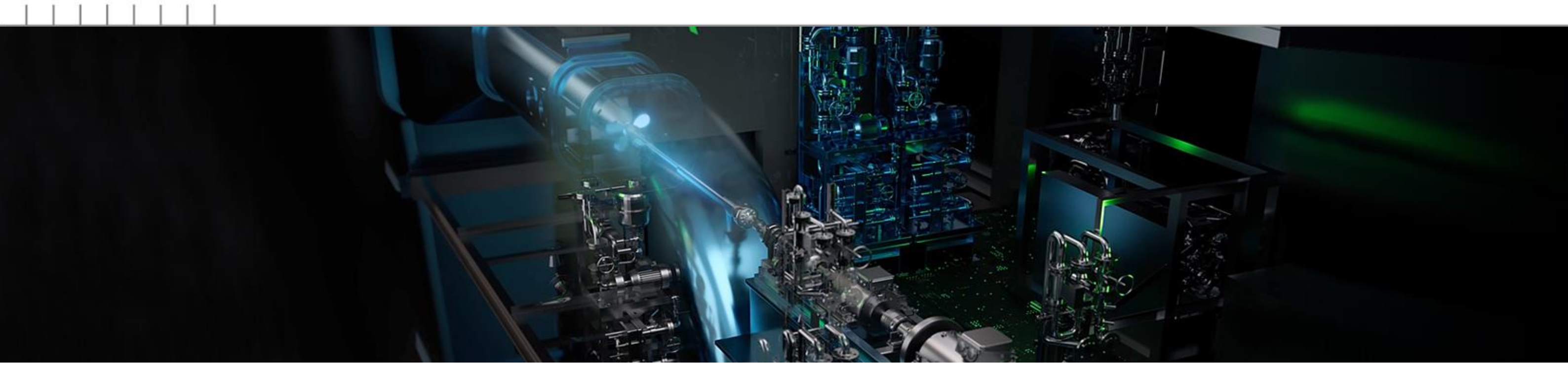


MARIN Zero Emission Services for Maritime Masterplan projects

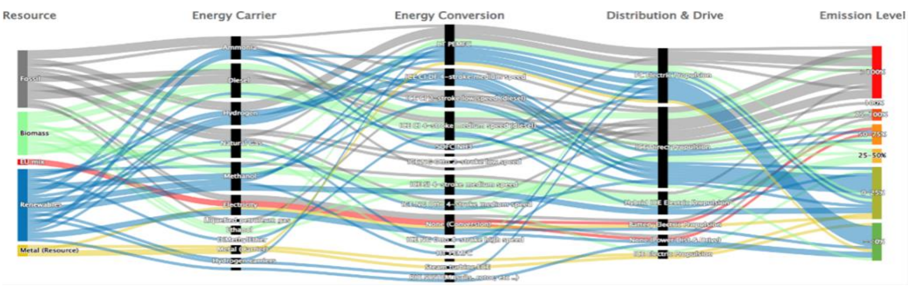
In the Maritime Master Plan, Dutch industry develops, builds and uses thirty ships with innovative designs and technologies that should lead to a climate-neutral maritime sector. As an independent research institute, MARIN can strengthen the consortia with our zero emission services for the development of all demonstration ships. We offer services from concept development to operation through the use of our dedicated knowledge, facilities and (simulation) models. In this way, we ensure that innovations can be achieved more quickly with more control over the associated uncertainties and risks, that there is objective insight into the effectiveness and reliability of emission-reducing technologies and that these technologies are optimally used on board.

Services overview

1. **Exploration**
   Operational analysis and technology selection.
2. **Scenario simulation**
   Evaluation of future or alternative designs in authentic operational conditions.
3. **Marine power system design**
   Developing a fit-for-purpose system design
4. **Simulation & testing**
   Risk mitigating when introducing low technology readiness level solutions.
5. **Validation & troubleshooting**
   Objective insight into the reliability of emission-reducing technologies, and tackle problems on board.
6. **Training & education**
   Crews, maintenance engineers and designers learn how to handle new technologies and systems.

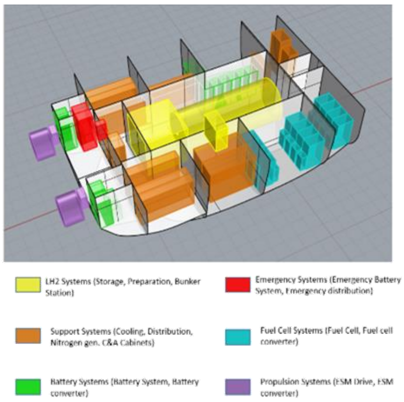
1. Exploration

This stage is all about understanding the real energy needs and system preferences by listening to the operators and performing an operational analysis. The first step is to ensure that the hull and propulsion are optimum to reduce energy needs. Classical techniques are existing for that phase (e.g. https://magazine.marin.nl/marin-report-138/eexi). The exploration will then define the input needed for a proper technology trade-off study where alternative operations and wind propulsion (www.marin.nl/en/research/wind-propulsion) can be considered. Once a preferred power and energy technology is chosen, the required systems and their support systems can be identified.



MARIN uses the SPEC tool to assess which energy carriers and energy converters are feasible for the reference ship and its operations.

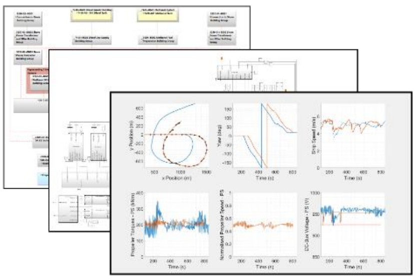
In order to provide a stable and efficient alternative, sustainable energy concept designs often demand combined technical solutions. As all alternative energy concepts come with their own characteristics, smart decisions can be made in this stage on the positioning of the power and energy systems equipment. Safety aspects, weight and volume requirements, specific class regulations or expensive interfaces are taken into account to provide solutions for the general layout.



System arrangements in a ship

Why work with MARIN?

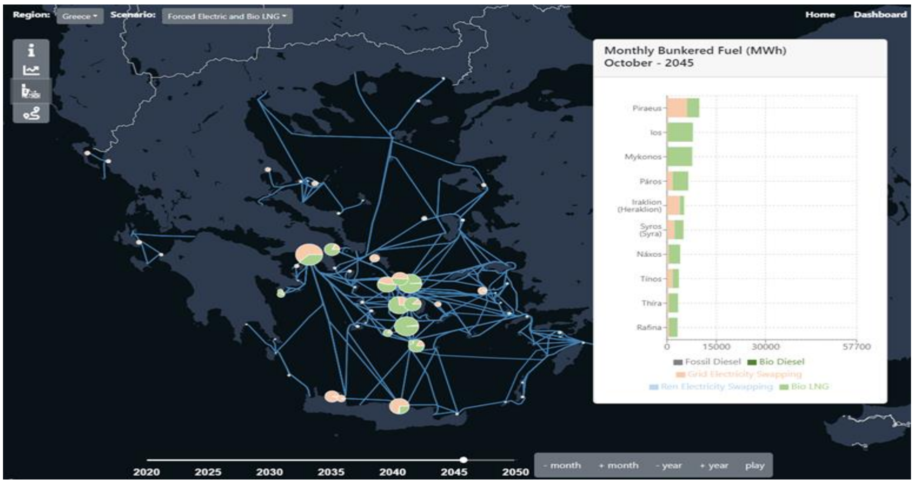
- We are an independent research institute without any patents of our own and handle your knowledge and data confidentially.
- A higher ranking and chance of awarding the subsidy through a higher quality of the project (criterion B), and the ability to convert data into high-quality (simulation) models and knowledge, using the latest data science techniques and thereby contributing to the Joint Maritime Digital Platform (criterion E).
- Multidisciplinary teams and state-of-the art test facilities.
- Our non-economic research in the Maritime Masterplan projects is 100% subsidized.



Simulating the same mission with two different configurations to compare.

2. Scenario simulation

Scenario simulations are a powerful method to evaluate future or alternative designs in authentic operational conditions, levered by hindcast environmental data. For this we create a simulation model (digital twin) at concept phase level. The scenario simulation models, including dynamic techno-economic components, allow authorities, ship and fleet owners, harbour and energy suppliers to launch alternative scenarios based on their current operations (see also: https://needs.application.marin.nl/). The model includes the energy supply, the harbour infrastructures (energy bunkering, charging or swapping and shipping logistics), the ships, the cargo capacity, the waterborne operations and the environmental conditions. Long-term hindcast data allow running scenarios and assess implementation strategies for the coming decades, from a technical and economic perspective.



3. Marine power system design

Once the operations of a vessel are defined and the technology is chosen, MARIN can create different power, propulsion and energy (PPE) configurations, which can be compared and assessed on a variety of aspects like expected system efficiencies, reliability and complexity allowing a suitable configuration to be chosen. This results in a layout of the PPE system with the sizing of components and the principal component interfaces.

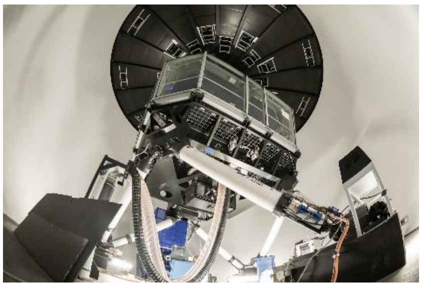
4. Simulation & testing

The risks involved with building these innovative vessels can be reduced by doing early-stage verification of the conceptual design. We create simulation models (digital twins) and use scaled-physical setups across multiple facilities to verify the PPE system designs:

virtual Zero Emission Lab (v-ZEL)

The virtual Zero Emission Lab is a modelling platform with an extensive set of mathematical models of PPE system components, where virtual representations of the designed system can be configured and tested. The model library consists of models with varying levels of complexity and fidelity and the appropriate models are chosen based on the tests to be performed. The PPE system model can be coupled to our hydrodynamic models to simulate and analyse the performance of the design in various conditions with respect to the design requirements.

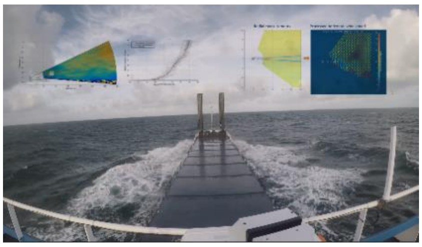
The physical Zero Emission Lab, containing a fuel cell, hydrogen, a modern dual fuel generator set, and sophisticated electrical power distribution.



The Large Motion Simulator in the SOSc with a moving bridge of 4 x 5 m on a hexapod.

Model test in our Seakeeping and Manoeuvring Basin.

Installation of measuring equipment in engine room



Validation of wind propulsion in operation using a LiDar wind scanner

Zero Emission Lab (ZEL)

This lab contains the physical hardware for a future ready engine room. Typical power components available in the lab are a hydrogen fuels cell, super-capacitors, electric machines, and an advanced internal combustion engine generator set. These can be extended using emulated components where v-ZEL models are used to emulate their behaviour by using generic power components. Additionally, the ZEL includes supporting components like the storage for energy carriers, electrical infrastructure in DC and AC, advanced automation and control systems, and integrated cooling. Besides propulsion, several auxiliary and payload consumers can be configured. All this engine room hardware connects to the hydrodynamics through a real propeller in our cavitation tunnel and an additional electric machine which is controlled by sophisticated hydrodynamic algorithms. These simulate the dynamical behaviour of the vessel including acceleration and deceleration, cavitation and ventilation, behaviour in waves and manoeuvring, etc.

The ZEL allows a developed design to be put through its paces in a realistic operational environment, albeit in a scaled manner, to test system performance and integration. It also serves as a demonstration tool where innovative PPE system designs can be experienced on lab-scale.

Coupling to other MARIN facilities

The involvement of the future crew in the design of the ship and its operation is a prerequisite for safe, effective and smart ships, offshore structures and their operations. With a coupling between the Seven Oceans Simulation centre (SOSc) and the v-ZEL or ZEL, the interaction between the user and the PPE system can be experienced and analysed allowing a validation of user requirements.

With a coupling between the model test basins and the v-ZEL or ZEL, the interactions between hydrodynamic behaviour and the PPE system can be validated on model scale.

5. Validation & troubleshooting

The Maritime Masterplan requires to demonstrate the reliability of simulation models and predictions using on-board measurements. MARIN serves the maritime industry with operational investigations and monitoring campaigns on board ships worldwide. Our measuring facility is SeaLab: the sea as a digital lab. SeaLab facilitates field labs in real operations at sea by measuring and observing the behavior of and the interaction between the ship, the environment and crew at sea. With these measurements we can validate the digital models (digital twins) of the PPE systems and improve them with our latest data science techniques. We use the models to provide an objective view into the effectiveness and reliability of emission-reducing technologies, provide insight and control to the crew to optimize the sailing with innovative PPEs, solve problems on board and realize improved new ship designs, thereby contributing to the Joint Maritime Digital Platform.

We developed a standardized method to validate the impact of emission reduction measures and technologies. We go through the following steps:

1. During the sea trial we determine the fuel efficiency, emissions (collaboration with TNO) and speed-power relationships in different load conditions.

Power measurements on board

Emission measurements during sea trials

For more information, please contact:

Christian Veldhuis
T + 31 625 30 79 15
E c.veldhuis@marin.nl

Thijs Hasselaar
T + 31 317 49 32 24
E t.hasselaar@marin.nl

2. We use this to validate the models for energy consumption and emissions.
3. We measure the operational profile of the ship over a number of weeks, by measuring the power of the largest consumers at high frequency, together with the speed over the ground and the loading conditions.
4. Using the validated models, we extrapolate the operational profile, supplemented with voyage simulations for a complete year to accurately determine energy consumption and total emissions over a year and we compare the well-to-wake emissions with a reference ship.

The step-by-step plan is identical for each ship, which ensures synergy in independently assessing the effectiveness and reliability of the new ships. The models and emission and power measurements are tailor-made for each case, because we validate various innovative designs and technologies.

6. Training & education

The machinery and bunker spaces of the future contain new technology that require education and training. A striking example is the introduction of modern electrotechnology and advanced control and automation. New fuels and energy carriers come with new properties and safety precautions.

In the recent years, MARIN has developed design, simulation and test skills for those new systems. With its Zero Emission Lab, MARIN even provides a physical laboratory, containing a fuel cell, hydrogen, a modern dual-fuel generator set, and sophisticated electrical power distribution. Crews, maintenance engineers and designers are able to experience there how these modern systems work, feel, sound and smell and what procedures they have to follow to operate them safely. When connected to the SOSc, the bridge operators and engine room crews can train together in a controlled simulation environment. MARIN's design, simulation and test capabilities offer excellent possibilities for education and training.