SMART MARITIME

sfi = Centre for Research-based Innovation

The Research Council of Norway

NORWEGIAN CENTRE FOR IMPROVED ENERGY EFFICIENCY AND REDUCED HARMFUL EMISSIONS FROM SHIP

ANNUAL REPORT 2021

SMART MARITIME

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Cover picture: MV Balboa Photo: Klaveness AS

SUMMARY

Sail-assisted bulk carrier model in SINTEF Ocean’s towing tank , Photo: SINTEF Ocean

ABOUT SFI SMART MARITIME

SFI Smart Maritime is a centre for research-based innovation dedicated to improving energy efficiency and reducing harmful emissions from ships. With particular attention to the Norwegian Maritime Industry, our mission is to provide our partners with technologies, tools and capabilities for effective identification, assessment and verification of performance optimization solutions.

The research activity is conducted in collaboration between **SINTEF Ocean**, **NTNU** and the Centre's 21 partners representing the entire maritime value chain: **ABB**, **Bergen Engines**, **DNV**, **Jotun**, **Kongsberg Maritime**, **HAV Design**, **Norwegian Electric Systems**, **Siemens-Energy**, **VARD Design**, **Wärtsilä Moss**, the **Norwegian Shipowner association**, the **Norwegian Coastal Shipowners Association**, the **Norwegian Maritime Authority**, and 8 major Norwegian ship owners; **BW Gas**, **Grieg Star, Höegh Autoliners, Klaveness**, **Kristian Gerhard Jebsen Skipsrederi, Odfjell Tankers**, **Solvang and Wallenius Wilhelmsen.**

The strength of the Centre is our network and the constructive dialog between our research community and industry partners. Smart Maritime has positioned as an attractive meeting place and platform for cooperation within energy efficient and environment-friendly shipping.

Since its establishment in 2015, the Centre har worked with pushing the state-of-the-art in each research discipline, provided insight on potential emission reduction from ships, tested out novel technology solutions, developed prediction models for hydrodynamics and power systems simulation, simulation tools for performance evaluation and benchmarking of designs on a full ship system level.

There is no doubt about the Norwegian Maritime Cluster's dedication to reduce GHG emissions from shipping and achieve IMO Goals, as testifies the number of spin-off research and innovation activities from the SFI Smart Maritime collaboration.

HIGHLIGHTS 2021

Active collaboration, regular communication, perseverance and collective trust were the most important ingredients of the solid results delivered by SFI Smart Maritime in 2021.

Highlights from 2021:

- Smart Maritime Simulator Platform has reached a new milestone, with further integration of Hydrodynamics and ship models (WP2) and power systems simulation models (WP3), including: Gymir plugin for ShipX and main Gymir Platform Developments Wind-assisted propulsion and Virtual Captain.
- The Centre's research and industry partners have launched 6 associated projects: 3 competence projects, 1 innovation projects with support from the Research Council, 1 Green Platform, and 1 projects with support from EU H2020.
- Smart Maritime has been more present in the media and has disseminated regularly and actively from 10 Webinars. I addition, the teams has published 10 scientific articles, 6 conference articles, and 22 academic lectures.
- Smart Maritime actively contributed to international policy debate (IMO and EU).
- SFI Smart Maritime carried on with bi-annual network meetings, and finally gathered in person in Trondheim after a 1.5 year break due to Covid-restrictions.
- Smart Maritime has developed a worked on a Seamap for shipping decarbonization, based cross disciplinary work and competence development over the past 5 years, with the ambition to serve as reference document and guideline for the industry, regulatory bodies and academia.

VISION AND OBJECTIVES

Our vision is the greening of maritime transport, and by that enabling the Norwegian maritime cluster to be world leading in environmentally friendly shipping by 2025.

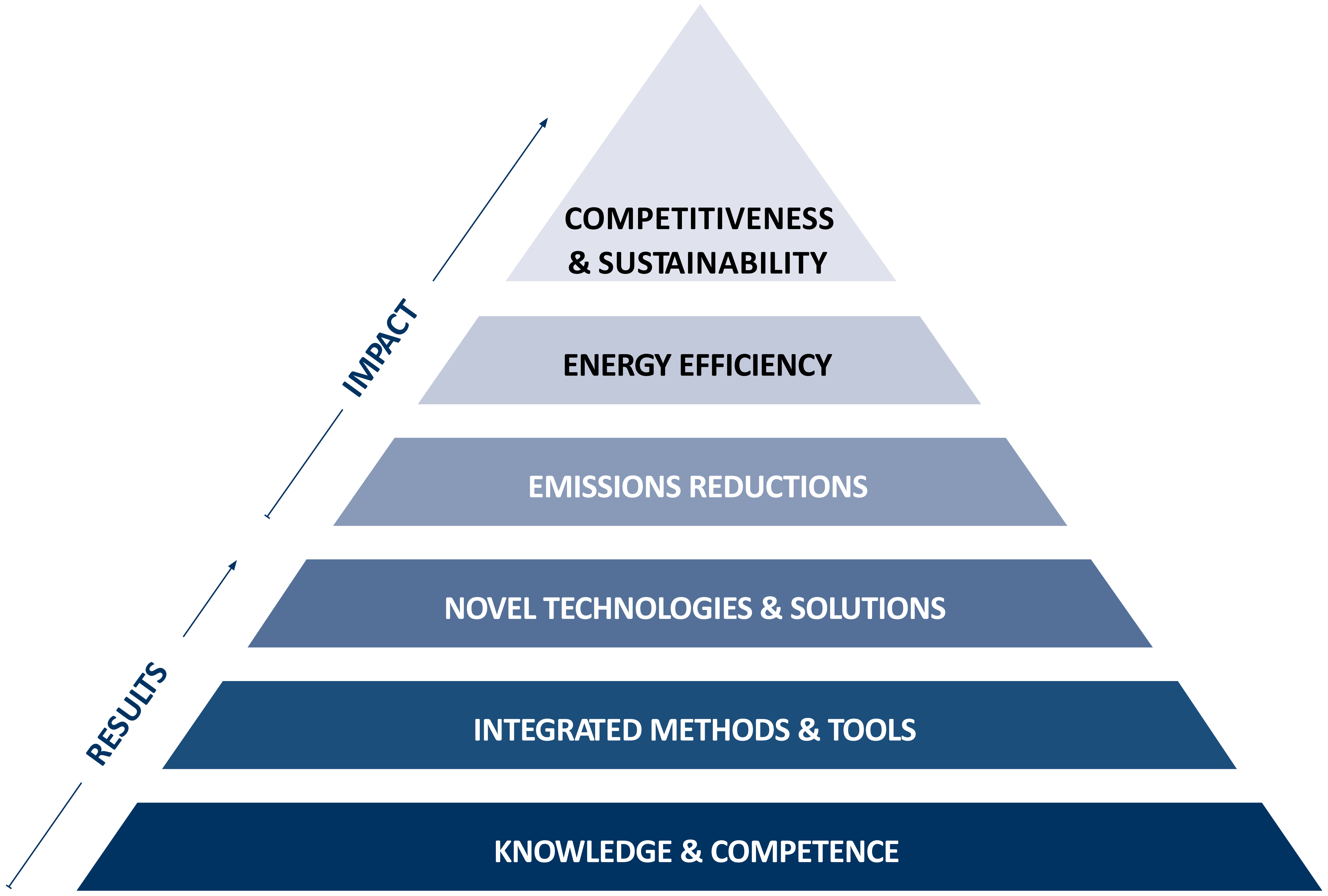
Our mission is to provide the Norwegian maritime sector with knowledge, methods and tools for effective identification and assessment of solutions and technologies.

Bow Summer., Odfjell. Photo credit: Christian Dahll

The three expected impact of SFI Smart Maritime are *increased competitiveness of the Norwegian maritime industry*, *increased energy efficiency in shipping* and *reduced harmful emissions from ships*. This will be achieved through three types of results from the Centre: *knowledge and competence, integrated methods and tools* and *novel technologies and solutions.*

The expected outcomes include:

1. More efficient and accurate early stage assessment of new ship designs.
2. Introduce new validation methods, such as correlating data from real-life conditions with simulation- and experimental data.
3. More accurate predictions of fuel consumption and emissions from alternative hull, propulsion and power system configurations and operational profiles.
4. Improved optimization of ship performance vs. cost profile at various operational profiles and sea states.
5. Improved methods and tools for cost and fuel optimization – on unit level and on fleet level.



SMART MARITIME

INNOVATION

SFI Smart Maritime stimulates innovation through active involvment of industry partners in research activity:

- Engage our partners: identify their innovation process, challenges, potential.
- Involve our partners in R&D projects.
- Support industry partners in establishing innovation projects.
- Facilitate dialog and joint industry collaboration.
- Multidisciplinary workshops (network meetings).
- Lab support to test, verify and implement new technologies and solutions.
- Scientific input (papers, conference presentations, PhD projects, webinars).

Photos: / Illustrations: Havila Capella, Kystruden; Solvang's Clipper EOS, Wärtsilä Moss; Zero Coaster, VARD.

Contribution to FN Sustainable development goals

Efforts to reducing harmful and GHG emissions from ships, and ensure adequate regulations are development at international level.

SFI contributes to promoting sustainable industrialisation and innovation in the maritime, transport and energy sectors.

Contribution to safe operations and reduction of impact on marine environment.

Strengthen cooperation between public, private and research communities towards green shipping.

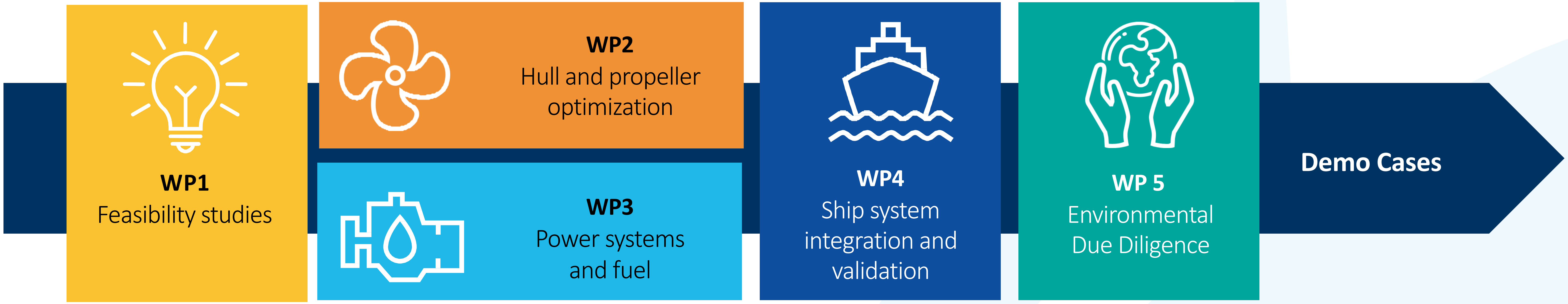
SMART MARITIME

RESEARCH STRATEGY

STAR HARMONIA, Photo: Grieg Star

SMART MARITIME

WORK PACKAGES / RESEARCH AREAS



The research strategy relies on five interconnected research areas (Work Packages, WP). WP1 serves as screening work package for identifying and assessing potential technologies and designs. WP2 and WP3 respectively develop models and tools for assessment of technologies and designs. These models are further integrated into a ship system simulation platform, enabling the virtual design and optimization of a ship by help of numerical simulation model (WP4). This holistic system-centred ship design method uses a modular simulation and analysis framework for accurate performance assessment for ship and ship systems under realistic full-scale operation-al conditions. Finally, hybrid LCA methods are used in combination with profit and opportunity cost models to verify environmental and economic benefits (WP5).

WP1: Feasibility studies

Objective

Develop assessment model and method for effective investigation of alternative designs at an early stage. Test and validate through series of feasibility studies.

Research need and background

There is a lack of assessment methods and tools to enable comparison of alternative designs at the feasibility stage of the design process. Current studies and state-of-the-art design practice regarding concept, speed and capability tends to be based on marginal improvements of existing designs and solutions instead of challenging todays practice. One explanation is that most vessels for the merchant fleet have been built by shipyards according to quite standardized designs to minimize building cost while more specialized vessels generally have been improvements and amendments of existing designs.

Research tasks

Feasibility studies method & tool	GHG emissions reduction potential	Feasibility studies (cases)

WP2: Hull and propeller optimization

Objective

Identify potential for energy savings by means of hull and propulsion optimization, and introduce novel approaches to improve efficiency.

Research need and background

Currently, most merchant vessels are designed for optimum performance in calm water. There is an increasing understanding of the importance of including sea- keeping and manoeuvring-related aspects, but it has not found its way into practical design work yet. The tools currently used in design of offshore vessels have a potential for being applied in the design of merchant vessels. Despite this, design for a balanced set of operational conditions is still at the development stage even for offshore vessels. Hydrodynamic performance and propulsion systems, with emphasis on operation in waves, are specially addressed in WP2.

Research tasks

Calm water performance	Energy-saving devices	Novel propulsion systems	Operations in waves
Friction-reduction Novel overall-design (main dim.)	Effect of waves and off-design operation Evaluation of in-service performance	Wave-foil propulsion Optimization of sail-assisted merchant vessels	Speed loss Interaction with engine Operational profile Above-water geom.

WP3: Power systems and fuel

Objective

Improve current designs and explore novel technologies, systems and solutions for energy efficient low- and zero-emission power and propulsion systems. Improve autonomy and reliability of power system.

Research need and background

Reducing fuel consumption and harmful emissions for different vessel types at different operation profiles and modes to comply with current and future IMO legislations is currently the main challenge for maritime transport. Traditionally the power solutions for seagoing vessels have been designed to ensure that the vessels have the required power to be seaworthy in rough weather and to achieve its desired design speed utilizing 85 % of its installed power resources on calm water.

Research tasks

Power system optimization	Combustion engine process	Waste Heat Recovery	Hybrid power systems
Modeling and simulation of power components and systems Fuel consumption estimation Steady-state and transient operating modes Alternative and emerging propulsion concepts	Advanced combustion control Novel injection strategies Alternative fuels (LNG, biofuels, alcohols, hydrogen, ammonia) Exhaust gas cleaning	Energy recovery Alternative power cycles and power system arrangement Thermoelectric power generation Heat management	Energy storage systems (batteries) Hybrid power generation, converters and distribution (AC and DC) Shore-to-ship battery charging

WP4: Ship System Integration and Validation

Objective

Enable performance evaluation and benchmarking of designs on a ship system level by combining monitoring data and simulations in a framework where component and subsystem models can be combined in a full ship system. Validate the results through laboratory and full-scale tests.

Research need and background

The research activity in WP 4 will consider how to technically integrate the components and sub-system developed in WP 2 and 3 in one simulation framework where the full complexity of the future operational profile of the vessels is considered. This holistic system-centered ship design process will enable accurate performance assessment of full ship systems in realistic operational conditions, and assessment of effects of energy efficiency improving measures. In addition, continuous optimization of these systems can be achieved by the combination of real-time monitoring and appropriate system simulations.

Research tasks

Simulation framework	Virtual ship design testing	Simulator validation
Open framework connecting physical domains and modeling regimes Support of Discrete-event simulation to enable long simulation durations Model library database	Methods for assessing system performance against operational profiles KPI's for benchmarking of alternative designs Ship configuration and scenario management	Methodologies for collection, filtering and use of full-scale measurement data Validate and calibate the ship system simulations

WP5: Environmental Due Diligence

Objective

Systematically assess the environmental and economic performance parameters of different ship and shipping system designs.

Research need and background:

Both international trade and maritime transport have increased at tremendous rates in the past decades. Maritime transport is estimated to contribute 3.3 % to the global anthropogenic CO_2 emissions, and the environmental consequences of increased trade are an important factor in the current climate debate. There is a need for detailed harmonized environmental and economic assessment of current and novel ship designs. In addition, there is a lack of suitable approaches for integration of such assessments with ship design and engineering workflows. WP5 will integrate state of the art methods for detailed climatic, environmental and economic analyses, primarily through the development and analysis of a fleetwide emission model - MariTEAM.

Research tasks

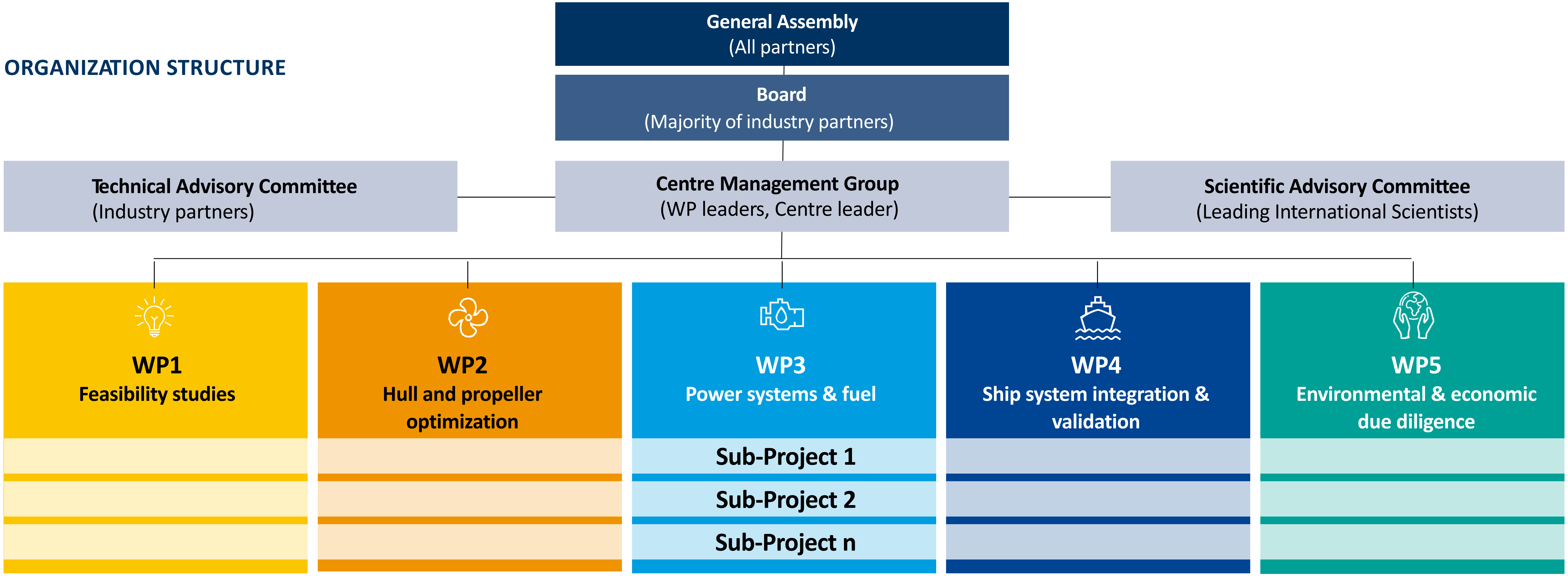
MariTEAM	Spatial-temporal impact	Life cycle assessment	Scenario analysis
Software development Theory-guided big data analytics	Environmental impacts located in time and space	Assess environmental impacts throughout supply chain and service lifetime	Fleet and route development Comparison of technology options

SMART MARITIME

ORGANIZATION


Sea of Heaven, Grieg Star. Photo: Reanmer Baldoza

ORGANIZATION STRUCTURE



SINTEF Ocean hosts the Centre in collaboration with research partner NTNU. The industry partners form the Technical Advisory Committee, covering major parts of the maritime value chain.

The Centre's long-term research activity is organised in five **Work Packages** (WP).

Board: operative decision-making body (7 members)

General assembly: representant from each Consortium partner.

Scientific Advisory Committee (SAC): audit and advice on research progress.

Technical Advisory Committee (TAC): advise the Centre Management on prioritization of R&D activities. Gathered twice a year at the biannual Network Meetings.

Board Members	Affiliation
Jan Øivind Svardal *(Chairman)*	Grieg Star
Jan Fredrik Hansen	ABB
Sverre Torben	Kongsberg Maritime
Ove Bjørneseth	VARD Design
Lars Dessen	Wallenius Wilhelmsen
Beate Kvamstad-Lervold	SINTEF Ocean
Bjørn Egil Asbjørnslett	NTNU
Sigurd Falch (observer)	Norwegian Research Council


Jan Øivind Svardal


Lars Dessen


Sverre Torben


Jan Fredrik Hansen


Beate Kvamstad-Lervold


Ove Bjørneseth


Bjørn Egil Asbjørnslett

Scientific Advisory Committee	Affiliation	Focus area
Professor Karin Andersson	Chalmers University of Technology, Gothenburg	WP 5
Professor Rickard Benzow	Chalmers University of Technology, Gothenburg	WP 2
Professor Harilaos Psaraftis	DTU – Technical University of Denmark	WP 4
Professor Osman Turan	Strathclyde University	WP 1
Professor Friedrich Wirz	TU Hamburg	WP 3

Centre Management Group	Affiliation	Role and responsibility
Trond Johnsen	SINTEF Ocean	Centre Director
Anders Valland	SINTEF Ocean	Deputy Director
Elizabeth Lindstad	SINTEF Ocean	WP1 Feasibility studies
Sverre Steen Sverre Anders Alterskjær	NTNU SINTEF Ocean	WP2 Hull and Propeller
Mehdi Zadeh	NTNU	WP3 Power systems and Fuel
Jon Dæhlen	SINTEF Ocean	WP4 Ship system Integration
Anders Strømman Helene Muri	NTNU	WP5 Environment and economy

Centre administration

Jan Andre Almåsbakk	SINTEF Ocean	Controller
Agathe Rialland	SINTEF Ocean	Administrative Coordinator


Trond Johnsen

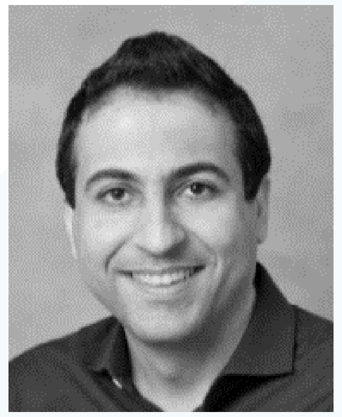

Anders Valland


Elizabeth Lindstad


Stein Ove Erikstad


Sverre Steen


S. Anders Alterskjær


Mehdi Zadeh


Jon Dæhlen


Anders Strømman


Helene Muri


Agathe Rialland


Jan Andre Almåsbakk

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CENTRE PARTNERS

The Centre collaborates closely with global industry players, national and international research communities and maritime networks. These partners are involved in scientific activity through business cases and subproject activity across the WPs.

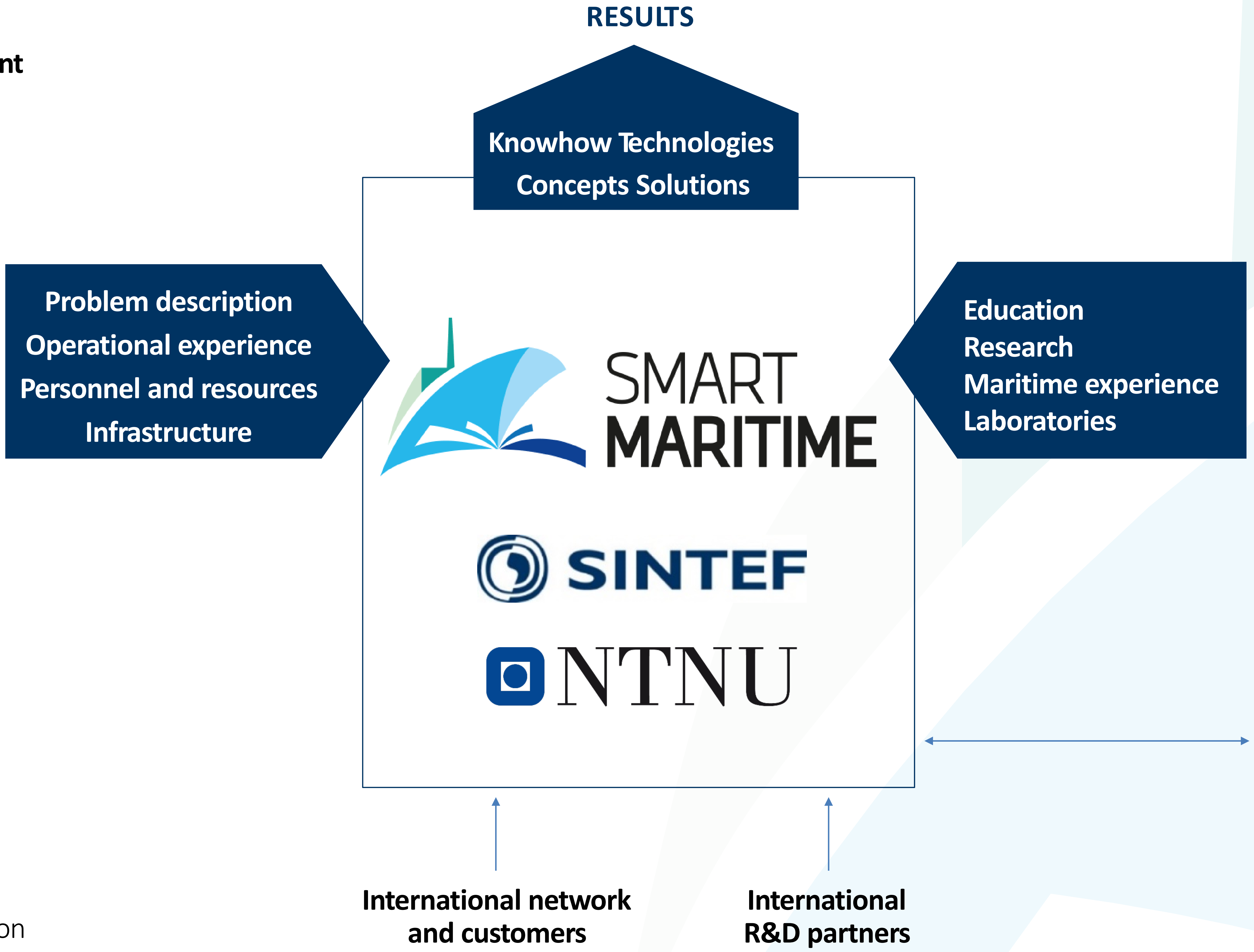
Coastal Bulker from associated project ZeroCoaster - Illustration: VARD

INDUSTRY PARTNERS

Design, shipbuilding & equipment
ABB
Bergen Engines
HAV Design
Jotun
Kongsberg Maritime
Norwegian Electric Systems
Siemens Energy
Vard Design
Wärtsilä Moss

Ship operators
BW Group
Grieg Star
KG Jebsen Skipsrederi
Höegh Autoliners
Odfjell
Solvang
Klaveness
Wallenius Wilhelmsen

Other partners
DNV
Norwegian Shipowners' Association
Norwegian Maritime Directorate
Kystrederiene



RESEARCH PARTNERS

SINTEF Ocean (host)

NTNU
Dept. for Maritime Technology
Industrial Ecology Programme

NTNU – Ålesund
Faculty of Maritime Technology and Operations

OCEAN SPACE CENTRE

SFI Scope aligned with Ocean Space Centre strategy.

RESSEARCH & INTEREST ORGANISATIONS

SINTEF Ocean (Host institution)

Department of Marine Technology; Industrial Ecology Programme;
Department of Ocean Operations and Civil Engineering (Ålesund)

DNV AS
world's largest ship and offshore classification society and a leading technical advisor to the maritime, energy and oil & gas industries.

Kystrederiene
The Coastal Shipowners Association works for promoting sea transport and marine services with focus on innovation and environmental-friendly solutions.

Norges Rederiforbund
Norwegian Shipowners' Association is a non-government organization serving more than 160 companies.

Sjøfartsdirektoratet
The Norwegian Maritime Authority has jurisdiction over ships registered in Norway and foreign ships arriving Norwegian ports.

SMART MARITIME

SHIP OWNERS

Grieg Star AS

Open Hatch general cargo, conventional Bulk / appr. 40 vessels. All vessels are a part of the G2 Ocean pool, a joint venture between Gearbulk and Grieg Maritime Group.

Wallenius Wilhelmsen ASA

RoRo / 125 vessels

Global supplier of RoRo shipping and vehicle logistics, controlling 125 vessels, servicing 15 trade routes worldwide. Wallenius Wilhelmsen Ocean operates an fleet of 50 RoRo vessels

Höegh Autoliners AS

PCTC / 45 vessels

Global supplier of transportation and logistics services for the RoRo segment, operating a fleet of owned and long-term charter PCTCs with capacity ranging from 2 300 to 8 500 ceu

BW Group

LNG, LPG, Product tankers, Dry bulk, Chemicals, FPSOs / 370 vessels.

BW Group is one of the world's leading maritime groups in the tanker, gas and offshore segments

Torvald Klaveness

Dry bulk, Container / 23 vessels

Operating in the container and bulk segment, Klaveness owns and operates a fleet of 17 combination carriers from 200 to 562 DWT, and 6 Container vessels from 500 to 740 TEU. Klaveness Chartering has a fleet of 140 vessels under management.

Odfjell

Chemical tanker / 120 vessels

World leaders in the global market for seaborne transportation and storage of chemicals and other specialty bulk liquids. The fleet consists of five main categories: Supersegregators with multiple segregations, large stainless steel chemical tankers, medium stainless steel chemical tankers, coated tonnage and regional fleets in Asia and South America.

Solvang ASA

LPG, petrochemical gases / 27 vessels.

One of the world's leading transporters of LPG and petrochemical gases. The fleet consist of 27 vessels – semi-refrigerated/ethylene carriers, LPG ships and VLGC (gas carriers).

KRISTIAN GERHARD JEBSEN SKIPSREDERI

PART OF THE KRISTIAN GERHARD JEBSEN GROUP

OSM MARITIME

Kristian Gerhard Jebsen Skipsrederi AS

Tanker, dry cargo, cement /50 vessels

Integrated shipping company involved in operation of tankers, dry cargo and specialized cement vessels. KGJS owned fleet: 13 Suezmax and LR 2 tankers and 2 OBOs in the SKS pool, 7 pneumatic cement carriers and Kamsarmax bulk carriers in the BTG pool

SHIP DESIGN & SHIP BUILDING

HAV Design

HAV Design AS (previously Havyard Design & Solutions AS) delivers safe, energy-efficient and environmentally friendly ship designs. HAV Design is part of the HAV Group (founded feb. 2021), an international provider of technology and services for maritime and marine industries, with special expertise in digitalisation, energy efficiency and zero-emission solutions in the marine and maritime industry.

Kongsberg Maritime

(replacing former SFI partner Rolls-Royce Marine, fully integrated part of Kongsberg Maritime since April 2019) specialises in the development and delivery of integrated vessel concepts for traditional merchant vessels, ROPAX, fishing vessels, offshore, research vessels and offshore installations.

Vard Design AS

Major global designers and shipbuilders of specialized vessels. VARD operates seven shipyards as well as subsidiary companies in the areas of design, electro, piping, accommodation and handling systems.

EQUIPMENT AND SYSTEM SUPPLIERS

ABB AS
Leading manufacturer of electric power and propulsion systems for ships. The product range also includes advisory systems for monitoring operational parameters.

Bergen Engines AS
A subsidiary of Rolls-Royce Power Systems within the Land & Sea Division of Rolls-Royce. Our medium speed gas and liquid fuel engines are supplied for a broad range of power generation applications.

Jotun AS
World's leading provider of paint systems and marine coatings to ship-owners and managers active in the newbuilding and dry-dock and maintenance markets.

Norwegian Electric Systems AS
Norwegian Electric Systems delivers smart control systems and energy designs that result in safe, efficient and environmentally friendly ships,. HAV Design is part of the HAV Group (founded feb. 2021)

SIEMENS AS
Siemens is among the world's leading suppliers of diesel-electric propulsion systems.

Wärtsilä Moss AS
Manufactures advanced inert gas and nitrogen solutions for marine and offshore oil and gas applications. Wärtsilä Norway delivers solutions for ship machinery, propulsion, automation, ship design, automation systems and liquid cargo solutions.

RESEARCH FACILITIES

The SFI makes use of own research facilities (SINTEF OCEAN and NTNU) as well as on-site laboratories from its industry partners.

SINTEF Ocean / NTNU

- Energy and machinery laboratory
- Hybrid power laboratory
- Fuel cell and hydrogen laboratory
- Towing tank
- Ocean basin
- Cavitation tunnel
- Circulating water tunnel
- Wave flume
- Marine Cybernetics Laboratory
- High Performance Computing: NTNU supercomputer Betzy, SINTEF cluster Unity2
- inhouse Softwares:
    - industry-standard ShipX workbench
    - Gymir software, for simulation of ships, including hydrodynamic, propulsor and machinery models based on agent-based discrete-event simulation in historic oceanographic data.

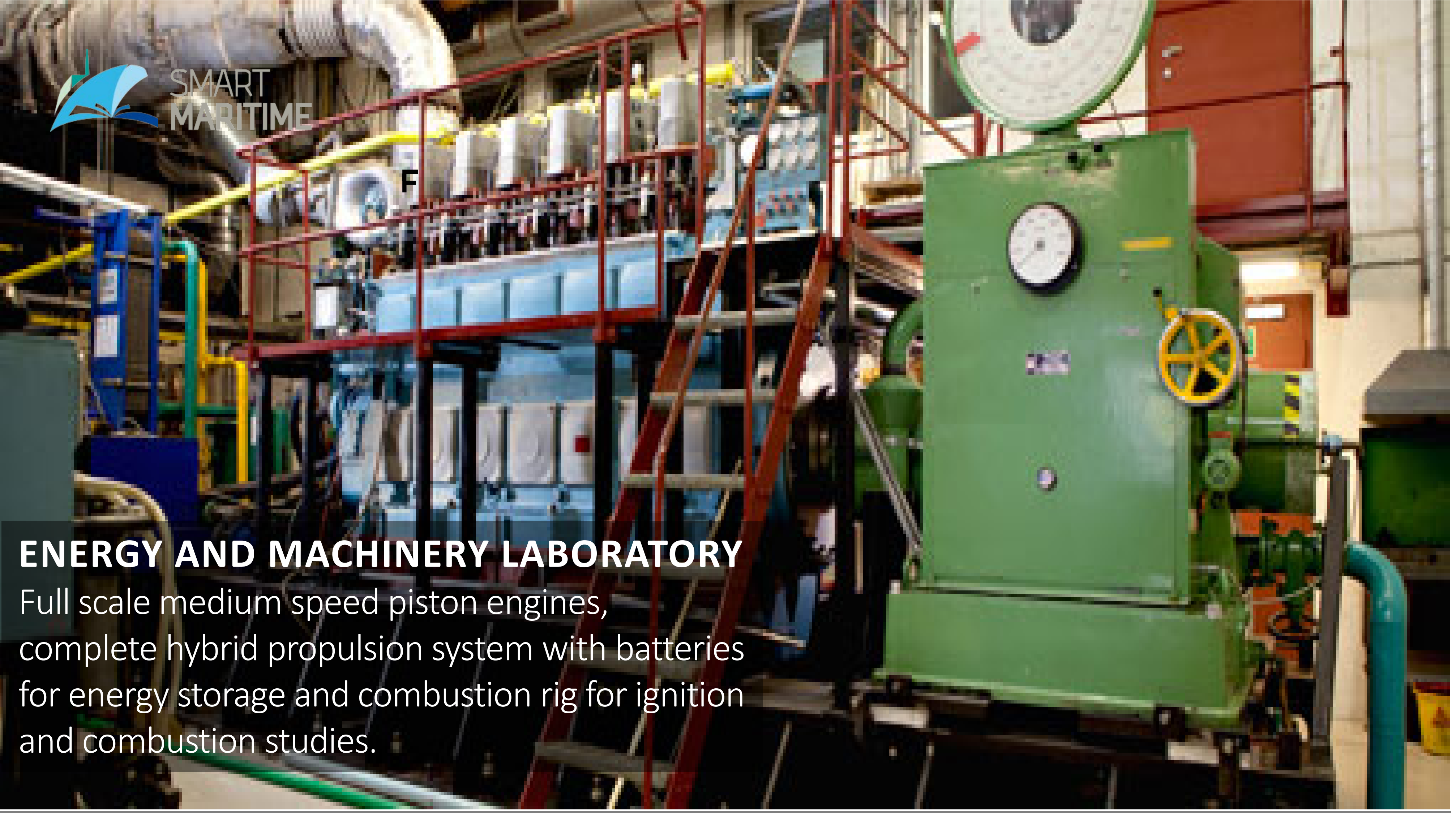
Industry partners' own laboratories

- Exhaust gas cleaning laboratory (Wärtsilä Moss)
- Power system laboratory (Norwegian Electric Systems)
- Laboratory for gas engine development, equipped with complete exhaust gas emission analysis (Bergen Engines)
- Clipper Harald, LPG tanker equipped with EGR, owner Solvang
- Simulation Centre (Kongsberg Maritime)

Open Simulation Platform (OSP)

open-source industry initiative for co-simulation of maritime equipment, systems and entire ships, co-developed by SINTEF, NTNU and DNV.

https://opensimulationplatform.com/



ENERGY AND MACHINERY LABORATORY

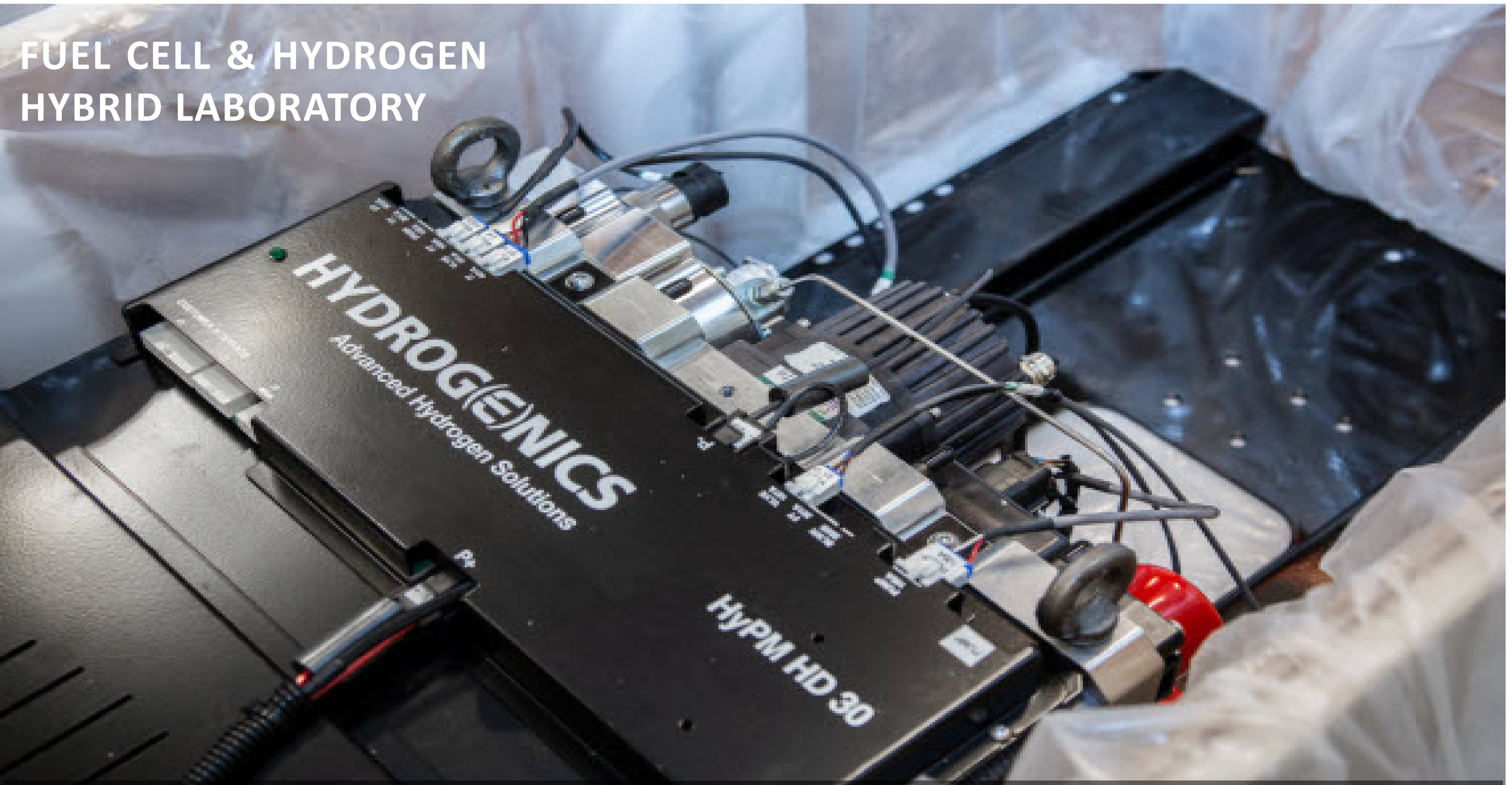
Full scale medium speed piston engines, complete hybrid propulsion system with batteries for energy storage and combustion rig for ignition and combustion studies.

Energy and Machinery Laboratory. Photo: NTNU/Sintef Ocean

COMBUSTION RIG

Combustion rig for ignition and combustion studies.

Energy and Machinery Laboratory. Photo: NTNU/Sintef Ocean



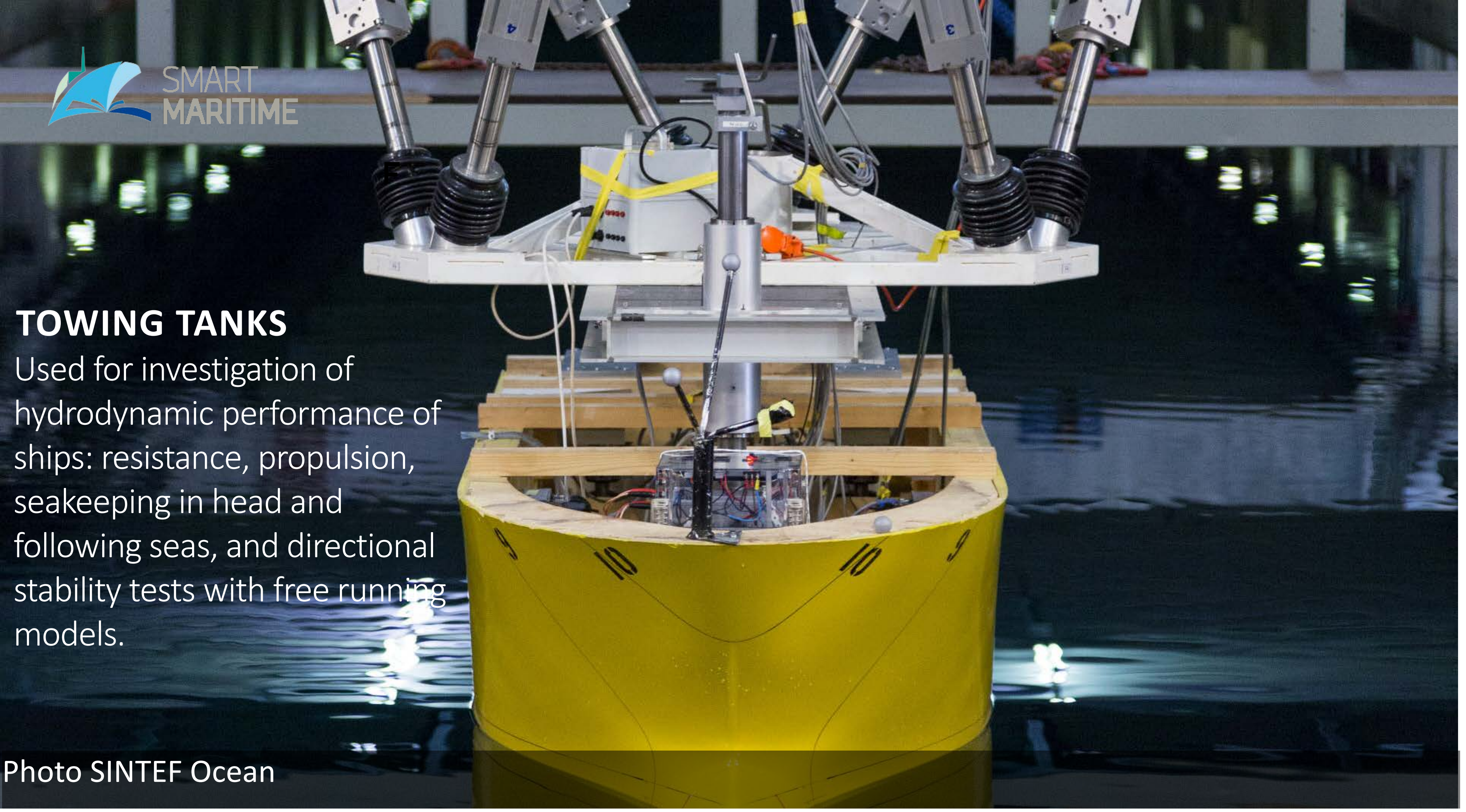
FUEL CELL & HYDROGEN HYBRID LABORATORY

Energy and Machinery Laboratory.

HYBRID POWER LABORATORY

Power and simulation lab for educational and research purposes. It enables the testing of novel marine power plants.

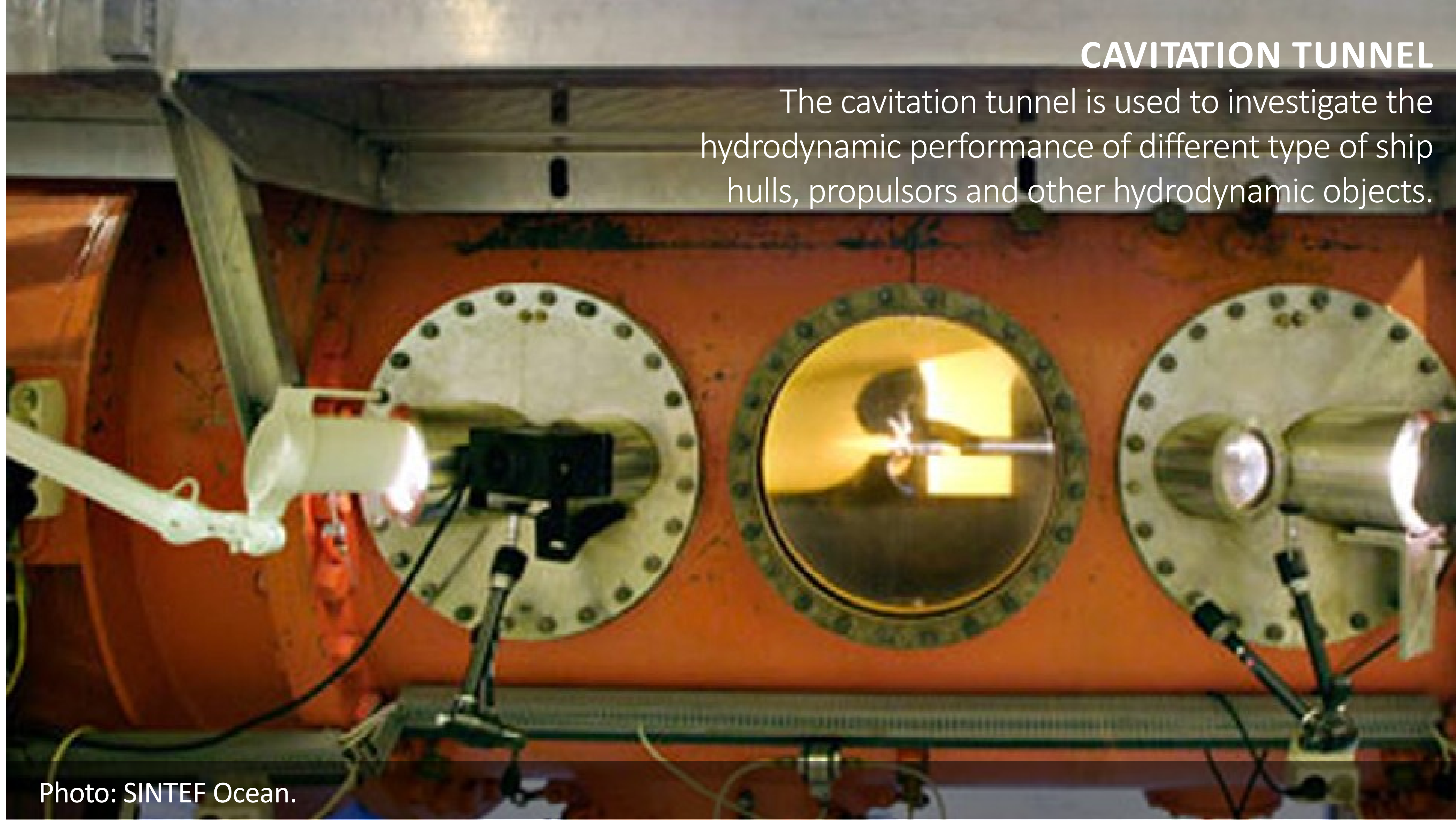
Hybrid Power Laboratory. Photo: NTNU/SINTEF Ocean



TOWING TANKS

Used for investigation of hydrodynamic performance of ships: resistance, propulsion, seakeeping in head and following seas, and directional stability tests with free running models.

Photo SINTEF Ocean



CAVITATION TUNNEL

The cavitation tunnel is used to investigate the hydrodynamic performance of different type of ship hulls, propulsors and other hydrodynamic objects.

Photo: SINTEF Ocean.

OCEAN BASIN

Used for basic as well as applied research on seakeeping and maneovering of ships, marine structures and operations. A total environmental simulation including wind, waves and current offers a unique possibility for testing of models in realistic conditions. Depth 10 m / Water surface 50 x 80 m

Photo SINEF Ocean/NTNU.

CIRCULATING WATER TUNNEL

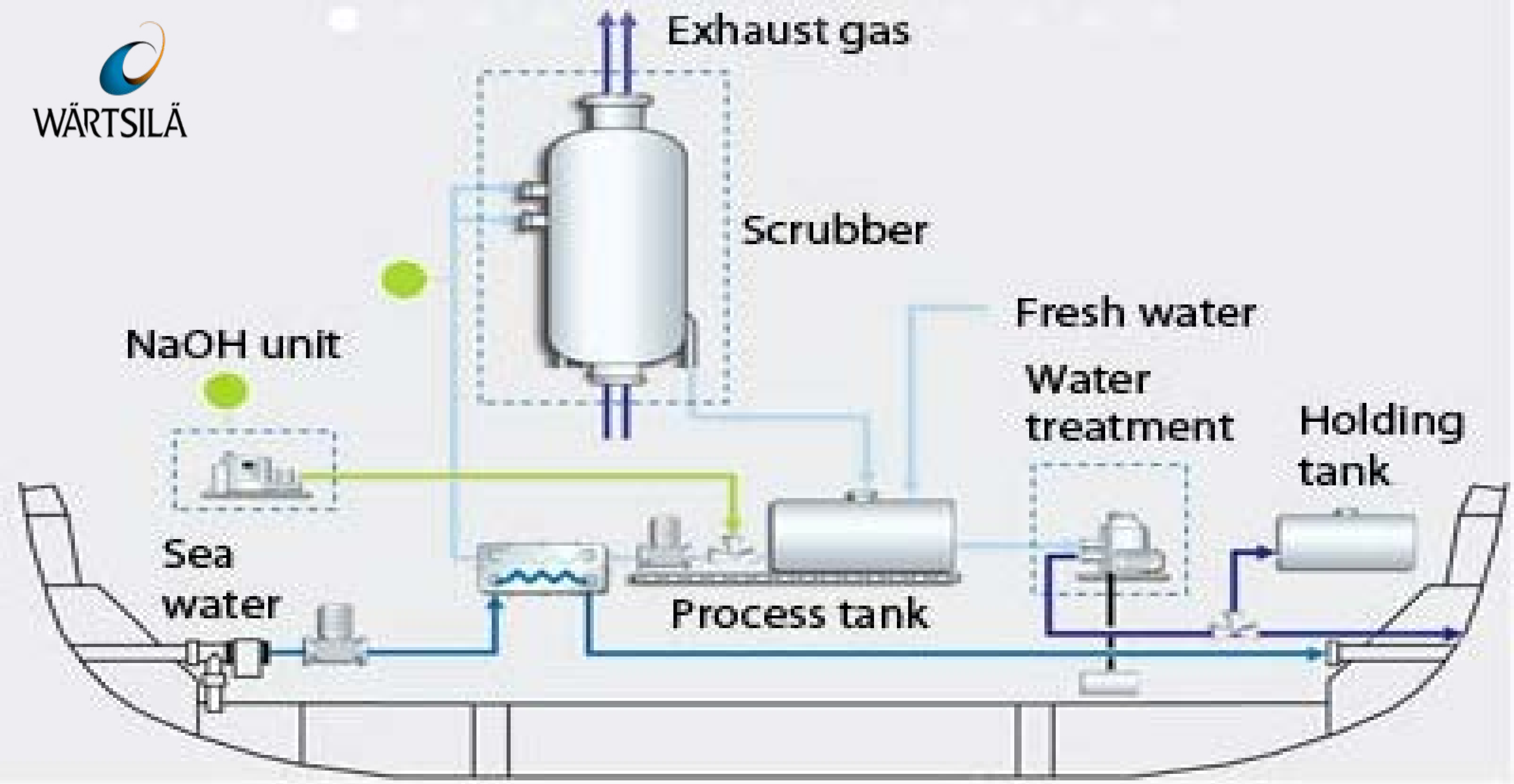
Test facility dedicated to optical measurement techniques and flow visualization.

Photo: SINTEF Ocean.

BERGEN ENGINES LABORATORY

Bergen Engines Laboratory for Gas engine development operating on LNG and equipped with complete exhaust gas emission analysis including PM (Particulate Matter).

Laboratory for gas engine development (Rolls-Royce Bergen Engines)



Exhaust gas cleaning laboratory (Wärtsilä Moss)

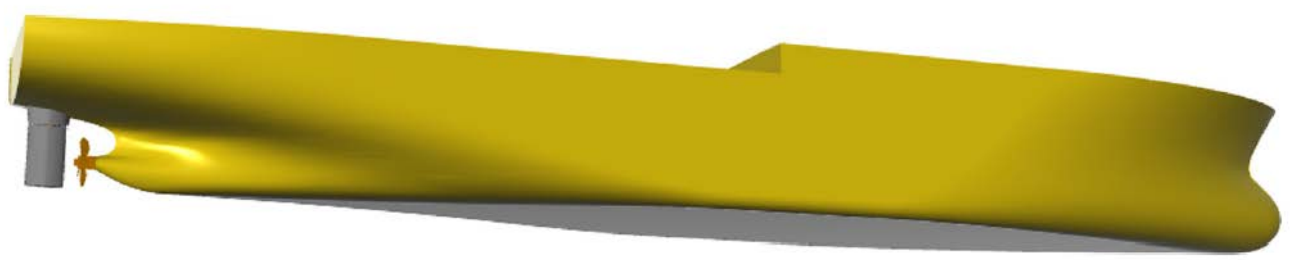
LPG tanker operating at coast of Norway on HFO equipped with Exhaust Gas Scrubber with open loop and wash water cleaning system. EGR (Exhaust Gas Recirculation system) for reduction of NOx emissions.

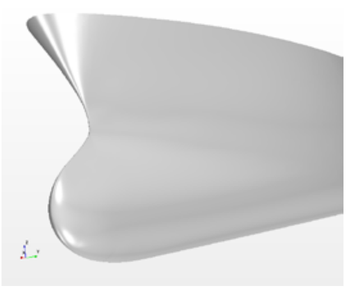
Clipper Harald. Photo: Solvang.

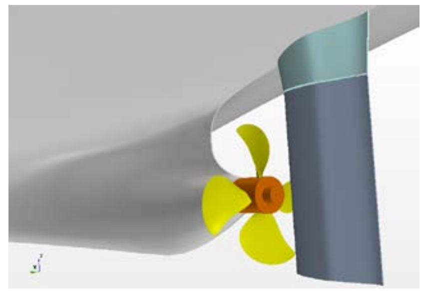
POWER SYSTEM LABORATORY - NORWEGIAN ELECTRIC SYSTEMS

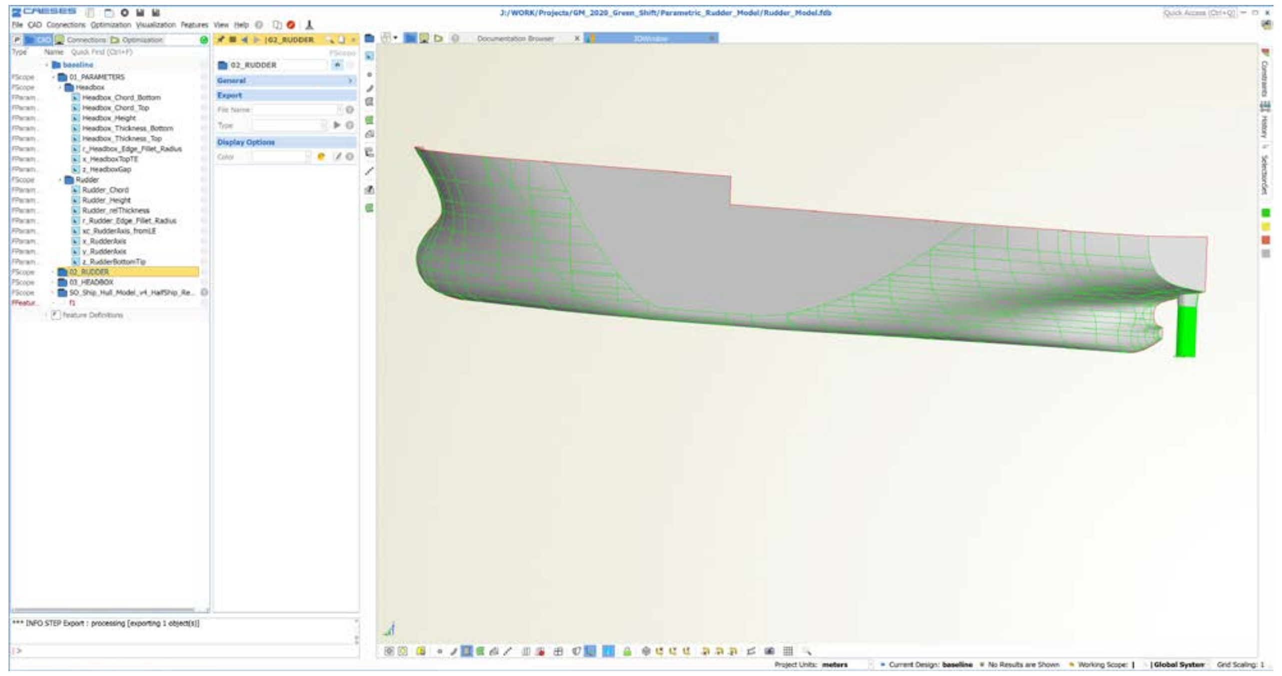
Photo: Norwegian Electric Systems

SINTEF Ocean bulk carrier (SOBC-1)





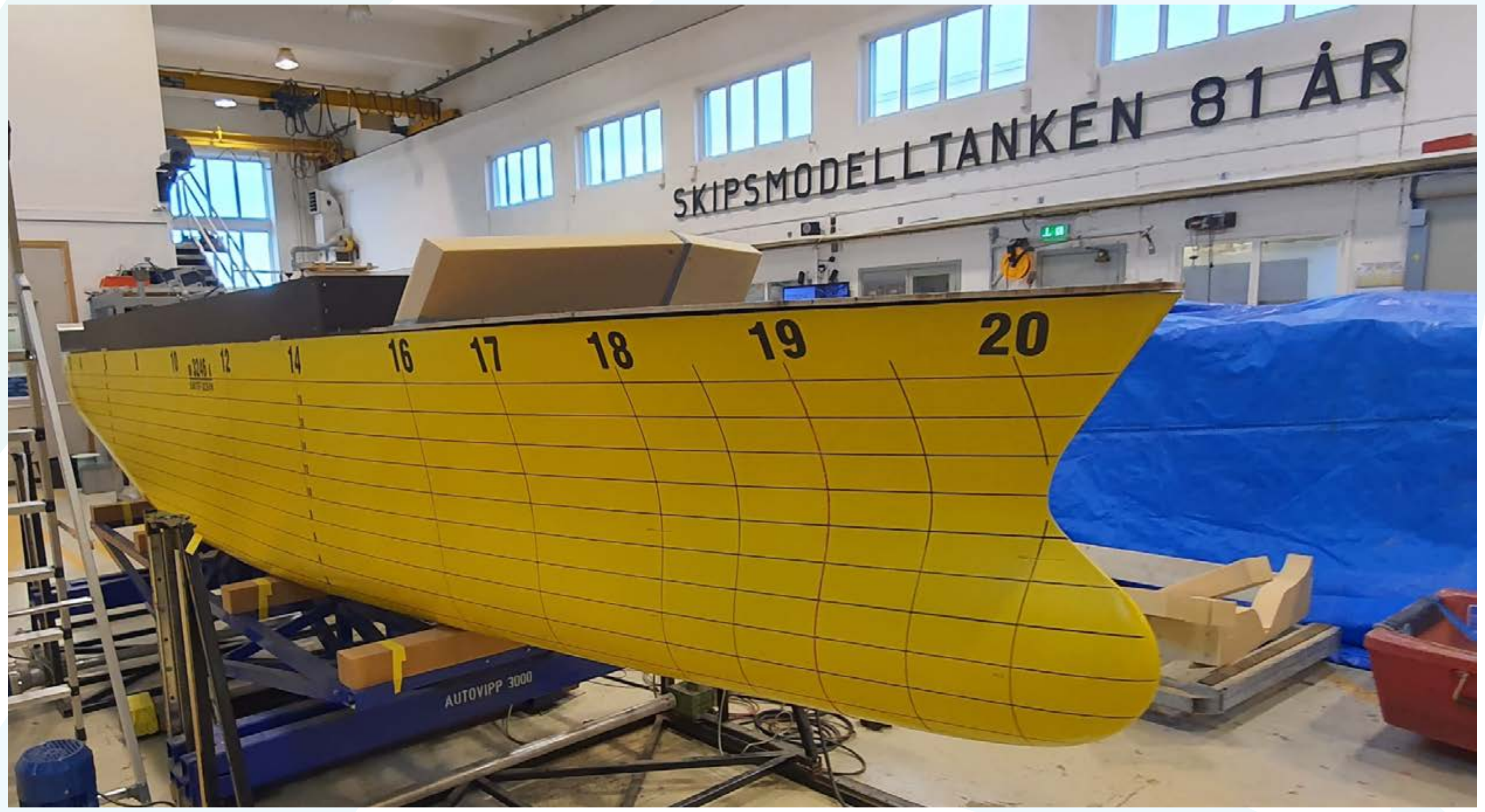




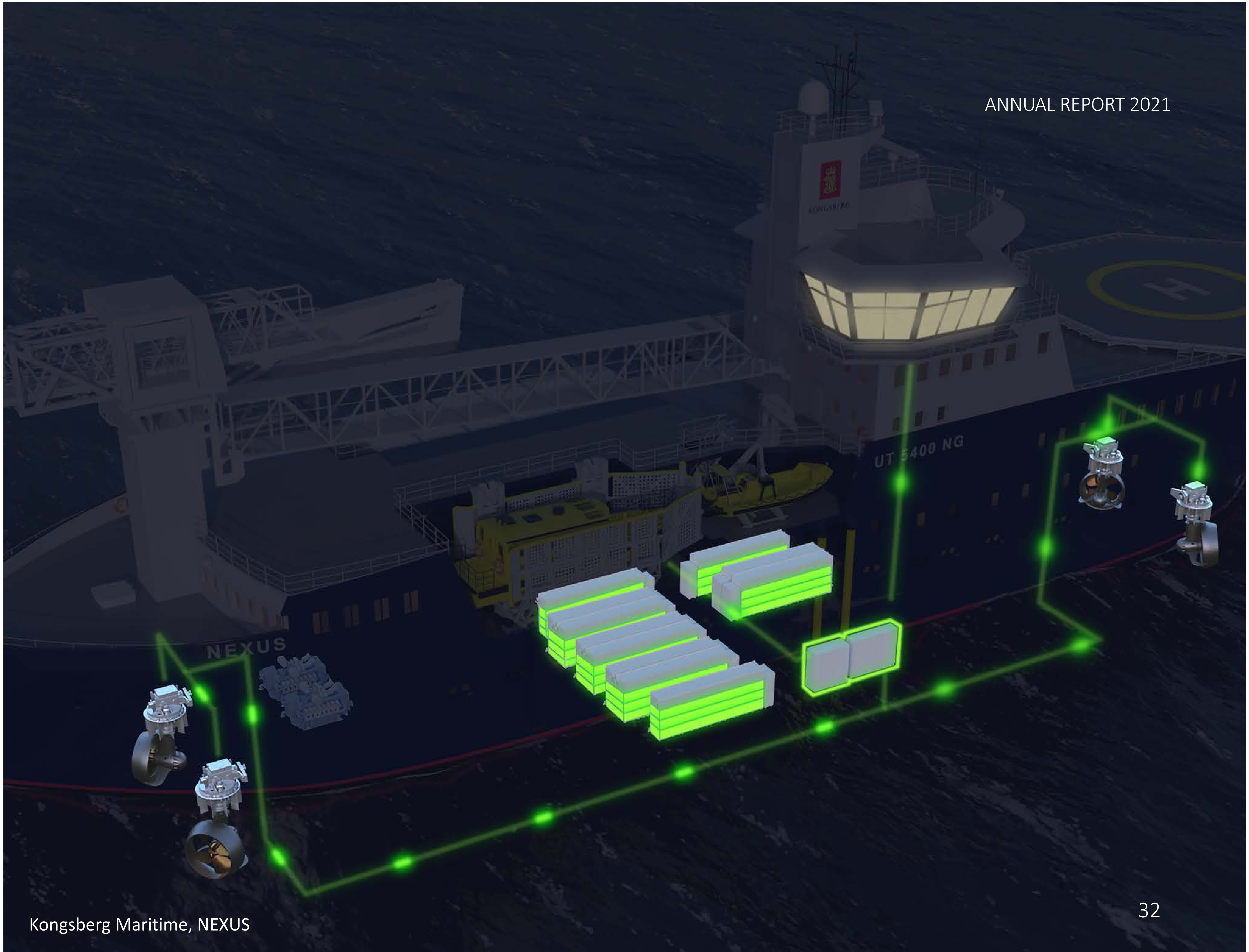
The SINTEF Ocean Bulk Carrier (SOBC-1) is an bulk carrier ship model with openly available geometry, including numerical models and a fully equipped physical model at scale 1/32.
It is representative of the medium-size, medium range, single-screw tank/bulk carriers, thus covering a large part of the global fleet.
This ship type is highly relevant for application of wind propulsors and therefore the SOBC-1 can be used as numerical and physical testbed.

The ship design features unconventional main dimensions originating from feasibility studies from SFI Smart Maritime, and it implements state-of-the-art solutions regarding the hull lines, controllable pitch propeller and high-efficiency rudder.
The ship is intended to serve as a testbed –physical and numerical –for various energy saving solutions and innovative "low-"/"zero-" emission technologies.
A test campaign was carried out in SINTEF Ocean's towing tank (May 2021), including both the conventional and wind-assisted propulsion tests. The results are published in Sauder & Alterskjær (2022).

Reference:
S. A. Alterskjær, T. Sauder, A. Bruyat, V. Krasilnikov (2021) "Ship design optimization – live from towing tank", SFI Smart Maritime Webinar, 27-04-2021
Sauder, T., & Alterskjær, S. A. (2022). Hydrodynamic testing of wind-assisted cargo ships using a cyber–physical method. Ocean Engineering, 243, 110206.
Photos: SINTEF Ocean



SCIENTIFIC ACTIVITIES AND RESULTS 2021



Kongsberg Maritime, NEXUS

SMART MARITIME

SCIENTIFIC RESULTS 2021 - HIGHLIGHTS

SMART MARITIME

HYDRODYNAMICS & PROPULSION

BW Pavilion Leeara, Photo: BW Group

Calm water performance

Friction Reduction – project RedRes

Contact: Kourosh Koushan, SINTEF Ocean, Project RedRes

The research project RedRes targets reduction of skin friction, which count for more than 70% of resistance of most ocean-going vessels. The project works on design and optimisation of the surface structure, and will test the developed surface structure on an ocean-going vessel.

Achievements 2021:

- Direct Numerical Simulations of laminar and transitional laminar-turbulent flow over one dimple, as well as over two different dimple patterns. DNS of laminar oscillatory flow over one dimple. Ready to start turbulent flow simulations in 2022.
- Model tests in the cavitation tunnel with different dimpled surfaces. Measurement of friction force using force cell and visualization of detailed flow.

Reference: Project RedRes - Reduction of ship emissions using innovative surface structures to reduce friction. 2020-2024 (RCN) SINTEF Ocean, NTNU, JOTUN, Grieg Star.

Operations in waves

Design Optimization for ships operating in real sea states

Contact: PhD Candidate Ehsan Esmalian (NTNU, WP2)

- Explore using components and methods from Gymir and ShipX.
- Two first scientific papers submitted

Speed loss - Added resistance due to waves

Contact: Martin Gutsch (SINTEF Ocean), IPIRiS KSP Project, Duration 2020 – 2024

- Validation tests using the new standard ship model. Combined SINTEF and NTNU activity.

Ship performance monitoring using in-service measurements and big data analysis

Contact: PhD Candidate Prateek Gupta (NTNU, WP2)

- Developed data-driven ship performance monitoring system using the in-service data recorded onboard the ships. Here, calibrated machine-learning models are used to predict the change in performance of a ship through propeller and hull cleaning events.
- Linear machine-learning methods, namely, PCR and PLSR, are shown to be producing comparable results with a well-established non-linear method, ANN, while modeling the hydrodynamic state of a ship using some simple non-linear transformations.
- A semi-automatic data processing framework is developed to process the data from a ship in-service for ship performance monitoring. Several common problems found in the data obtained from a ship in-service are discussed and solutions are suggested

Wind-powered ships

Hydrodynamics modelling of wind powered merchant vessels

Contact: PhD Candidate Jarle Kramer and Prof. Sverre Steen (NTNU, WP2)

Four practical simplifications for modeling the hydrodynamic properties of a wind-powered cargo ship with CFD and a route simulation model is evaluated. We first test how much the drift-induced hull forces are dependent on Froude number, model scale, and heel angle. Then, we test the mathematical assumptions in the MMG maneuvering model, with particular focus on the rudder resistance as a function of drift angle, rudder angle and propeller thrust. The overall goal is to see if the hydrodynamics of the ship can be modeled with both a simplified CFD setup and a simplified route simulation model. For each tested simplification, we find that they can be used under specific conditions, but not always. We give specific recommendations based on our results. To improve the predicted rudder resistance from the MMG model, we suggest a slightly modified model based on classical lifting line theory. All the numerical experiments are performed using the open source CFD library OpenFOAM. The simulation setup is described, including details of the mesh design. The numerical uncertainty is quantified, and the simulations are compared against benchmark experiments.

Reference: Kramer, J. V., & Steen, S. (2022). Simplified test program for hydrodynamic CFD simulations of wind-powered cargo ships. Ocean Engineering, 244, 110297.

Hybrid testing techniques for wind-assisted propulsion (publication Sauder et al. 2021)

Contact: Professor Thomas Sauder (NTNU)

- A novel method to test wind-assisted ships in hydrodynamic laboratories is presented.
- The physical ship model, including propulsion units, interacts in realtime with a numerical sail model during free-running tests.
- The method is applied to investigate the benefits and limitations of wind-assistance on a 190 m bulk-carrier, equipped with four rotor sails.
- Key performance indicators are presented and analyzed for steady wind profiles with various directions and velocities.

Sauder, T., & Alterskjær, S. A. (2022). Hydrodynamic testing of wind-assisted cargo ships using a cyber–physical method. Ocean Engineering, 243, 110206.

Impact of wind propulsion on the propeller and power system

Contact: Postdoc Dražen Polić (NTNU, WP3)

- Performance of aerodynamic devices (sails/rotors), propeller and machinery
- Performance and velocity prediction program (PPP and VPP) –validation with existing hybrid test results published by SINTEF Ocean

SMART MARITIME

POWER SYSTEMS AND FUELS

Photo: Norwegian Electric Systems.

Power systems and fuel

Shore to ship charging systems

Contact: PhD Candidate, Siamak Karimi (NTNU, WP3)

- Reliability modelling and assessment of shore-to-ship charging systems: comparison of design scenarios.
- Review of technologies: onshore and offshore charging
- Established a novel power architecture as universal multi-vessel shore-to-ship charging system.

Publications:

S. Karimi, M. Zadeh, and J. A. Suul " Operation-based Reliability assessment of Shore-to-Ship Fast Charging Systems," 58th Industrial & Commercial Power Systems Technical Conference) (ICPS)

S. Karimi, "To-ship power transfer: concept, principle, topology," in SFI-Smart Maritime webinar , Oct., 2021.

S. Karimi, M. Zadeh and J. A. Suul, "A Multi-Layer Framework for Reliability Assessment of Shore-to-Ship Fast Charging System Design," in IEEE Transactions on Transportation Electrification , 2021.

Fuel cells & optimization of marine power plants

Contact: PhD Candidate Kamyar Maleki (NTNU, WP3)

- Bond Graph Approach for Modelling of Proton Exchange Membrane Fuel Cell System (Conference-Published)
- Dynamic Modelling of PEM Fuel Cell System for Simulation and Sizing of Marine Power Systems (Journal-Accepted)
- System-Level Modeling of Marine Power Plant with PEMFC System and Battery (Journal-under review)
- Developing Co-Simulation approach for the vessel operation and the generic hybrid power plant

Publications:

Tavakoli, Sadi; Malekibagherabadi, Kamyar; Schramm, Jesper; Pedersen, Eilif. (2021) Fuel consumption and emission reduction of marine lean-burn gas engine employing a hybrid propulsion concept. International Journal of Engine Research.

Malekibagherabadi, Kamyar; Skjong, Stian; Pedersen, Eilif. (2021) Bond Graph Approach for Modelling of Proton Exchange Membrane Fuel Cell System. Proceedings of the 2021 international conference on bond graph modeling and simulation (ICBGM'2021).

Hybrid Power systems

Hybrid Electric Power and Propulsion

Contact: PhD Canditate Marius Ulla Hatlehol (NTNU, WP3)

- Robust control for electric propulsion
- Power system modelling of selected case vessel with DC propulsion. A hybrid power system model consisting of a variable speed genset, a permanent magnet propulsion system, and an energy storage system is developed based on the port-Hamiltonian framework. The models have been used to study the dynamic interactions between the different components to identify root causes for instability.
- Review of hybrid power systems, electric propulsion.
- Review of Regenerative power / potential for heat recovery

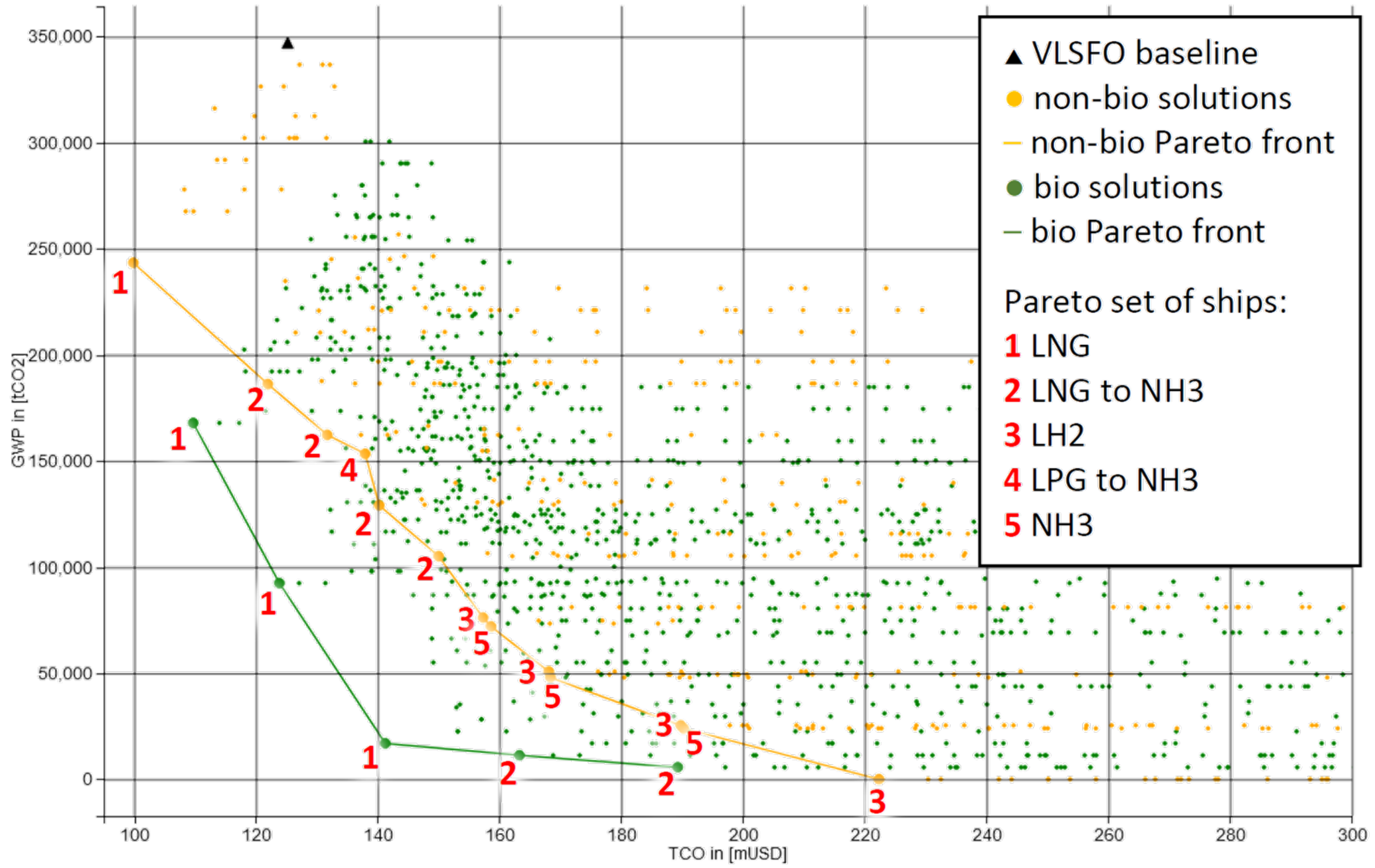
Publications:

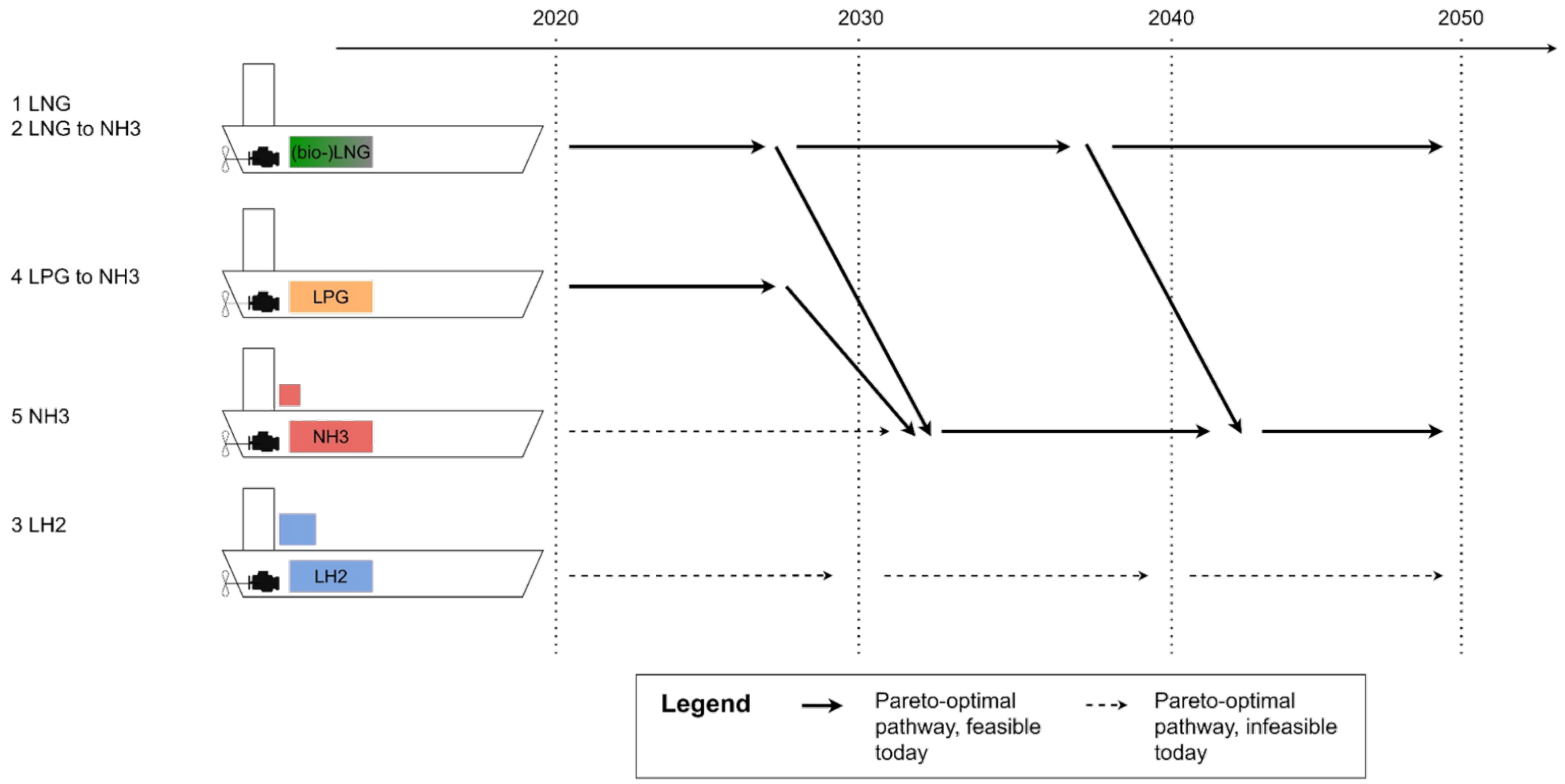
Zadeh, Mehdi; Yum, Kevin Koosup; Hatlehol, Marius Ulla. Hybrid Power Systems. SFI Smart Maritime Webinar; 2021-03-09

Webinar presentation: "Regenerative power / potential for heat recovery / hybrid cycle". Zadeh, Mehdi; Hatlehol, Marius Ulla; Gabrielii, Cecilia H. Energy Efficiency Onboard. SFI Smart Maritime Webinar; 2021-06-22

Paper"Super-Twisting Algorithm Second-Order Sliding Mode Control of a Bidirectional DC-to-DC Converter Supplying a Constant Power Load", submitted for the IFAC CAMS 2022 Conference.

Fuels and power systems





Optimal ship lifetime fuel and power system selection

Contact: PhD Candidate Benjamin Lagemann (NTNU, WP4)

Alternative fuels and fuel-flexible ships are often seen as promising solutions for achieving significant greenhouse gas reductions in shipping. We formulate the selection of alternative fuels and corresponding ship power systems as a bi-objective integer optimization problem. We apply our model to a Supramax Dry-bulker and solve it for a lower bound price scenario including a carbon tax. Within this setting, the question whether bio-fuels will be available to shipping has significant effect on the lifetime costs. For the given scenario and case study ship, our model identifies LNG as a robust power system choice today for a broad range of GHG reduction ambitions. For high GHG reduction ambitions, a retrofit to ammonia, produced from renewable electricity, appears to be the most cost-effective option. While these findings are case-specific, the model may be applied to a broad range of cargo ships.

Case:

- Supramax bulk carrier
- Power system options: VLSFO, LNG, LH2, NH3, LPG, Methanol
- Newbuild & retrofit costs

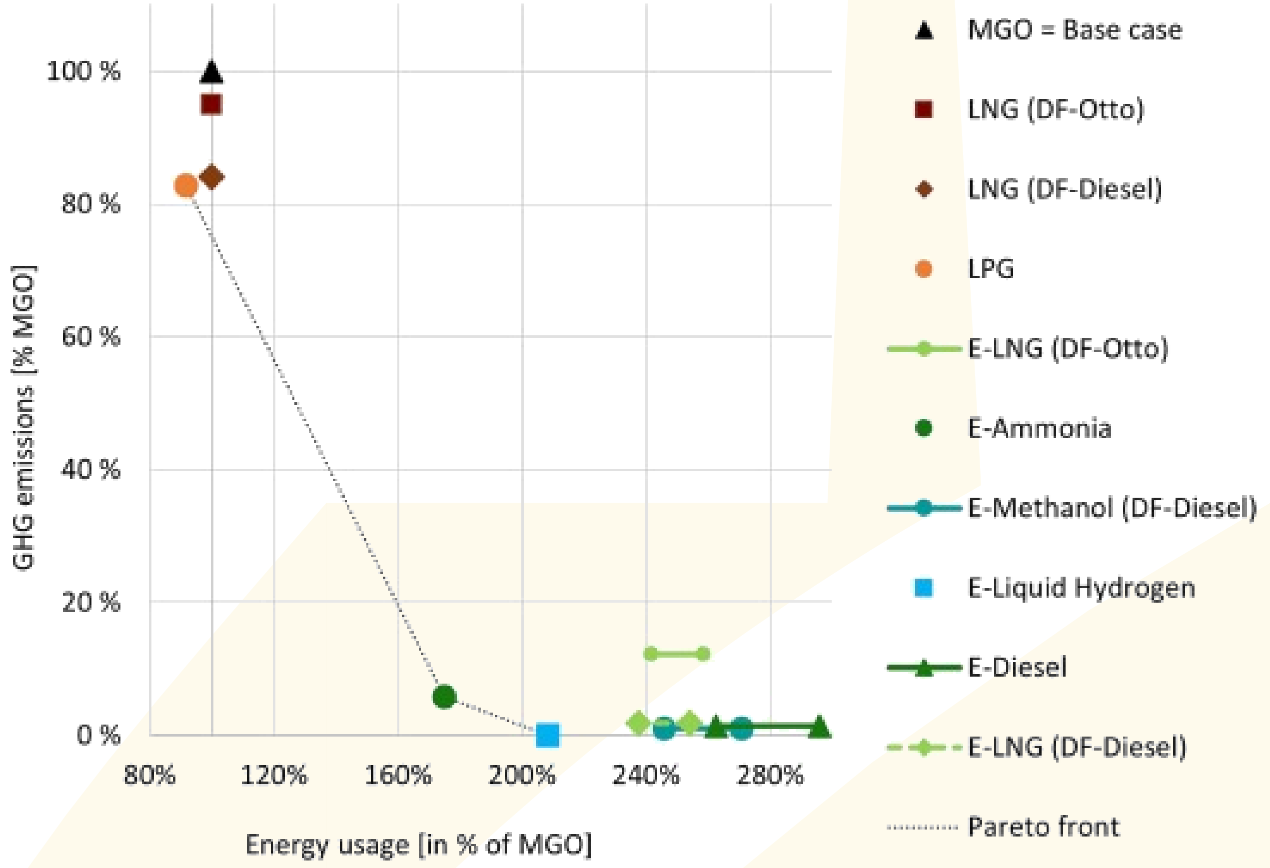
Reference: Lagemann, B., Lindstad, E., Fagerholt, K., Rialland, A., & Erikstad, S. O. (2022). Optimal ship lifetime fuel and power system selection. Transportation Research Part D: Transport and Environment, 102, 103145.

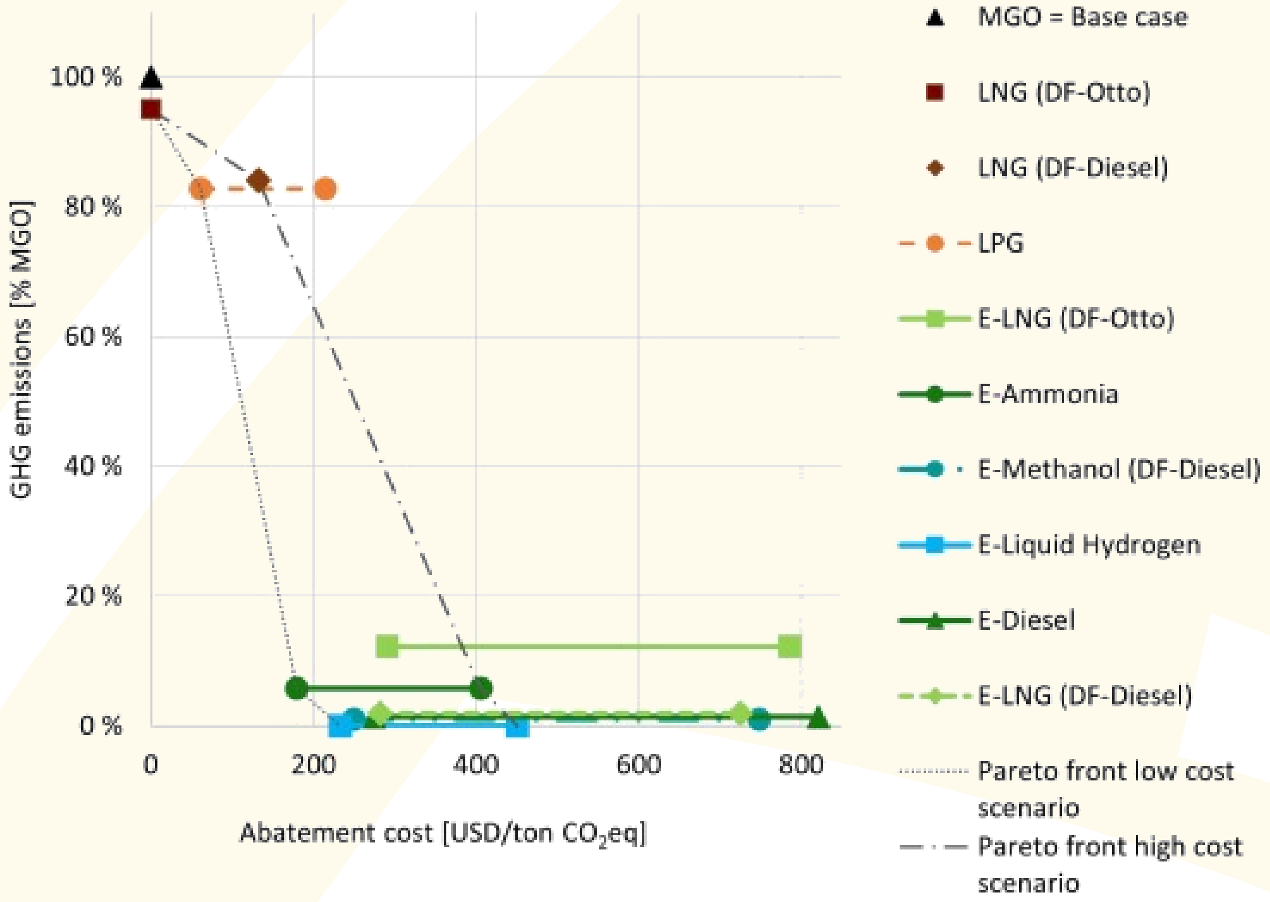
Fuels and power systems

The potential role of E-fuels

Contact: Elizabeth Lindstad (SINTEF Ocean, WP1)

- Zero carbon fuels made from renewable sources (hydro, wind or solar) are by many seen as the most promising option to deliver the desired GHG reductions. Fthe study evaluates Well-to-Wake GHG emissions, energy use and lifecycle cost for E-fuels (E-Hydrogen, E-Ammonia, E-Diesel, E-LNG, E-Methanol).
- The results indicate dual-fuel engines and systems as the most robust path to these alternative fuels, to ensure flexibility in fuel selection, prepare for growing supplies and reduce risks.
- E-fuels will double or triple the maritime sector's energy consumption Well-to-Wake.
- The GHG reduction potential of E-fuels depends entirely on abundant renewable electricity.
- A narrow, maritime focus is counter-productive to a global decarbonization strategy.





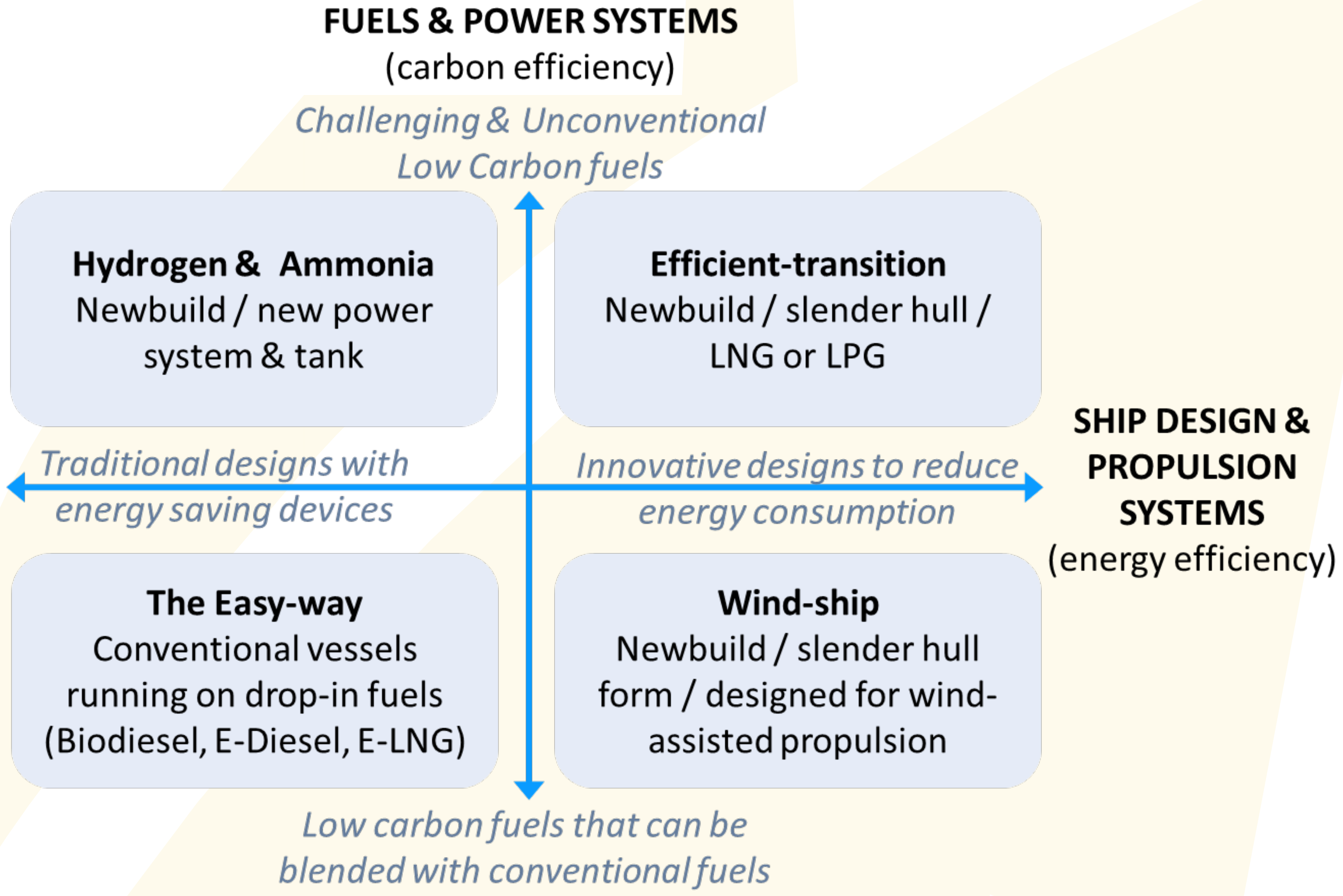
Publications:

Lindstad, E.; Lagemann, B.; Rialland, A.; Gamlem, G. M. & Valland, A. (2021). Reduction of maritime GHG emissions and the potential role of E-fuels. Transportation Research Part D: Transport and Environment, 101, 103075.

Shipping decarbonization scenarios

Contact: Agathe Rialland & Elizabeth Lindstad (SINTEF Ocean, WP1)

- Shipping largest contribution to reaching net zero will be on improving energy efficiency through technical, design and operational measures.
- The present study demonstrates that even fundamentally different solutions pathways contribute to significant GHG reduction.
- No matter which technology path for decarbonizing shipping is considered, energy use Well-to-Wake should not be neglected.
- The options for nearly zero-GHG fuels are either a total shift to new fuel types and power systems (hydrogen/ammonia) or synthetic E-fuels. The latter only affects costs and is hence the *Easy-way* from a shipping industry perspective.
- It is necessary to acknowledge that the maritime industry is embedded in a global energy production-consumption system to avoid the shift of responsibility from one industry to another.
- The *Wind-ship* and *Efficient-transition* illustrate paths in which the shipping industry take the lead and responsibility.
- In contrast, in the *Hydrogen & Ammonia* and *Easy-way* scenarios, the shipping industry depends very much on the energy sector's ability to produce enough new renewable energy.
- The scenarios demonstrate the importance of adopting a broad view on technology and strategy development, to understand the potential of distinct GHG reduction measures, and how distinct technologies and measures can work together.

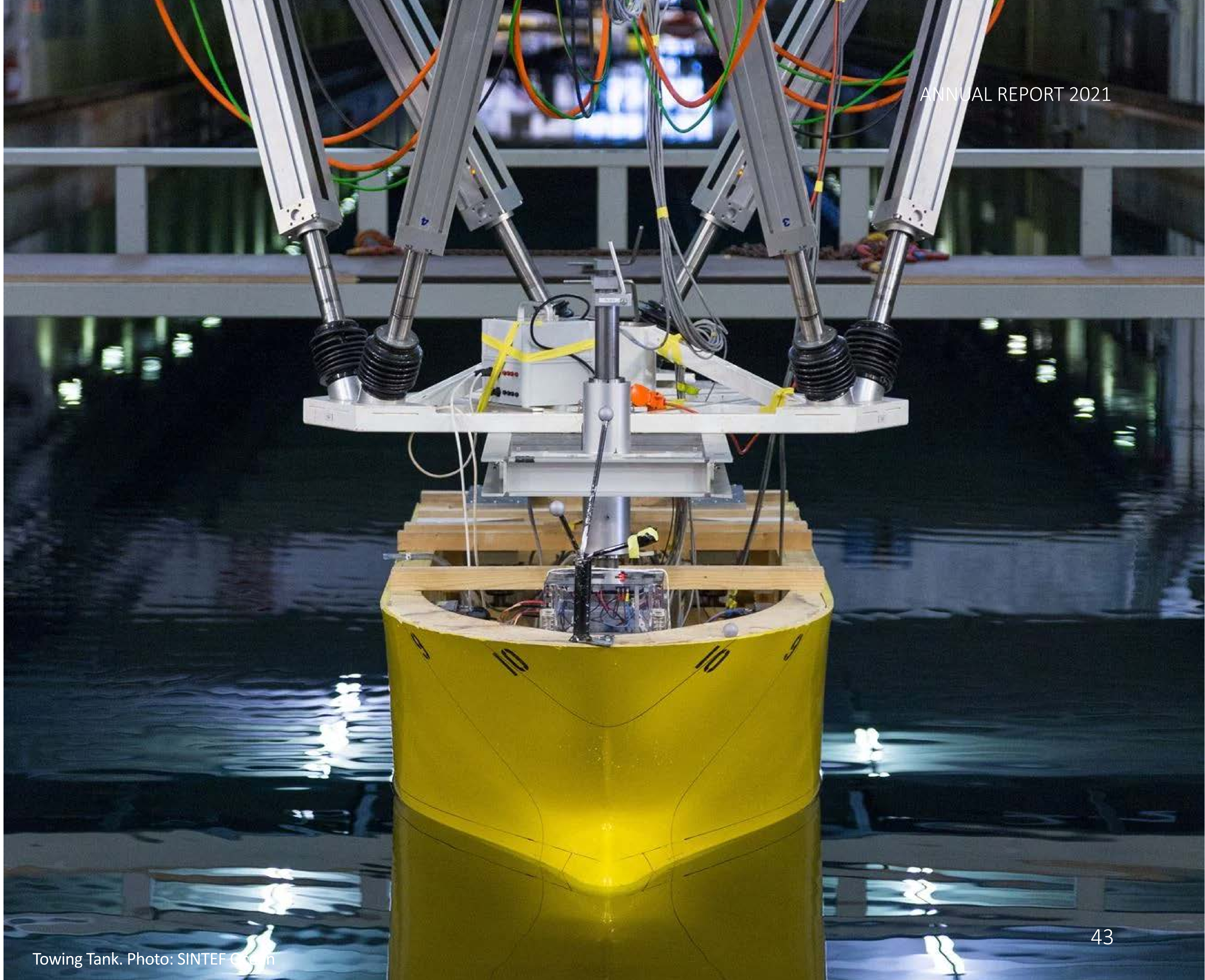


Publications:

Rialland, A., Lindstad, E., 2021 Shipping decarbonization scenarios. 29th Conference of the International Association of Maritime Economists. 25 – 27. November 2021, Rotterdam.

SMART MARITIME

SIMULATION PLATFORM

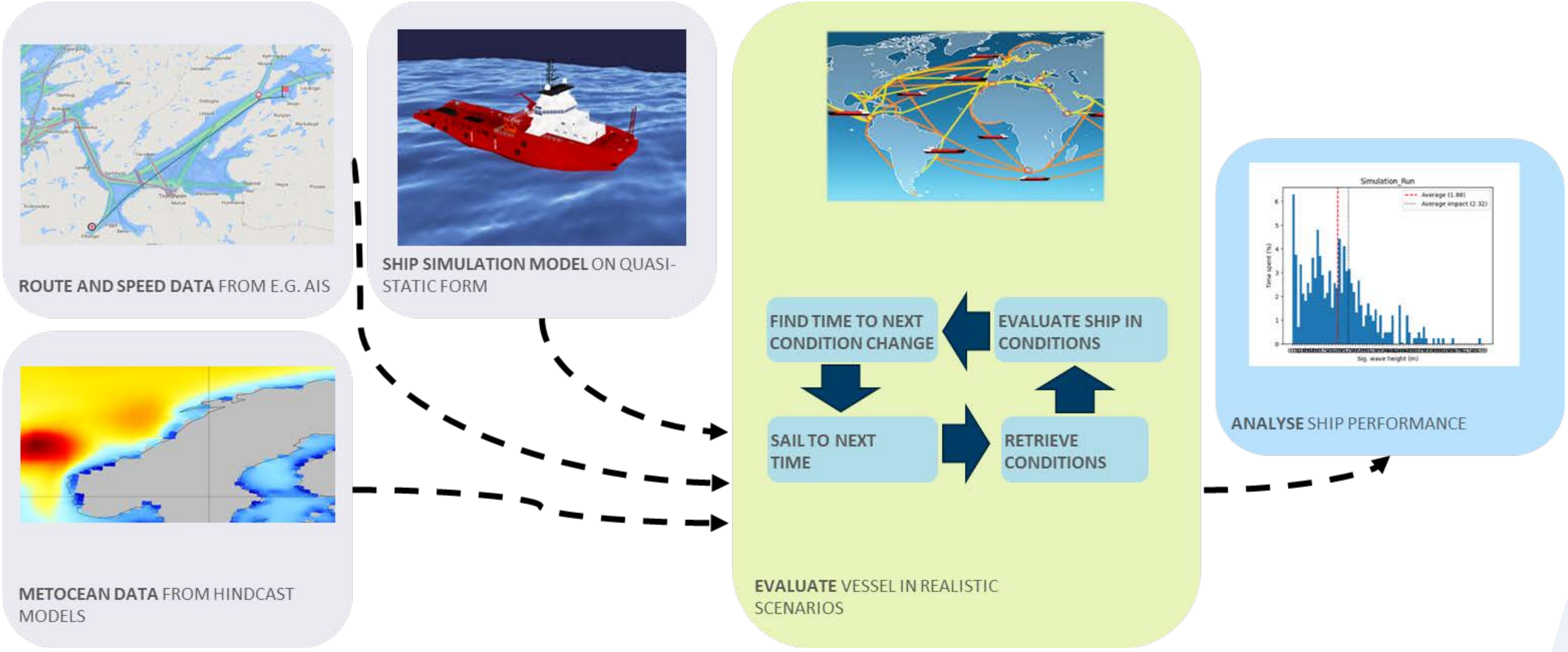


Towing Tank. Photo: SINTEF [illegible]n

GYMIR UPDATES

Contact: Jon S. Dæhlen (SINTEF Ocean, WP4)

Gymir plugin for ShipX



Cloud-based simulation

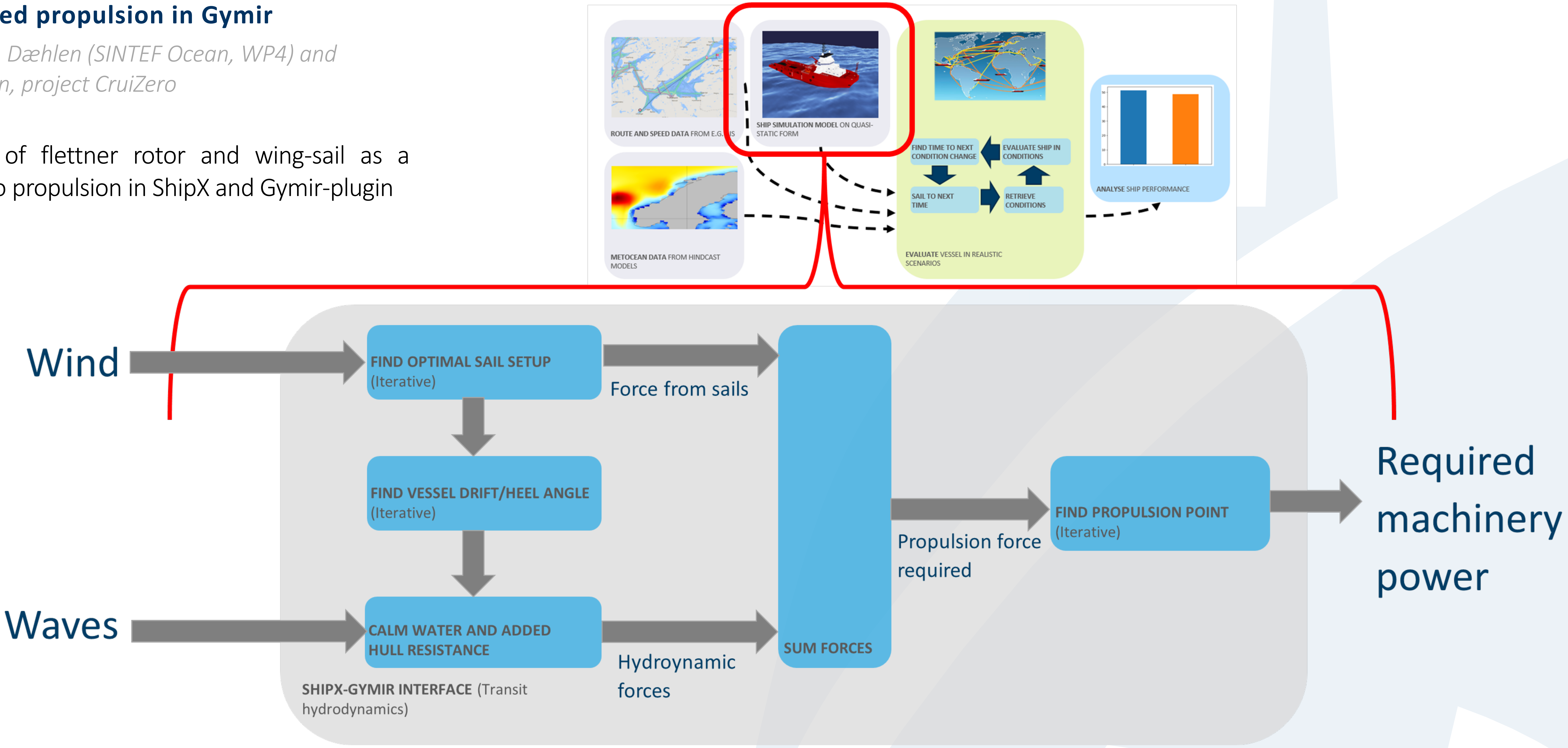
- Gymir simulation engine
- Ship model database
- Weather retrieval directly from weather service provider's servers using OpenDAP
- Animation of simulation
- Post processing of simulation results

Reference: Dæhlen, Jon. SFI Simulation Platform: latest developments. SFI Smart Maritime WEBINAR Simulation Platforms; 2020-10-09

Wind-assisted propulsion in Gymir

Contact: Jon S. Dæhlen (SINTEF Ocean, WP4) and Anders Östman, project CruiZero

Introduction of flettner rotor and wing-sail as a contributor to propulsion in ShipX and Gymir-plugin

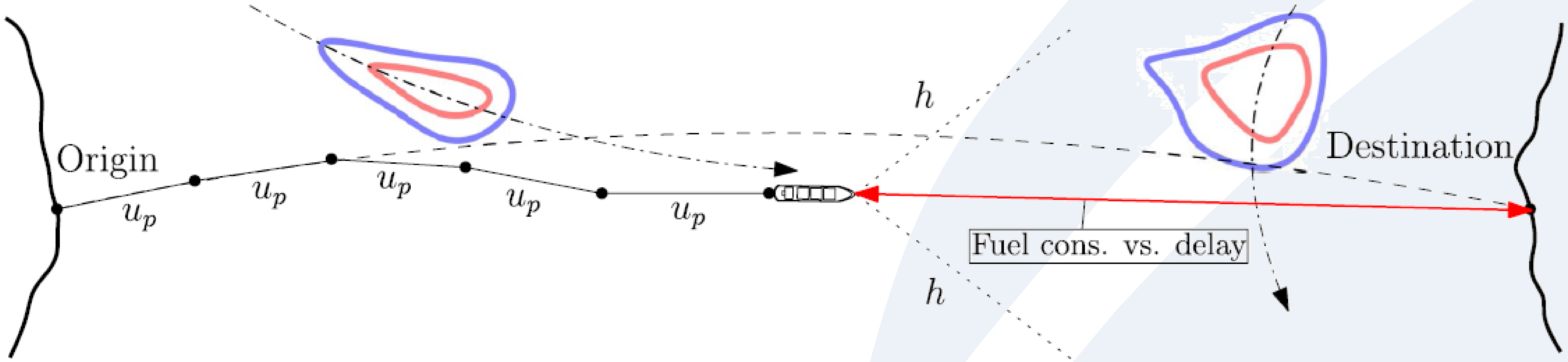


Reference: Dæhlen, Jon. SFI Simulation Platform: latest developments. SFI Smart Maritime WEBINAR Simulation Platforms; 2020-10-09

"Virtual Captain": Active route and speed decisions in Gymir

Contact: Jon S. Dæhlen and Endre Sandvik (SINTEF Ocean, WP4)

Goal: more realistic evaluation of unproven technology by active route and speed decisions in simulation.
Implement strategy developed in Smart Maritime PhD project Simulation-based design (E. Sandvik, WP4).



References:
Dæhlen, Jon. SFI Simulation Platform: latest developments. SFI Smart Maritime WEBINAR Simulation Platforms; 2020-10-09
Sandvik et al. (2020) Operational sea passage scenario generation for virtual testing of ships using an optimization for simulation approach, J. Marine Science and Technology, pp.1-21.

System alternatives for modular, zero-emission high-speed ferries

Contact: PhD Candidate Benjamin Lagemann (NTNU, WP4)

Low emission requirements exert increasing influence upon ship design. The large variety of technological options makes selecting systems during the conceptual design phase a difficult endeavor. To compare different solutions, we need to be able to exchange individual systems and directly evaluate their impact on the design's economic and environmental performance. Based on the idea of model-based systems engineering, we present a modular synthesis approach for ship systems. The modules are coupled to a discrete event simulation and allow for a case-based assessment of system configurations. We apply this method to a high-speed passenger ferry and show how it can provide decision support for hydrogen- and battery-based system architectures.

Reference:
Lagemann, B.; Seidenberg, T.; Jürgenhake, C.; Erikstad, S. O. & Dumitrescu, R. (2021). System alternatives for modular, zero-emission high-speed ferries. SNAME International Conference on Fast Sea Transportation, doi.org/10.5957/FAST-2021-054

MARITIME TRANSPORT ENVIRONMENTAL ASSESSMENT MODEL (MariTEAM)

Contact: Helene Muri (NTNU)

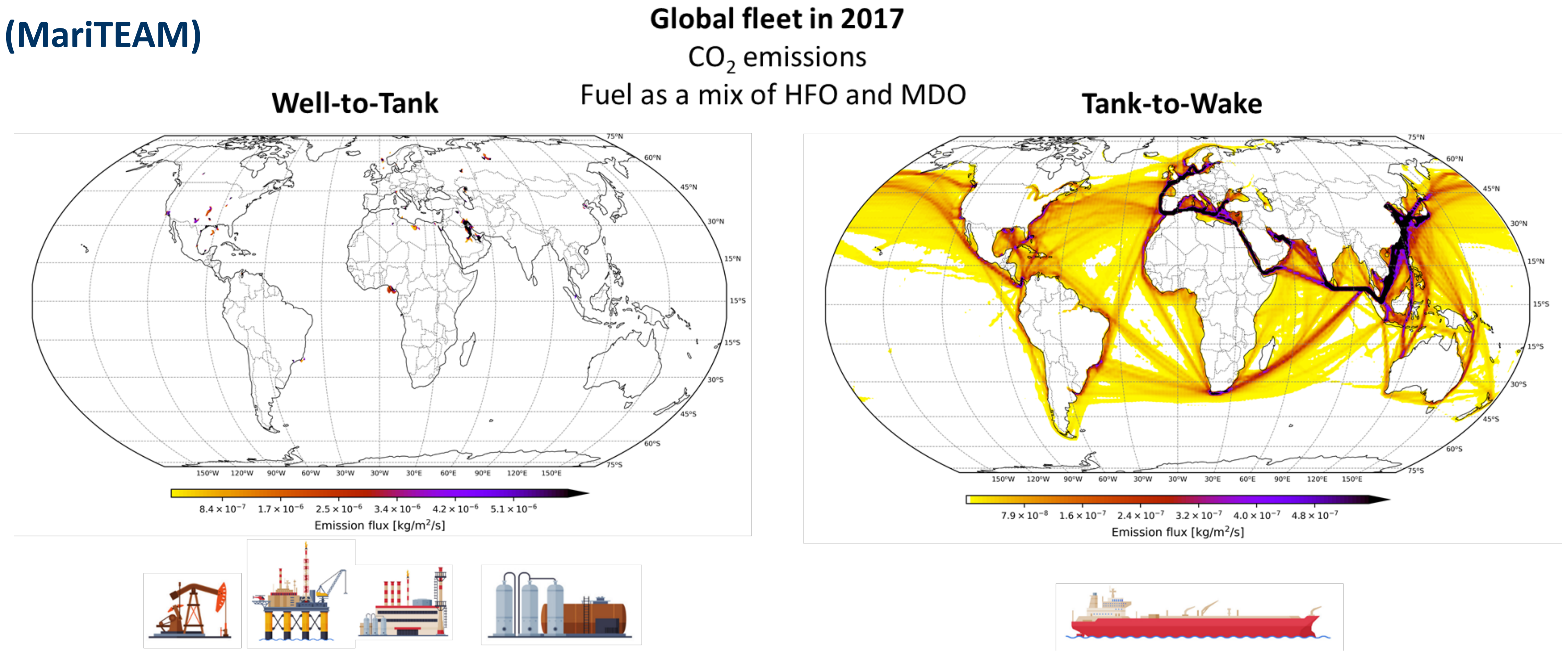
MariTEAM model development

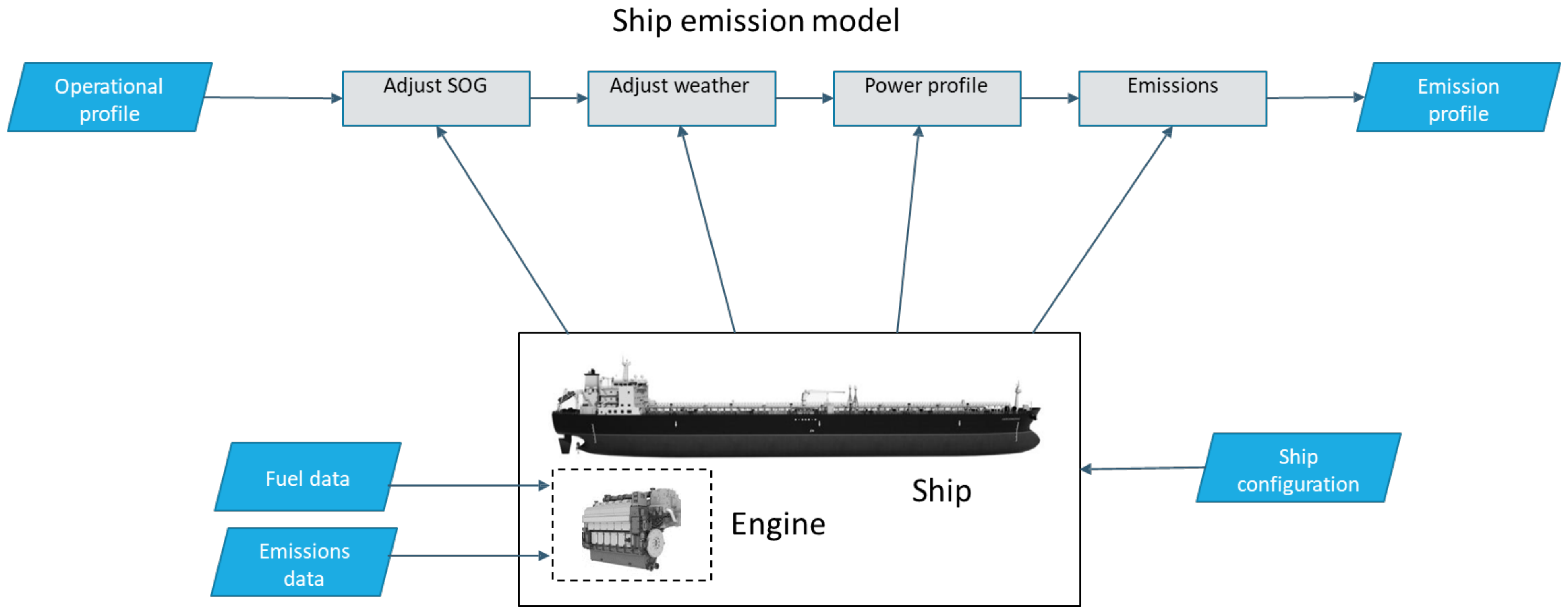
Fleet level emission assessment

- Fleet stock scenario model
- Geospatial LCA and climate footprint of fuels

Fleet emission inventory

- Ship level assessment
- Battery electric ferry case.
- Evaluation of power prediction models





COOPERATION

Rotor test – Fouling rate test. Photo: Jotun.

SMART MARITIME

COOPERATION
INDUSTRY - RESEARCH - ACADEMIA

Smart Maritime enjoys a network of highly motivated industry representatives, striving for knowledge and excellence. The participation of maritime professionals in research is crucial for the good progress of our projects.

Industry participation includes the following:

- Sharing of operational data
- Measurement and test experiments
- Laboratory or test ship for research
- Direct involvement in research work
- Cooperation on model and tool development
- Participation at workshops and webinars
- Scientific discussion, knowledge sharing
- Associated and spin-off projects
- Co-supervision / support to Master theses
- Dissemination, co-authorship

Illustration: Clipper EOS equipped with omboard CCS (Photo: Solvang-Wärtsilä)

NETWORK MEETINGS 2021

The research team and the Technical Advisory Committee gather at bi-annual network meetings to exchange ideas and experience, keep updated on scientific progress, discuss new challenges and new reseach and innovation initiatives.

In 2021, the network could finally meet in person after 3 consecutive digital events.

04 MAY 2021
Dialog on new research and innovation initiatives
Online - Participants: 45

9-10 NOVEMBER 2021
Planning of 2021 activities
Trondheim - Participants: 50

Pictures:
Trondheim, 8-9 Nov 2021
- Kvilhaugen Gård.
- Banksalen.

SMART MARITIME

WEBINARS 2020

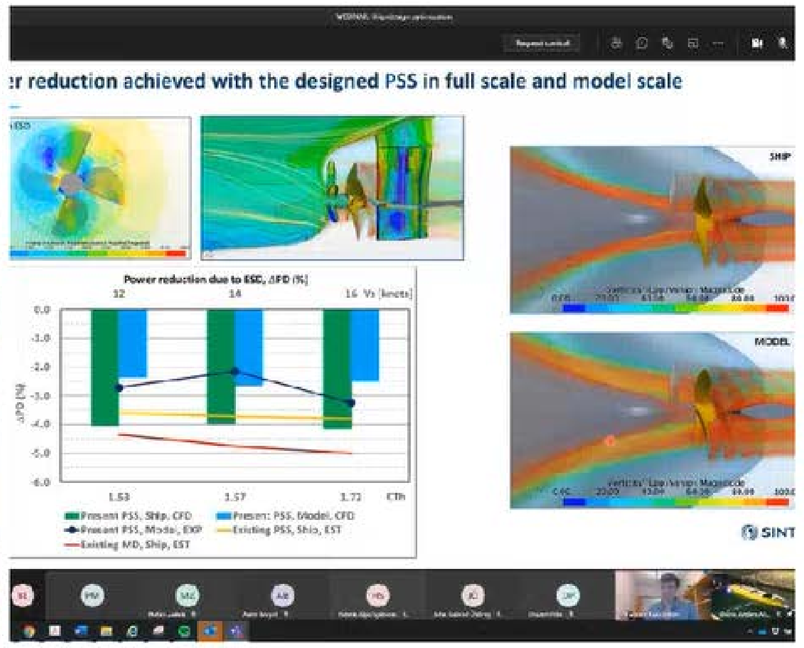
Online seminars and lectures are offered to the Centre members for providing update on ongoing research and maintain scientific discussion with industry partners.

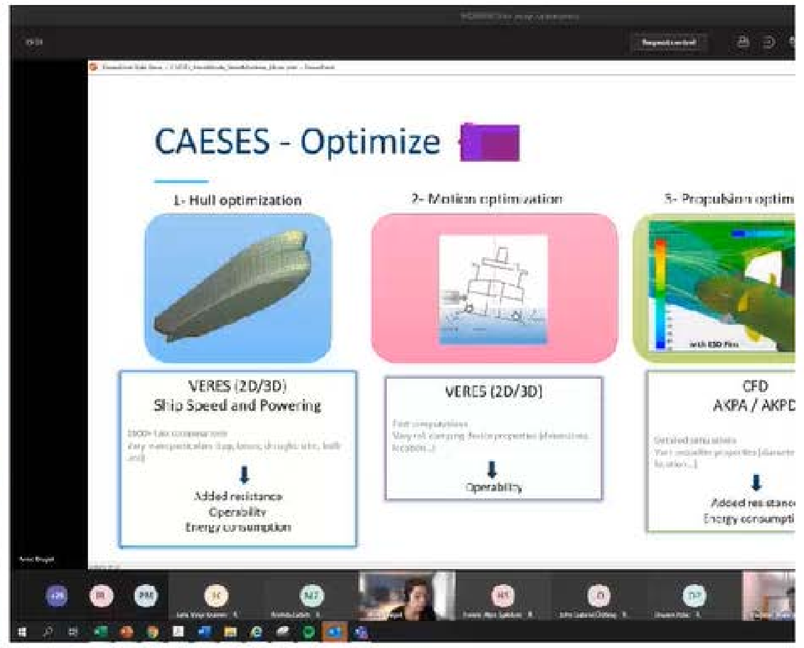
Topic	Presenters	Date	Participants
Carbon Intensity Indicator	SINTEF Ocean, Klaveness: E. Lindstad, M. Wattum	Jan. 21	#43
Maritime emissions estimation model (W/ CLIMMS)	NTNU: D. Kramel, H. Muri, Prof. A.H. Strømman	Feb. 16	#43
Hybrid Power Systems	NTNU, SINTEF Ocean: Prof M. Zadeh, K. K. Yum, M. U. Hatlehol	Mar. 9	#49
Maritime Policy updates	SINTEF Ocean: E. Lindstad	Mar. 23	#35
Big data application in the maritime sector	NTNU: Prof S. Steen, P. Gupta, YoungRong Kim	Apr. 20	#54
Ship design optimization – live from towing tank	SINTEF Ocean: S. A. Alterskjær, T. Sauder, A. Bruyat, V. Krasilnikov	Apr. 27	#41
Håndtering av skip i dårlig vær	Kompetanseforum for krevende fartøysoperasjoner	Jun. 2	
Energy Efficiency on-board	NTNU, SINTEF Energy: Prof M. Zadeh, M. U. Hatlehol, C. Gabriellii	Jun. 22	#50
Alternative fuels	SINTEF Ocean: E. Lindstad	Sept. 16	#38
To-ship power transfer for sustainable propulsion	NTNU, SINTEF Energy: Prof M. Zadeh, S. Karimi, J. Suul	Oct. 7	#45
Simulation platform - Gymir-ShipX plug-in release	SINTEF Ocean, NTNU: J.S. Dæhlen, B. Lagemann	Oct. 29	#48
CLIMMS - Reducing Maritime GHG Emissions	NTNU Indecol, SINTEF Ocean	Nov. 19	

Interactive webinar

Webinar on Ship Design Optimization, with live demo from the SINTEF Ocean Towing tank.
The meeting presented the concept and design of the SINTEF Ocean Bulk Carrier (SOBC-1), and ongoing work on simulation-driven design approach, to conclude with presentation of model experiments with wind assisted SOBC-1, live from the SINTEF Ocean's Towing Tank.

Presenters: Anders Alterskjær, Vladimir Krasilnikov, Anne Bruyat, Thomas Sauder.





Pictures:
Screenshots from
Webinar 27-04-2021

NATIONAL COOPERATION

National research and expertise centres

Cooperation on simulation methods and tools among SFI Smart Maritime, MOVE, EXPOSED, and newly launched SFI Autoship.

Strategic research collaboration agreement through GEMINI-centre for maritime logistics (SINTEF/NTNU 2018-2022)

Low-emission research centre: Cross-disciplinary cooperation on case study of offshore supply with emission-free fuels, including integration of optimization and simulation models.

Smart Maritime is represented in

- NCE Maritime CleanTech
- Grønnkystfartprogram
- Kompetanseforum for krevende marinoperasjoner

Spin-off and associated projects

New opportunities are explored every year by partners of Smart Maritime for further research or commercialisation activity.
In 2021, based on active collaboration among the Centre partners, 6 new collaboration projects were launched.

University collaboration

NHH. Norwegian School of Economics. Collaboration with Centre for Applied Research at SNF (Samfunns- og næringslivsforskning) on maritime economics.

INTERNATIONAL COOPERATION

EU's framework programme

Several of the Centre's industry partner are involved in at least one EU project on similar topics as Smart Maritime. Per 2020, SINTEF Ocean and Smart Maritime partners were involved in 5 H2020 projects with high relevance and synergy with Smart Maritime in terms of scientific activity or industrial challenges; 3 of these were launched in 2020.

Academic and research cooperation

- Scientific advisory committee, consisting of 5 Professors with expertise covering research area of the Centre. Chalmers University (SE), U. Strathclyde (UK), DTU (DK), TU Hamburg (GE)
- Cross-university PhD program (Cotutelle) NTNU / DTU Denmark.
- Cooperation with Chalmers University of Technology, Sweden on fouling and anti-fouling for reduction of friction.
- Cooperation with UC Berkeley on utilization of super-hydrophobic surfaces and flow separation detection and control (partly financed by a Peder Saether Grant).
- KEDGE Business School (FR) and KLU Kühne Logistics University (GE) on maritime economic studies.
- Aalborg university: cooperation on shore-side power supply.

International cooperation on policy development

- IPCC International Panel on Climate Change: Prof. A. H. Strømman and Dr. Helene Muri (NTNU) designated as co-author for the IPCC's Sixth Assessment Report.
- ESSF: European Shipping Sustainability Forum: Chief-scientist Elizabeth Lindstad expert advisor, contributor and task-lead for working groups: Alternative Fuels and Ship Energy Efficiency, coordinating submissions to IMO and ISO.
- Dr. Lindstad, one of three external experts in BIMCO's WG on Alternative Fuels which started autumn 2021
- IMO / MEPC: SFI Smart Maritime participants are actively involved in IMO consultations, either through Norwegian delegation or international forums and industrial initiatives.
- UNCTAD: contribution to UNCTAD expert assessment for IMO.
- MAREFORUM. Dr. Lindstad regular panel speak at one of the most global and influential forums for the maritime and shipping industry.
- SNAME fellowship attributed to Dr Elizabeth Lindstad in 2017
- WSA – Wind Ship Association: SINTEF Ocean associated member
- ITTC – Technical committee member

ASSOCIATED PROJECTS

Project title	Period	Funding	Smart Maritime Partners
HOLISHIP - HOLIstic optimisation of SHIP design and operation for life cycle	(2016-2020)	EU H2020	Kongsberg Maritime, DNVGL, SINTEF
Hybrid testing - Real-Time Hybrid Model Testing	(2016-2020)	MAROFF, KPN	NTNU, SINTEF
SATS - Analytics for ship performance monitoring in autonomous vessel	(2018-2020)	MAROFF, KPN	NTNU, SINTEF
Open simulation platform	(2018-2020)	JIP	DNV GL, Kongsberg Maritime, SINTEF, NTNU
Digital twin for lifecycle operations	(2018-2022)	MAROFF	DNV GL, Kongsberg Maritime, SINTEF, NTNU
CLIMMS - Climate change mitigation in the maritime sector	(2019-2023)	MAROFF, KPN	NTNU, SINTEF, Rederiforbund + all 8 ship owners SFI-partners
SmartShipRouting	(2019-2021)	MAROFF, IPN	NCS, NES, Havila, Havyard, SINTEF
RuteSim: Simuleringsbasert Ruteplanlegging	(2019-2020)	MAROFF, IPN	Grieg Star, WWO, KGJS, SINTEF, Nansen
Digital twin yard	(2019-2021)	MAROFF, IPN	DNVGL, Rolls-Royce, NTNU, SINTEF
FreeCO2ast	(2019-2022)	PILOT E	Havyard, Havila , SINTEF
Extension of Hybrid Lab	(2019-2019)	ABB	ABB, SINTEF
Autoship	(2019-2022)	EU H2020	Kongsberg, SINTEF
RedRes - Innovative surface structures to reduce friction	(2020-2023)	MAROFF, KPN	JOTUN, SINTEF, NTNTU, Grieg Star
IPIRIS - Improving Performance in Real Sea	(2020-2023)	MAROFF, KPN	VARD, Havyard, Kongsberg, SINTEF, NTNU
CruiseZero – Zero-emission expedition cruise	(2020-2022)	MAROFF, IPN	VARD, ABB, SINTEF
PEZOS - Plug-In Electric Zero-emission Offshore-ship	(2020-2022)	MAROFF, IPN	VARD, SINTEF
Bio4-7seas - Biofuels in deep sea shipping for climate change mitigation	(2020-2023)	ENERGIX, KPN	NTNU, SINTEF
ZeroCoaster - Zero-emission coastal bulk shipping	(2020-2022)	MAROFF, IPN	VARD, ABB, DNV GL, SINTEF
Air-lubrication	(2020-2022)	MAROFF, IPN	Jotun, SINTEF
Gaters	(2020-2022)	EU H2020	Strathclyde, SINTEF
Aegis	(2020-2023)	EU H2020	SINTEF
VesselAI	(2021-2024)	EU H2020	Kongsberg, SINTEF
CCShip – Carbon Capture and Storage onboard ships	(2021-2024)	MAROFF, KSP	Klaveness, Wärtsila, NCCS, Calix,SINTEF, NTNU
AMAZE - Ammonia zero emission	(2021-2023)	MAROFF, IPN	Bergen Engines, SINTEF, NTNU
SEA-Co - Safer, easier and more accurate Co-simulations	(2021-2025)	MAROFF, KSP	DNV, Kongsberg, SINTEF, NTNU
ISTS - Intelligent ship transport systems	(2021-2024)	MAROFF, KSP	SINTEF, Kongsberg, DNV, Grieg, Kystverket, Sjøfartsdirektoratet
ZeroKyst – Decarbonization of ships for seafood sector	(2021-2024)	Green Platform	Siemens, SINTEF, NTNU
ProfSea - Ship Operational Performance in Following Sea	(2021-2024)	NFR, KSP	Kongsberg, SINTEF, NTNU
Ecorouter - Route optimization integrating low-carbon technologies	(2022-2024)	MAROFF, IPN	KGJS, OSM, Odfjell

INDUSTRIAL INNOVATION

Skal løse skipsfartens klimagassproblem med multifuel brenselcelle

Rederiet Odfjell satser ikke alt på en hest i kappløpet for å nå nullutslipps shipping. Tester brenselcelle som kan gå på alt fra LNG med karbonfangst til ammoniakk og hydrogen.

Modulbygde skip skal gjøre det lettere å bytte til utslippsfritt

Norges mål om å redusere utslipp fra skipsfarten med 50 prosent innen 2030, betyr at det må bygges minst 400 utslippsfrie skip til nærskipsfart og 700 lavutslippsskip. Zerocoaster kan være løsningen.

Solvang-skip får karbonfangst og lagring om bord

Rederiet Solvang skal i 2023 montere et CCS-anlegg om bord på etylenskipet Clipper Eos. Det blir verdens første anlegg for karbonfangst og lagring på et skip.

Source: Teknisk Ukeblad

SMART MARITIME

THE RESEARCH TEAM

Smart Maritime's research team consists of 30 research scientists from two institutions NTNU and SINTEF Ocean.

The Centre has so far financed 13 PhD students and 4 Postdoc researchers.

SKS Satilla. Photo: Capt R. Revnyuk, Kristian Gerhard Jebsen Skipsrederi.

PHD STUDENTS AND POSTDOCTORAL RESEARCHERS - 2021

Name	Nationality	Period	Topic	Supervisor
Postdoctoral researchers SFI Smart Maritime				
Dražen Polić	HR	2020-2022	Impact of wind propulsion on the propeller and power system. (WP3)	Prof. Eilif Pedersen, NTNU
PhD students SFI Smart Maritime - WP3 Power systems and fuels				
Prateek Gupta	IN	2018–2022	Ship performance monitoring using in-service measurements and big data analysis methods	Prof. Sverre Steen, NTNU
Ehsan Esmailian	IR	2019-2022	Optimization of ships for operation in real sea states	Prof. Sverre Steen, NTNU
Jarle Kramer	NO	2020-2022	Hydrodynamic modelling of wind-powered merchant vessels	Prof. Sverre Steen, NTNU
PhD students SFI Smart Maritime - WP3 Power systems and fuels				
Kamyar Maleki	IR	2019-2022	A Simulator Approach to Concept Analysis and Optimization of marine Power Plants	Prof. Eilif Pedersen, NTNU
Yuan Tian	CN	2020-2023	Modelling and simulation of ship exhaust gas cleaning system	Prof. Eilif Pedersen, NTNU
Siamak Karimi	IR	2019-2022	Modelling and optimal design of marine hybrid electric power systems	Prof. Mehdi Zadeh, NTNU
Marius Ulla Hatlehol	NO	2021-2024	Modelling, Design and Control of Hybrid Electric Power and Propulsion	Prof. Mehdi Zadeh, NTNU
PhD students SFI Smart Maritime - WP4 Ship System Integration and Validation				
Benjamin Lagemann	GE	2019-2022	Concept Ship Design for Future Low-Emission Shipping Technology	Prof. Stein-Ove Erikstad, NTNU
Funding from other sources				
Diogo Kramel	BR	2019-2022	LCA marine fuels	
YoungRong Kim	CH	2019-2022	Efficient fleetwide modelling	


Dražen Polić


Prateek Gupta


Ehsan Esmalian


Kamyar Maleki


Siamak Karimi


Marius Ulla Hatlehol


Yuan Tian


Benjamin Lagemann


Jarle Kramer

RESEARCH TEAM - SINTEF OCEAN


S. Anders Alterskjær


Anne Bruyat

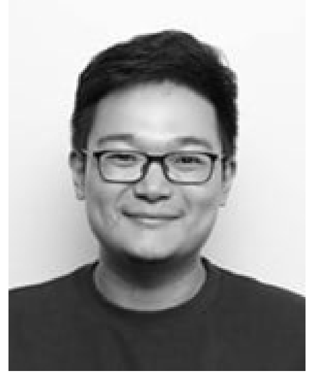

Torstein Ingerbrigtsen Bø


Jon Schonhovd Dæhlen


Gunnar Malm Gamlem


Martin Friedwart Gutsch


Pierre-Yves Henry


Fengjian Jiang


Trond Johnsen


Ulrik Jørgensen


Kourosh Koushan


Kevin Koosup Yum


Ruben A.I. Kristiansen


Marius Indbryn Krogseng


Elizabeth Lindstad


Jørgen Nielsen


Agathe Rialland


Endre Sandvik


Thomas Sauder


Luca Savio


Renato Skejic


Dag Stenersen


Anders Valland


Anders L. Östman

RESEARCH TEAM - NTNU


Bjørn Egil Asbjørnslett


Stein Ove Erikstad

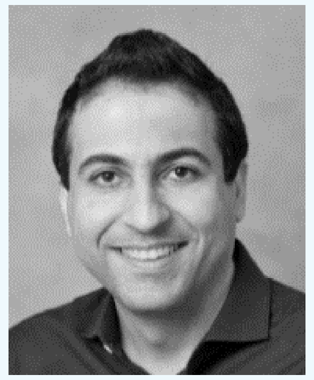

Helene Muri


Eilif Pedersen


Sverre Steen


Anders H. Strømman


Vilmar Æsøy


Mehdi Zadeh

RESEARCH TEAM

Name	Institution	Main research area
S. Anders Alterskjær	SINTEF Ocean	Hull and propeller hydrodynamics
Anne Bruyat	SINTEF Ocean	Numerical Hydrodynamics
Torstein Ingebriktsen Bø	SINTEF Ocean	Marine hybride systemer
Jon Dæhlen	SINTEF Ocean	Data simulations and optimizing
Gunnar Malm Gamlem	SINTEF Ocean	Energy systems
Martin Friedwart Gutsch	SINTEF Ocean	Ships and Ocean Structures
Pierre-Yves Henry	SINTEF Ocean	Ships and Ocean Structures
Fengjian Jiang	SINTEF Ocean	Ships and Ocean Structures
Trond Johnsen	SINTEF Ocean	Data simulations and optimization
Ulrik Jørgensen	SINTEF Ocean	Simulations and programming
Kourosh Koushan	SINTEF Ocean	Hull and propeller hydrodynamics
Kevin Koosup Yum	SINTEF Ocean	Simulation, Machinery
Ruben A.I. Kristiansen	SINTEF Ocean	Ships and Ocean Structures
Marius Indbryn Krogseng	SINTEF Ocean	Ships and Ocean Structures
Elizabeth Lindstad	SINTEF Ocean	Feasibility studies
Jørgen Nielsen	SINTEF Ocean	System simulation

Name	Institution	Main research area
Agathe Rialland	SINTEF Ocean	Feasibility studies
Endre Sandvik	SINTEF Ocean	Simulering
Thomas Michel Sauder	SINTEF Ocean/NTNU	Marine hydrodynamics and cybernetics
Luca Savio	SINTEF Ocean/NTNU	Marine Hydrodynamics
Renato Skejic	SINTEF Ocean	Marine Engineering
Dag Stenersen	SINTEF Ocean	Hybrid propulsion
Anders Valland	SINTEF Ocean	Hybrid propulsion
Anders L. Östman	SINTEF Ocean	Marine hydrodynamics
Henning Borgen	SINTEF Ålesund	Virtual ship design
Bjørn Egil Asbjørnslett	NTNU	Feasibility studies
Stein Ove Erikstad	NTNU	Data simulations and optimization
Anders Strømman	NTNU	Environmental assessment
Helene Muri	NTNU	Environmental assessment
Eilif Pedersen	NTNU	Power systems and fuel
Sverre Steen	NTNU	Hull and propeller hydrodynamics
Mehdi Zadeh	NTNU	Marine Hybrid Power Systems
Vilmar Æsøy	NTNU Ålesund	Power systems and fuel

TECHNICAL ADVISORY COMMITTEE

ABB
Jan-Fredrik Hansen

Bergen Engines
Leif Arne Skarbø

BW LNG
Olav Lyngstad

DNV
Hendrik Brinks

Grieg Star
Jan Øivind Svardal

HAV design
Kristian Voksøy Steinsvik

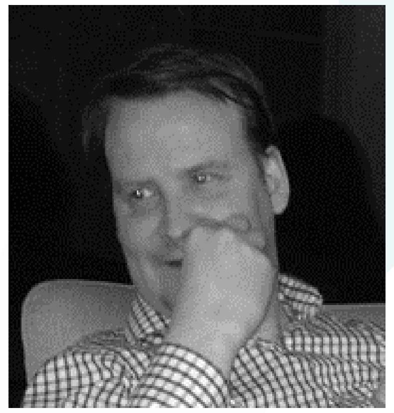
Jotun
Angelika Brink

Höeh Autoliners
Henrik Andersson

KG Jebsen Skipsrederi
Jan Berntzen

Kystrederiene
Tor Arne Borge

Kongsberg Maritime
Sverre Torben



Odfjell
Veine Huth

Norwegian Electric Systems
Ole Georg Rørhus

Norges Rederiforbund
Jahn Viggo Rønningen

Siemens Energy
Stig-Olav Settemsdal

Sjøfartsdirektoratet
Kolbjørn Berge

Solvang
Tor Øyvind Ask

Torvald Klaveness
Martin Wattum

VARD Design
Ove Bjørneseth

Wallenius Wilhelmsen
Lars Dessen

Wärtsilä Moss
Sigurd Jenssen

INDUSTRY NETWORK

ABB	Bergen Engines	BW	DNV GL	Grieg Star	HAV Design	Höegh Autoliners	Klaveness
Jan-Fredrik Hansen* Espen-Stubberod Olsen	Jan Eikefet Leif Arne Skarbø* Matthew Bloss	Olav Lyngstad*	Hendrik Brinks* Hans Anton Tvete	Roar Fanebust Silje Monslaup Jan Øivind Svardal* John Gabriel Östling	Daniel Aaro Kay Lorgen Arve Nedreberg Kristian Osnes Stig Endre Moe Kristian V. Steinsvik* Kåre Nerland	Henrik Andersson* Sondre Nilsen Thea Valvatne	Andreas Haavik Audun Eriksen Ernst André Meyer Anders M. Sorheim Martin Wattum *

Jotun	Kristian Gerhard Jebsen Skipsrederi	Kystrederiene	Norwegian Electric Systems	Odfjell	Kongsberg Maritime
Angelika Brink* Manolis Levantis Stein Kjølberg	Jan Berntzen Ole-Johan Haahjem* Øyvind Monsen Stein Håvard Sunnavåg	Tor Arne Borge*	Ole-Georg Rørhus*	Veine Huth * Vegard Marken	Martijn de Jongh Markus Heimdal Hans Martin Hjørungnes Bjørn-Erik Osmark Harald Myrlund Sverre Torben* Bjørnar Vik

Norges Rederiforbund	Siemens Energy	Sjøfartsdirektoratet	Solvang	Vard Design	Wallenius Wilhelmsen	Wärtsilä Moss
Jahn Viggo Rønningen*	Lars Barstad Tor Ove Haugan Vemund Kårstad Mona Khorasani Odd Moen* Kenneth P. Tjong Stig-Olav Settemsdal	Kolbjørn Berge*	Tor Øyvind Ask*	Ole Bjørneseth* Andreas Buskop Tim Mak Kjell Morten Urke	Lars Dessen* Sergey Ushakov	Jan Gannefors Sigurd Jenssen* Sergio R. Palencia

* Primary contacts

SMART MARITIME

COMMUNICATION AND DISSEMINATION

Photo: Siemens

COMMUNICATION

Priority is given to communication towards the Centre's industry partners, Technical Advisory Committee and Board, to ensure good dialog with the core research team and involvement in research projects.

Our main communication channels are:

Website

www.smartmaritime.no contains *public information* about the Centre and a publication database accessible by the Centre members. News and events are also administrated on the website.

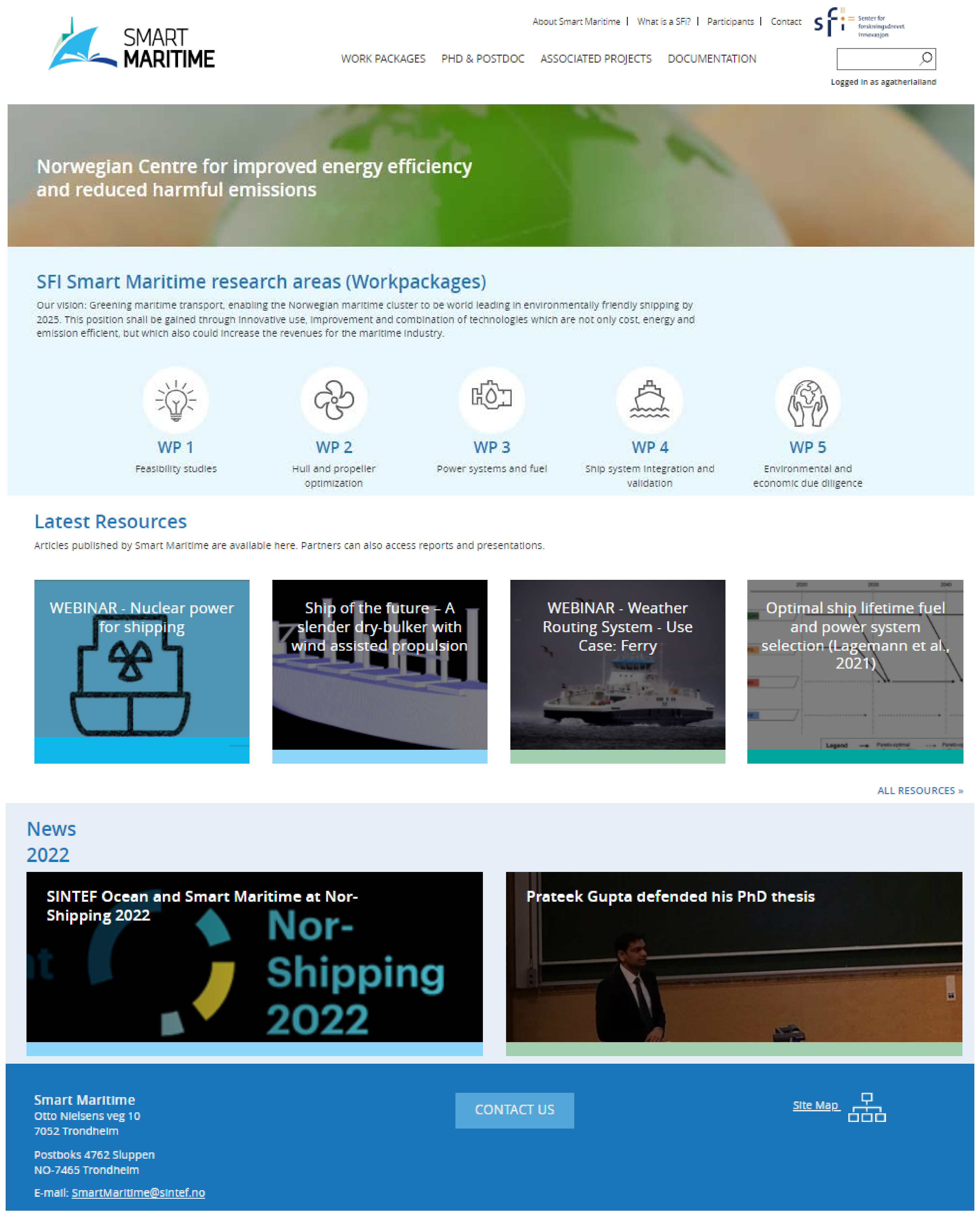
Workshops

The large majority of technical workshops on research topics and associated projects meetings has been handled as digital meetings in 2021.

Webinars

Smart Maritime maintained the frequency of Webinars in 2021 in order to keep partners regularly updated on scientific progress and maintain the dialog between research team and industry partners despite the covid-19 restrictions.

Webinars have been extended to other forums, open to external participants, and involving industry partners in the preparation and discussion.



DISSEMINATION > Smart Maritime in the media 2021

TU

Havila Capella: Nå er første kystruteskip levert

Havila Kystrutens nye skip er spekket med norske nyvinninger.

Modulbygde skip skal gjøre det lettere å bytte til utslippsfritt

Norges mål om å redusere utslipp fra skipsfarten med 50 prosent innen 2030, betyr at det må bygges minst 400 utslippsfrie skip til nærskipsfart og 700 lavutslippsskip. Zerocoaster kan være løsningen.

Solvang-skip får karbonfangst og lagring om bord

Rederiet Solvang skal i 2023 montere et CCS-anlegg om bord på etylenskipet Clipper Eos. Det blir verdens første anlegg for karbonfangst og lagring på et skip.

Skal løse skipsfartens klimagassproblem med multifuel brenselcelle

Rederiet Odfjell satser ikke alt på en hest i kappløpet for å nå nullutslipps shipping. Tester brenselcelle som kan gå på alt fra LNG med karbonfangst til ammoniakk og hydrogen.

Source: Teknisk Ukeblad

DISSEMINATION > International arena

SNAME
THE INTERNATIONAL COMMUNITY FOR MARITIME AND OCEAN PROFESSIONALS

MARE FORUM
• EST 1999 •

ITTC

IMO

ISO

IWSA International Windship Association

European Commission

SCIENTIFIC PUBLICATIONS

Journal articles

Cariou, P., Lindstad, E., Jia, H. 2021. The impact of an EU maritime emissions trading system on oil trades, Transportation Research Part D: Transport and Environment, 99(2021)

Ghimire, P., Zadeh, M., Pedersen, E., Thorstensen, J. 2021.. Dynamic modeling, simulation, and testing of a marine DC hybrid power system. IEEE Transactions on Transportation Electrification

Gupta, P., Taskar, B., Steen, S., Rasheed, A. Statistical modeling of Ship's hydrodynamic performance indicator. Applied Ocean Research 2021.

Karimi, S., Zadeh, M. and Suul, J. A. "A Multi-Layer Framework for Reliability Assessment of Shore-to-Ship Fast Charging System Design," in IEEE Transactions on Transportation Electrification , 2021.

Kramel, D., Muri, H., Kim, Y., Lonka, R., Nielsen, J. B., Ringvold, A., Bouman, E. A., Steen, S., Strømman, A. H. Global Shipping Emissions from a Well-to-Wake Perspective: The MariTEAM model. Environmental Science and Technology 2021.

Lagemann, B.; Seidenberg, T.; Jürgenhake, C.; Erikstad, S. O. & Dumitrescu, R. (2021). System alternatives for modular, zero-emission high-speed ferries. SNAME International Conference on Fast Sea Transportation, doi.org/10.5957/FAST-2021-054

Lindstad, E., Lagemann, B., Rialland, A., Gamlem, G., Valland, A., 2021 Reduction of Maritime GHG emissions and the potential role of E-fuels. Transportation Research Part D

Tavakoli, Sadi; Malekibagherabadi, Kamyar; Schramm, Jesper; Pedersen, Eilif.
Fuel consumption and emission reduction of marine lean-burn gas engine employing a hybrid propulsion concept. International Journal of Engine Research 2021 s.

Gupta, et al. (2021). Statistical Modeling of Ship's Hydrodynamic Performance Indicator. Applied Ocean Research 111 (2021) 102623. doi.org/10.13140/RG.2.2.10492.56964

Gupta P., Rasheed A., Steen S. (2021) Ship Performance Monitoring using Machine-learning. Submitted to Journal of Ocean Engineering, preprint arXiv:2110.03594 (2021).

Conference articles

Dæhlen, J., Sandvik, E., Rialland, A., Lagemann, B. A Method for Evaluating Ship Concepts in Realistic Operational Scenarios using Agent-based Discrete-Event Simulation. COMPIT'21 - 20th Conference on Computer and IT Applications in the Maritime Industries; 2021-08-09 - 2021-08-10

Karimi, S., Zadeh, M. and Suul, J. A. " Operation-based Reliability assessment of Shore-to-Ship Fast Charging Systems," 58th Industrial & Commercial Power Systems Technical Conference) (ICPS) (Accepted for presentation.)

Lagemann, B., Seidenberg, T., Jürgenhake, C., Erikstad, S.O., and Dumitrescu, R. 2021. System alternatives for modular, zero-emission high-speed ferries, SNAME International Conference on Fast Sea Transportation, Providence, Rhode Island, USA, October 2021

Lindstad, E., Rialland, A., Gamlem, G., Valland, A., 2021 Assessment of Alternative Fuels and Engine Technologies to Reduce GHG. SNAME maritime convention 2021. Rode Island 27-29 October 2021

Muri, H. On track to meet the Paris Agreement?. Energy Transition Conference; 2021-04-26

Rialland, A., Lindstad, E. Shipping decarbonization scenarios, 29th Conference of the International Association of Maritime Economists, IAME, 25-27 Nov. 2021, Rotterdam NL.

Malekibagherabadi, Kamyar; Skjong, Stian; Pedersen, Eilif. Bond Graph Approach for Modelling of Proton Exchange Membrane Fuel Cell System. I: Proceedings Of The 2021 International Conference On Bond Graph Modeling And Simulation (ICBGM'2021). The Society for Modeling and Simulation International 2021 ISBN 978-1-7138-3946-0. s. 192-2041

LECTURES

Media / interview / podcast

Muri, H. Abels Tårn. NRK P2 [Radio] 2021-06-11

Muri, H. "Code red for planet Earth" - latest findings by the IPCC. NTRANS webinar; 2021-08-25

Muri, H. Karbonfangeren. Ukeadressa 2021-10-30

Muri, H. Klimahåp i havet. Gemini, 2021-04-21

Muri, H; Strømman, A H. :FNs klimapanel Det er mulig å unngå de verste konsekvensene. Forskning.no 2021-08-10

Muri, H; Strømman, A H. Rapid action can help prevent the worst consequences of global warming. Norwegian SciTech News 2021-08-09

Kramel, D; Muri, H; Strømman, A H; Kim, Y; Lonka, R; Nielsen, J B; Ringvold, A; Bouman, E A; Steen, S. A novel bottom-up global ship emission inventory for conventional and alternative fuels in a well-to-wake approach. EGU Annual General Assembly 2021; 2021-04-30

Conference lecture

Lindstad, E. Designing the Ship of the Future 2. MARE FORUM; 2021-01-07

Lindstad, E. Alternative Fuel Pathways. 3rd Greentech in Shipping Virtual Forum; 2021-03-02

Lindstad, E. Designing the Ship of the Future 3. MARE FORUM; 2021-02-04

Lindstad, E. Designing the Ship of the Future 4. MARE FORUM; 2021-03-04

Lindstad, E. Methodology to calculate the life cycle, well-to-wake (WTW) Greenhouse gas (GHG) emissions of fuels used onboard ships.. European commission – ESSF, 2021-03-17

Lindstad, E. Designing the Ship of the Future 5. MARE FORUM; 2021-04-01

Lindstad, E. Scrubbers and Conventional Fuels versus " E-fuels ans Synthetic E-fuels". Riviera; 2021-04-06

Muri, Helene. On track to meet the Paris Agreement?. Energy Transition Conference; 2021-04-26

Lindstad, E. Designing the Ship of the Future 6. MARE FORUM; 2021-05-06

Lindstad, E. Hvor er de største teknologiske barrierene mot omstilling til Grønn skipsfart. Digitalt web-møte; 2021-05-21

Lindstad, E. Alternative Fuel Pathways- The key role of shippers in the de-carbonization of Maritime Transport. Movin on Summit - SC4Good@MOS21; 2021-06-01

Lindstad, E. Designing the Ship of the Future 7. MARE FORUM; 2021-06-03

Lindstad, E. Hvordan kan utslippene fra skipsfarten reduseres med minst 50% før 2050. Norges Rederiforbund Trainee Program; 2021-06-09

SMART MARITIME

STATEMENT OF ACCOUNTS 2021

	Funding		Cost	
Research council	10 848	(37 %)		
The Host Institution (SINTEF ocean)	8 859	(30 %)	12 756	(43 %)
Research Partner (NTNU)	4 197	(14 %)	12 887	(43 %)
Industry partners	5 813	(20 %)	4 026	(14 %)
Equipment			48	(0.2 %)
Total NOK ‘000	29 717		29 717	

Foto: Sjøfartsdirektoratet

Illustration: Zero emission ferries, HAV Design

SMART MARITIME

sfi Centre for Research-based Innovation

The Research Council of Norway

ANNUAL REPORT 2021

Host: SINTEF Ocean, Marinteknisk senter Tyholt, Otto Nielsens vei 10, 7052 Trondheim • PO.Box 4125 Valentinlyst, NO-7450 Trondheim • Web: www.smartmaritime.no