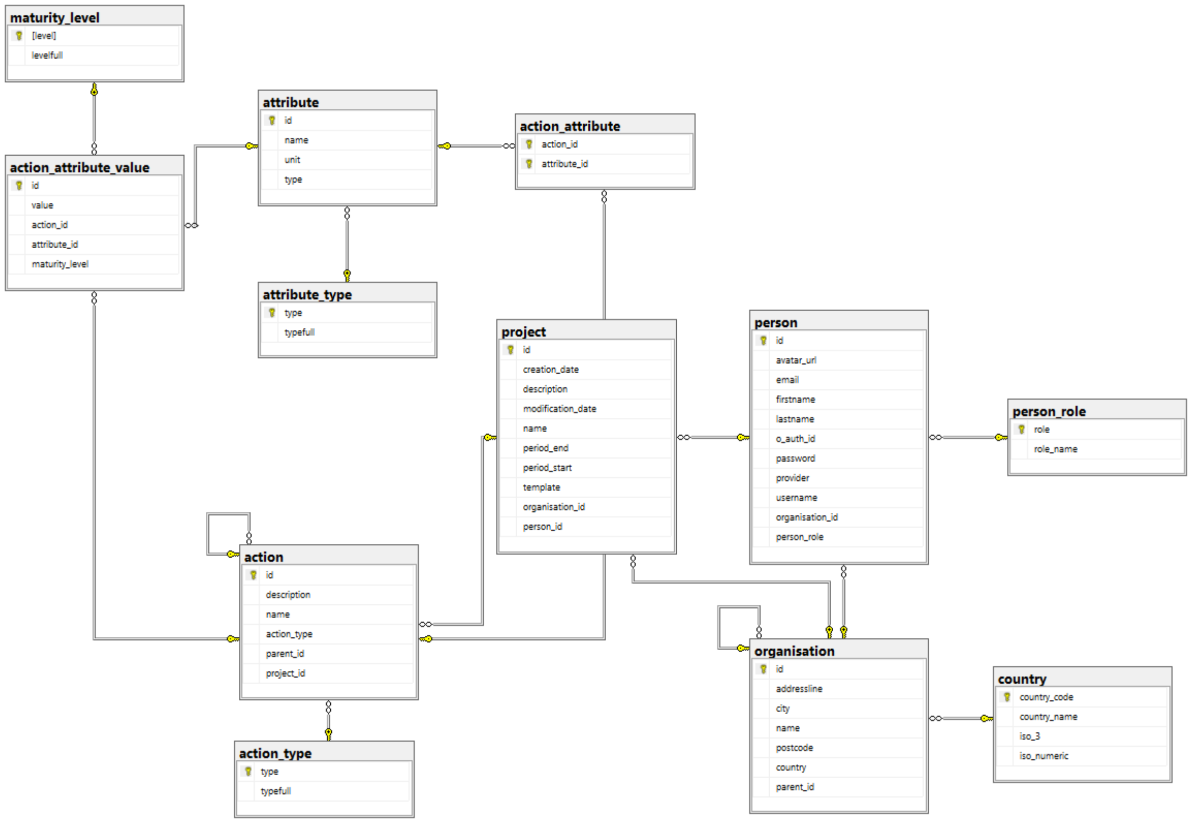

Figure 11: Overview of data model

7.2.7. Model components

Overview of main Entities & Attributes

The following list provides an overview oft he main objects in the data model which will be refined during the implementation phase. The actual implementation specification will contain additional attributes such as timestamps, versioning information, technologiy alternatives, etc. In a later implementation step, the best practise guide defined will also be integrated.

1. Project

Represents an analysis (e.g. SEPI for 2024) for an organization.

Main attributes:

- Description
- Creation date
- SEPI period

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- Evaluation scope

2. Person

Represents an individual responsible for managing or creating a project.

Main attributes:

- User name, password
- Person name
- Organisation
- Role

3. Organization

Represents a business, institution, or group managing multiple projects. This object is typically only used when more than one shipyard will be served by a specific instance of the SEPI tool.

Main attributes:

- Organisation name
- Meta data

4. Action

Defines a structured workflow or activity within a project. The same object is also used for modeling the layout structure at the yard. The aim of modeling these elements is to build the structure of the process and layout trees for collecting data and SEPI calculation. It is not determined to duplicate a full-featured process model but represents a static subset dedicated to a specific calculation project.

Main attributes:

- Name
- Action type

5. Attribute

Defines a specific characteristic that can be associated with a process or a layout object. While the attributes will typically be identical for each element in the trees, software-wise they can still be set individually to get an as great amount of flexibility, especially during the implementation period when not all data areas will be covered.

Main attributes:

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- name of the attribute
- unit
- value

6. Attribute_Type

Defines the type of an attribute. Used to determine the section of the SEPI calculation (climate change, water use, …).

Main attributes:

• Type

7. Maturity_Level

Represents a maturity assessment level.

Main attributes:

- Level

8. Relationship

Links **projects, processes, and attributes** with **maturity levels and values**.

9. Process_Attribute

Defines which attributes are linked to a specific process.

10. Key Relationships

1. **Process** can be hierarchical (linked to a parent process).

2. **Attributes** are linked to **Processes** through **Process_Attribute**.

3. **Relationships** define the link between **Projects, Processes, and Attributes**, including **Maturity Levels**.

4. **Maturity Levels** and **Attribute Types** are predefined classifications.

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8. Definition of data maturity and allocation to processes

8.1. Data maturity

According to the results of WP 1, the data maturity to be referenced to each consumer uses the following levels:

- Measured (e.g. by meters in the hall)
- Calculated (by distribution of measurements at a higher level according to supporting information such as technical specifications)
- Estimated (by using supporting documents or other non-measured data)
- Generic (by estimating without any specific evidence)
- Not applicable (no data produced)

The table below shows the level in greater detail. The maturity level is not only determined by the method of collecting data but also by the quality of the data source.

Maturity	Description
Level 5	Standards + R&L Future + Traceable CSRD = Digital Yard model + real time L4 process activities measured (IOT) , Specific Supplier data (LCA/CMP) E1-5 Objective - measured, energy & material Scope1,2,3 inflow, Best Available Techniques (BAT) with the lowest current environmental impact is implemented.
Level 4	Standards + R&L Future + Traceable CSRD = Digital Yard model + Identify hotspots (based on consumption E1 and E3 and estimated/calculated E2, E4 and E5 emissions) and measure data at yard activity level 4, including technology variations, with supplier specific Scope 3 data, allows top down and bottom up comparison, to plan hotspot improvement at process level 4….and LCA improvement planning, where ships that have a lower impact during the use phase (yachts) might benefit from reduced manufacturing footprint.
Level 3	R&L + Standards + Mature CSRD = Identify hotspots (based on consumption E1 and E3 and estimated/calculated E2, E4 and E5 emissions) and measure their data at yard sub process level 3, which can be directly used for SEPI / CSRD can be used for LCA input
Level 2	R&L + Basic CSRD = Yard sub process L2 measured / calculated, L3 estimated % improvements, estimated annual purchased energy & material Scope1,2,3 LCA + Narrative improvement areas = GME level 4 + E1-5 estimated, target is related to baseline 1
Level 1	R&L + Basic CSRD = Yard impact annual yard purchased energy (Scope 1,2,3 annual input for product LCA) + main function at L2 Narrative improvement areas = GME level 3 + E1-5 estimated, target is related to baseline 1

Table 2: Overview of maturity levels

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8.2. Integration of maturity data in the software model

The data maturity according to this definition can only be captured on layout level. Since the SEPI calculation on process level also requires the definition of the maturity level, extension of the mapping will be needed to cover the maturity in addition to the distribution of the data. Since the exact method of this maturity mapping has not been defined yet, the software will implement the possibility to perform this task without actually activating it for the first prototype. Instead, the user will manually set the maturity levels in the process tree until a concept has been defined.

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9. Supplementary data

9.1. Administrative data

In addition to the core functionality related to SEPI, the tool will also include administrative data to handle user access and organisational data. This includes the collection and handling of supplementary information that, while not directly tied to SEPI processes, is essential for managing the tool's usage across different contexts. Specifically, data about the organisation will be stored, which is particularly relevant for companies operating multiple shipyards. This allows for a structured and scalable approach to user and data management.

Each user will be associated with specific identifying details such as their name and affiliated organisation. Access to the system will be secured through password protection, and user roles will be defined to distinguish between different levels of responsibility and access: modeller (creating, editing and population of models), data collector (only entering data into existing projects), calculator (running SEPI calculations and selecting suitable visualisations and reports) and administrator (running and configuring the system). These roles help ensure that users only access the functionalities and data relevant to their tasks, thereby guaranteeing data integrity and security.

To further strengthen access control and align with industry standards, the system will support multi-factor authentication (MFA) and single sign-on (SSO). This allows seamless integration with existing shipyard authorisation and identity management systems, facilitating a user-friendly yet secure login experience. Overall, these administrative capabilities provide a robust foundation for the tool's operation within complex organisational environments.

9.2. Additional project data

The tool also captures information describing the respective calculation project. This includes the time frame for which the calculation is conducted, as well as the specific purpose of the calculation—whether it is to determine the overall SEPI score, to analyze SEPI in relation to specific processes or departments, or to evaluate potential improvement measures. Additionally, versioning is applied to ensure that changes and developments in the calculations can be tracked over time. The individuals responsible for the project are also clearly identified to ensure transparency and traceability throughout the process.

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10. Interfacing with external applications

10.1. Purpose of data retrieval

The system supports the import of different data elements, including the layout model, the process model, and the mapping between them. It also enables the collection of data related to energy consumption and environmental pollution, with input sourced directly from measuring facilities installed throughout the shipyard.

One of the main challenges in this context lies in the way data is typically collected. In most cases, data collection is organized according to the physical shipyard layout—often in line with standards such as ISO 50001—rather than being structured around operational processes. While this approach aligns with existing infrastructure, it creates a disconnect between the data and the process-oriented models required for advanced analysis.

An additional difficulty is that introducing extra steps to reorganize or reformat the data, although necessary, tends to reduce user acceptance and increases the likelihood of errors. Moreover, the individuals or systems responsible for collecting the data are often unaware of the relationship between the measurements and the underlying processes, which further complicates integration.

To address these issues, the proposed solution is pragmatic and builds on existing practices. Data should continue to be collected directly from the points where it is measured, maintaining compatibility with current procedures. Separately, the process model can be developed independently to reflect the operational structure of the shipyard. The final step involves manually mapping the collected data to the relevant processes, thereby establishing the necessary link between measurement and analysis without disrupting the data acquisition workflow.

10.1. Allocation of input data

Input data will be needed according to the process structure. As shown in the following picture. However, in most cases the shipyard layout is not a 1:1-representation of the process model. Instead they will be collected compatible with ISO50001 which is orientated towards the actual consumers. Therefore, the interfaces need to be flexible enough to capture the data even if it is organised differently. Therefore, the interfaces will be design in a way the system that provides the data will have to declare the node in the layout or process tree to which the data should be assigned. It is up to the application itself to map the data between the different data models.

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		Input/ Allocation					
		Processes				Physical Assets	
		Process Landscape (Level 1)	Main Function (Level 2)	Sub Process (Level 3)	Activity/ Technology (Level 4)	Consumer (Level 4.1)	Building/Site
Container for information	Process Landscape (Level 1)		X			X	
	Main Function (Level 2)			X		X	X
	Sub Process (Level 3)		X		X	X	X
	Activity/ Technology (Level 4)			X		X	X
	Consumer (Level 4.1)	X	X	X	X		X
	Building/Site		X	X	X	X	

Figure 12: Allocation of consumers to process levels and sites

10.2. Data mapping

Figure 13: Example of a graphic shipyard layout view

In the SEPI system, data collection will continue as it is done today, focusing on information about consumed resources and emissions. This data can be transferred into the SEPI tool either manually or through interfaces established with existing systems and tools at the shipyard. Importantly, all data input with respect to measurements will take place within the layout view, which aligns with how data is typically collected at the operational level. In order to also cover data about innovative technologies that are not yet in use or for corrections, data editing is also possible on the process side. The mapping of such changes back into the layout view will be implemented at a later point in time.

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Once the data is entered, a mapping process is required to link specific locations in the layout to the corresponding processes. This mapping can either be done once—if the distribution of processes and measurements remains stable—or tailored individually for each SEPI project. The responsibility for this task lies with experts in process modeling, as a thorough understanding of both the physical layout and the operational processes is essential. Technologies implemented at various locations will also be mapped within this framework. Moreover, the mapping is bidirectional, meaning it also allows for connections from the process view back to the layout. This is particularly useful for assessing the potential impacts of introducing innovative technologies, as their effects can be evaluated across both dimensions.

Once the mapping is complete, the SEPI tool automatically populates the process model by transferring the relevant data from the layout view into the process view. This enables the calculation of key performance indicators (KPIs) and the visualization of results within the process-oriented structure of the tool.

From a technical perspective, the implementation involves realizing both the layout and process "trees." In software terms, the layout tree is treated as another form of process tree, meaning the structure and variables are consistent across both. Each node within these trees contains the same types of variables, and at the top level—representing the entire shipyard—the data is theoretically identical in both trees. The software stores the layout tree, the process tree, and the mapping between them in the database.

Depending on how a shipyard is organized, a SEPI project can be configured by selecting a specific process tree, layout tree, and the appropriate mapping. The maturity level of the input data must also be taken into account. While assigning maturity levels is relatively straightforward in the layout view, transferring and interpreting those levels in the process view during mapping can present certain challenges. Nonetheless, this structured approach ensures that data is accurately linked and effectively visualized, supporting robust environmental performance analysis.

10.3. Information Flow

In this analysis we will observe the digital shipyard model In the SEPI environment and describe the interaction with other tools (e.g. reporting, SEPI, LCA Tools, Ship and Product Passports) respectively the demand and required information which flows between these tools.

The data which is used to feed the Generic Shipyard Model / Digital Twin / Improved Digital Twin will be re-used to serve the reporting tool, Ship Circular Materials Passport, Ship Lifecycle Passport as well as other possible interfaces. This reduces the amount of work for the user.

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The Generic Shipyard Model enables the yard to understand its yard processes and to be able to compare its emissions with the benchmark values within the SEPI environment. It also enables the yard to establish an improvement plan and to decide on possible technologies to reduce its environmental footprint.

With the Digital Twin a hot spot analysis will be possible to be able to identify high emissions within the yard scope. Improvement measures can be identified and compared to the benchmark values within the SEPI environment. The Improved Digital Twin will show possible emission reductions but also the improved yard.

Based on the distribution of the projects run throughout the dedicated year, the already used information for calculating the environmental footprint of the yard can also be used for the Ship Lifecycle Passport. This means that the emissions of the yard can be identified to be able to relate them to the product ship (LCA calculation). Therefore, a calculation method needs to be in place to be able to break down the yard's emissions to a specific ship.

The emissions will be saved to a database and can be compared to other years, projects (possibly through LCA-tool), etc.

10.4. Data input/output and tools to be accessed

Data input into the SEPI tool will primarily come from Business Process Management (BPM) tools and applications that measure resource consumption and emissions. To enable this, individual development work is required for each external system that offers either an API or file-based data transfer capabilities.

In the initial implementation phase, the focus will be on establishing interfaces specifically for exchanging data with BPM tools, as these are central to process modeling and already widely used in shipyards. A sample interface for measurement tools will only be developed within the CirclesOfLife project if participating shipyards are able to provide access to suitable applications that support such integration.

Until these interfaces are fully developed and operational, the population of the SEPI tool will be carried out manually. This ensures that data can still be entered and the tool can function effectively during the early stages of implementation, even in the absence of automated data exchange.

10.4.1. Input data from shipyard layout view

Importing data into the shipyard layout view will require a software tool that can generate a data collection sheet on its own and populate the required minimum dataset (measurement location, data group, amount, unit, source) together with information describing the location in the layout tree. The alternative would be the option to fill in a prepopulated data collection

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sheet provided by the SEPI tool. Both approaches require support from the shipyard tool side and will therefore not be implemented for the first prototype.

10.4.2. BPM interfaces

Interfaces with BPM tools will be needed to retrieve process models from the shipyard and to return SEPI results for further processing. For the import, the BPM tool will have to create an XML file preferably in BPMN 2.0 format. The processes to be considered by the SEPI tool should be marked with a specific attribute, indicating the use for the SEPI calculation. The import could consider the entire model or only the processes on level 4 which especially can be used when the modelling is being done base upon the CirclesOfLife generic shipyard model. The SEPI tool will convert the input file into a static tree and retain the imported model unchanged. This allows for exporting results at a later point in time. While it is possible to edit a manually created model, this will not be possible for an imported model unless the user disconnects the SEPI model from the original BPM (making it impossible to export the data back into the BPM tool). The reason for this is the inability of the SEPI tool to create a full BPM and consequently the loss of the 1:1 relationship between the imported model and the copy in the tool.

MAVIM (a commercial tool used by DAMEN) and CAMUNDA (an open source tool) will be the BPM tools the SEPI application will be able to connect with initially. However, it is expected that the implementation of the interface will allow for a smooth connection with other BPM tool, especially when they are also capable of generating XML files. It should be noted that the SEPI tool will also support the fully manual creation of a process tree which will be needed if the shipyard is not yet using a BPM tool. This functionality will also be used for the creation of the layout tree as it is not expected that the shipyard layout will be modelled by a BPM-like approach.

A simple BPM modelled by CAMUNDA is shown in Figure 14. Below an excerpt of the XML representation is given. By editing the XML file, data can be transferred back into the BPM tool as long as the integrity of the model structure is maintained.

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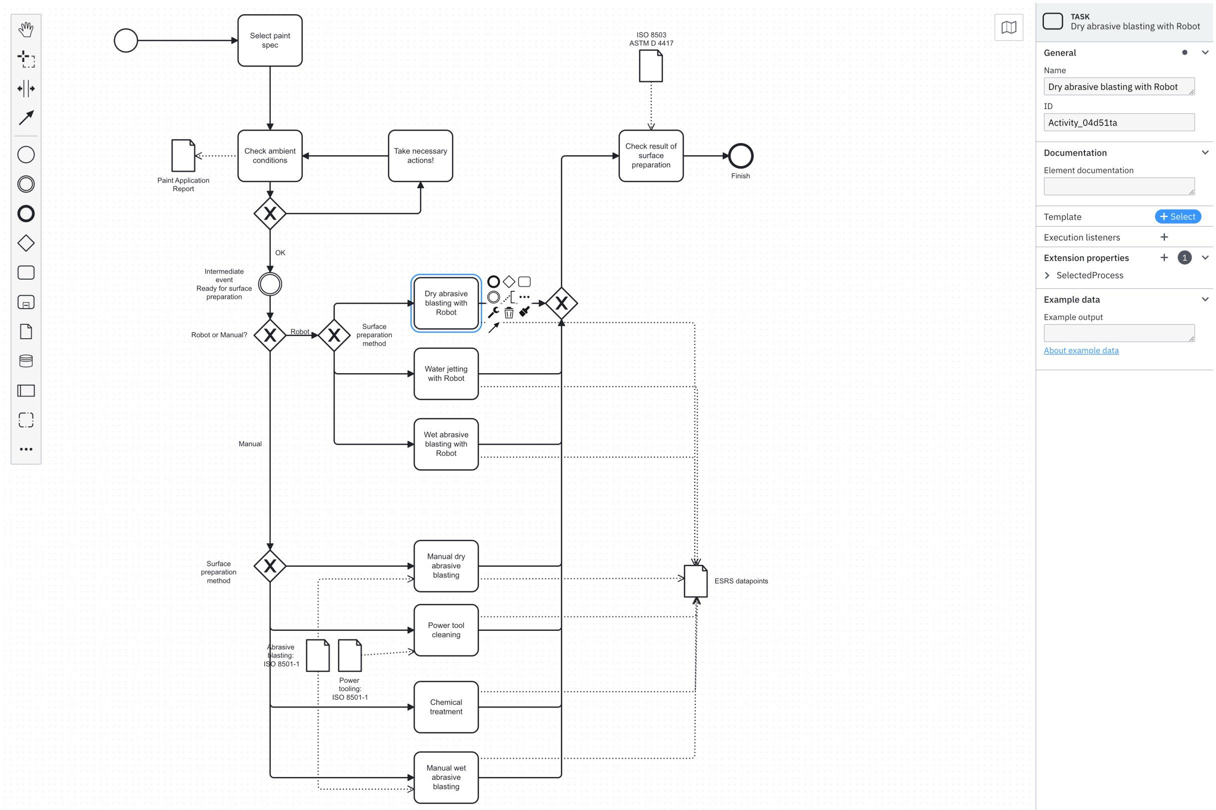

Figure 14: CAMUNDA model (graphic representation)

<?xml version="1.0" encoding="UTF-8"?>
<bpmn:definitions xmlns:bpmn="http://www.omg.org/spec/BPMN/20100524/MODEL" xmlns:bpmndi="http://www.omg.org/spec/BPMN/20100524/DI" xmlns:dc="http://www.omg.org/spec/DD/20100524/DC" xmlns:zeebe="http://camunda.org/schema/zeebe/1.0" xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" xmlns:di="http://www.omg.org/spec/DD/20100524/DI" xmlns:modeler="http://camunda.org/schema/modeler/1.0" id="Definitions_1pmkwtb" targetNamespace="http://bpmn.io/schema/bpmn" exporter="Camunda Modeler" exporterVersion="5.35.0" modeler:executionPlatform="Camunda Cloud" modeler:executionPlatformVersion="8.6.0">
<bpmn:process id="Process_0szvsu0" isExecutable="true">
<bpmn:startEvent id="StartEvent_1">
<bpmn:outgoing>Flow_0noua1j</bpmn:outgoing>
</bpmn:startEvent>
<bpmn:dataObjectReference id="DataObjectReference_0a1kmo5" name="ISO 8503
ASTM D 4417" dataObjectRef="DataObject_0ojwz55" />
<bpmn:dataObject id="DataObject_0ojwz55" />
<bpmn:dataObjectReference id="DataObjectReference_0hy9skj" name="ESRS datapoints" dataObjectRef="DataObject_0vzui2j" />
<bpmn:dataObject id="DataObject_0vzui2j" />
<bpmn:dataObjectReference id="DataObjectReference_0qhl1uv" name="Abrasive
blasting:
ISO 8501-1" dataObjectRef="DataObject_1fk4cbq" />
<bpmn:dataObject id="DataObject_1fk4cbq" />
<bpmn:dataObjectReference id="DataObjectReference_1rd2t75" name="Power
tooling:
ISO 8501-1" dataObjectRef="DataObject_1smntly" />
<bpmn:dataObject id="DataObject_1smntly" />
<bpmn:dataObjectReference id="DataObjectReference_0qt6104" name="Paint Application Report" dataObjectRef="DataObject_08v4y6f" />

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```
<bpmn:dataObject id="DataObject_08v4y6f" />
<bpmn:endEvent id="Event_1csaymw" name="Finish">
  <bpmn:incoming>Flow_0fq87n8</bpmn:incoming>
</bpmn:endEvent>
<bpmn:task id="Activity_0qwtkha" name="Manual wet abrasive blasting">
  <bpmn:incoming>Flow_1q5rg9y</bpmn:incoming>
  <bpmn:outgoing>Flow_030sfn4</bpmn:outgoing>
  <bpmn:property id="Property_0elc0f5" name="__targetRef_placeholder" />
  <bpmn:dataInputAssociation id="DataInputAssociation_0vf97vl">
    <bpmn:sourceRef>DataObjectReference_0qhl1uv</bpmn:sourceRef>
    <bpmn:targetRef>Property_0elc0f5</bpmn:targetRef>
  </bpmn:dataInputAssociation>
  <bpmn:dataOutputAssociation id="DataOutputAssociation_0fm3efd">
    <bpmn:targetRef>DataObjectReference_0hy9skj</bpmn:targetRef>
  </bpmn:dataOutputAssociation>
</bpmn:task>
```


The following two figures show the envisaged architecture once the SEPI tool has been integrated into the shipyard environment. In step 1, communication runs via the interfaces as described above. In step 2, a further integration into the software architecture could be possible by integrating the SEPI tool directly with the shipyard data platform. However, this complex step lies beyond the scope of CirclesOf-Life. The SEPI tool will nevertheless be capable of using external databases instead of the builtin one.

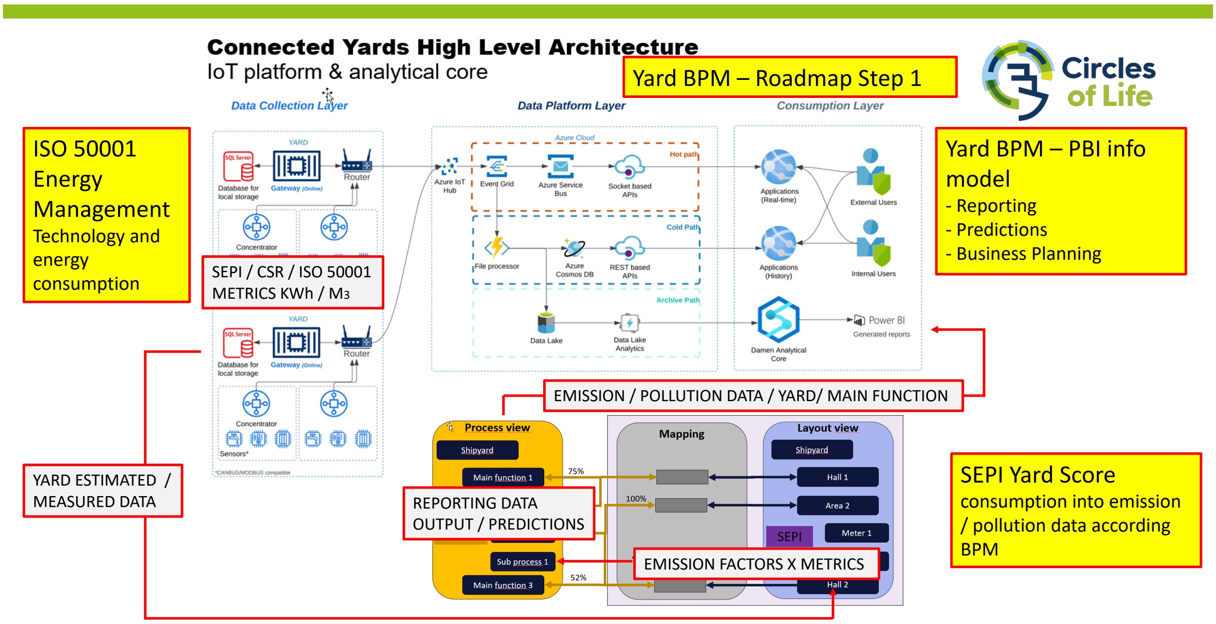

Figure 15: Shipyard dataflow using data import from yard tools and exporting results into postprocessing tools

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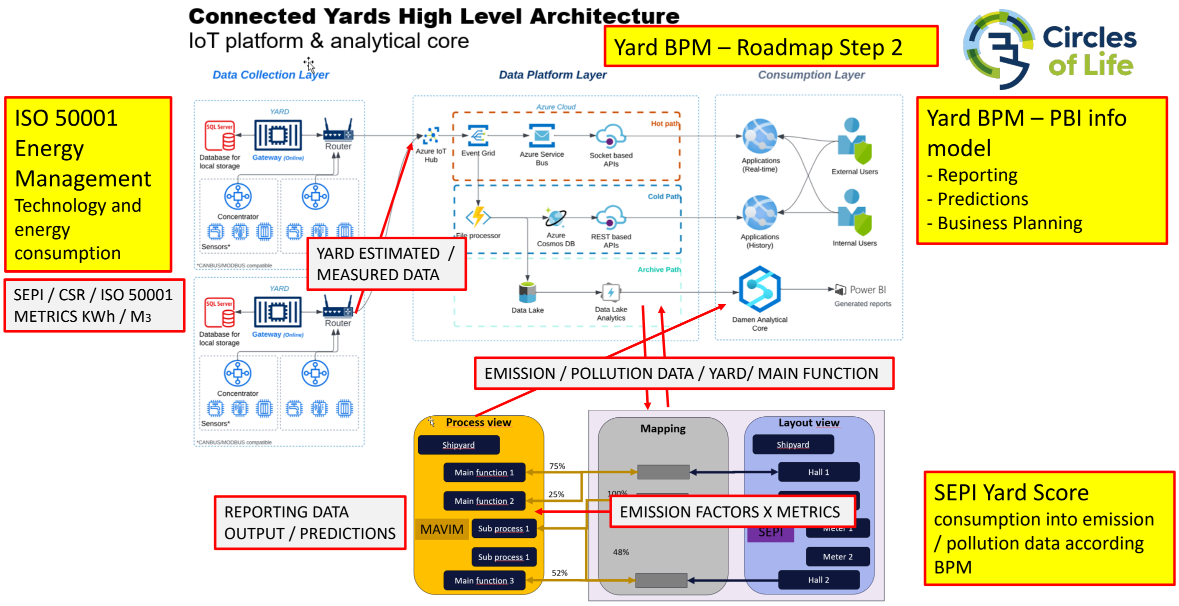

Figure 16: Advanced communication between SEPI tool and shipyard data platform

When retrieving data from applications or databases, two different approaches are possible:

- Exchange with files (e.g. Excel, JSON, XML), either structured or in arbitrary format
- API (Application Programming Interface) to directly communicate with the application via a network or on the same computer

While the API solution is most likely the quickest option and also has a high reliability, there are also some drawbacks. First of all, such an API must exist and needs to be available to the SEPI tool. This includes provision of appropriate access rights, a technology that can be accessed by the tool and also a proper documentation. Such an API might be complex, can undergo incompatible changes over time and might also be subject to restrictions with respect to data exchange, volume, etc. Therefore, it is recommended to use this approach only for wide-spread standard applications, in-house applications (especially with access to interfaces and source codes) or applications that officially offer the API to the customers. In any case, the API approach would require implementation effort for each new software the SEPI tool should be connected to. Therefore, this approach will not be followed when performing the implementation in CirclesOfLife.

On the other hand, data exchange using files works without such an API and can be used as long as the software to be connected is able to create output file containing the required data (as a fallback, it is always possible to populate an exchange file manually but this should be restricted to error corrections as it is most likely easier to enter larger amounts of data directly into the SEPI tool).

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When exchanging data via files they can be organised in a structured way or analysed in the format the exporting applications can provide without additional implementation work. Since the unstructured approach requires more effort on the SEPI tool side and still does not guarantee correct results, CircleOfLife will only be able to handle structured files. For pragmatic reasons implementation will start with MS Excel files that are wide-spread and for which libraries are already available. Although importing Excel files also might be affected by different challenges (data types, reordered cells, etc.) they are well-understood. Therefore, the SEPI tool will predefine an import format that enables other applications to transfer data into the nodes of the layout and/or process tree. The definition is straightforward and mainly contains variable names, units and values, together with information that describes the data set and fields in more detail. The cells are protected to make it more difficult for users to accidentally corrupt the file. However, since the exporting application might not necessarily fill in a template but may also generate the entire Excel file automatically, it is still necessary to implement comprehensive error handling mechanisms.

The Excel file looks as follows and will be extended as more KPIs will be covered:

The template has been developed in Task 1.5 and provides a structured approach for gathering essential process and technology-level information. The sheet can be tailored to suit the specific requirements of each case study. Therefore, further development and refinement of data collection sheet will continue under WP3. The following data collection sheet is proposed as a starting point.

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Completed by:			Date of completion:
Process identification:	Process Functional Unit:		Reporting location:
Description of process:			Technology ID & Description:
Climate Change	Units	Quantity	Description of sampling procedures
Air emission – GHG and air pollutants (e.g., CO_2, CH_4, N_2O)			
Pollution	Units	Quantity	Description of sampling procedures
Spill Prevention and Stormwater Management (e.g., fuel, lubricants, suspended solids)			
Surface Treatments & Coatings (e.g., VOCs, solvents, paint residues)			
Water & Marine Resource	Units	Quantity	Description of sampling procedures
Spill Prevention and Stormwater Management (e.g., Heavy metals, oils, suspended solids)			
Surface Treatments & Coatings (e.g., Copper, zinc, micro-particles)			
Biodiversity & Ecosystem	Units	Quantity	Description of sampling procedures
Surface Treatments & Coatings (e.g., Copper, zinc, micro-particles)			
Resource & Circular Economy	Units	Quantity	Description of sampling procedures
Waste Management (e.g., Steel Scrap and Slag, offcuts)			

Figure 17: Data collection sheet - initial concept

While this table shows the conceptual view, the actual realisation muss be more comprehensive to cover all data required for the SEPI calculation. This especially includes information about data maturity, detailed information of the time the data was captured and, especially for E1 related data items, the source of the consumed substance or the emitted material. This could be the energy mix for electricity, the location the freshwater came from, etc. Therefore, the table to be implemented counts additional columns as shown in the following table. In addition to that, the table will be preconfigured to support the user in collecting the requested data. The resource fields will provide a list of possible items relevant for the respective data group. Unit, source and maturity level will also be lists instead of free text fields. This approach ensures that the data can be correctly processed by the SEPI calculation. In case of additional resources, varying units or unknown sources the underlying databases will have to be adapted. Especially for the resources and the sources accompanying information from supporting database will be required for correct data processing. Therefore, the data collection

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sheet will contain data fields for identifying them as generated by the SEPI tool to identify files generated by external applications that have a higher likelihood of containing invalid data.

<table>
<tr><td colspan="3">Completed by: Company X</td><td colspan="4">Date of completion: 1.2.2025</td></tr>
<tr><td colspan="2">Process identification:
Process 1 (70%)
Process 2 (30%)</td><td>Process Functional Unit: CGT/year</td><td colspan="4">Reporting location: Hall 1</td></tr>
<tr><td colspan="3">Description of processes: xxx xxx xxx xxxxx xxx xx xx x</td><td colspan="4">Technology ID & Description: xx xx xxxx xxxx xxxx</td></tr>
<tr><td>Climate Change (E1)</td><td>Unit</td><td>Quantity</td><td>Time</td><td>Source</td><td>Maturity level</td><td>Description of sampling procedures</td></tr>
<tr><td>Electricity</td><td>kWh</td><td>5.000</td><td>August 2025</td><td>EU mix 2024</td><td>3</td><td>Meter in Hall 1</td></tr>
<tr><td>Diesel Oil</td><td>t</td><td>300</td><td>August 2025</td><td>MDO</td><td>3</td><td>Refill of tank 25</td></tr>
<tr><td>Hydrogen</td><td>t</td><td>200</td><td>August 2025</td><td>Wind energy driven hydrolyse</td><td>3</td><td>Device 234</td></tr>
<tr><td>Water & Marine Resource (E2)</td><td>Unit</td><td>Quantity</td><td>Time</td><td>Source</td><td></td><td>Fresh water supply, invoice 4711</td></tr>
<tr><td>Fresh water</td><td>m^3</td><td>2.000</td><td>August 2025</td><td>Fresh</td><td>2</td><td></td></tr>
</table>

Figure 7: Data Collection Sheet

10.5. Implementation priorities and schedule

The development process follows a structured, step-by-step approach to integrate data and models into the SEPI system. The first step involves importing data into the model tree using a predefined Excel template. This enables a standardized and efficient way to bring relevant information into the system. Following this, the second step establishes a connection between existing BPM (Business Process Management) tools and the business process tree within the SEPI framework, ensuring that operational workflows are accurately represented.

The third step focuses on mapping the layout and process trees to one another, creating the foundation for transferring data between the physical and process-based views. In the fourth step, data from the layout tree is transferred into the process tree, allowing for the calculation of key performance indicators in a process-oriented context. Eventually, a fifth step will also enable data transfer in the opposite direction—from the process tree back to the layout tree—to support comprehensive analysis and advanced use cases, such as evaluating the effects of changes in process design.

In terms of timeline, steps one and two are scheduled for completion by the end of 2025. Steps three and four will follow and are expected to be finalized by mid-2026. The final step—bidirectional data transfer—will be implemented by the end of the overall project.

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Initially, SEPI score calculations will be limited to emission category E1, with categories E2 and E3 to be integrated in later phases of the project. This phased rollout ensures a stable and manageable implementation while progressively expanding the system's analytical capabilities.

10.6. SEPI tool interface for other applications

Towards the later stages of development, the SEPI tool will provide an API that allows external access to its database. This interface is intended to enable the insertion of process models and measurement data directly into the system. However, the implementation of this API is not considered a high priority, as it would require external applications to undergo additional software development—an effort that is unlikely to be undertaken during the CirclesOfLife project timeframe.

Nonetheless, since both the visualization module and the internal data transfer mechanisms between data collection and SEPI calculation will rely on the same underlying technology, much of the required interface infrastructure will already be created during the prototype phase. At a later stage, the interface will be adapted to ensure it is usable by external developers.

The chosen technology for this interface is a web service, which will include appropriate authorization mechanisms to control the insertion and retrieval of data, ensuring secure and reliable integration with external systems.

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11. Overview of KPIs

The final status of the SEPI tool should be the coverage of the ESRS topics according to the following figure. Within CirclesOfLife, implementation will concentrate on the environment aspects (E1 to E5) as this data is already being collected today and is quantifiable. To create a proof-of-concept, implementation will start with Climate Change (ESRS E1) and then continue with E2 – E5, depending on the data already available at the shipyards. The data will be collected via the layout tree into the node most suitable for the yard and then aggregated to the higher level nodes. Additionally, it will be transferred into the process model via the mapping module. Most data will be collected as is. However, to store some of the information required for the SEPI calculation, conversions might needed (e.g. from energy consumption to CO_2 emission. The respective algorithms will be covered in the following chapters if already known.

Figure 18: ESRS topics

11.1. Climate change (E1)

The objective of collection climate change related data is to provide an understanding of the shipyard's total energy consumption and the share of fossile as well as *renewable energy* in its overall energy mix. To collect this information, the energy consumption will be collected, in particular:

- total energy consumption of the yard in a defined time frame from fossil sources
    - fuel consumption from coal and coal products;

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    - fuel consumption from crude oil and petroleum products;
    - fuel consumption from natural gas;
    - fuel consumption from other fossil sources;
- total energy consumption from nuclear sources
- total energy consumption from renewable, subdivided into
    - fuel consumption for renewable sources including biomass
    - biofuels
    - biogas
    - hydrogen from renewable sources
- consumption of purchased or acquired electricity, heat, steam, and cooling from renewable sources
- consumption of self-generated non-fuel renewable energy.
- consumption of *purchased or acquired electricity, heat, steam, or cooling* from fossil sources
- where applicable, *non-renewable energy* production and *renewable energy* production

For the SEPI calculation, the energy will be converted into GHG emission (as CO_2 equivalent). To determine the emission, the SEPI tool will make use of the fuel table that has originally been developed by the JOULES project [JOULES 2017] for the LCPA software tool.

All emissions should be subdivided into Scope 1, 2 and 3. While the Scope 1 and 2 emissions can be calculated directly from the shipyard consumption, the Scope 3 emissions need to be collected from the responsible suppliers.

In case the shipyard performs measures for GHG removal or mitigation, this will also be documented in metric tonnes of CO2eq resulting from projects it may have developed or contributed to in its upstream and downstream value chain; and the amount of GHG emission reductions or removals from climate change mitigation projects outside its value chain it has financed or intends to finance through any purchase of carbon credits.

11.2. Pollution (E2)

The objective of collecting pollution data is to provide an understanding of the emissions that the shipyard generates in the air, water and soil in its own operations. The following data will be collected:

- emissions of air pollutants
- emissions to water

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- emissions of inorganic pollutants
- emissions of ozone-depleting substances
- microplastics

The software will use a generic approach to collect this data of data, i.e. a generic data model that enables the user to individually define the pollutant and the unit it will be represented in. In order to ensure that a pollutant is covered identical in all locations it occurs, the entries will be defined in an independent list that will become available to each node in the layout and process trees.
In addition to the pollution, the production, use, distribution, commercialisation and import/export of substances of concern and substances of very high concern on their own, in mixtures or in articles will be documented. The objective is to enable an understanding of the impact of the yard on health and the environment through substances of concern and substances of very high concern on their own. Furthermore, an understanding of the material risks and opportunities, including exposure towards those substances and risks arising from changes in regulations shall be created.

To fully cover the E2 specification, not only the actual generated pollution should be measured, but also the financial effects from pollution-related impacts, risks and opportunities.

11.3. Water and marine resources (E3)

The principle is to provide an understanding of how the shipyard is managing the use of water and other marine resources. The data items to be collected are:

- total water withdrawals in thousands of m^3
- total water consumption in thousands m^3
- total water discharges in thousands m^3

Additionally, if a certified water management system is available, additional data will be collected:

- total water recycled or reused in thousands m^3
- total water stored in thousands m^3

11.4. Biodiversity and ecosystems (E4)

Although important, topic E4 will not be considered for the development of the first software version. Major reason is the concentration of measurable values (E1 – E3) while E4 is mainly dedicated to non-quantifiable parameters.

11.5. Resource Use and circular economy (E5)

Like E4, the E5 values will not be covered in the first stage of software development. However, since the variables considered in this area are quantifiable and measurable, implementation

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will be feasible in a similar way as for E1 – E3. Therefore, E5 will have precedence over E4 when it comes to further implementation steps.

The principle to be followed under E5 is to provide an understanding of the resource use in the course of the shipyard's own operations, considering separately renewable and non-renewable resources and including transparency on virgin versus non virgin materials and on sustainable versus regenerative source.

The following data will be gathered:

- the overall total weight of materials used during the reporting period;
- the weight in both absolute value (tons) and percentage of renewable input materials used to manufacture the yard's products and services (including packaging); and
- the weight in both absolute value (tons) and percentage, of reused or recycled input materials used to package the yard's products.

With respect to resource outflows, it is envisaged is to provide an understanding of how the shipyard is contributing to circular economy by increasing the durability, reparability, upgradability, reusability or recyclability of the products and materials. The resource outflows represent the circularity of materials or products that are intentionally designed to contribute to circular economy.

The collected data will include the amount in both absolute and percentage terms of material and products that are designed along circular principles: durability, reusability, repairability, disassembly, remanufacturing/refurbishment, recycling or other optimisation of the use of the resource.

Waste data will be collected as follows:

- the total amount of waste generated
- for each of hazardous and non-hazardous waste, the amount by weight diverted from disposal by recovery operation type and the total amount summing all three types. The recovery operation types to be reported on are:

— preparation for reuse

— recycling

— other recovery operations;

- for each of hazardous and non-hazardous waste, the amount by weight averted to disposal by recovery operation type and the total amount summing all three types. The recovery operation types to be reported are:

— incineration

— landfilling

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- other disposal operations
- the total amount and percentage of non-recycled waste.

- If applicable, the system will also collect the total amount of hazardous waste and radioactive waste generated by the shipyard.

11.6. Social and governance KPIs (S1 – S4 and G1)

Sections S and G are left out for the moment. In order to implement them in the SEPI tool, KPIs must be defined and the relationship to E1-E5 is to be determined in terms of SEPI calculation. This effort would go beyond the possibilities of the CirclesOfLife project. However, the system architecture will be generic enough to consider these KPIs at a late point in time without major changes in the architecture.

11.7. SEPI calculation kernel

The primary purpose of the SEPI kernel is to calculate the Shipyard Environmental Performance Indicator based on input data collected directly at the yard. This calculation is not automatic but is explicitly triggered by the user, allowing control over when and how the results are generated.

A key component of the calculation involves the conversion of energy consumption data into greenhouse gas (GHG) emissions. To perform this conversion accurately, the system requires information about the amount of energy consumed, the specific energy sources used, and the relevant conversion factors. All other measured values—such as emissions or material consumption—can be directly incorporated into the SEPI calculation without the need for conversion.

The SEPI is calculated for each node in the process tree, converting environmental impacts from each ESRS (European Sustainability Reporting Standards) category into corresponding SEPI values. A total SEPI score is then derived for each process, aggregating the results across the entire tree structure. The final SEPI value depends on a set of weighting factors applied to the different categories; however, these weighting methods are still being developed. Additionally, a total SEPI score is calculated for the top level of the process tree, providing an overall performance indicator.

The same calculation method is also supported for the layout tree, ensuring consistency across both structural views. When all data has been accurately captured and correctly mapped, the SEPI score at the top level should be identical in both the layout and process trees, confirming the integrity and coherence of the data throughout the system.

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12. Target groups and appropriate visualisation concepts

12.1. Visualisation and reporting goals

The system is designed to display the SEPI (Shipyard Environmental Performance Indicator) score, as defined in Work Package 1, not only at the overall shipyard level but also for more detailed, lower-level components. To support communication and analysis, the data can be exported for use in presentations or for further processing in external tools.

Different target groups are taken into account, ensuring that the presentation and structure of the information can be tailored to the needs of various stakeholders, whether they are technical experts, management, or external evaluators. In addition, the system enables the documentation of SEPI score development over time, allowing users to track progress and identify trends in environmental performance.

Data can also be prepared to enable meaningful comparisons between different shipyards. In doing so, the type of shipyard is considered to ensure that comparisons are fair and contextually appropriate. Beyond environmental performance tracking, the collected and processed data can be consolidated for other reporting or compliance purposes, such as fulfilling requirements under the Corporate Sustainability Reporting Directive (CSRD).

12.2. General user interface design

The software will be realised as web-based application. Therefore, the user interface will run in any recent web browser (Chrome, Edge, Safari, Firefox, etc.). The following figures give a first impression of the user interface design.

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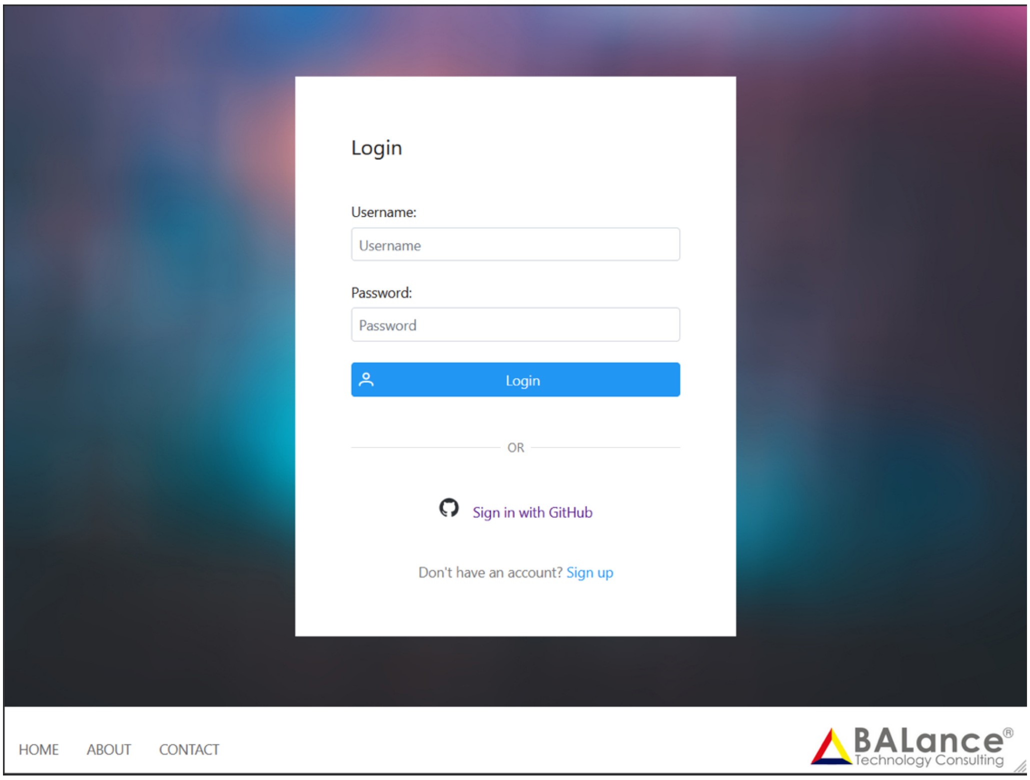

Figure 19: SEPI tool login window

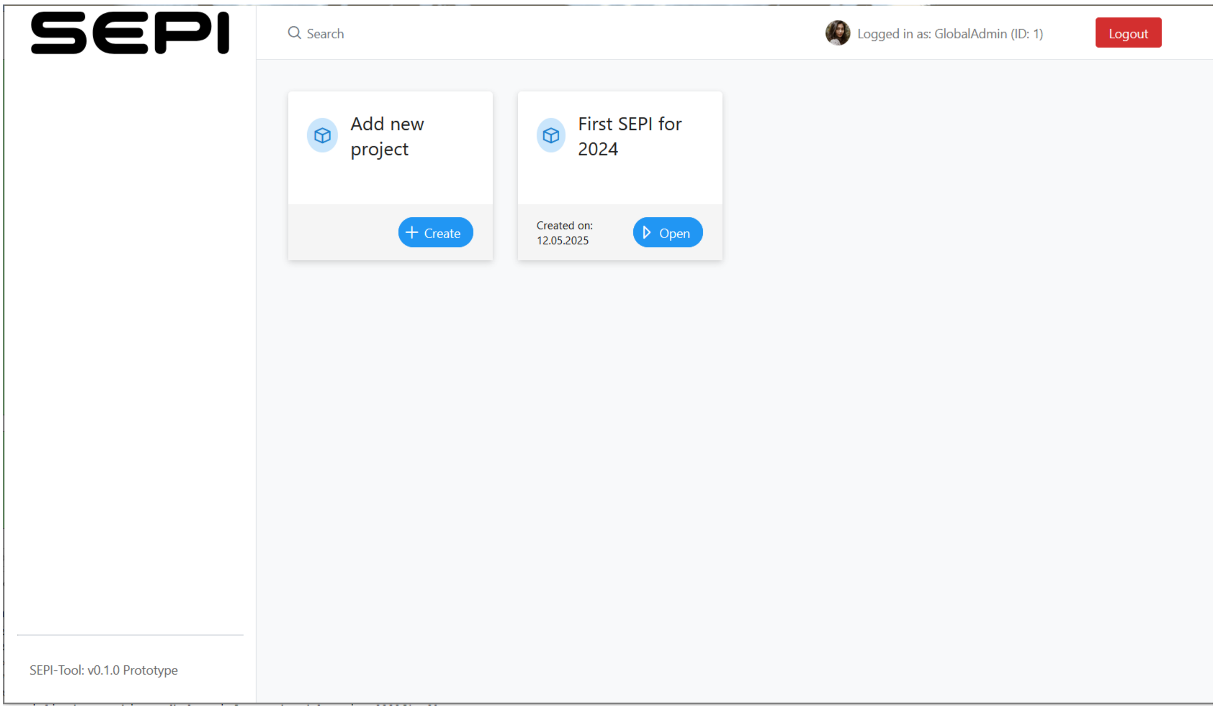

Figure 20: Project selection

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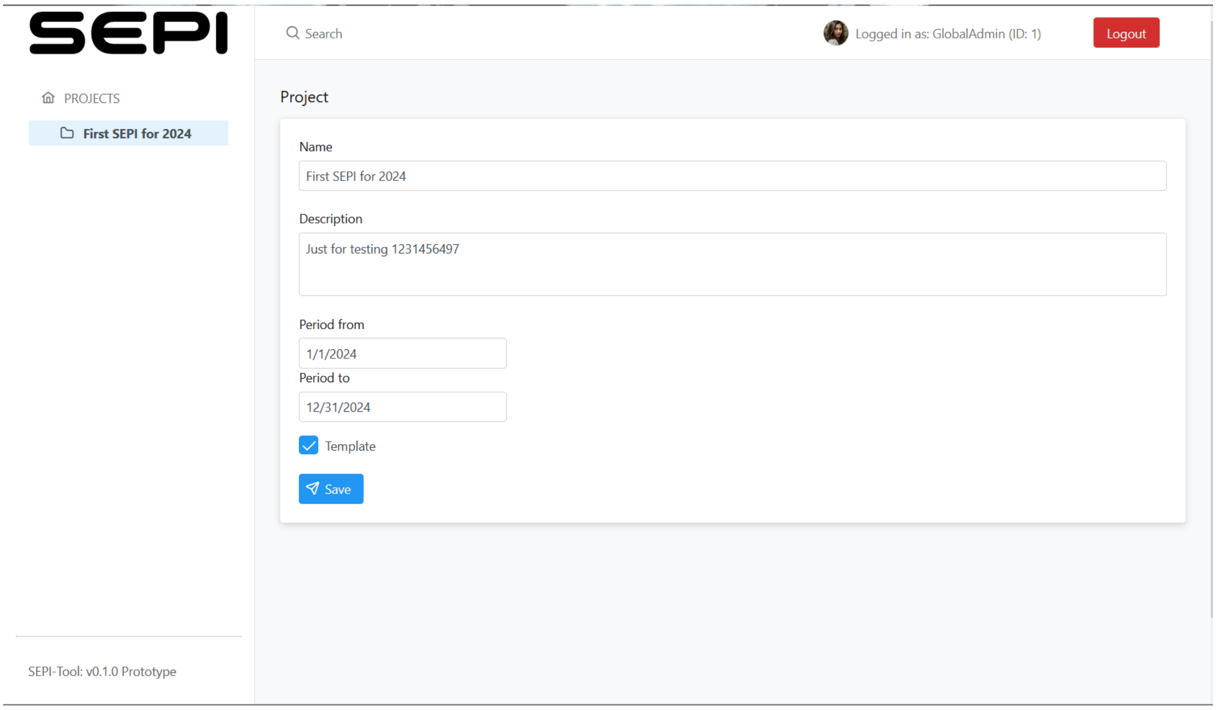

Figure 21: Project details

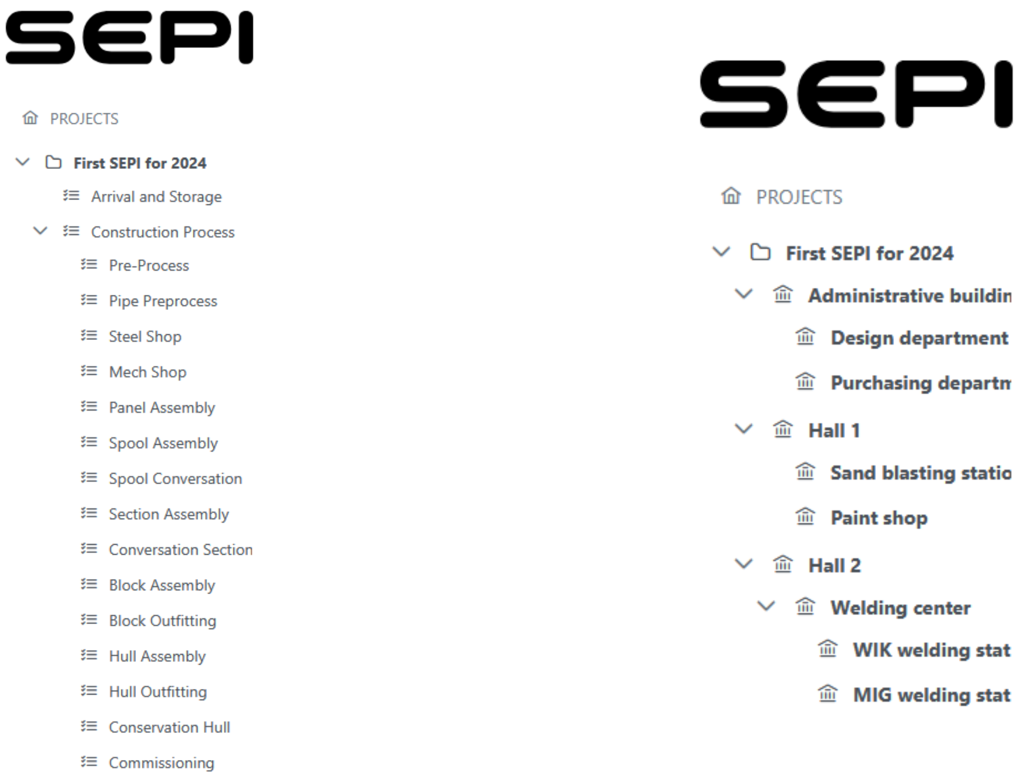

Figure 22: Sample view of the SEPI trees (processes and layout)

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12.3. Advertising and management view

The system supports the generation of information intended for public communication, making it easier to share environmental performance data in a transparent and accessible way. This functionality can be used to inform policy making by providing clear, high-level insights into shipyard operations and sustainability metrics. Additionally, it serves purposes in advertising and sales, where simplified and visually engaging data presentations can help demonstrate a company's commitment to environmental responsibility.

For these audiences, the information is presented in a general format, without going into technical details. The view is aligned with the GME (Green Marine Europe) method, offering a consistent and recognizable structure for stakeholders familiar with this approach. A matrix format is used to display values alongside their corresponding maturity levels, providing a quick and comprehensible overview of data quality and completeness.

To maintain clarity and accessibility, the data is visualized only at the top two hierarchical levels. Rather than presenting complex or detailed figures, the system relies on intuitive visual tools such as bar or pie charts. This ensures that the information remains easy to understand while still conveying the most important performance indicators.

12.4. Technical and optimisation view

The system offers detailed insights into the emissions generated across the entire shipyard, as well as within specific departments. It provides in-depth information for each key performance indicator (KPI) and each individual measuring point, allowing users to analyze environmental impacts with a high level of precision. The primary objective of this functionality is to support the optimization of processes and the reduction of emissions throughout the yard.

Users can access data at a very granular level, down to specific activities, enabling targeted analysis and informed decision-making. To support further analysis and integration with other systems, the platform includes comprehensive export functions. These allow users to export raw data, calculation results, and graphical representations, ensuring flexibility in how the information is used. Additionally, the data is structured to serve as a reliable input for post-processing in external applications or databases, making it suitable for advanced analysis or reporting beyond the system itself.

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13. Visualisation of results and report generation

13.1. Introduction and visualisation concepts

The SEPI tool is designed to present results in a way that meets the specific needs of various target groups, ensuring that the level of detail, visualization style, and information content are appropriate for each audience. To achieve this, users will have the ability to configure the output according to their requirements, including selecting the type of diagram and the specific elements to be included in the report. Different output views can be chosen, allowing for tailored presentations depending on the use case.

The implementation will support multiple visualization approaches, and users will be able to determine which of these should be set as the default for their purposes. In total, three main types of output will be provided: visual display on screen, such as through a web interface; exportable and editable documents, such as PDF or Word files for use in reports or presentations; and raw data exports, which can be used for further postprocessing or integration with external tools.

Given the complexity and scope of possible reporting needs, the implementation will focus primarily on the presentation types most relevant and useful for shipyards. A fully comprehensive solution covering all conceivable output formats would exceed available resources and is therefore not planned for the initial rollout.

13.2. Scoring system

The SEPI will be based on objective measurement of the ESG topics, supported by the narrative maturity steps defined by GME and CSRD.

The scoring system has 2 axes, one for maturity of accuracy of data, hotspot analysis, improvement planning and simulation of yard operations towards a fully digital yard model. The other axis is related to ESG topics and subtopics, which is reference a baseline performance achieved in 2008, up to a lowest possible impact using BAT at the time. For the GHG impact the highest score for E1 will be net zero, which is currently under discussion with EU member states to confirm if this target is feasible by 2050 and will be confirmed within the duration of the project.

The SEPI ESG Score has a range of 1 to 100, with 1 being the baseline at 2008, with a small margin to ensure all yards can achieve a score. The ESG sub-topics will be weighted and aggregated into one SEPI Score.

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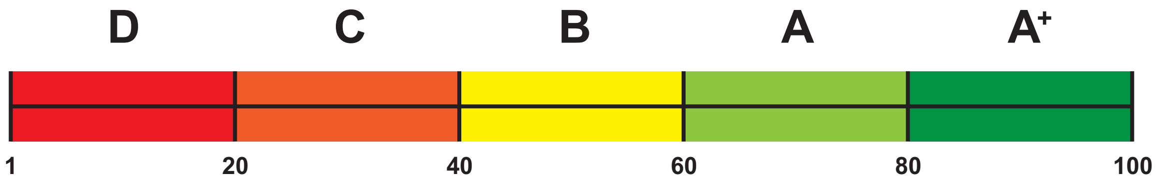

Figure 23: Preliminary SEPI scoring range

The E1 to E5 and S3 cover the most important environmental impact topics, so they will be given the highest weighting in the scoring algorithm.

To visualise the performance a colour system will be applied. The colour of the score, for the E1 to E5 categories, indicates the bandwidth of the performance.

All the main functions within the generic yard model will be scored accordingly to assist in hotspot analysis. If the yard has a high maturity for data measurement, then the same method will be applied down to activity level 4, so that the process and technology improvements can be identified and described in the yard improvement plan, as is used for CSRD reporting, so that yards are able to reuse this data for corporate reporting.

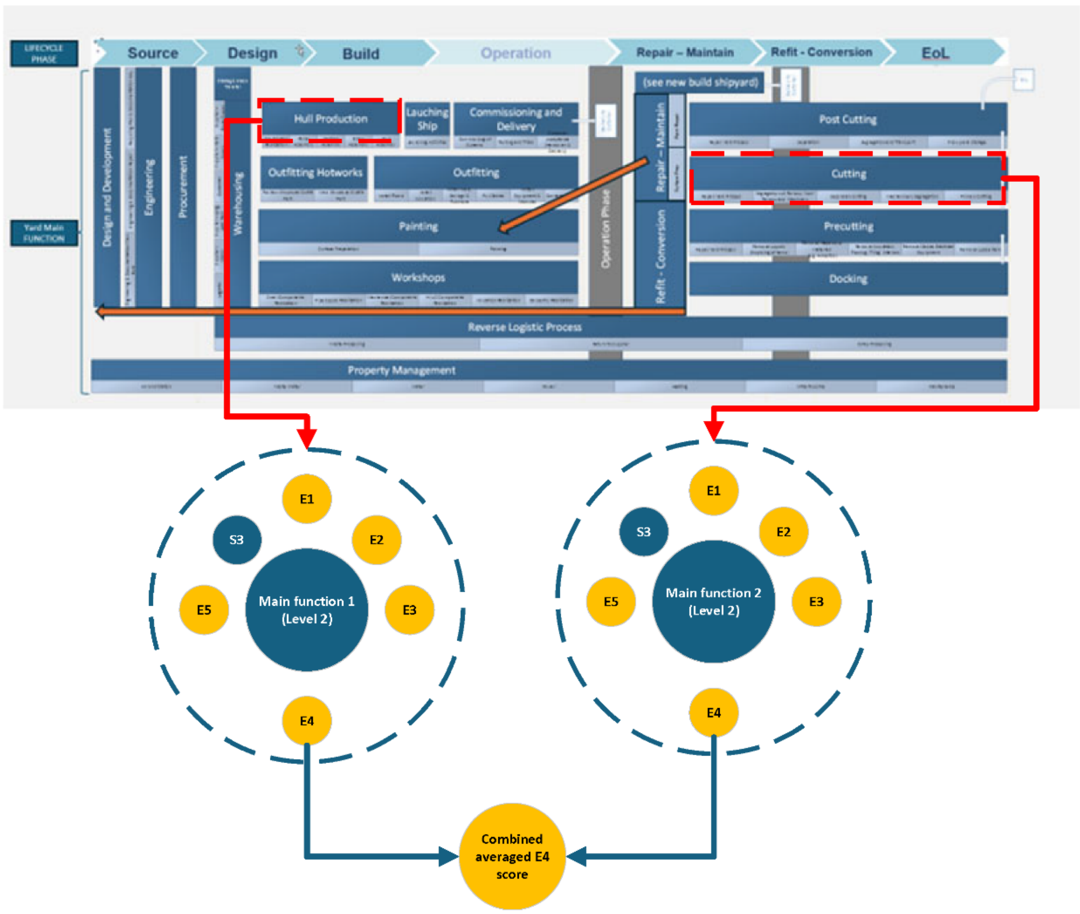

Figure 24: Every main function is scored according to the ESRS categories, which is combined into a score per topic for the whole yard.

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The sub-topics can be averaged to give an overall score for each ESRS main topic. The weighting for the main topics may also be weighted. The weighting factor will be further developed in WP2, according to EU policy (e.g. Financial weighting).

13.2.1. Baseline scoring level

The baseline, will be determined by benchmarking the yards in the consortium, with the historical data which is available from yards that have conducted CSR reporting, with data that has been reported reliably, going back to 2008, so that the technology used at that point in time can be used as a lowest level of the rating bandwidth, so we will try to gather data from that year onwards, to set the lowest level of performance.

The reason for selecting 2008 derives from the latest EU directive, "Fit for 55 at 2030", which uses 2008 as a reference point to calculate the reduction of 55% to 2008. If a yard reduces it's CO2 equivalent emissions by 55%, from the baseline performance rating, by 2030 the yard will receive a green label A+. This means that the yard is on target for net zero at 2050.

The EU have defined a BAT list of technologies[1] , which should be applied to the improvement plans at the yard. If the yard applies the BAT, it still has to measure and score the main function within the bandwidth. For the maritime sector and the lifecycle shipyards in specific, research has to be conducted on identifying the gaps in BATs. CoL would like to recommend to the EU to start on building the BAT database on shipyard specific BATs not yet covered by any other BATs. The case studies of CoL will be a starting contribution to this effort.

Therefore, the yards must be benchmarked, to gather the baseline data and performance level.

Where the yard is currently incapable of measuring a topic, the reference baseline performance score will be applied by default. To avoid this situation, we intend to set the baseline performance low, the SEPI score should immediately improve once the yard starts estimating, calculating, or measuring any of the ESG topics.

The upper limit for the SEPI score is 100 which equals to net-zero for E1. For E2 to E5 topics this would mean that the yard does not produce any waste, it does not contribute to climate change, all water is recycled and that there is no pollution to air, soil or water, and has a well-established and functioning social and governance apparatus.

The baseline and the weighting of the individual ESG topics will be further developed in WP1, in cooperation with GME, to align the measurement maturity and improvement plans for both scoring systems.

[1] EU Industrial Emissions Directive – Best Available Techniques (BAT) reference documents: BAT reference documents | EU-BRITE

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13.3. Result overview

The SEPI tool will present results in multiple visual formats to support clear and flexible interpretation. A qualitative matrix combines the performance results with the corresponding maturity levels, offering a structured overview of both data quality and environmental outcomes. For a more general representation, bar charts are used to provide an at-a-glance understanding of overall performance across key categories. Additionally, spider web diagrams are available to visualize the distribution and balance of performance indicators, making it easier to identify strengths, weaknesses, and areas for improvement in a comprehensive and intuitive manner.

The foundation of the report will be based on the analysis of main functions within the SEPI Generic Yard business process model, so that the ESG performance can be consistently reported and traced back to the baseline repository, or application database.

The report shall also include the improvement plan for the hotspots that are identified using the prediction, or calculation of environmental performance. The report structure will be aligned with the GME reporting format, so that the 2 reports can be linked and support each other. The visualisation of the SEPI scoring system will also use a trend graph of performance for the main KPIs, which uses the previous 3 years of performance, as a reference. The reason for including this is to declare a transition towards the main EU milestones, for example the 55% reduction at 2030, onto net zero at 2050. The trend will be described in the report, supported by the historical data.

The reports shall allow for detailed analysis, from main ESRS topics down to sub-topics. The topics that are material to the yard have been estimated in WP1.1B. The SEPI tool should have functionality that facilitates this analysis, with the appropriate output documents.

13.3.1. Visualisation of the SEPI Scoring System

The overall performance score will be derived from adding together the performance for the main environmental topics and a letter, which relates to the maturity level, so E1 to E5 and S1, S3 added together according to the agreed weighting, so that an overall yard rating will be a letter and a number, e.g. A1.

The maturity scale for measuring accuracy and improvement analysis will be from D to A+. D is the lowest maturity and A+ the highest, so 5 levels in total. The two scales are then combined so that the overall SEPI score is represented in a linear visualisation. The weighting of the environmental topics, E1 to E5, are visualised by the width of the bar, which combines performance, maturity and weighting.

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For the CoL project a pictorial representation has been designed. See Figure 25 and Figure 26.

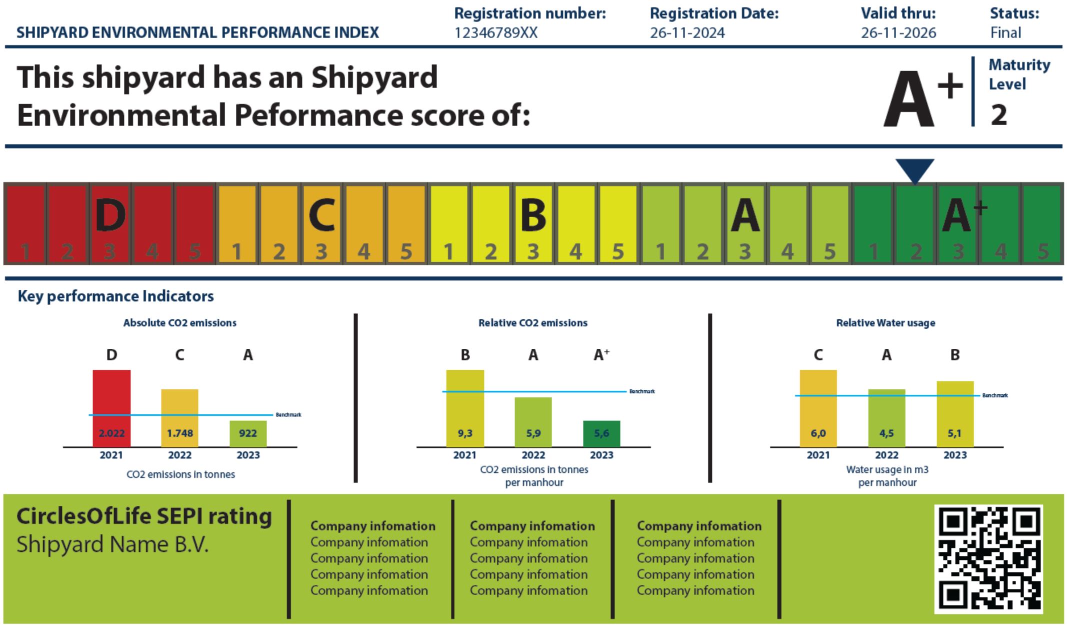

Figure 25. SEPI scoring visual 001

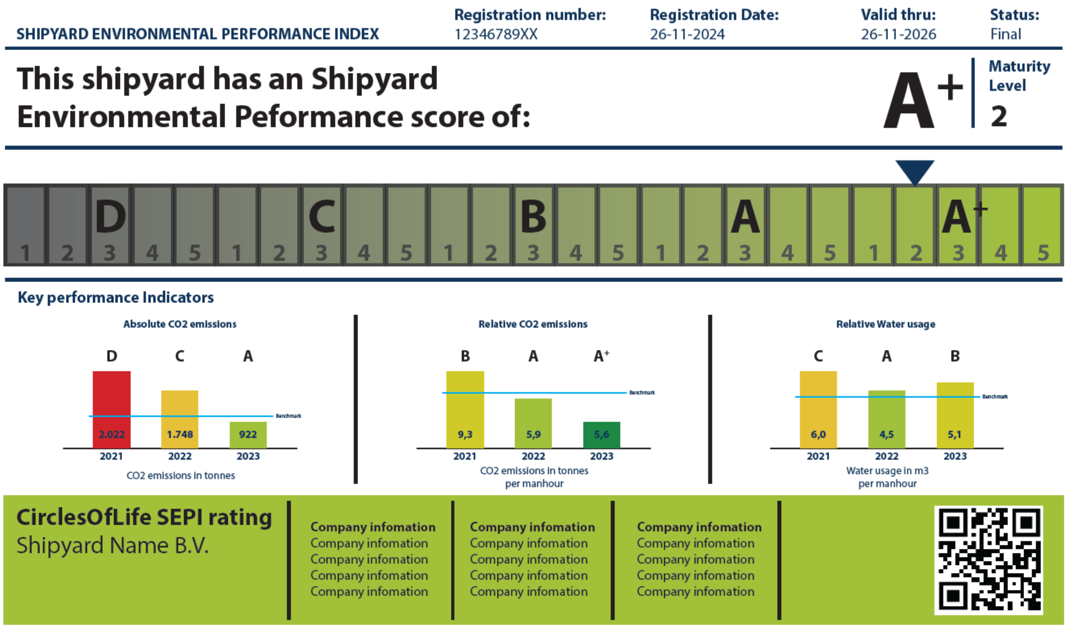

Figure 26: SEPI scoring visual 002

An alternative visualisation is to have a 2 dimension scoring system. See Figure 27 and Figure 28 below

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This depicts the performance axis and the maturity axis, but maintains the letter and number format as above.

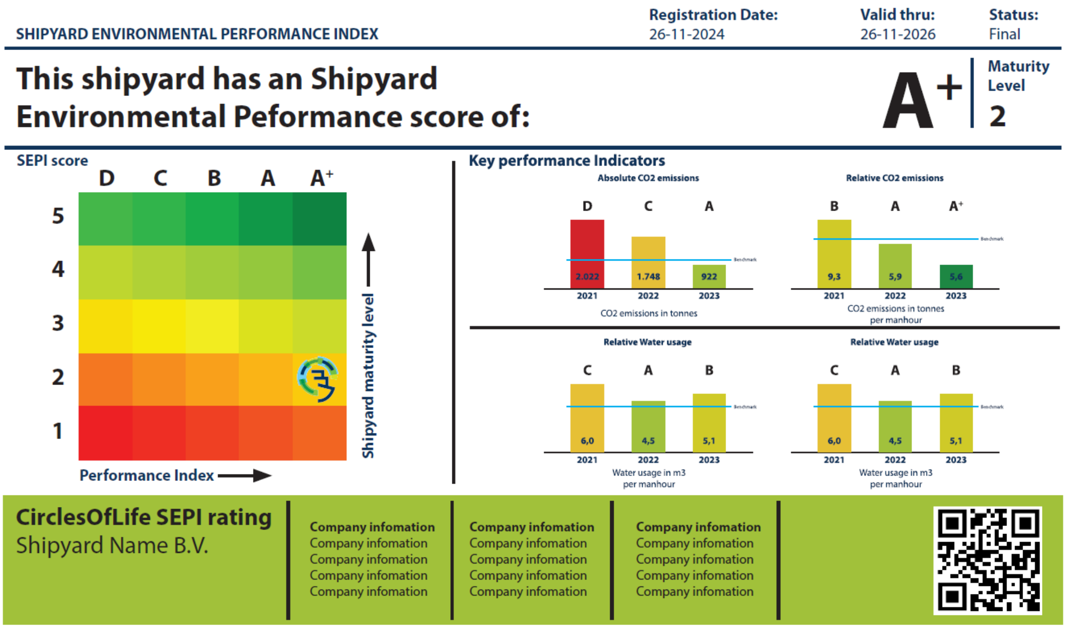

Figure 27: SEPI scoring visual 003

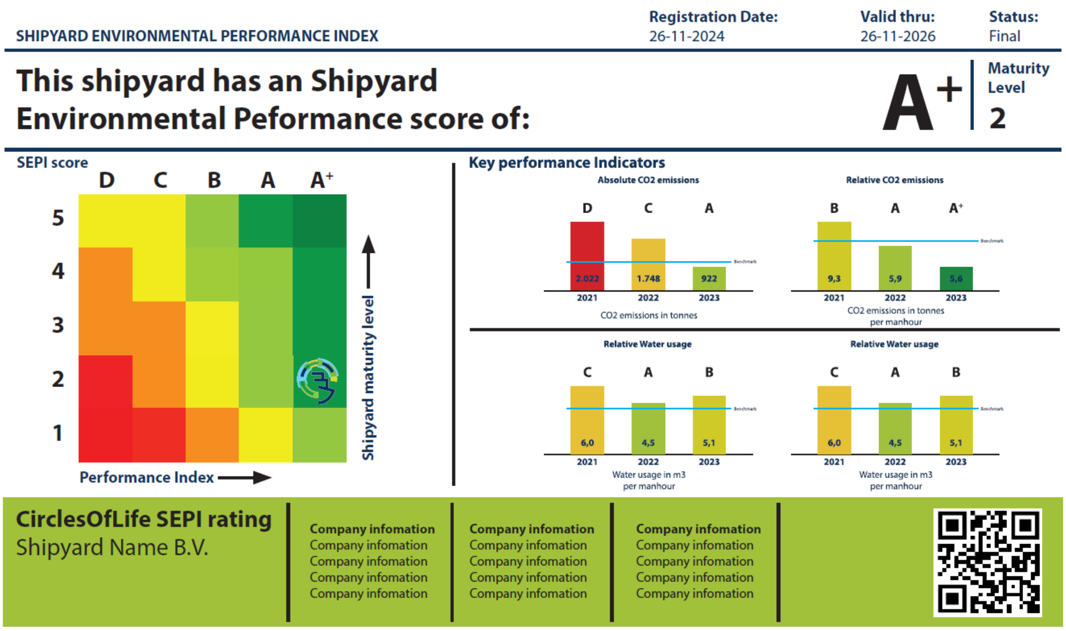

Figure 28: SEPI scoring visual 004

Another alternative visualisation is to have a circular scoring system. See Figure 29.

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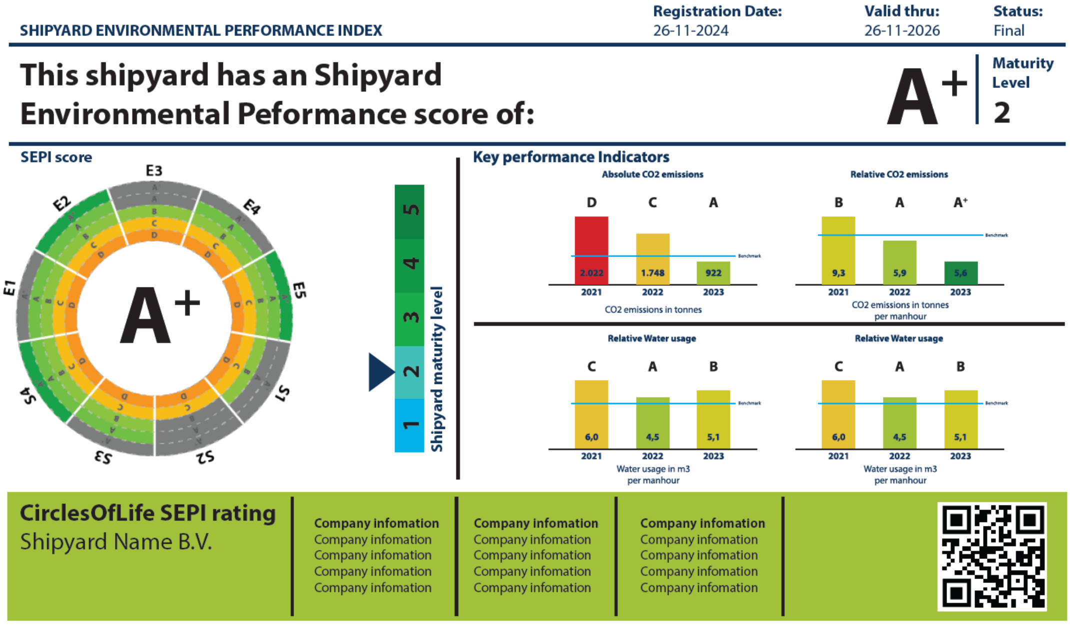

Figure 29: SEPI scoring visual 005

Which visualisation is best suited will be tested in the sample implementation. Different approaches will be implemented and tested by the users in the project. In order to avoid unnecessary implementation effort, test implementations might be limited to a subset of the KPIs and will not fully show all details. Once the tests have shown which variants will be the most appropriate ones, final implementation will concentrate on these. For the tests, sample data will be used as it seems to be unrealistic to collect data from three years in the required level of detail.

13.4. Detail view

The system provides a variety of visualization options to support effective analysis and communication of results on a detailed level. Charts and graphs can be generated to represent the overall outcome or to break down the information by individual processes or process levels, depending on the desired level of detail. Users can choose between displaying qualitative results for a high-level overview or detailed numerical values for in-depth analysis. In addition, a comprehensive table is available that clearly presents both the input and output data, ensuring transparency and traceability throughout the evaluation process. The detail view is intended to support a closer look into single processes that might require optimisation. Therefore, such results are mainly targeted to internal use and less important for publications. It will also be closely connected to exporting data into external tools such as BPM software for post-processing activities.

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13.5. Report generation

13.5.1. Concept and supported file formats

Purposes of the reports generated by the SEPI tool are mainly

- generation of documents with comprehensive on results
- export of result data for post processing by external software tools

While the first ones will be intended as documents to be read and distributed or will serve as basis for SEPI result documentation, the export functionality will serve as data collection for post-processing by tools that support additional analysis functionality. This could include creation of specific visualisation, generation of shipyard-specific reports or data storage in external databases. During the implementation, the foundations for the report creation will be laid out and some sample reports will be prepared as proof-of-concept. It will be up to the shipyards to specify additional reports depending on the envisage tasks.

The reports will be based on the detail view of the SEPI tool, i.e. the data-orientated output rather than the visualisation. The output mainly contains tables covering input data, output data and calculation results. Considered File format are XLSX, CSV, PDF, DOCX, XML, JSON, BPMN 2.0, single charts also as TIF or JPEG. Which formats will actually be implemented, depends on the envisaged use cases. In a first step, Excel files will be supported for exporting raw data for postprocessing, PDF files for visualisation, and BPMN files to export business process models. For the single chart export, one graphic format will be selected, depending on the availability in the implementation toolbox. Whether other formats will already be available within CirclesOfLife, depends on the requirements of the connected applications as well as on the support by the toolboxes used.

13.5.2. Reports to be realised

The SEPI tool will support different types of reports to meet the needs of the user groups addressed, from operational staff to executive management, regulators, and external stakeholders. These reports will therefore vary in depth, format, and focus. Not all reports will be implemented immediately. The CirclesOfLife project will concentrate on some sample reports that have the highest relevance for the shipyards. This will include on report as PDF document and one report exporting raw data.

Report types the SEPI tool will support directly or via export of data into an external report generation tool are:

Overview Reports

- **Target Audience:** Management, decision-makers, public stakeholders
- **Content:**

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- Total SEPI score at yard and main function levels
    - Summary of key indicators (e.g., energy use, emissions)
    - High-level insights and trends
- **Format:** Dashboard, PDF, PowerPoint, or simple web reports
- **Purpose:** Quick understanding of environmental performance

Detailed Technical Reports

- **Target Audience:** Environmental engineers, analysts, auditors
- **Content:**
    - SEPI scores per process, per ESRS category
    - Emission breakdowns, energy/resource consumption
    - Maturity levels of input data
- **Format:** Excel, interactive dashboards, or detailed PDFs
- **Purpose:** In-depth performance analysis and data verification

Process-Level Reports

- **Target Audience:** Operations managers, process owners
- **Content:**
    - Environmental performance of specific processes or departments
    - Input-output data per process node
    - Suggestions for optimization
- **Format:** Table reports, spider charts, bar graphs
- **Purpose:** Operational improvement and process control

Comparative Reports

- **Target Audience:** Corporate management, benchmarking teams
- **Content:**
    - Comparison between shipyards, projects, or time periods
    - Normalized SEPI scores
    - Yard type consideration and performance context
- **Format:** Summary tables, ranking charts, spider webs
- **Purpose:** Benchmarking and strategic planning

Time-Series and Trend Reports

- **Target Audience:** Continuous improvement teams, sustainability officers
- **Content:**
    - SEPI trends over time
    - Changes in emissions, consumption, and data quality
- **Format:** Line graphs, historical tables, annotated graphs
- **Purpose:** Tracking progress and identifying long-term improvements

Public and CSR Reports

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- **Target Audience:** General public, media, NGOs, investors
- **Content:**
  - Simplified data visualizations (bar/pie charts)
  - General performance summaries without technical detail
  - Highlights of environmental initiatives
- **Format:** Infographics, web summaries, brochures
- **Purpose:** Communication, transparency, and brand reputation

Regulatory and Compliance Reports

- **Target Audience:** Regulatory bodies, auditors
- **Content:**
  - Structured environmental data aligned with ESRS or CSRD
  - Conversion methods, data sources, documentation of assumptions
- **Format:** Audit-ready documentation, structured data formats (e.g., XML, JSON)
- **Purpose:** Fulfilling legal and reporting obligations

Raw Data and Export Reports

- **Target Audience:** Analysts, IT teams, external tools
- **Content:**
  - Input data, SEPI calculations, maturity levels
  - Export of raw and processed data
- **Format:** CSV, Excel, API export
- **Purpose:** Post-processing, integration with external databases or tools

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14. Conclusion

The SEPI tool to be developed within WP 2 implements data collection, SEPI score calculation, and result visualization. It will utilize a generic shipyard model, allowing users to select a predefined model and adjust activities as well as technologies. The software includes a process inventory database, which can be integrated or separate, and a simplified digital twin representing the shipyard's site and processes. The tool will feature two interconnected model trees: one for the shipyard's process model and another for the shipyard layout model, facilitating data collection and SEPI calculation.

SEPI calculation will be based upon a hierarchical process model with four levels: main functions, sub-processes, activities, and technologies. The SEPI system supports the import of data elements, including layout and process models, and energy consumption data. Data will be collected from measuring facilities and mapped to processes, ensuring compatibility with existing practices. The system interfaces with BPM tools for process model retrieval and SEPI result export, utilizing XML files in BPMN 2.0 format.

The SEPI tool will support manual process and layout tree creation, and data exchange will be facilitated through structured files, initially focusing on MS Excel. The development process involves importing data into the model tree using a predefined Excel template and establishing connections between BPM tools and the business process tree within the SEPI framework.

Implementation will be performed in phases, with the first focusing on mapping layout and process trees and transferring data between them. Initially, SEPI score calculations will be limited to emission category E1, with categories E2 and E3 to be integrated later. The tool will eventually provide an API for external access to its database, enabling the insertion of process models and measurement data.

The SEPI tool calculates the Shipyard Environmental Performance Indicator based on input data, including energy consumption and emissions. The SEPI score, ranging from 1 to 100, is derived from ESG topics and subtopics, with E1-E5 and S3 receiving the highest weighting. The tool supports various visualization options, including on-screen displays, exportable documents, and raw data exports, tailored to different target groups. Rating will use a baseline from 2008 to calculate a yard's ESG performance, with a goal of achieving a green label A+ by 2030. The tool will present results in various visual formats, including matrices, bar charts, and spider web diagrams, to provide a comprehensive overview of performance and areas for improvement.

Different reports are generated for various audiences, including corporate management, continuous improvement teams, the general public, regulatory bodies, and analysts. These reports serve purposes such as benchmarking, strategic planning, tracking progress, communication, and fulfilling legal obligations.

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Implementation of the tool has already started, with the goal to present a first prototype to the end-users by the end of 2025 and the complete software at the end of the project one year later.

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15. List of Tables

16. List of Figures

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17. References

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