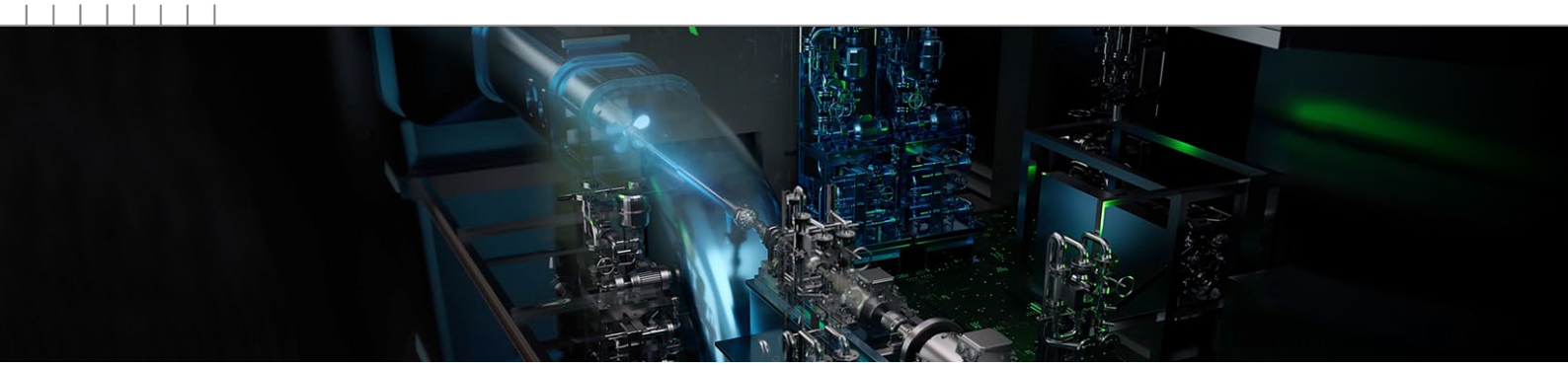


Zero Emission Services

Effective decision making on upcoming alternative propulsion, power and energy systems on ships

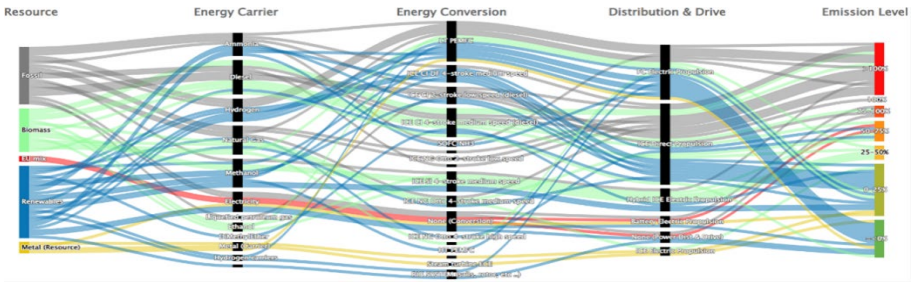
Design offices, shipping companies and shipyards are searching for cleaner ways to transport, but the variety of alternative energy solutions to choose from is wide and continuously developing. What emissions are produced during my operations? Which alternative energy and power technologies are available, feasible and affordable for my operations? Is wind propulsion applicable? How far can I reduce my energy needs? As an independent research institute MARIN monitors, explores and optimizes solutions to your needs and operations. Our Zero Emission Services assist you in decision making on upcoming alternative propulsion, power and energy systems (PPE) onboard of your ships. Additionally, MARIN can support the zero emission implementation strategy for your fleets and the energy infrastructure at regional level.

Services overview

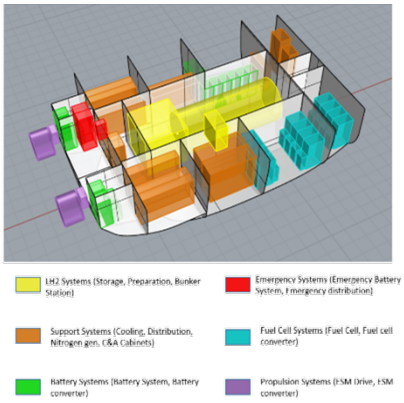
1. **Exploration**
   Operational analysis and technology selection.
2. **Scenario simulation**
   Evaluation of future or alternative designs in authentic operational conditions.
3. **Marine power system design**
   Developing a fit-for-purpose system design that meets your requirements.
4. **Simulation & testing**
   Risk mitigating when introducing low technology readiness level solutions.
5. **Trouble shooting**
   Comprehensive support to tackle challenges from a system integration perspective.
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 obvious 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. At this stage, we already start to create a functional overview of the total system that can be matched with the intended operations. This will form the basis of the propulsion, power and energy system integration. System layout and interfaces are based upon requirements from class, control & operability and technical dependencies of components.



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



System arrangements in a ship

Why choose MARIN?

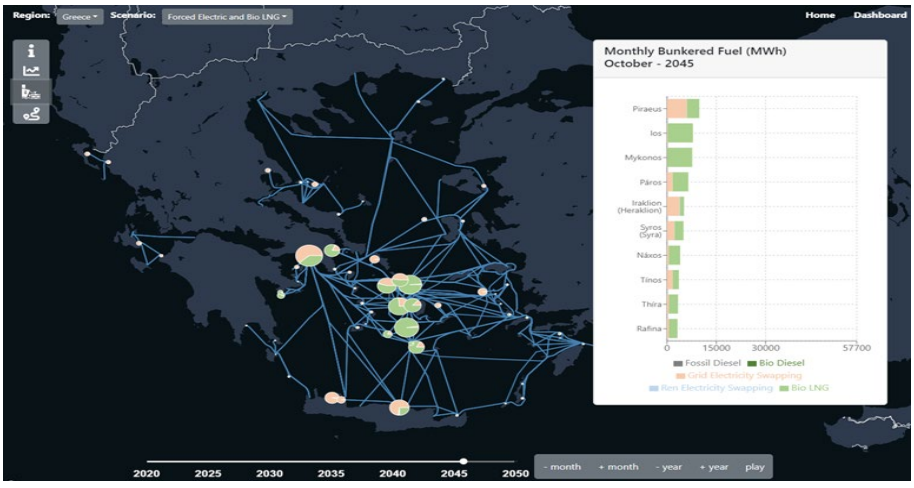
- Independent advice.
- Integrated PPE system and hydrodynamic expertise.
- International maritime network.
- State-of-the art test facilities.
- Multidisciplinary team enables holistic approach.

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 and alike are taken into account to provide solutions for the general layout.

2. Scenario simulation

Scenario simulations are a powerful method to evaluate future or alternative designs in authentic operational conditions, levered by hindcast environmental data. It gives access to a digital twin (from the ship and the operations) at concept stage. Ranging from individual ship and system performance to fleet and energy infrastructure requirements, such simulations facilitate the preparation and anticipation of forthcoming strategies and operations. Furthermore, they enable the evaluation of the viability of alternative energy sources, such as wind, along specific routes and trade.

The scenario simulation models, including dynamic techno-economic components, can allow policy makers, regional and national 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.



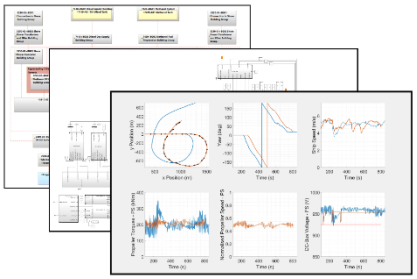
3. Marine power system design

Once the operations of a vessel are defined and the technology is chosen, it is up to the system design to make it happen. As an operator, you want the ship's systems to be able to deliver the operations requested by the crew. The system must be fit-for-purpose, reliable, and robust.

MARIN can create different 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.

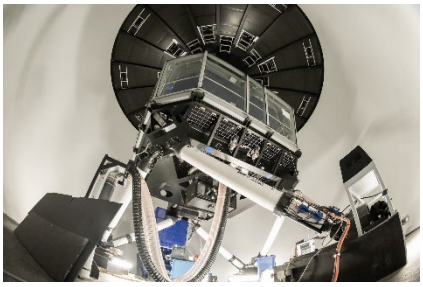
Our mission 'Better Ships, Blue Oceans'

Research institute MARIN is a provider of advanced expertise and independent research to the maritime industry. Using the newest test facilities and simulators and working together with an extensive innovation and research network we achieve our goal: the development of cleaner, safer and smarter ships and sustainable use of the sea.



Simulating the same mission with two different configurations to compare.

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.

4. Simulation & testing

The risks involved with building these innovative vessels can be reduced by doing early-stage verification of the conceptual design. These verification tests ensure that the specified requirements are being met even in the initial phases of design. Moreover, they can provide feedback on the design and refine design specifications. MARIN supports this process by employing simulations and scaled-physical setups across multiple facilities for the verification and validation of 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 MARIN's hydrodynamic models for coupled simulations where the performance of the design can be simulated and analysed in various conditions.

The v-ZEL can be used to model the developed designs and test that they meet the design requirements and can also be used to refine design specifications. Moreover, the v-ZEL models can be coupled to different MARIN facilities to perform coupled tests and studies.

Zero Emission Lab (ZEL)

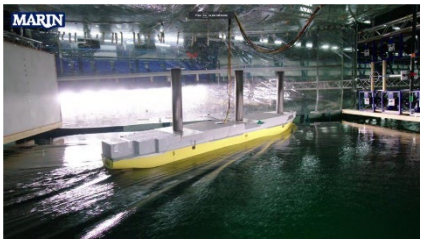
This lab contains the physical hardware for a future ready engine room. Typical power components available in the lab are a hydrogen fuels cell, super-capacitors, electric machines, and an advanced internal combustion engine generator set. These can be extended using emulated components where v-ZEL models 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.



Model test in our Seakeeping and Manoeuvring Basin.

Using on board trial and/or monitoring data to validate simulations and assess performance.

For more information and to discuss how to use these services for your projects, research or training, please contact:

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MARIN serves the maritime industry with operational investigations and monitoring campaigns on board ships worldwide. These can serve as input for the operational analyses and provide data for full-scale validation of developed PPE designs.

5. Troubleshooting

Future proof PPE systems involve intricate high-tech subsystems demanding top-tier integration across mechanical, electrical and automation & control boundaries. MARIN offers comprehensive support when problems arise. With our team of naval architects, mechanical, electrical, control & automation specialists as well as our on-board measuring and hydrodynamic experts, we specialise in a multi-disciplinary approach, tackling challenges from a system integration perspective. We address your queries and issues through measuring, modelling, virtual and physical testing, analysis, consultation and reporting and are able to demonstrate the proposed solution.

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.