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RETROFIT SOLUTIONS TO ACHIEVE 55% GHG REDUCTION BY 2030

Software application and user documentation for web-based application

WP 1 – Safe and Sustainable Retrofitting solutions – Synthesis, AI and Web-based selection
Task 1.4 – Development of web-based application
D1.4 – Software application and user documentation for web-based application
Partners involved: AES, FSYS
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Executive Summary

The report describes the web-based tool, its functionality, configuration and operating instructions for users. Examples are provided, guiding users through data entry, import, and preparation, as well as the different options and choices for cost-benefit assessment.

The deliverable describes the development stage of the web-based application, evidencing the results of the RETROFIT55 project. The application will serve as a Decision Support System (DSS) enabling to assess Greenhouse Gas Emission (GHG) reductions in waterborne transport prior to installing energy saving technologies on board vessels. AI tools support this innovative approach.

The software solution being development is specified with its functionality, configuration and operating instructions for users. Firstly, the workflow from starting a RETROFIT55 analysis to achieving the final results has been drafted. Secondly and based on this, the functionality for the individual steps have been converted into software modules:

- Sign in
- Select project
- Define Vessel
- Define evaluation scenarios and cases
- Assess the results and choose best rated results

The individual steps are accompanied by graphical and numerical presentations. Screenshots illustrate how the end user will be guided through the web-based application.

1 Introduction

As more and stricter regulations concerning the environmental performance of seagoing vessels come into force, a strong need for performance improvements in terms of energy efficiency and emission reduction for the large fleet of existing vessels is arising.

An essential contribution to solve this challenge is to develop de-carbonization solutions and green technologies which can be combined and integrated to reduce fuel consumption and Greenhouse Gas (GHG) emissions.

The main objective of WP1 which is presented here is the development of a decision support framework as well as to generate a web-based tool for the selection, combination and implementation of various retrofitting technologies. The aim is to demonstrate that a suitable synthesis of technologies developed in WP2 to WP6 that may lead to at least 35% reduction in ship emissions without compromising fleet operational performance and ship safety. The environmental footprint of the proposed solutions will be assessed by utilizing the Life Cycle Assessment (LCA) methodology under ‘before’ and ‘after’ scenarios and endeavor the inclusion of end-of-life GHG emissions. Decision support criteria will account for cost-benefit and safety targets. It can also be used to evaluate the equivalent emissions footprint under different operational scenarios for ship segments of relevance to EU shipping. It is envisaged that the tool developed will practically assist end users (ship owners and shipyards) with the selection of the most suitable solutions in terms of environmental, safety, and economic benefits. The web-based tool shall support design teams and shipyards as well as operators in identifying promising retrofitting solutions and combinations of systems.

The application offers thorough guidance to ship owners, shipyards, design offices, and operators on the energy efficiency technologies/solutions and relevant industry standards, regulatory approvals, best practice guidance, and easy-to-customize strategies for retrofitting whilst minimizing the commercial risk of deployment. Lastly, the application enables the user to simulate investment scenarios (CAPEX, OPEX), for the life cycle of each specific ship type, measure the performance of the ship/fleet, assess regulatory compliance, and share the solutions through the platform with ship charterers, classification societies, flag administrations, and other stakeholders.

The underlying idea to enhance conceptual and early design processes has been based on methods developed in the projects HOLISHIP [1], MARIDATA [2], and SHIPLYS [3].

2 System overview

To achieve the objective to provide a tool for decision support for assessing safe and sustainable ship retrofitting options, an interactive web application for ship designers, shipyards, ship owners and operators has been designed. The application shall be easy to access (no installation effort, no complex configuration) and straight forward to operate and give thorough guidance on the energy efficiency technologies/solutions and relevant industry standards, regulatory approvals, best practice guidance, and easy-to-customize strategies for retrofitting while reducing the commercial risk of deployment.

Most importantly, the application is created to consider the interactions of different technologies when applied to the vessel as the effects caused by one system will often have some side-effects on other aspects of the vessel. This in turn requires the capability to perform fundamental engineering analysis tasks.

The application shall enable users to simulate investment scenarios (considering CAPEX, OPEX and other operational criteria) for the life cycle, measure the performance of the ship, assess regulatory compliance, and share the solutions via a common platform with other stakeholders.

The essential benefit of such an approach is to quickly evaluate most promising options for retrofit projects for a distinct vessel, with selectable combinations of retrofitting options and applied to different scenarios.

Potential solutions shall be assessed according to individual optimization targets, e.g. compliance, environment, cost, efficiency or downtime. To consider all major influences, a life-cycle oriented approach is used that considers multiple life-cycle stages (retrofit → operation → maintenance).

As a rapid, up front evaluation, it is not realistic to try to provide a perfect design tool replacement. Nevertheless, it shall be good enough for a meaningful selection following the principles of the 80/20 rule, providing sufficiently reliable insight to determine the most promising solutions.

Considering all possible combinations of retrofitting options and technologies will lead to a large number of scenarios. Therefore, some initial selection will be useful. For example, certain technologies may not be applicable to a specific ship type or operational profile. Furthermore, certain combinations will “fail early” in the sense that they will violate given constraints.

Major challenges are to have reasonably good data on the actual operating conditions that are experienced by the ship to be refitted and to work with a sufficiently accurate representation of the systems that have the highest impact on energy consumption such as the ship hull, the propeller(s), appendages, or the main and auxiliary engines. It can be readily seen that each retrofitting option needs a lot of inputs and requires a lot of analyses (e.g. numerical simulations). Furthermore, different retrofitting options influence each other. For example, a modification of the bulbous bow will be different if a system for wind-assistance ship propulsion (WASP) is retrofitted or not. Without a WASP the ship will run on a straight course (most of the time) while with a WASP a drift angle is introduced (along with small heel angles), increasing the number/range of operational scenarios for which an optimum has to be found [4].

The evaluation is to be based on the following types of input

- Owner & Operator Requirements
- Shipyard capabilities and preferences

- Decision criteria and thresholds
- Ship characterization
- Ship documentation including CAD data (if available, this can help to simplify import of data such as the hull form definition)

The output provided by the system includes:

- Summary of provided vessel, operational and economic data
- Scenario and case description
- Evaluation results

A typical usage scenario is depicted in .

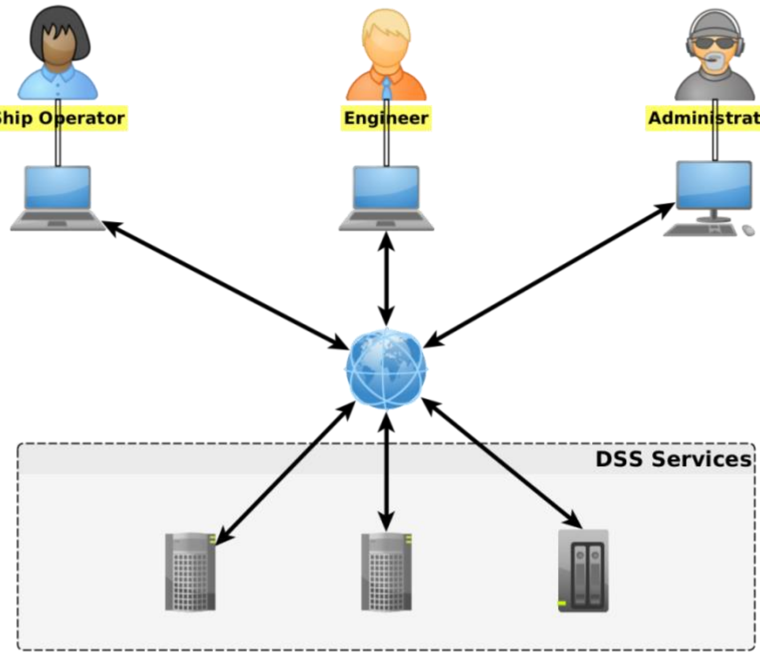


Figure 1: Usage scenario.

Note, that as a result of the web-based access close cooperation between different types of users is possible. Data entered or results generated by one participant can be reviewed by other users with little effort.

Figure 2 provides an overview of the main components of the system. The user accessible application is represented by the Vessel Configuration application, which provides the functionality to enter data, define scenarios, perform the evaluation and to generate and inspect results. It can be run in a web-browser window.

The application interacts with several services, accessible over the network: the Project Service is responsible for all data management tasks such as storing and retrieval of project data. The Catalogue Service provides additional data about catalogued (i.e. read-only) information such as technologies and computational methods available for evaluation purposes.

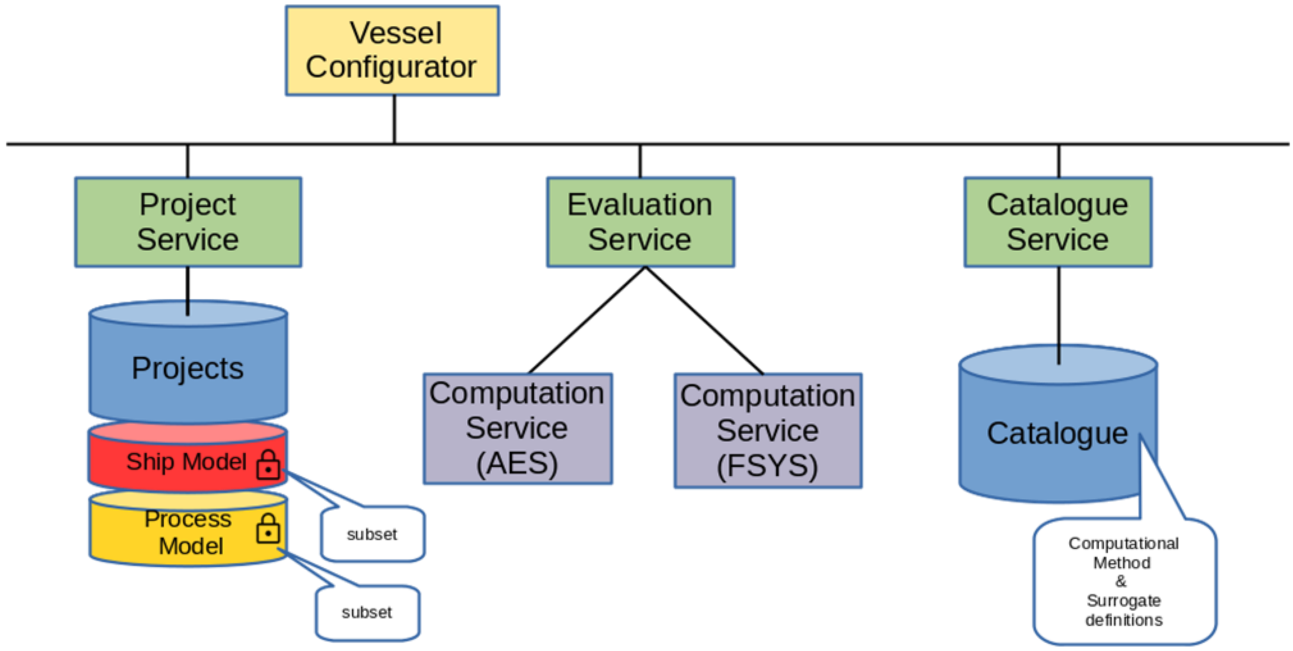


Figure 2: System architecture.

3 Roles and rights

Each user is assigned a specific role, along with appropriate rights, that determine access to various functions within the system. This role-based access control ensures that users can interact with the platform in accordance with their responsibilities and permissions. Additionally, it is possible to define roles and associated rights with a high degree of granularity. For example, administrators have the flexibility to activate or deactivate specific graphical user interface (GUI) components, providing control over what elements are visualized and which remain hidden. This level of customization allows for tailored user experiences, ensuring that only relevant information and tools are accessible based on the user's role, thereby enhancing both security and usability.

4 Workflow

To assist the user in entering the data required for a project, a straightforward sequence of steps for data entry have been defined, which effectively constitute a workflow that is intended to be easy to manage and helping to guide a user through the evaluation of project solutions.

The model of the ship under investigation is established via the user interface by entering the required input data that defines the fundamental properties of the vessel being investigated, such as main particulars, hull form, main equipment, weight distribution and load cases.

As a next step feasible retrofit technology options and operational profiles are selected. This allows the user to narrow down the search to specific requirements.

Based on the input data provided, a so-called scenario needs to be defined. A scenario represents the fundamental choices of a real-world application, e.g. by selection of operation profiles, specific constraints for technologies and finally optimization goals and priorities.

Once these two steps have been completed, the evaluation process can be carried out. This is a mostly automated step, in which the system determines the required calculation steps based on the provided input, the selected technologies as well as the given optimization goals. Figure 3 below illustrates the main working phases when using the system and how data is being organized as part of this process.

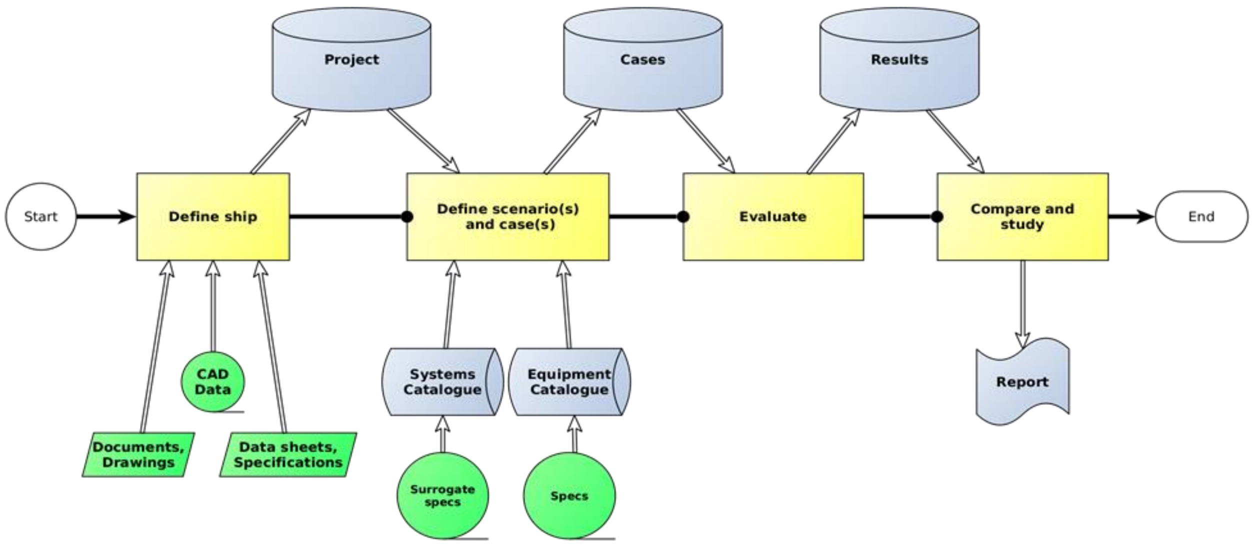


Figure 3: Principal workflow phases.

5 Prerequisites, Setup and Preparations

Access to the application is straightforward: using a browser (supported are Chrome, Edge, or Firefox – other browsers may also work but have not been tested) on a platform with sufficient memory (16 GBytes or more, 8 GByte may work as well in many cases) and moderate CPU power is all that is required to get started.

Connecting to the system simply requires entering the URL of the service in the browser address line. This will open the entry form to sign into the system. At the time of issuing the Deliverable, the system is still undergoing project-internal testing, therefore details of a publicly accessible URL and the method of acquiring access credentials must be enquired from project partners.

To prepare the creation and assessment of a specific project, the following sources of information will be required for input data or are deemed helpful to provide more details:

- Main Particulars
- Midship Section
- Hullform data such as frame stations, lines plan, offset tables, or CAD model
- Capacity Plan
- Equipment List
- Weight Distribution
- Load Manual
- Financial Data pertaining to operating cost

Thought should also be given to the following aspects:

- The intended operational profile for the vessel after retrofitting has been implemented. This should include all stages of operation including expected maintenance periods etc.
- A prioritised list of green technologies. The main purpose here is to exclude those technologies in advance, which will not be applicable to the project, e.g. due to technical constraints.

6 Application functions

In this section, a walkthrough for the different application functions is provided. Each step is explained based on a typical screenshot showing the data entered or presented for a sample project.

The individual screenshots are accompanied by a reference figure indicating the relationship to the conceptual workflow of the application.

6.1 Sign in

Working with the system requires a user account. The account registration is done beforehand by the system administrator who specifies the role to be assigned to the user.

To support secure multiuser operation, each user must first sign into an account by entering an assigned user name and by specifying a password. When using the system for the first time, the identify is confirmed through a code sent to their registered email address (see Figure 4).

Once the sign-in procedure is successfully completed, the user gets access to specific functions and views according to assigned role and the appropriate rights.

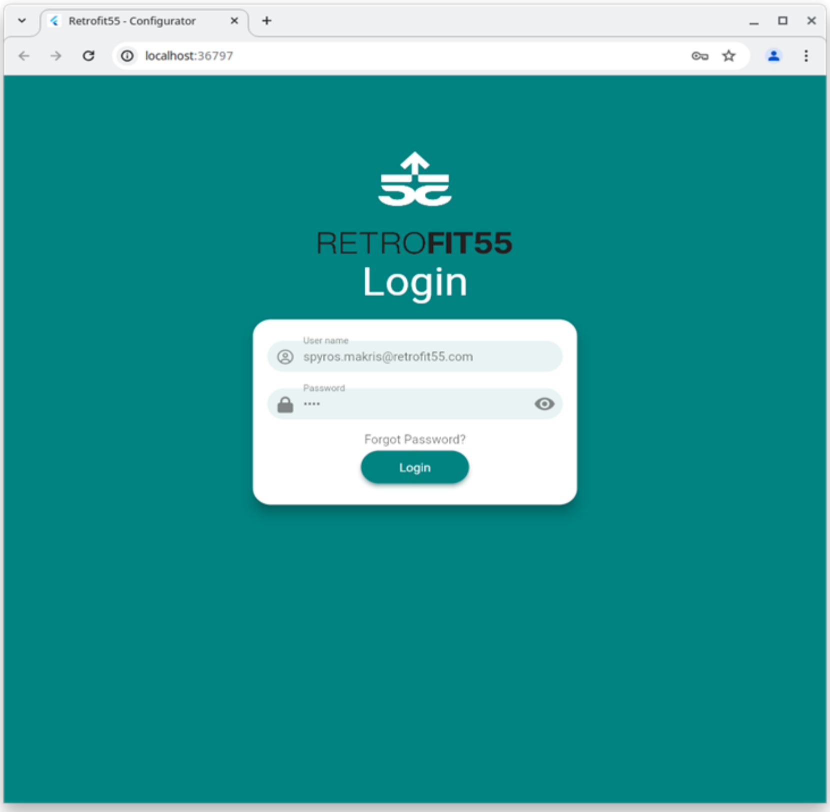


Figure 4: Sign in environment.

6.2 Select project

Upon successful authentication, the system provides the user with two distinct pathways (see Figure 5) to proceed:

- The first option enables the selection of an already existing project, thereby allowing the user to resume their work from the most recently saved state. This feature ensures continuity and preserves the integrity of previously conducted operations.
- Alternatively, users can initiate a new project, granting them a fresh working environment tailored to novel objectives or experimental configurations.

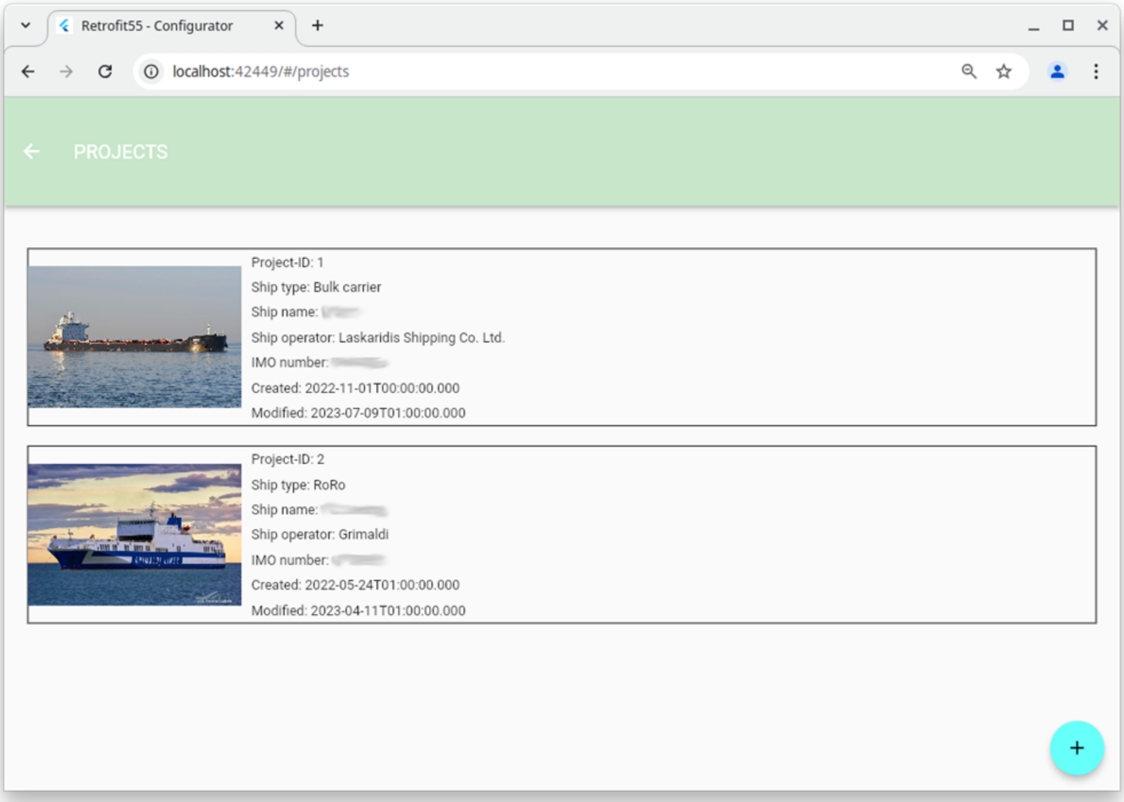


Figure 5: Project selection environment.

6.3 Ship defining phase

The creation or selection of a project will enter the 'define ship' phase of the workflow (see Figure 6).

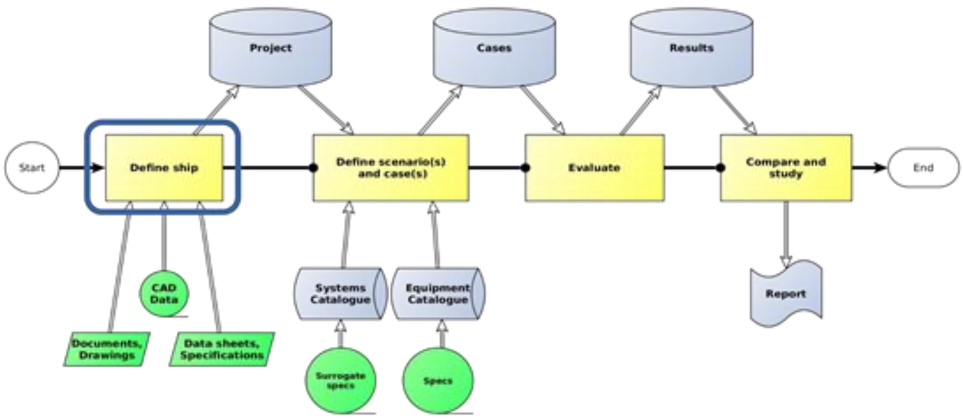


Figure 6: Ship definition phase.

6.3.1 Main particulars selection

In the main particulars section (see Figure 7), the user is prompted to input critical project-specific information, including an acronym for identification, the corresponding build number, and the type of vessel under consideration. Among these parameters, the vessel type plays a pivotal role, as it directly influences subsequent computational processes. Specifically, it serves as a fundamental determinant in evaluating and identifying optimal combinations of green technologies that may be feasibly implemented. The accuracy and specificity of this input are therefore essential for ensuring the relevance and reliability of the proposed sustainable solutions.

Users are also required to input the vessel's key dimensional attributes, including length overall, moulded breadth and depth, draught, and deadweight. These parameters form the fundamental dataset for characterizing the vessel's physical profile and operational envelope. Importantly, the comprehensiveness of the information provided at this stage directly affects the scope and precision of the subsequent analysis. The more detailed the input, the higher the number of constraints that can be integrated into the algorithmic search for appropriate green technology solutions, thereby enhancing the relevance and feasibility of the proposed configurations.

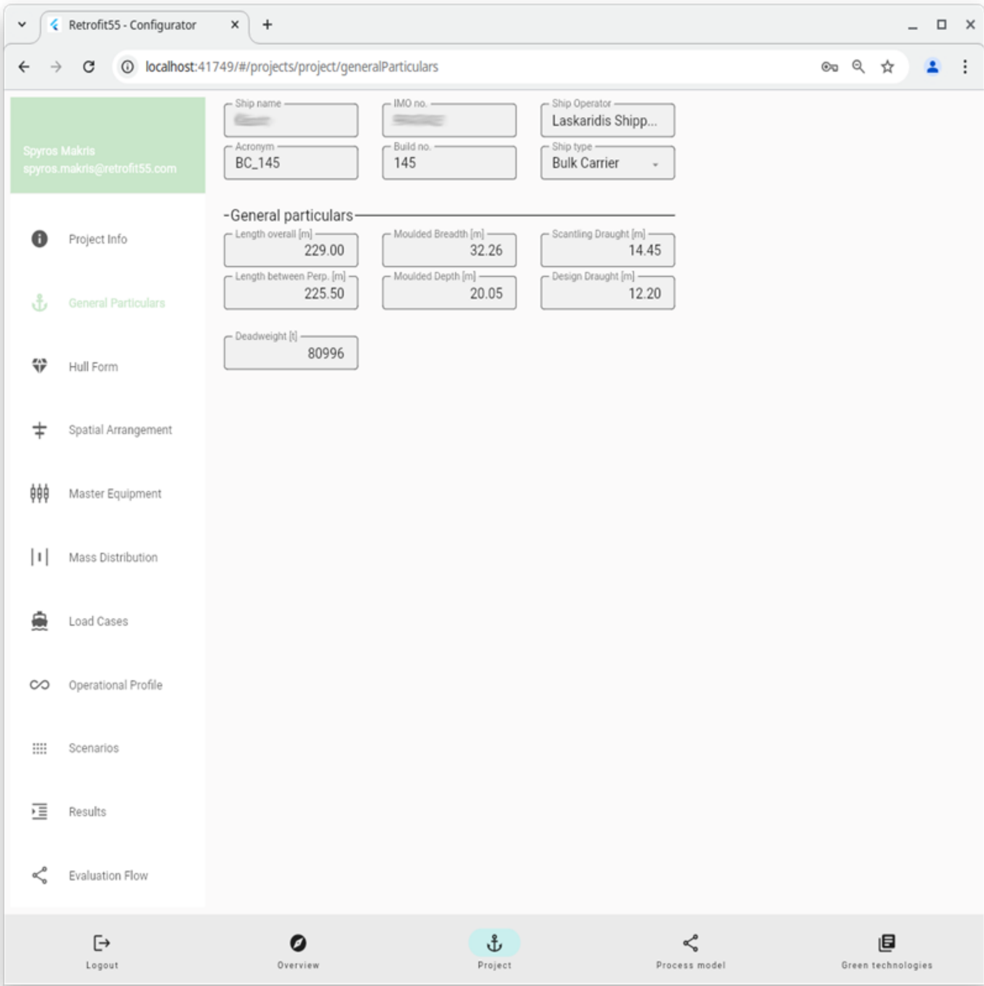


Figure 7: Main particulars selection environment.

6.3.2 Hull form definition

The hull form definition phase accommodates two alternative approaches, acknowledging the practical variability in the availability of detailed CAD models.

Importing a CAD model

When a hull form CAD model is accessible, it can be directly imported into the system using the [Import] button (see Figure 8), allowing for precise geometric representation and subsequent analysis. For import the following formats are supported: OBJ (Wavefront obj).

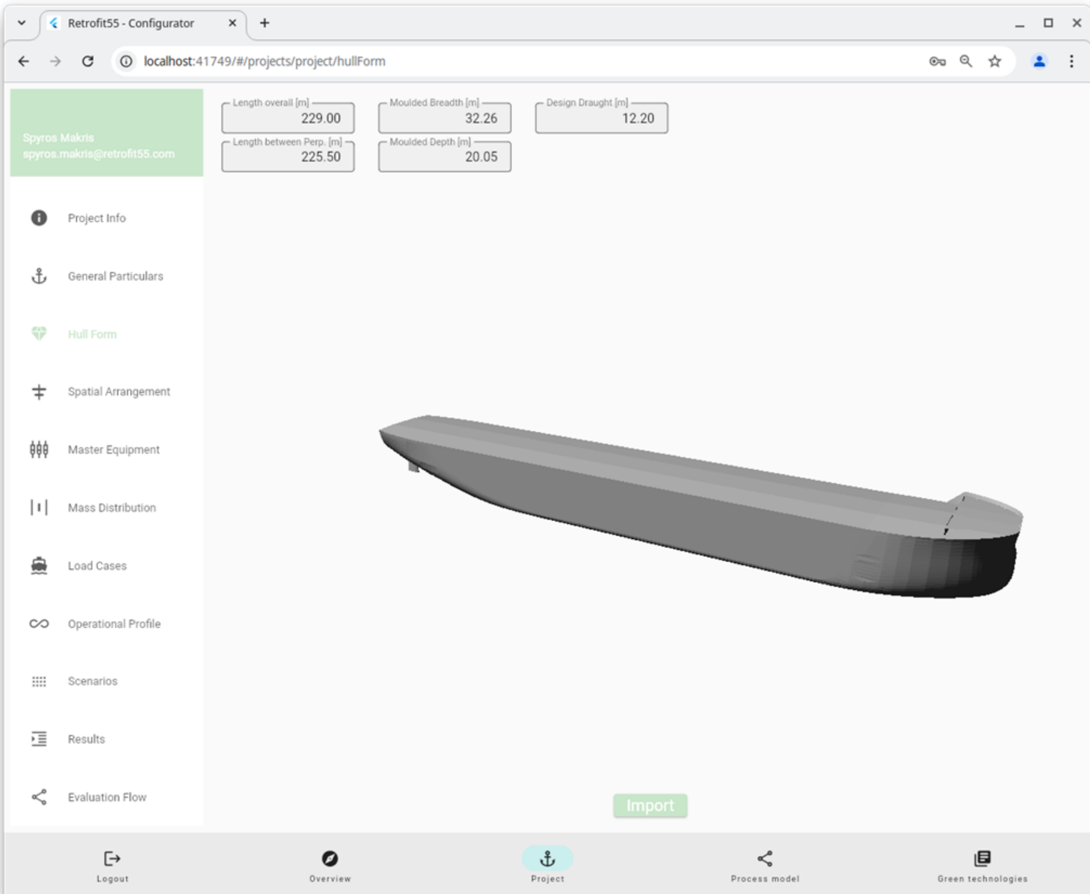


Figure 8: CAD hull form import environment.

Automatic hull form generation

However, recognizing that such detailed digital assets may not always be available—particularly during early design stages or after years of operation—the system also supports the rapid generation of a sufficiently accurate hull form approximation, for details of the approach see [5]. This is achieved by inputting a minimal set of additional parameters, enabling the continuation of analyses without compromising overall fidelity. This dual-method flexibility ensures adaptability across a broad range of project maturities and data availability scenarios. The parameters length overall (Loa), length between perpendiculars (Lpp), moulded breadth (B), moulded depth (D) and design draught (T) are already defined as main particulars and thus cannot by changed. The following additional parameters are required to define the hull form characteristics:

Primary parameters:

- bilge radius
- start midbody (as a ratio of Lpp)
- end midbody (as a ratio of Lpp)
- x coordinate of transom
- x coordinate of propeller nozzle
- z coordinate of propeller above base
- propeller hub diameter

Additional optional parameters can be provided for further fine tuning:

- WL angle at stem
- bulb length (as a ratio of Lpp)

After the generation has been completed, the resulting hull form will be displayed, including a table indicating the compliance of the generated hull form characteristic values with these ones entered for the baseline (see Figure 9).

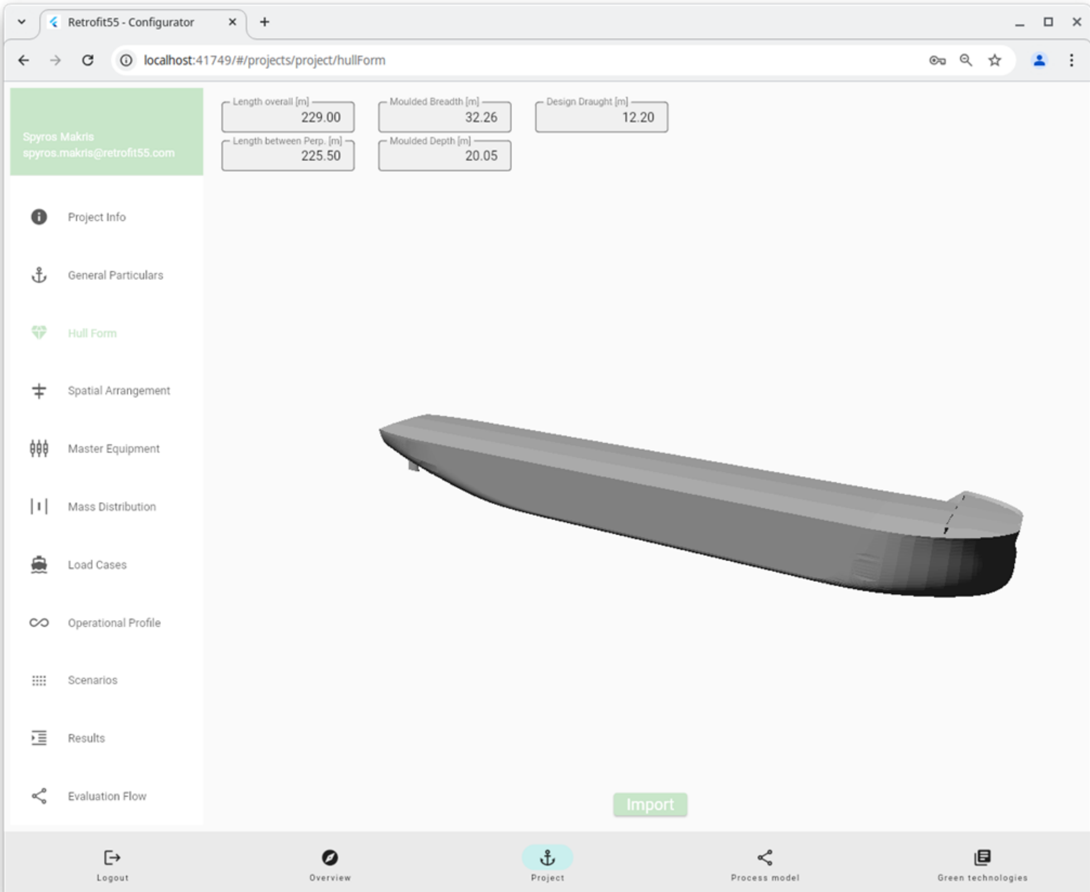


Figure 9: Automatic hull form generation environment.

6.3.3 Spatial arrangement definition

The definition of spatial arrangement constitutes another crucial step in the vessel design process, particularly when assessing the integration potential of green technologies. This stage involves outlining the internal distribution and allocation of space within the vessel. For technologies that demand specific volumetric or locational requirements - such as energy storage systems, exhaust treatment units, or alternative fuel tanks - it is essential to establish spatial constraints early in the process. By explicitly defining the spatial arrangement, the system can more accurately evaluate the feasibility of incorporating various sustainable technologies, ensuring that proposed solutions are not only technically viable but also spatially compatible with the vessel's design (see Figure 10).

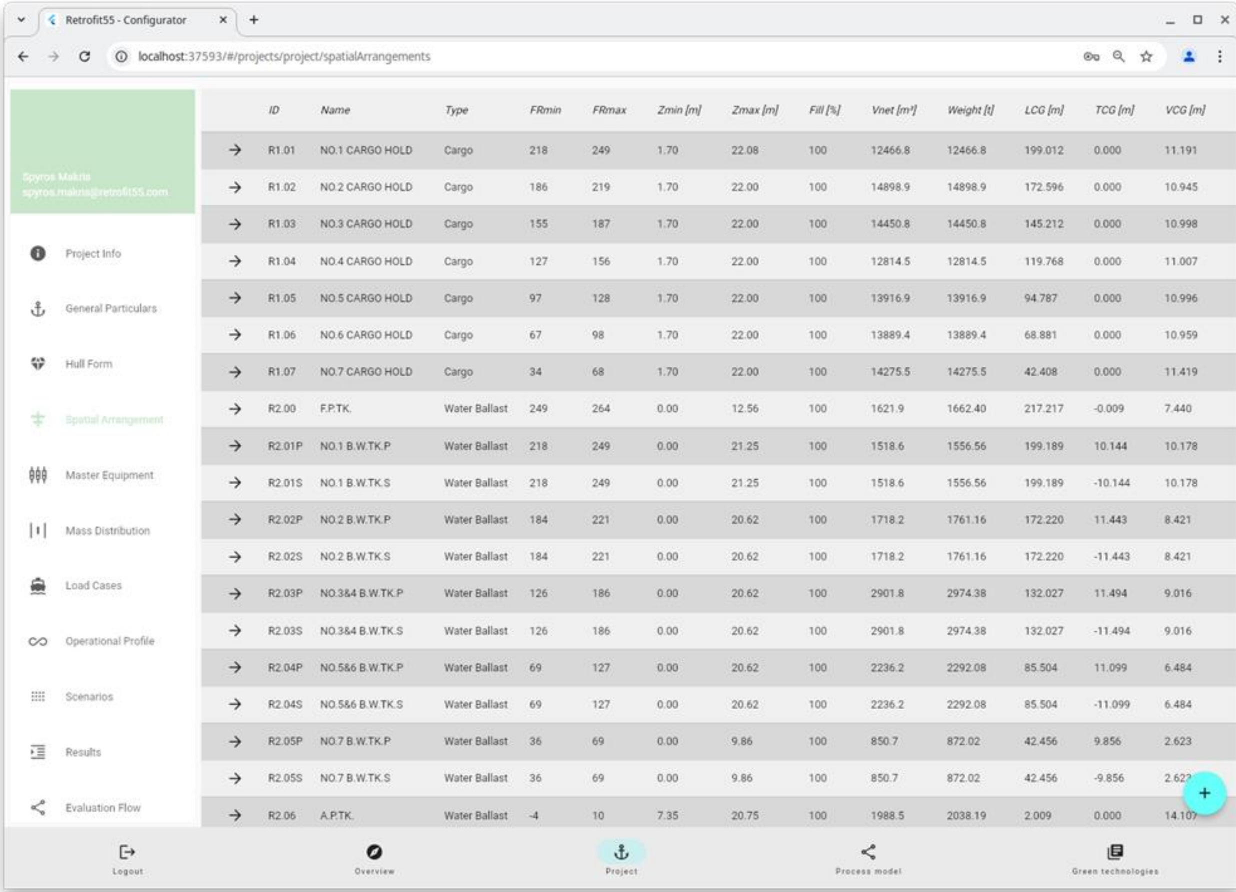
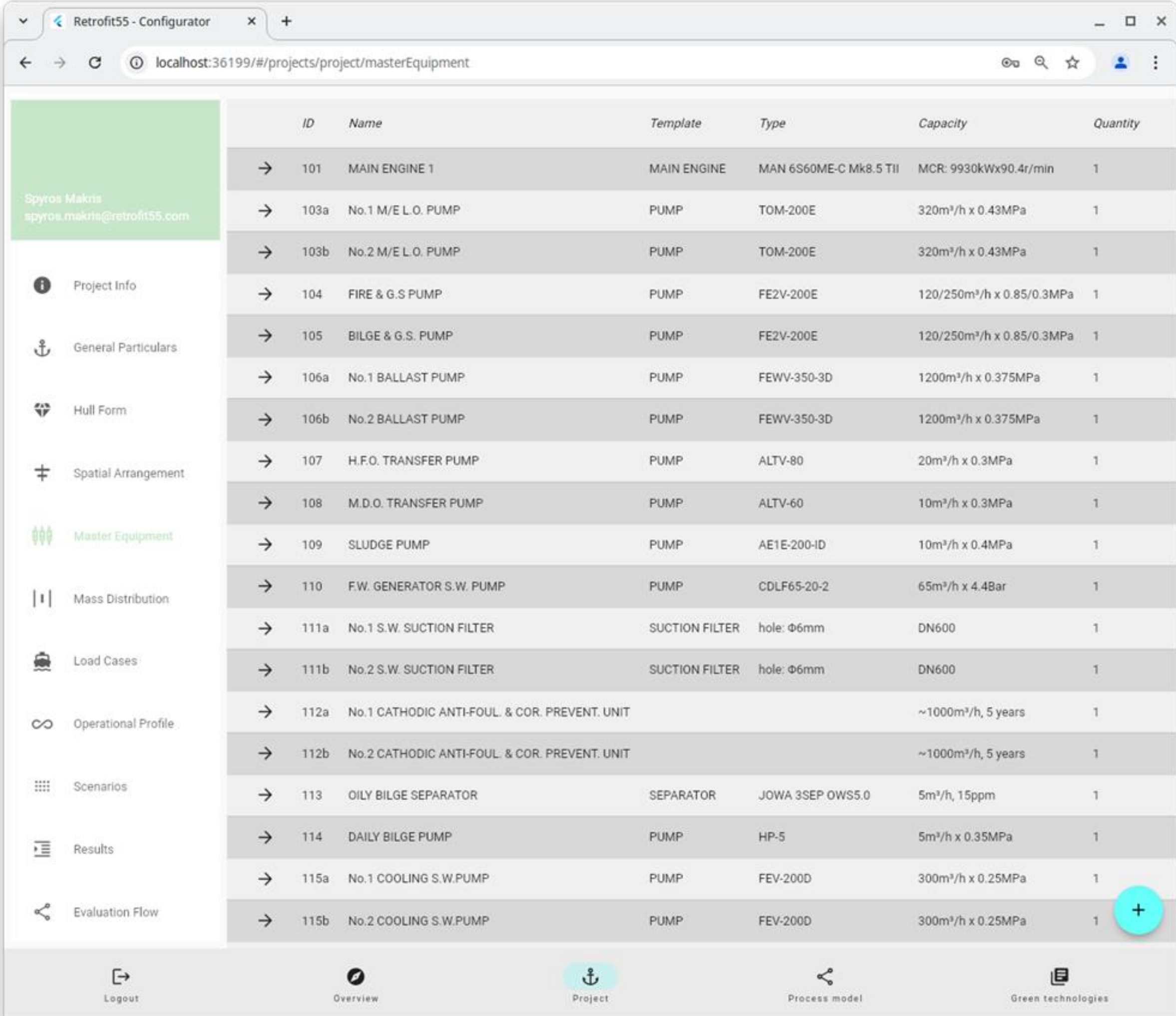


Figure 10: Spatial arrangement definition environment.

6.3.4 Master equipment definition

The definition of master equipment pertains to the identification and characterization of major onboard systems, particularly those that may already embody green technologies. This information is critical for evaluating potential interdependencies between existing equipment and additional sustainable solutions proposed by the configurator. Recognizing the importance of minimizing manual input effort, the system allows for the master equipment to be either directly imported or defined using a pre-established equipment catalogue (see Figure 11).



ID	Name	Template	Type	Capacity	Quantity
101	MAIN ENGINE 1	MAIN ENGINE	MAN 6S60ME-C Mk8.5 TII	MCR: 9930kWx90.4r/min	1
103a	No.1 M/E L.O. PUMP	PUMP	TOM-200E	320m³/h x 0.43MPa	1
103b	No.2 M/E L.O. PUMP	PUMP	TOM-200E	320m³/h x 0.43MPa	1
104	FIRE & G.S PUMP	PUMP	FE2V-200E	120/250m³/h x 0.85/0.3MPa	1
105	BILGE & G.S. PUMP	PUMP	FE2V-200E	120/250m³/h x 0.85/0.3MPa	1
106a	No.1 BALLAST PUMP	PUMP	FEWV-350-3D	1200m³/h x 0.375MPa	1
106b	No.2 BALLAST PUMP	PUMP	FEWV-350-3D	1200m³/h x 0.375MPa	1
107	H.F.O. TRANSFER PUMP	PUMP	ALTV-80	20m³/h x 0.3MPa	1
108	M.D.O. TRANSFER PUMP	PUMP	ALTV-60	10m³/h x 0.3MPa	1
109	SLUDGE PUMP	PUMP	AE1E-200-ID	10m³/h x 0.4MPa	1
110	F.W. GENERATOR S.W. PUMP	PUMP	CDLF65-20-2	65m³/h x 4.4Bar	1
111a	No.1 S.W. SUCTION FILTER	SUCTION FILTER	hole: Φ6mm	DN600	1
111b	No.2 S.W. SUCTION FILTER	SUCTION FILTER	hole: Φ6mm	DN600	1
112a	No.1 CATHODIC ANTI-FOUL. & COR. PREVENT. UNIT			~1000m³/h, 5 years	1
112b	No.2 CATHODIC ANTI-FOUL. & COR. PREVENT. UNIT			~1000m³/h, 5 years	1
113	OILY BILGE SEPARATOR	SEPARATOR	JOWA 3SEP OWS5.0	5m³/h, 15ppm	1
114	DAILY BILGE PUMP	PUMP	HP-5	5m³/h x 0.35MPa	1
115a	No.1 COOLING S.W.PUMP	PUMP	FEV-200D	300m³/h x 0.25MPa	1
115b	No.2 COOLING S.W.PUMP	PUMP	FEV-200D	300m³/h x 0.25MPa	1

Figure 11: Master equipment definition environment.

6.3.5 Mass distribution definition

The mass distribution definition serves a critical function in the holistic assessment of a vessel's stability, structural integrity, and operational performance. By specifying how mass is distributed across the vessel's length, breadth, and depth — including components such as machinery, cargo, fuel, ballast, and green technologies — engineers can accurately evaluate the vessel's center of gravity, trim, and overall hydrostatic behavior (see Figure 12).

This information is essential for ensuring compliance with stability criteria, avoiding excessive structural loads, and optimizing fuel efficiency. Moreover, in the context of integrating new green technologies, an accurate mass distribution model helps assess the impact of added equipment on the vessel's dynamic behaviour and aids in determining suitable locations to avoid compromising vessel performance or safety.

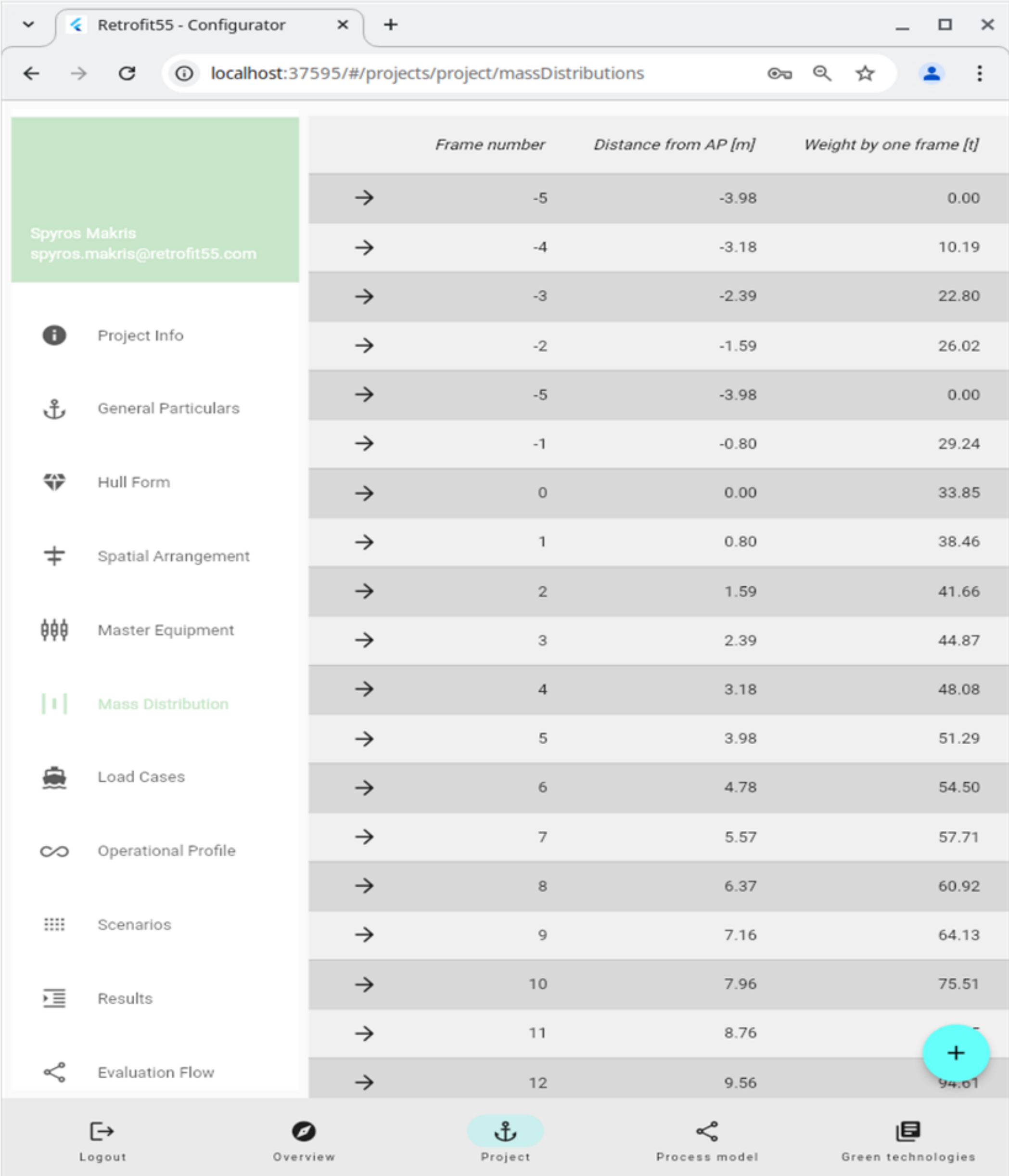


Figure 12: Mass distribution definition environment.

6.3.6 Load cases definition

The consideration of different load cases - which represent varying operational conditions such as cargo weight, fuel load, ballast, and environmental factors - is crucial when selecting new green technologies for installation (see Figure 13). This is because the performance of these technologies can be highly sensitive to changes in the vessel's operational state. For example, energy storage systems, fuel efficiency measures, or exhaust treatment technologies may behave differently under various load conditions, which can affect their effectiveness and long-term reliability. Additionally, load cases directly impact the vessel's stability, trim, and fuel consumption, all of which must be optimized in tandem with the integration of green technologies. By taking load cases into account, designers can ensure that the selected technologies function efficiently under all operational scenarios, avoiding potential issues such as equipment overload, performance degradation, or safety hazards. Moreover, incorporating load case analysis into the decision-making process enables the selection of solutions that are not only technically feasible but also adaptable to the vessel's dynamic operational conditions.

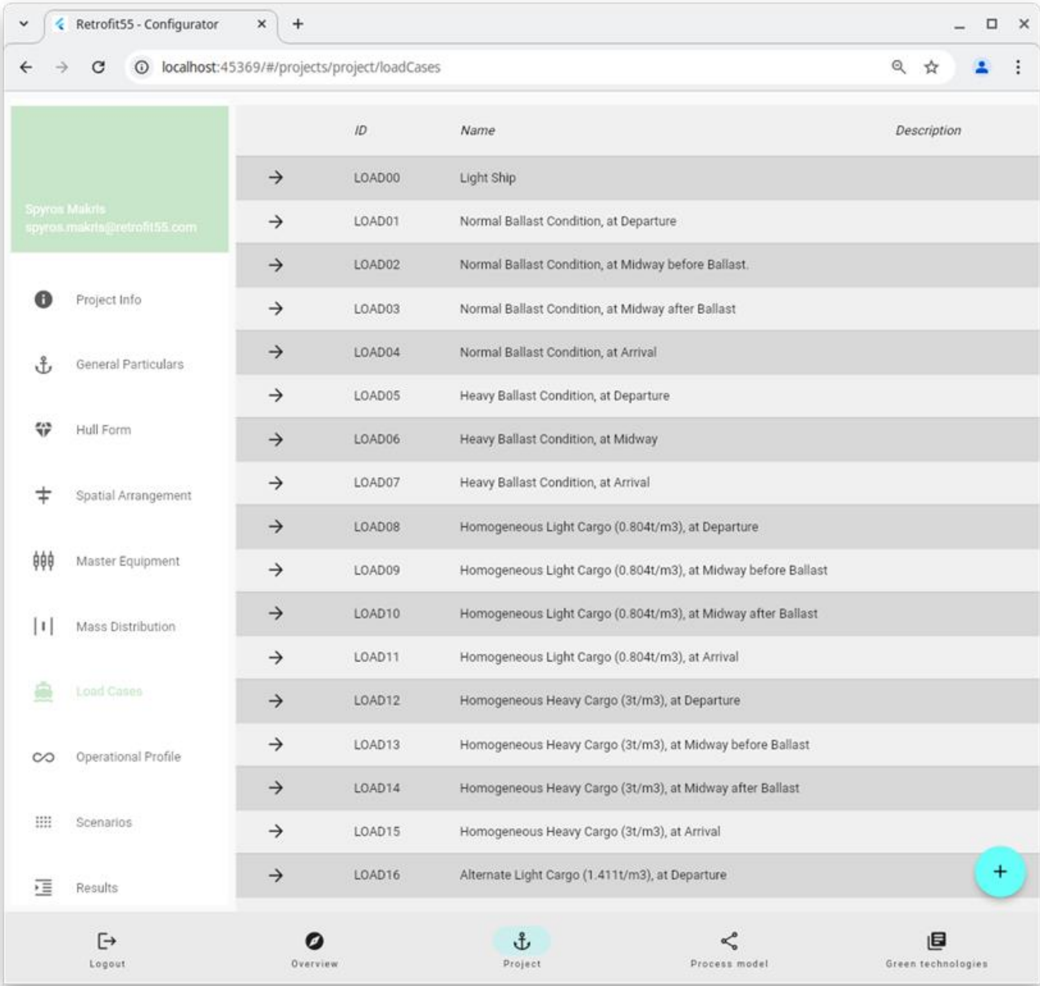


Figure 13: Load cases definition environment.

The application provides an entry form for any number of load cases (typically 5-20 cases will be sufficient, depending on the ship type and variability of the operational profile).

Figure 14 shows the details of the selected load case representing heavy cargo during departure. Again, the relevant data can be imported or entered ad hoc.

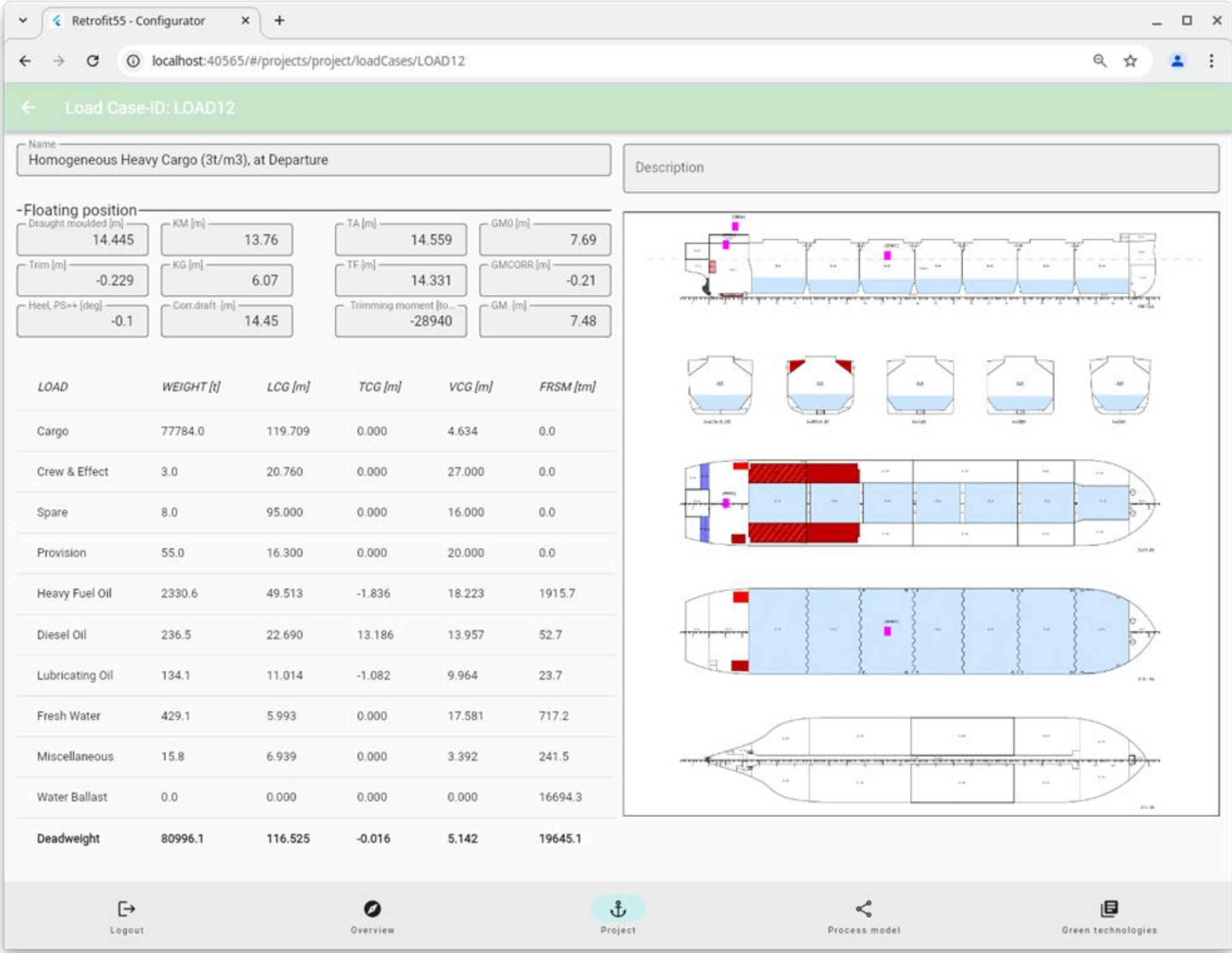


Figure 14: Detail of the selected load case.

6.4 Scenario and cases definition

With the baseline data of the vessel now being defined we can start with the definition of scenarios and cases (see Figure 15).

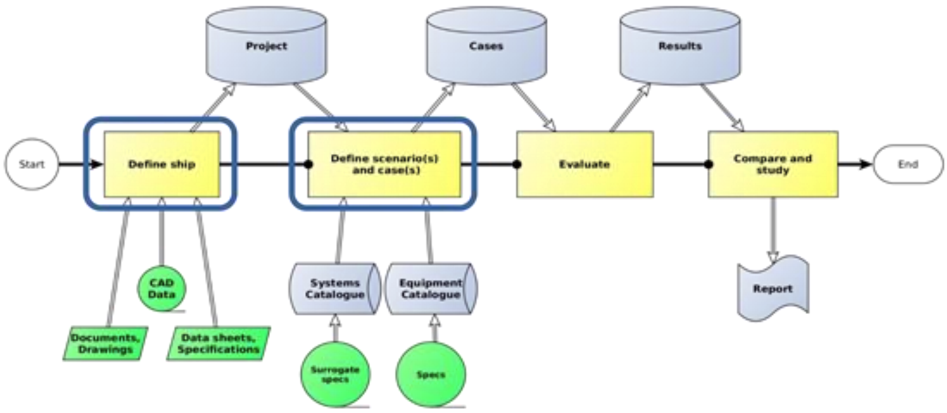


Figure 15: Scenarios and cases phase.

6.4.1 Operational profile definition

As a first step, the definition of the operational profile (see Figure 16) of a vessel involves outlining the typical operational parameters, including speed, fuel consumption patterns, routes, and time spent under various operational conditions.

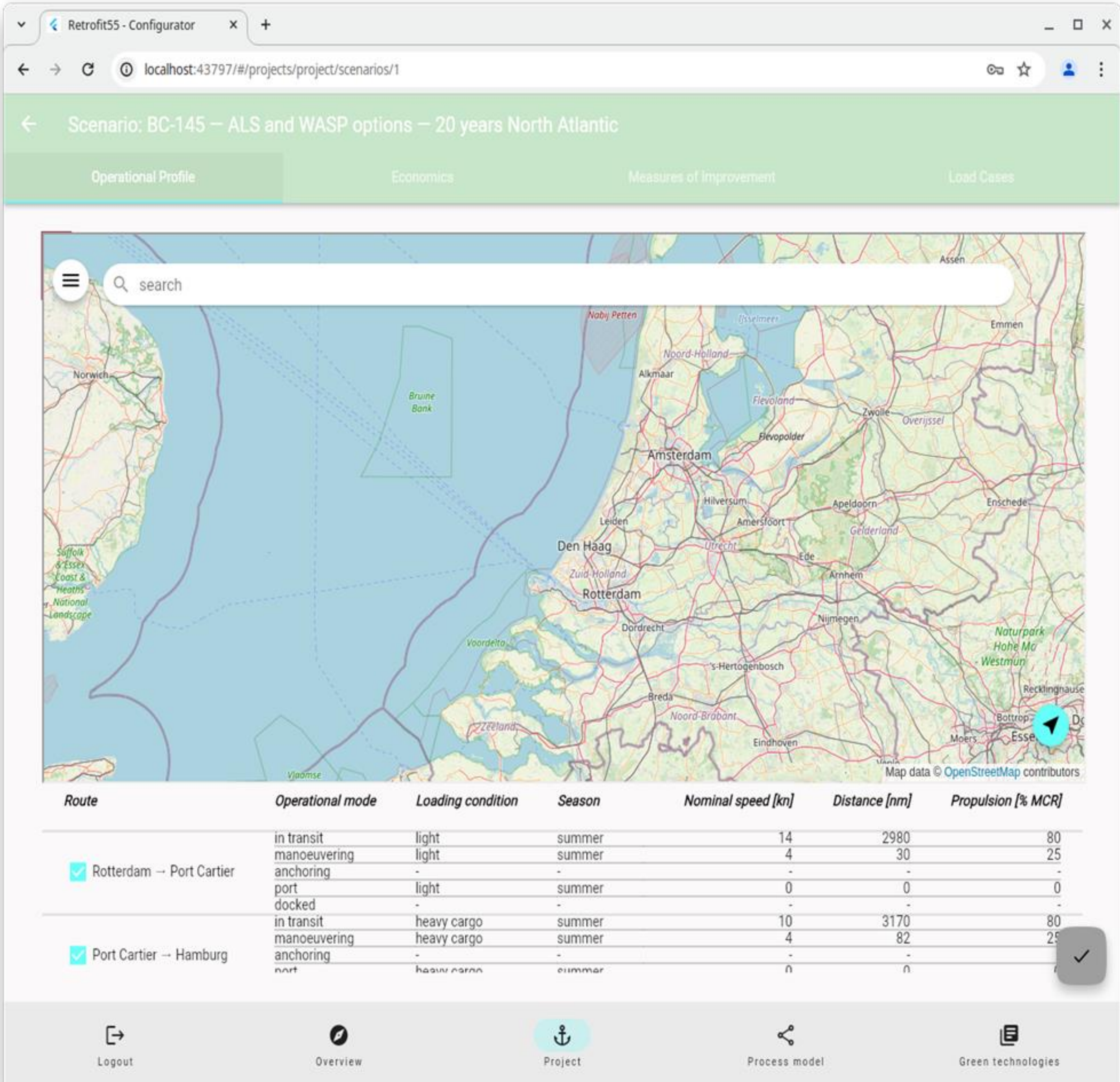


Figure 16: Operational profile definition.

This data is crucial for accurately calculating the potential fuel savings that can be achieved by implementing appropriate green technologies. By understanding the vessel's operational profile, the configurator can tailor its recommendations to maximize efficiency and minimize environmental impact.

Additionally, external factors such as weather conditions associated with specific routes play a significant role in the performance of certain technologies, such as Wind-Assisted Ship Propulsion (WASP) systems. These technologies, which rely on external wind forces to assist in propulsion, are directly influenced by the prevailing weather patterns, and their efficiency can vary considerably depending on route-specific climatic conditions. Therefore, a comprehensive understanding of both the operational profile and weather conditions is essential for selecting and optimizing green technologies that will deliver the greatest benefits in real-world operational scenarios.

6.4.2 Definition of economic and technological scenarios

Here various scenarios can be specified and the actual calculation process started. The predefined entered data in previous forms is used as baseline and can be modified if necessary.

Economic scenario

Within the Economics tab, users have the ability to define key financial parameters, such as the expected development of fuel prices over time, the applicable discount rate, and the investment horizon (see Figure 17).

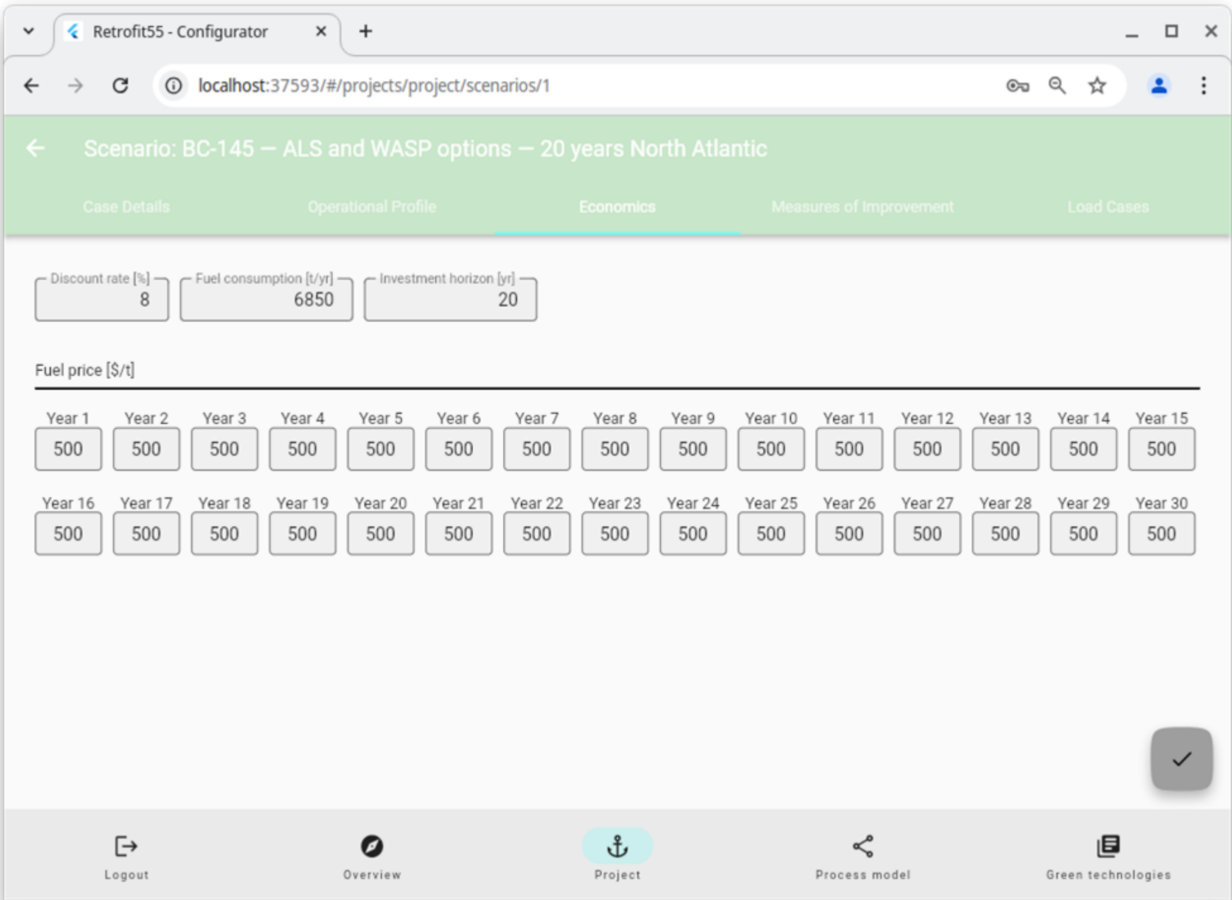


Figure 17: Financial parameter definition.

These factors are integral to determining the optimal mix of green technologies, as they directly influence the economic viability and long-term benefits of each solution. The investment horizon is set by default to correspond with the vessel's expected lifespan, ensuring that technology recommendations are aligned with the vessel’s operational and financial lifecycle. However, this horizon can be adjusted as needed to accommodate specific scenarios, such as evaluating technologies that are intended to be used only for a shorter period. In such cases, the investment horizon would reflect the desired operational timeframe, allowing for a more tailored assessment of the green technologies' financial impact during that specific period.

Measures of improvement

Under the measures of improvement section, users have the option to predefine which green technologies should be considered during the evaluation process (see Figure 18).

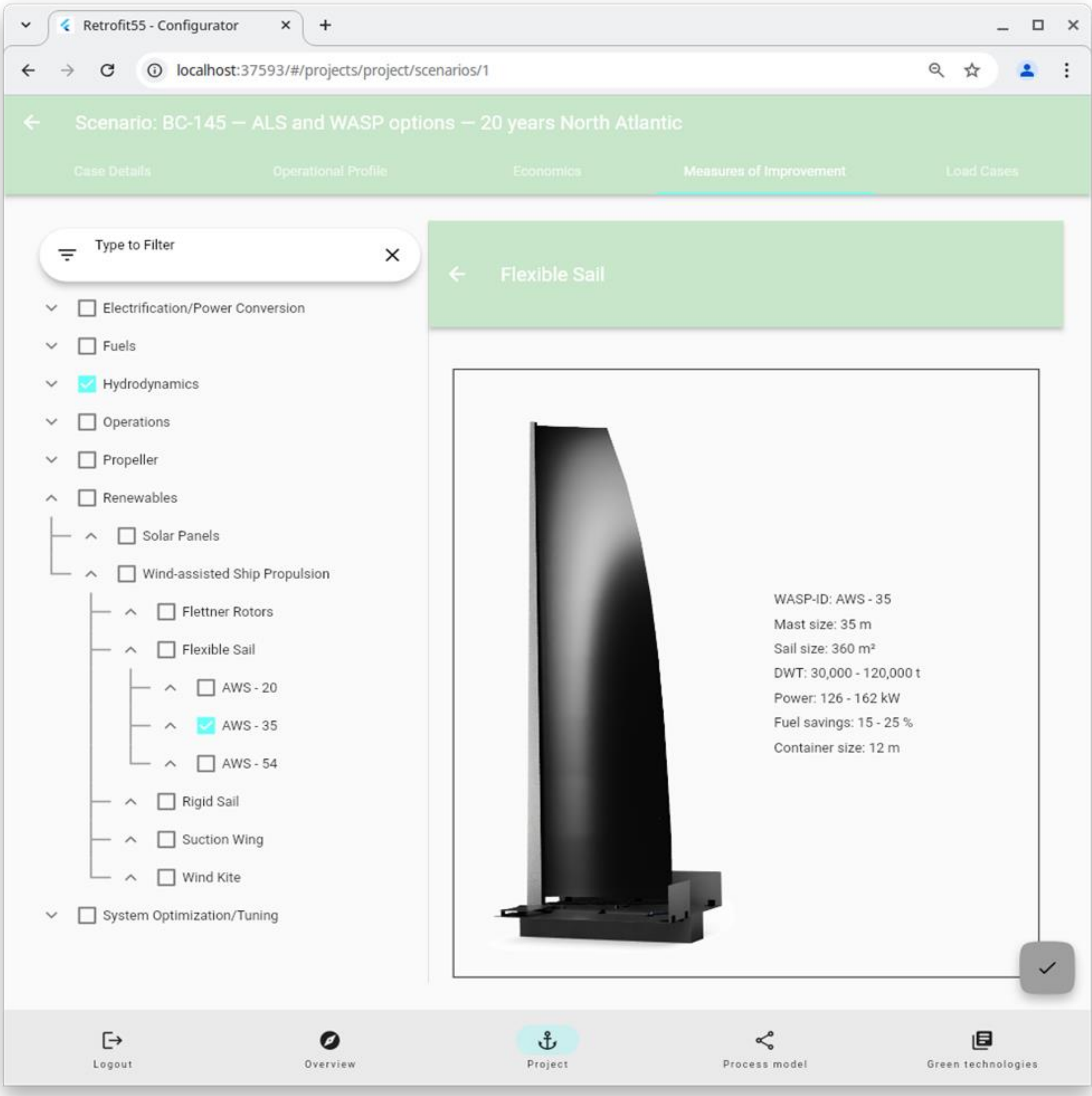


Figure 18: Measures of improvement selection example.

This feature allows for a more focused analysis, ensuring that only relevant technologies are assessed based on the specific needs and objectives of the project. By restricting the pool of potential green technologies at the outset, the system can streamline the evaluation process, reducing the computational time required to derive the optimal solution. This targeted approach not only enhances efficiency but also ensures that the selected technologies are directly aligned with the project's goals, ultimately leading to more effective and timely decision-making.

In total the following main categories containing subcategories have been identified so far:

- Electrification/ Power Conversion
- Fuels
- Hydrodynamics
- Operations
- Propeller
- Renewables
- System Optimization/Tuning

6.4.3 Optimization goals setting

Finally, within the Tab Case details, the life time expectation for the vessel has to be entered and various optimization objectives can be defined. Three different objective categories can be selected which are Economical, Environmental and Planning (see Figure 19). By preselecting the objective category appropriate targeted KPIs to be optimized can be selected afterwards.

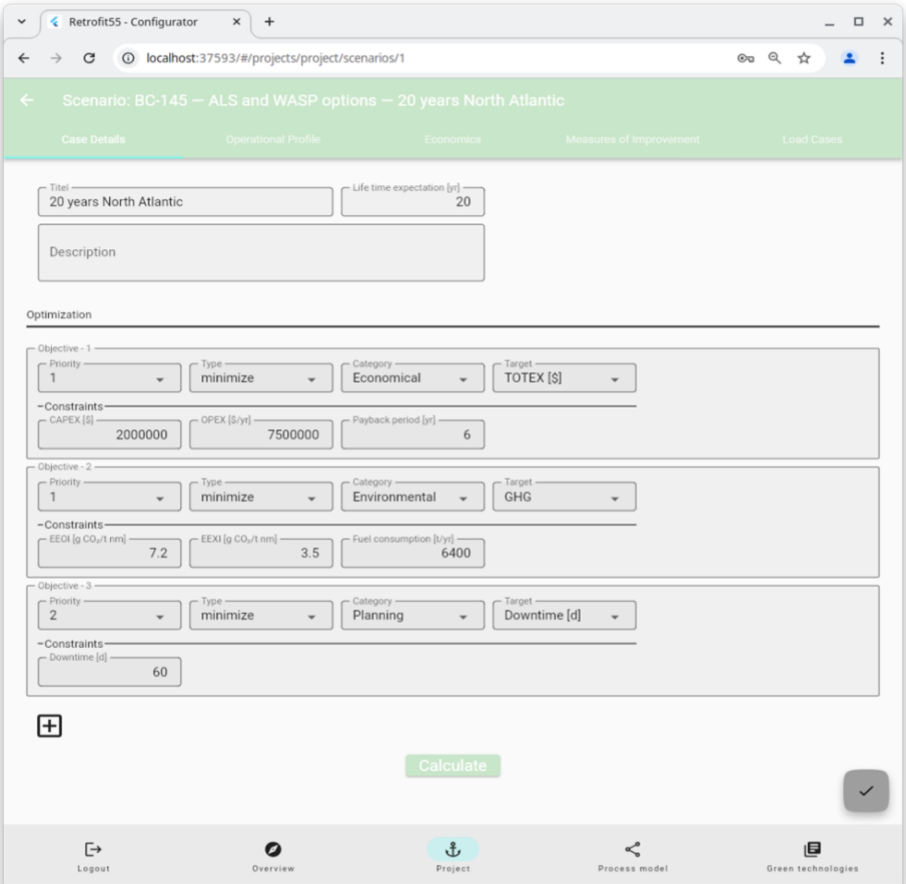


Figure 19: Optimization goals setting.

Furthermore, it is possible to prioritize specific objectives and enter constraints to be considered during the multi criteria optimization. Especially when the green technologies to be considered during the evaluation are not limited by the user there are potentially a lot of combinations of various green technologies possible and by predefining the optimization objectives the most optimal solutions are offered.

These steps complete the case definition.

6.5 Evaluation

We proceed now with the evaluation phase (see Figure 20), which is started by clicking on the [Calculate] button.

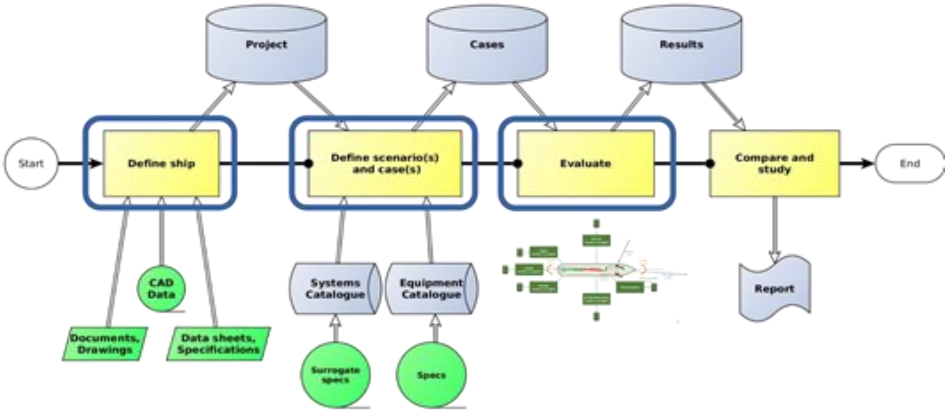


Figure 20: Evaluation phase.

Evaluation will execute the necessary calculation steps by determining required data, executing the corresponding calculations and assessing the optimization goals. In case of missing data that is required to complete this step the evaluation will pause, offering the option to enter such data (this is only feasible for simple type of data) or stopping the evaluation process in order to go back to enhance data entry.

The evaluation process is internally controlled by a process definition that captures all relevant computational steps and monitors required data flows. This is based on the technology described in [4].

6.6 Results assessment

Once the evaluation has been completed, the final stage to inspect the results in being entered (see Figure 21).

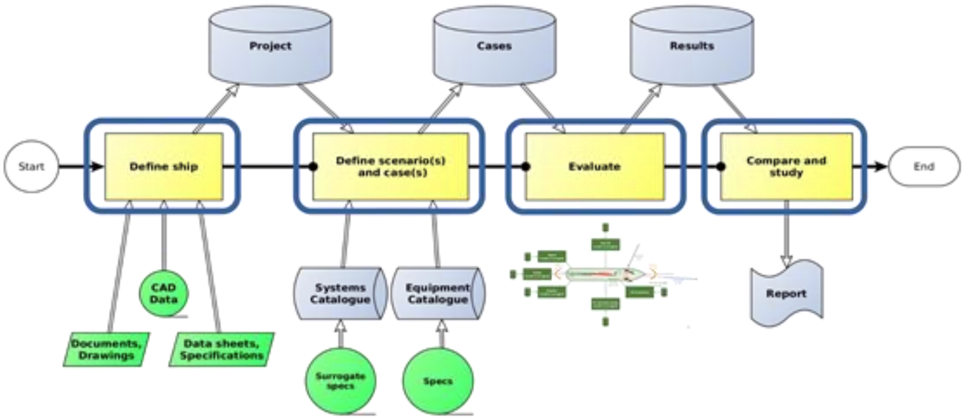


Figure 21: Results assessment phase.

For each specific scenario, the system provides a set of results that summarize key parameters related to all suitable green technologies that were preselected from the catalogue and considered during the evaluation process. These results are ranked according to the predefined optimization objectives, offering a clear overview of the most effective technologies based on the selected criteria. Within the result table, users can select suitable measures, which are then visualized in corresponding charts, allowing for a dynamic and comprehensive analysis (see Figure 22). According to the selected optimization categories - *Economical*, *Environmental*, and *Planning* - the KPIs are presented as both absolute and percentage values, providing a nuanced view of how each technology contributes to the overall project goals.

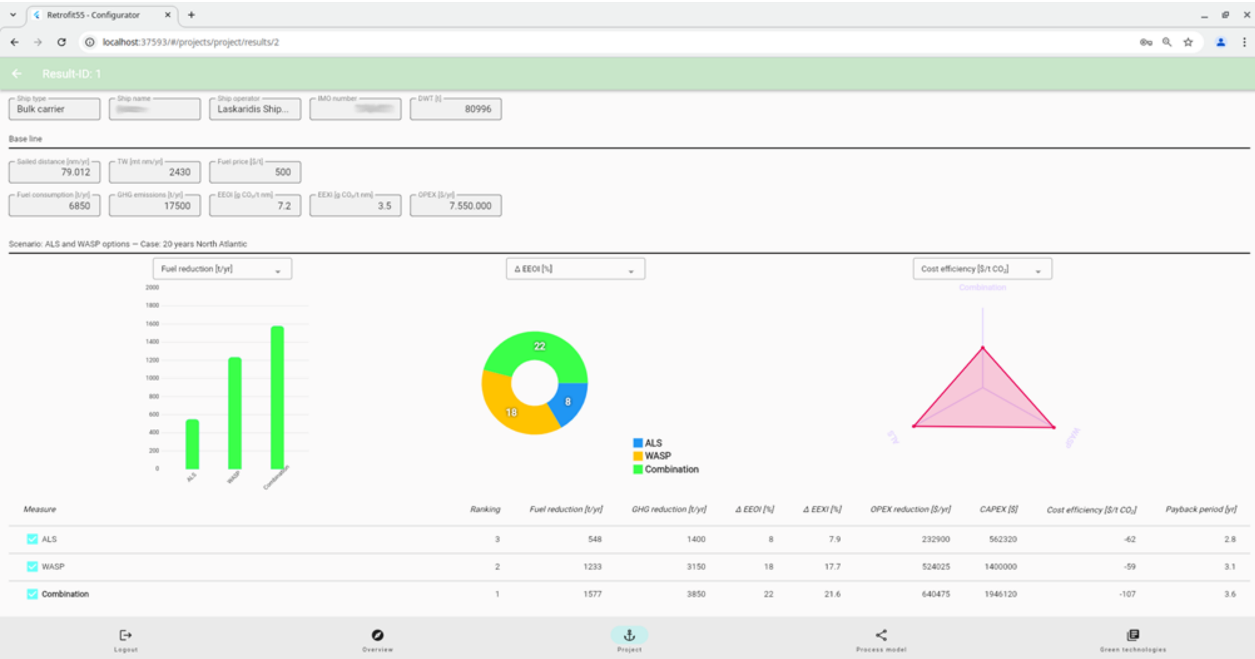


Figure 22: Results tables.

The most essential KPIs include:

- Fuel reduction: expressed as the decrease in fuel consumption in tonnes per year relative to the baseline scenario,
- CII / GHG reduction: indicating the reduction in GHG emissions in tonnes per year compared to the baseline,
- EEOI reduction: representing the percentage improvement relative to the baseline,
- EEXI reduction: representing the percentage improvement relative to the baseline,
- OPEX reduction: calculated as the annual savings in operational costs derived from fuel reductions. This metric also accounts for future fuel price developments and includes additional maintenance costs associated with the selected green technologies,
- CAPEX: includes the investment costs required for technology implementation. This covers equipment price, installation, and initial training. If multiple technologies are installed within the same shipyard and time frame, a reduction factor is applied to account for overlapping installation activities,
- Cost efficiency: defined as the net present value of cost savings divided by the GHG reduction over the shorter of either the vessel's lifetime or the duration of the green technology measure.

Negative values indicate cost-effective solutions, with more negative values reflecting higher profitability, and

- Payback period (ROI): discounted payback period representing the number of years it takes to break even from undertaking the initial expenditure for the green technology, by discounting future cash flows due to OPEX reduction.

7 Future directions

This document describes the current state of development. As to be expected, many additional insights and ideas have evolved during development.

Some future additions, that have been identified, are:

- consideration of deviations/uncertainties regarding the potential improvements. These KPI might be also useful to make a better decision when it comes to choose the most suitable green technology or combination of those;
- an overview showing all available green technologies as a table providing information regarding the price, potential savings etc. might be useful to make a preselection easier for the end user;
- generation of an installation overview of selected technologies, including a realistic graphic depiction of the arrangement on the vessel (Figure 23). This requires sufficiently detailed descriptive information of the components and there placement and will also require a good quality CAD model of the ship baseline arrangement.

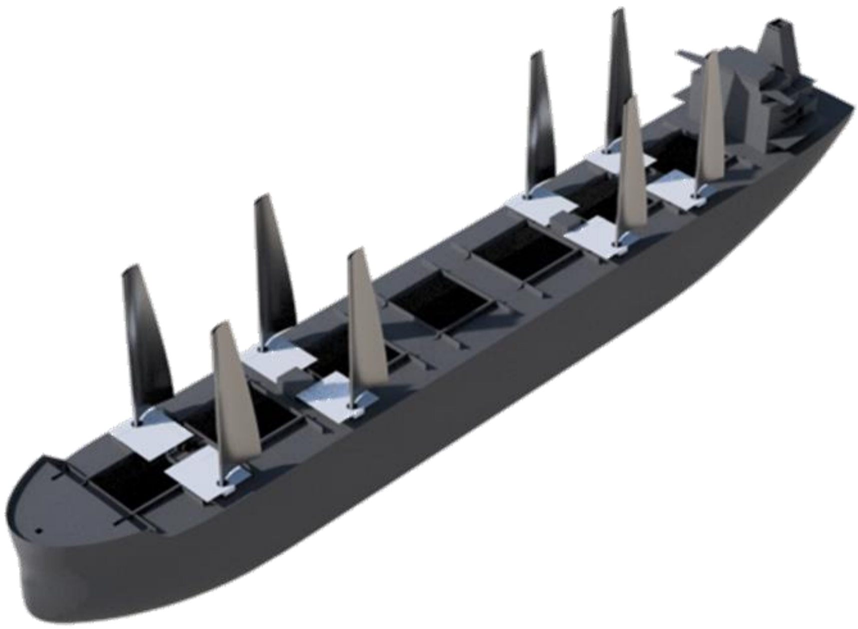


Figure 23: Qualitative ship arrangement.

Apart from this it is expected that upcoming tasks to further test and validation activities to apply the application to more real-world cases will surely provide input to further improve or streamline the user interaction and user interfaces.

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