Senter for forskningsdrevet innovasjon

SMART MARITIME

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

ANNUAL REPORT 2019

TABLE OF CONTENTS

Cover picture: Vard designer cruiseskip med vindkraft. Foto: Vard.

SMART MARITIME

SUMMARY OF 2019

BW Pavilion Leeara, Photo: BW Group

SUMMARY OF 2019

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 focus is on technological solutions within hydrodynamics - hull and propellers - and machinery system - energy optimization, exhaust emissions and fuels.

Research activity is conducted in collaboration between SINTEF Ocean, NTNU and the Centre's 21 industry partners are leading maritime actors: 10 solutions and technology providers ABB, Bergen Engines, DNV GL, Jotun, Kongsberg Maritime, Havyard Group, Norwegian Electric Systems, SIEMENS, Vard Design, Wärtsilä Moss; 8 of the biggest Norwegian deepsea ship owners, Wallenius Wilhelmsen, Solvang, Grieg Star, Kristian Gerhard Jebsen Skipsrederi, BW Gas, Höegh Autoliners, Odfjell, and Torvald Klaveness; as well as the Norwegian Shipowner association, the Norwegian Coastal Shipowners Association, and the Norwegian Maritime Authority.

The strength of the Centre is our network and the frequent and constructive dialog between our research community and industrial 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: carried out a review of 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 ships, and together we bear the responsibility to identify realistic and feasible solutions for upgrading the global merchant fleet and reducing shipping emissions by 50%.

2019 has been a milestone year for Smart Maritime.

- The Centre has increased focus on the simulation platform and ship concepts for demonstrating possible solutions to achieve energy efficiency and emissions reductions necessary for a sustainable maritime industry.
- The Centre has demonstrated the potential that can be reached when combining efforts, through Demo-cases of Deep Sea low Emissions ship concepts and one Zero emission cruise concept.
- We have started 7 associated research and innovation projects
- We have received confirmation of trust and support from the Research Council of Norway. After mid-way evaluation, we received green light to continue until the end of the Centre's funding period (2015-2023).
- We have grown and welcome on board 4 new partners: ship owners and operators BW Gas, Höegh Autoliners, Odfjell, Torvald Klaveness.
- We have reinforced our research team with 4 new PhD

In 2019, SFI Smart Maritime has published 11 scientific publications, 20 conference lectures and academic presentations, 14 media contributions.

SMART MARITIME

Highlights from 2019

The main scientific achievements are presented in the section “Scientific activities and results” on page 35-49.

SIMULATION PLATFORM

- Smart Maritime simulation platform
- Gymir, Ship Performance Simulation

DEMONSTRATION CASES

- Zero-emission cruise
- Low-emission deep-sea vessel: vessel concept and simulation

POWER AND PROPULSION

- Model Predictive Control of Marine Power Plants With Gas Engines and Battery
- Methane Slip Summarized: Lab vs. Field Data
- Shipboard Electric Power Conversion

HYDRODYNAMICS

- On Total Resistance of Ships in a Seaway
- Length and hull shape importance to reach IMO's GHG target
- The need to amend IMO’s EEDI to include a threshold for performance in wave
- Analysis of in-service data of ship performance

Clipper Hebe. Photo: Solvang

NORSK SAMMENDRAG

SFI Smart Maritime fokuserer på forbedring av energieffektivitet og reduksjon av skadelige utslipp fra skip. Senteret søker å forsterke konkurransekraften til norsk maritime industri gjennom ny teknologi, verktøy og effektive løsninger på industriens utfordringer. Målet er å finne svar på hvordan det er mulig å oppnå økt energieffektivitet og reduserte utslipp innen den maritime sektoren, også med bruk av konvensjonell teknologi og drivstoff. De tekniske forskningsområdene er innenfor hydrodynamikk (skrog og propell) og fremdriftsmaskineri (energioptimalisering, avgassutslipp og drivstoff), og det legges vekt på betrakting av skipet som system. Smart Maritime jobber med utvikling av systemorienterte verktøy som analyserer effekten av energieffektiviserende løsninger og tiltak for skrog og propell, kraftsystemer og drivstoff under realistiske operasjonsmønster og værforhold. Målet er å kunne effektivt simulere og optimalisere skipet virtuelt i tidlig designfase. Smart Maritimes verktøykasse suppleres en livssyklus modell for analyse av miljøpåvirkning av nye tiltak på skips- og flåtenivå.

Bedriftspartnerne våre er toneangivende maritime bedriftene ABB, Bergen Engines, DNV GL, Jotun, Kongsberg Maritime, Havyard Group, Norwegian Electric Systems, SIEMENS, Vard Design, og Wärtsilä Moss, samt 8 av de største norske deepsea rederiene Wallenius Wilhelmsen, Solvang, Grieg Star, Kristian Gerhard Jebsen Skipsrederi, BW Gas, Höegh Autoliners, Odfjell, Torvald Klaveness, og Norges Rederiforbund, Kystrederiene og Sjøfartsdirektoratet.

Senterets styrke er vårt nettverk og den jevnlige og konstruktive dialogen mellom forsknings- og industripartnerne. Smart Maritime har etablert seg som en tiltrekkende møteplass og samarbeidsplattform innen energieffektive og miljøvennlig shipping.

Siden oppstart i 2015 har Smart Maritime utviklet og satt i bruk kraftige analyse- og prediksjonsmodeller og verktøy for beregning og simulering av tekniske løsninger innen energieffektivisering og utslippsreduksjon. Disse verktøyene er testet og brukt i cases i samarbeid med industri og har bidratt til utvikling av lav- og null-utslipps skipskonsepter.

Det er ingen tvil om at den norske maritime klyngen er tilordnet til å redusere utslipp og miljøpåvirkning fra skip og bidra til IMOs mål, og senteret skal ikke gi seg før dette er oppnådd.

2019 har vært en milepæl for Smart Maritime.

- Senteret har spisset aktiviteten mot simuleringsverktøyene og skip konsepter som demonstrerer mulige løsninger for å oppnådd energieffektivisering og utslippsreduksjon som er nødvendig for en mer bærekraftig maritime sektor.
- Senteret har anvendt simulatoren i mulighetsstudier og har utforsket potensialet som kan oppnås gjennom demo-case av deepsea lav utslipps skip og null-utslipps cruise skip.
- Senterets forskning og industri deltakere har satt I gang 7 assosierte forskning- og innovasjonsprosjekter.
- Senteret har fått bekreftet Forskningsrådets tillit og støtte til SFI SmartMaritime. Som følge av midtveisevaluering, har vi fått grønt lys til å fortsette fram til slutten av finansieringsperiode (2015-2023).
- Senteret har vokst med fire nye rederipartnerne: BW Gas, Höegh Autoliners, Odfjell, Torvald Klaveness.
- Senteret har forsterket sitt Research team med fire nye doktorgradsstudenter.

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. This position will be gained through innovative use, improvement and combination of technologies, which are cost-, energy- and emission efficient, and will strengthen the competitiveness of the Norwegian maritime industry.

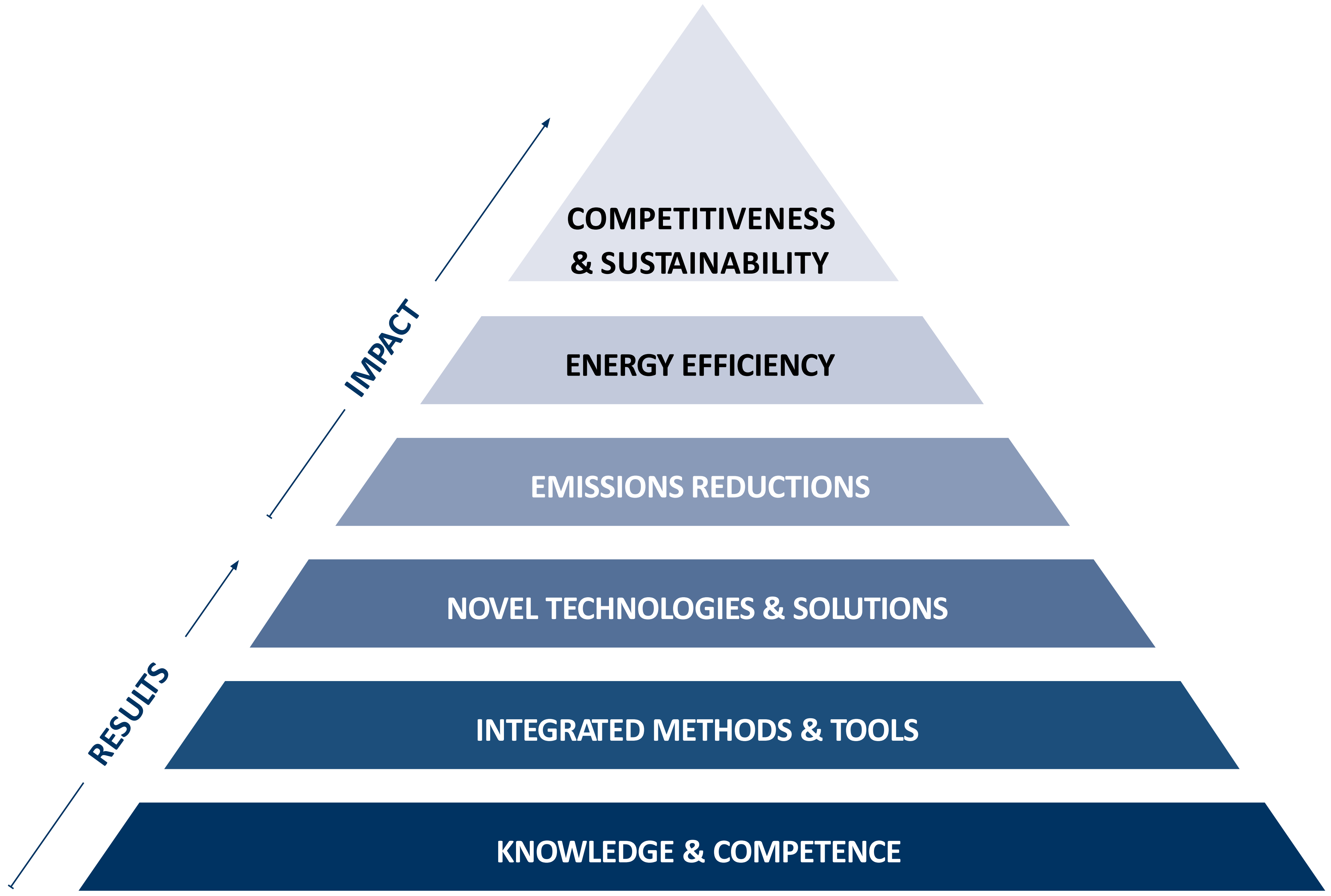
Our mission is to provide the Norwegian maritime sector with knowledge, methods and tools for effective identification and assessment of solutions and technologies.

MV Baru, Maiden voyage, Bunbury. Photo: Torvald Klaveness

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:

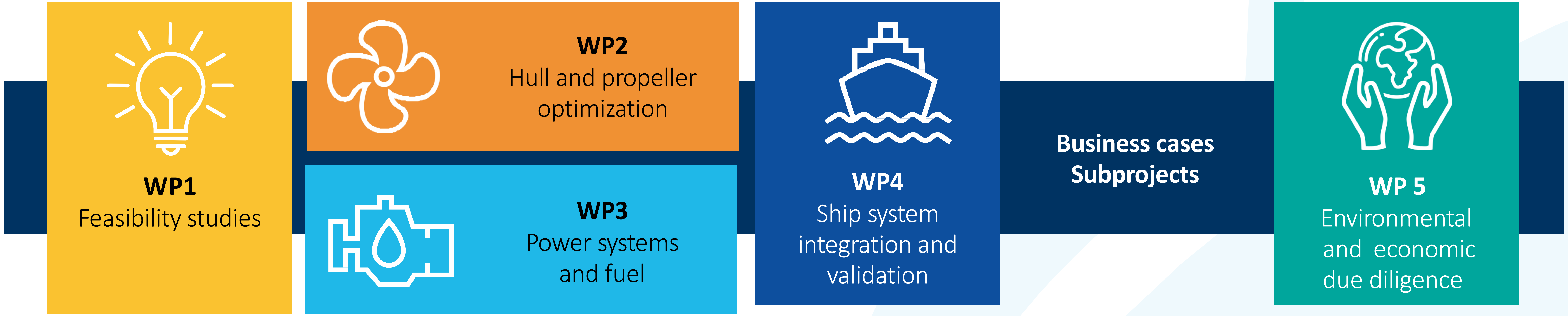
1. More efficient and accurate early stage assessment of new ship designs.
2. Introduce new validation methods, such as correlating data from real-life conditions with simulation- and experimental data.
3. More accurate predictions of fuel consumption and emissions from alternative hull, propulsion and 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.



RESEARCH STRATEGY AND PLAN

Högh Traveller, Höeh Autoliners_Photo credit: Ignacio-Rey

WORK PACKAGES / RESEARCH AREAS



The research activity is divided into five work packages (WP). These follow a concept development process: WP1 produces feasibility studies to screen the most promising options for energy and emissions reductions. These are further explored and tested in WP2 and WP3. Thereafter WP4 offers a ship system integration platform based on models developed in WP2 and WP3, and used to validate solutions and technologies through simulation of ship performance. Finally, WP5 completes the concept development process by providing environmental and economic due diligence of concepts and solutions at ship and fleet level.

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)

Focus 2019

- Hybridization and other options for meeting EEDI 2025
- Measures and options for 50% GHG reduction
- 2020 Sulphur cap options
- Contribution to specification of rapid hull model estimator to be implemented in the simulator Gymir

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.

Focus 2019

- Frictional resistance reduction
  - Effect of roughness and fouling
  - Use of super-hydrophobic surface, flow separation control and detection
- Utilization of in-service data
  - «Big data» analysis and machine-learning methods
- Performance in a Seaway
  - Safe return to port calculations
  - Speed loss and added power due to steering and manoeuvering
  - Supporting the tools development related to Gymir
  - Added resistance – Amplitude dependence, model test analyses
  - Engineering-type calculation of added resistance due to waves

WP3: Power systems and fuel

Objective

Improve current designs and explore novel technologies, systems and solutions for energy efficient low emission propulsion power systems.

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 systems
Modeling and simulation of power components and systems Fuel consumption estimation Steady-state and transient operation modes Alternative 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	Hybrid concepts Energy storage systems (batteries) Energy converters and transmissions Optimal control

Focus 2019

Models for simulation of power system performance in steady-state and transient operation modes

Fully operational marine-size constant volume combustion rig capable for both liquid (including biofuels) and gas (potentially hydrogen) fuel studies

- Modelling of emission abatement systems and alternative power cycles
- Assessment of feasibility and advantages of WHR systems

Better utilization of batteries for different applications in maritime sector through optimization of power and energy management

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

Focus 2019

Proof-of-concept implementation of Gymir, incl.:

- Hull and propulsor models from WP2
- Machinery simulator from WP3

Testing Gymir on use-cases:

- deep-sea shipping
- expedition cruise

Validation study comparing simulated and measured fuel consumption.

WP5: Environmental and Economic Due Diligence

Objective

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

Research need and background:

Both maritime trade and international 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 costs assessment of current and novel ship designs. In addition, there is a lack of good approaches for integration of such assessments with ship design and engineering workflows. WP5 will integrate state of the art methods for detailed environmental and economic analyses.

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	Environmental impacts throughout supply chain and service lifetime established	Fleet and route development Comparisons of technology option

Focus 2019

Data access, aquisition, cleaning:

- Weather data
- Ship profiles
- Port call data

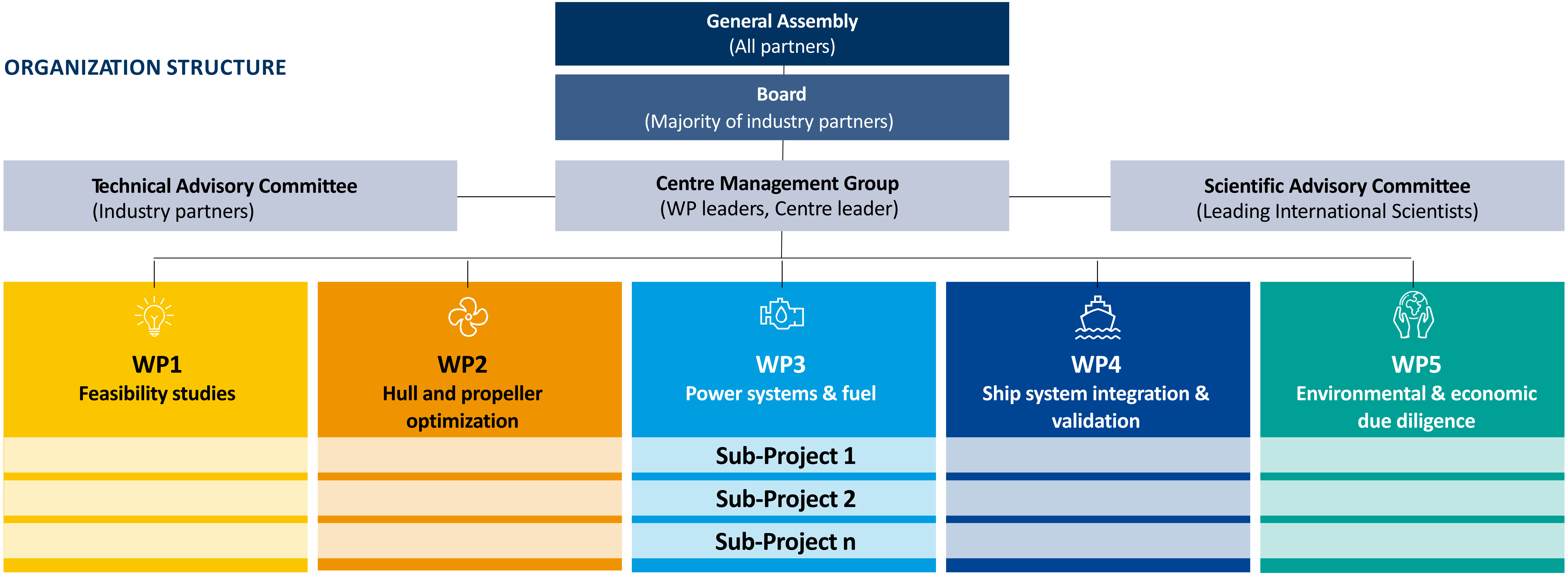
Model development and test

- Implement and test weather drag module
- Develop and test ship track completer
- Matching of each vessel's location with instantaneous wind and waves
- Creation of emission curves for species: CO2, SOx, NOx,BC, CO, OC, EC

ORGANIZATION

Esvagt Froude, Photo: Havyard Group

ORGANIZATION STRUCTURE



Matrix organization with long-term research performed in **Work Packages** (WP), and short-term cross-disciplinary applied research in collaboration with industry partners performed in **Sub-Projects** (WP).

Board: operative decision-making body (7 members, mostly from industry)

General assembly: ultimate decision-making body of the Project

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

Technical Advisory Committee (TAC): advise the Centre Management on prioritization of R&D activities (WP and SP) to be conducted within Smart Maritime. The TAC is gathered together twice a year at the biannual Network Meetings.

Board Members	Affiliation
Jan Øivind Svardal *(Chairman)*	Grieg Star
Jan Fredrik Hansen	ABB
Per Ingeberg	Rolls-Royce Marine
Kjell Morten Urke	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

Per Ingeberg

Jan Fredrik Hansen

Beate Kvamstad-Lervold

Kjell Morten Urke

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 &	NTNU	WP2 Hull and Propeller
Sverre Anders Alterskjær	SINTEF Ocean	
Mehdi Zadeh	NTNU	WP3 Power systems and Fuel
Jon Dæhlen	SINTEF Ocean	WP4 Ship system Integration
Anders Strømman &	NTNU	WP5 Environment and economy
Helene Muri	NTNU	

Centre administration

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

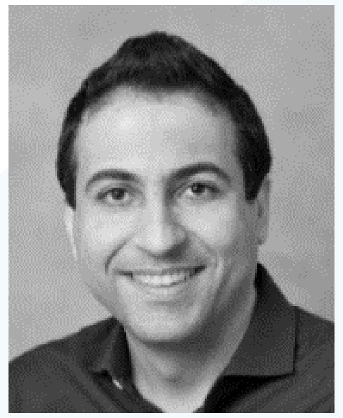

Trond Johnsen


Anders Valland


Elizabeth Lindstad


Sverre Steen


Sverre Anders Alterskjær


Mehdi Zadeh


Jon Dæhlen


Anders Strømman


Helene Muri


Agathe Rialland


Jan Andre Almåsbakk

Technical Advisory Committee - Partners primary contacts

ABB
Jan-Fredrik Hansen

Bergen Engines
Leif Arne Skarbø

BW LNG
Olav Lyngstad

DNV GL
Hendrik Brinks

Grieg Star
Jan Øivind Svardal

Havyard Group
Kristian V. Steinsvik

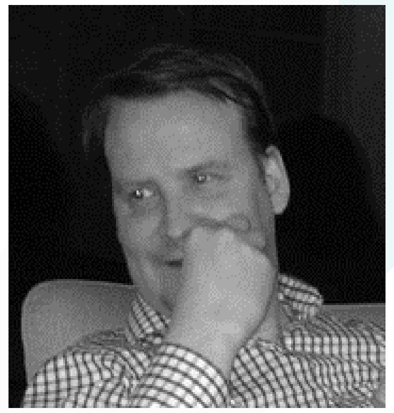
Jotun
Angelika Brink

Höeh Autoliners
Christian Dahll

KG Jebsen Skipsrederi
Ole-Johan Haahjem

Kystrederiene
Tor Arne Borge

Kongsberg Maritime
Per Ingeberg



Odfjell
Veine Huth

Norwegian Electric Systems
Ole Georg Rørhus

Norges Rederiforbund
Gunnar Malm Gamlem

Siemens
Stig-Olav Settemsdal

Sjøfartsdirektoratet
Kolbjørn Berge

Solvang
Tor Øyvind Ask

Torvald Klaveness
Christoffer Bøhmer

VARD
Kjell Morten Urke

Wallenius Wilhelmsen
Lars Dessen

Wärtsilä Moss
Sigurd Jenssen

Roar Fanebust, **Grieg Star**
Coordinator of T.A.C

PARTNERS

The Centre collaborates closely with global industry players, national and international research communities and maritime networks.

SINTEF Ocean hosts the Centre in collaboration with research partners NTNU and NTNU Aalesund. The industry partners, together forming the Technical Advisory Committee, cover major parts of the maritime value chain: ship system suppliers, ship designers, ship owners and stakeholder groups.

These partners are involved in scientific activity through business cases and subproject activity across the WPs.

Photo: Sjøfartsdirektoratet.

INDUSTRY PARTNERS

Design, shipbuilding & equipment

ABB
Bergen Engines
Havyard
Jotun
Kongsberg Maritime
Norwegian Electric Systems
Siemens
Vard Design
Wärtsilä Moss

Ship operators

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

Other partners

DNV GL
Norwegian Shipowners' Association
Norwegian Maritime Directorate Kystrederiene

RESULTS

Knowhow Technologies
Concepts Solutions

Problem description
Operational experience
Personnel and resources
Infrastructure
(ships & equipment)

SMART MARITIME

SINTEF

NTNU

Education
Basic/applied research
Maritime experience
Laboratories

International network and customers

International R&D partners

RESEARCH PARTNERS

SINTEF Ocean (host)

NTNU
Department 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.

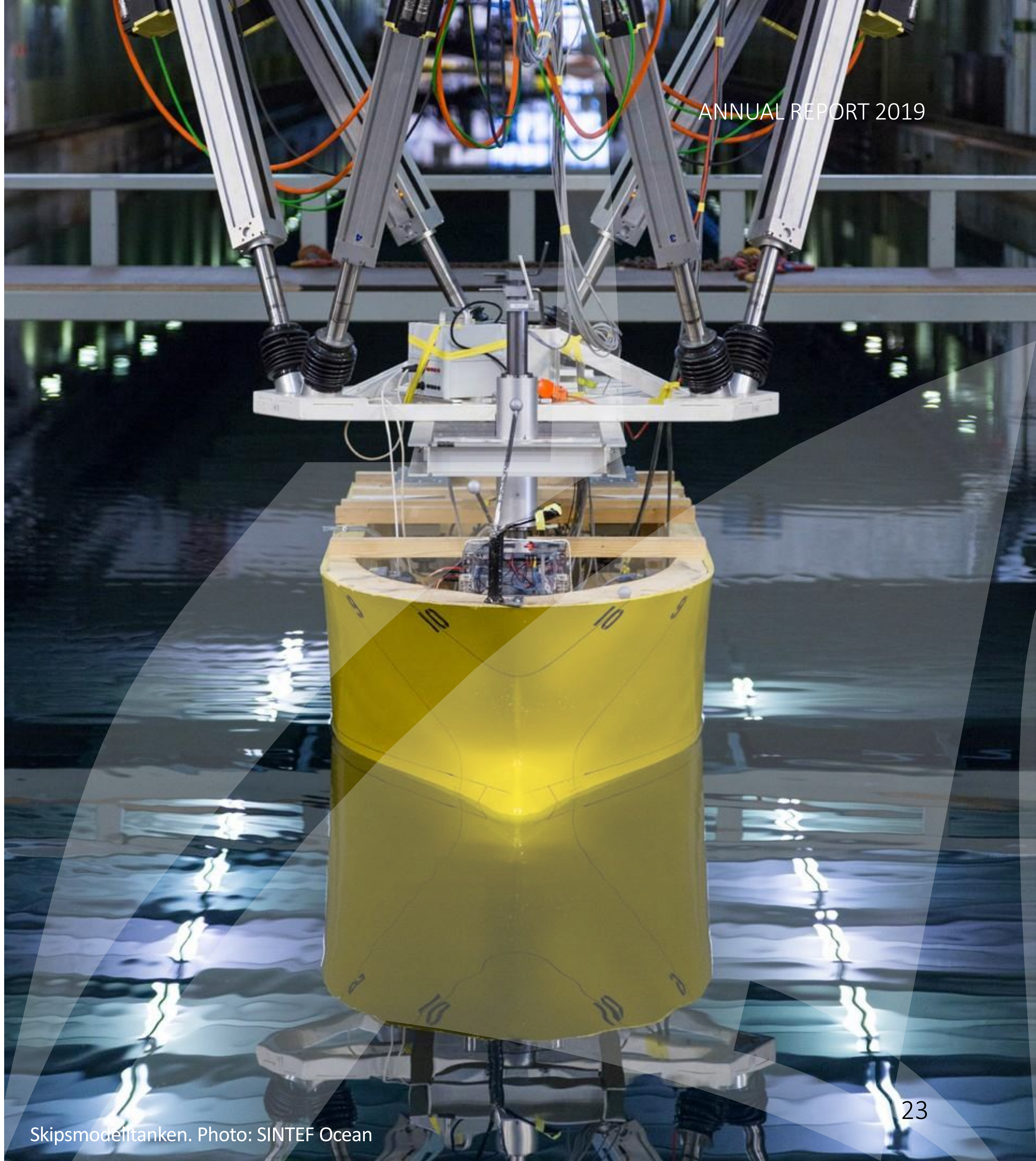
FUTURE INTEGRATION INTO THE OCEAN SPACE CENTRE

NTNU and SINTEF Ocean have developed a joint strategy for Ocean Space Centre where Smart Maritime is one of five strategic areas for research and education.

SINTEF Ocean is planning to carry on Smart Maritime activity beyond 2023 and ultimately integrate it into the Ocean Space, thus continuing the joint effort between SINTEF Ocean, NTNU and the Norwegian maritime industry.

The Ocean Space Centre (OSC) Centre is estimated to come into place by 2025, and will be the largest single investment in maritime research infrastructure in modern times in Norway.

SFI Smart Maritime will contribute strongly to the development the OSC machinery and seakeeping laboratories in terms of building the necessary competence to run the next generation laboratory, to educate the researchers and to develop competence and systems that integrates physical testing in laboratories and in field with numeric models and simulation.



Skipsmodelltanken. Photo: SINTEF Ocean

RESEARCH PARTNERS, SERVICE AND STAKEHOLDER ORGANIZATIONS

SINTEF Ocean (Host institution)

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

DNV GL 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.

INDUSTRIAL PARTNERS – SHIP OWNERS

Grieg Star AS
Open Hatch general cargo, conventional Bulk / 34 vessels

Wallenius Wilhelmsen ASA
RoRo / 130 vessels

Höegh Autoliners AS
PCTC / 45 vessels

Solvang ASA
LPG, petrochemical gases / 27 vessels

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

Od|fjell
Chemical tanker / 120 vessels

Kristian Gerhard Jebsen Skipsrederi AS
Tanker, dry cargo, cement /50 vessels

Torvald Klaveness
Dry bulk, Container / 130 vessels

INDUSTRIAL PARTNERS – DESIGN & SHIPBUILDING

HAVYARD
CHANGE OUR INDUSTRY

Havyard Group ASA
Fully integrated Ship Technology company and deliver products and services within the complete value chain from vessel design to support of vessels in operation. Market segments include Energy, Seafood and Transport.

KONGSBERG

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™
a Fincantieri company

Vard Design AS
Major global shipbuilder of offshore and specialized vessels for offshore oil and gas exploration, production and service.

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 System AS

NES is an innovative, high-tech electrical company with a focus on diesel electric and hybrid electric systems for the global marine market.

SIEMENS AS avd corporate centre & real estate

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 (parent) delivers solutions for ship machinery, propulsion, automation, ship design, automation systems and liquid cargo solutions.

RESEARCH FACILITIES

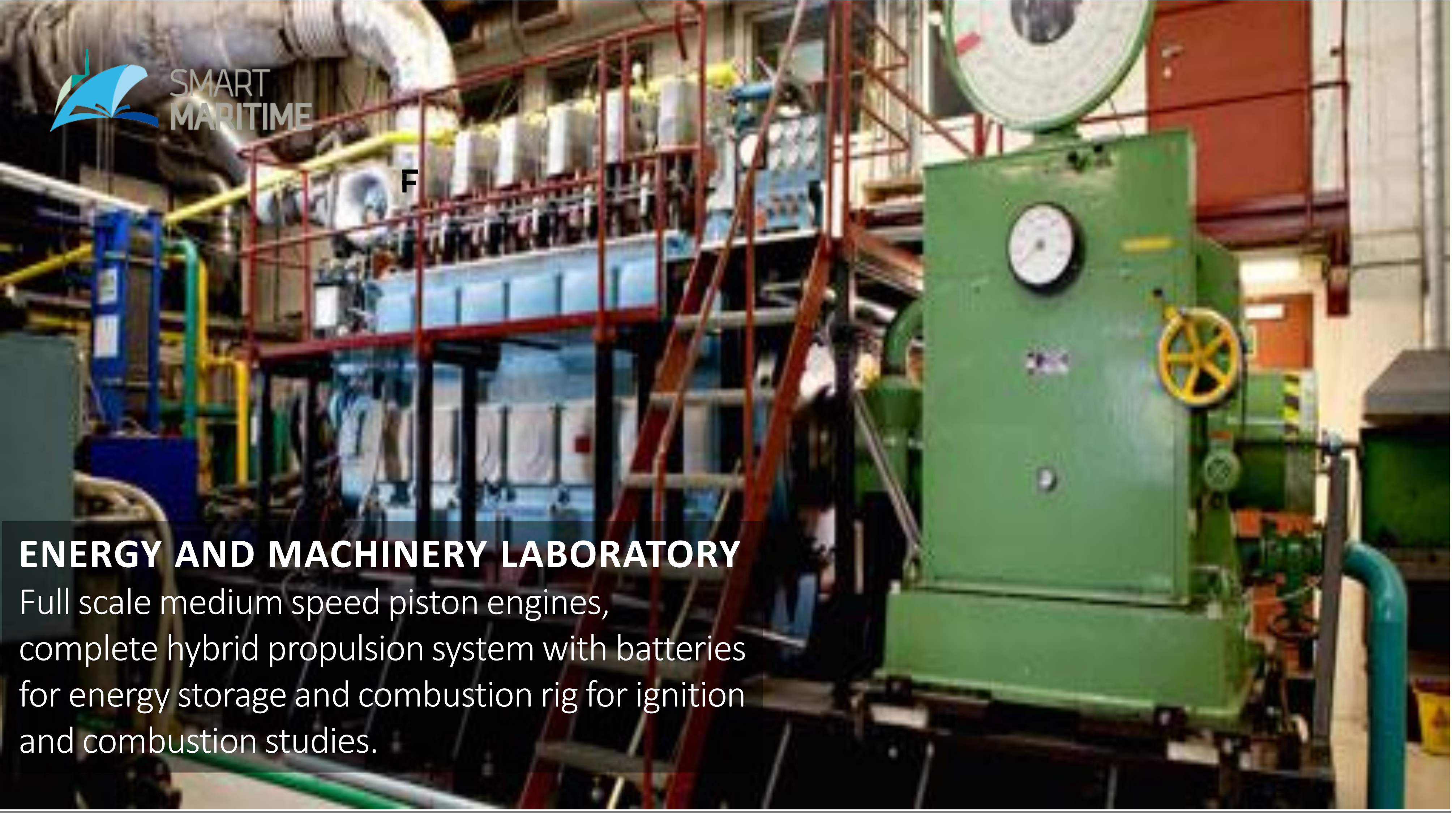
The SFI makes use of own research facilities (SINTEF OCEAN and NTNU) as well as on-site laboratories from its industry partners.

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

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)



ENERGY AND MACHINERY LABORATORY

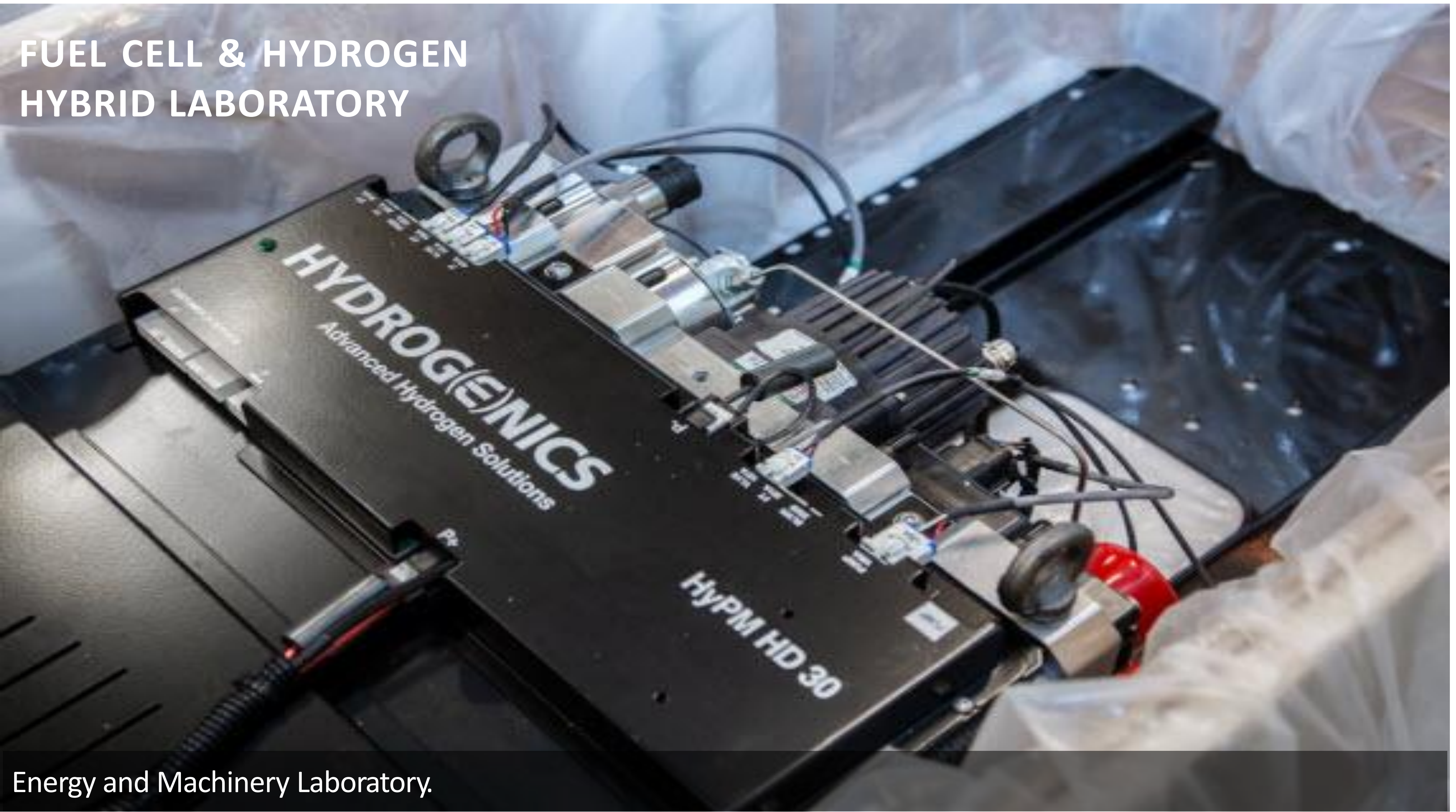
Full scale medium speed piston engines, complete hybrid propulsion system with batteries for energy storage and combustion rig for ignition and combustion studies.

Energy and Machinery Laboratory. Photo: NTNU/Sintef Ocean

COMBUSTION RIG

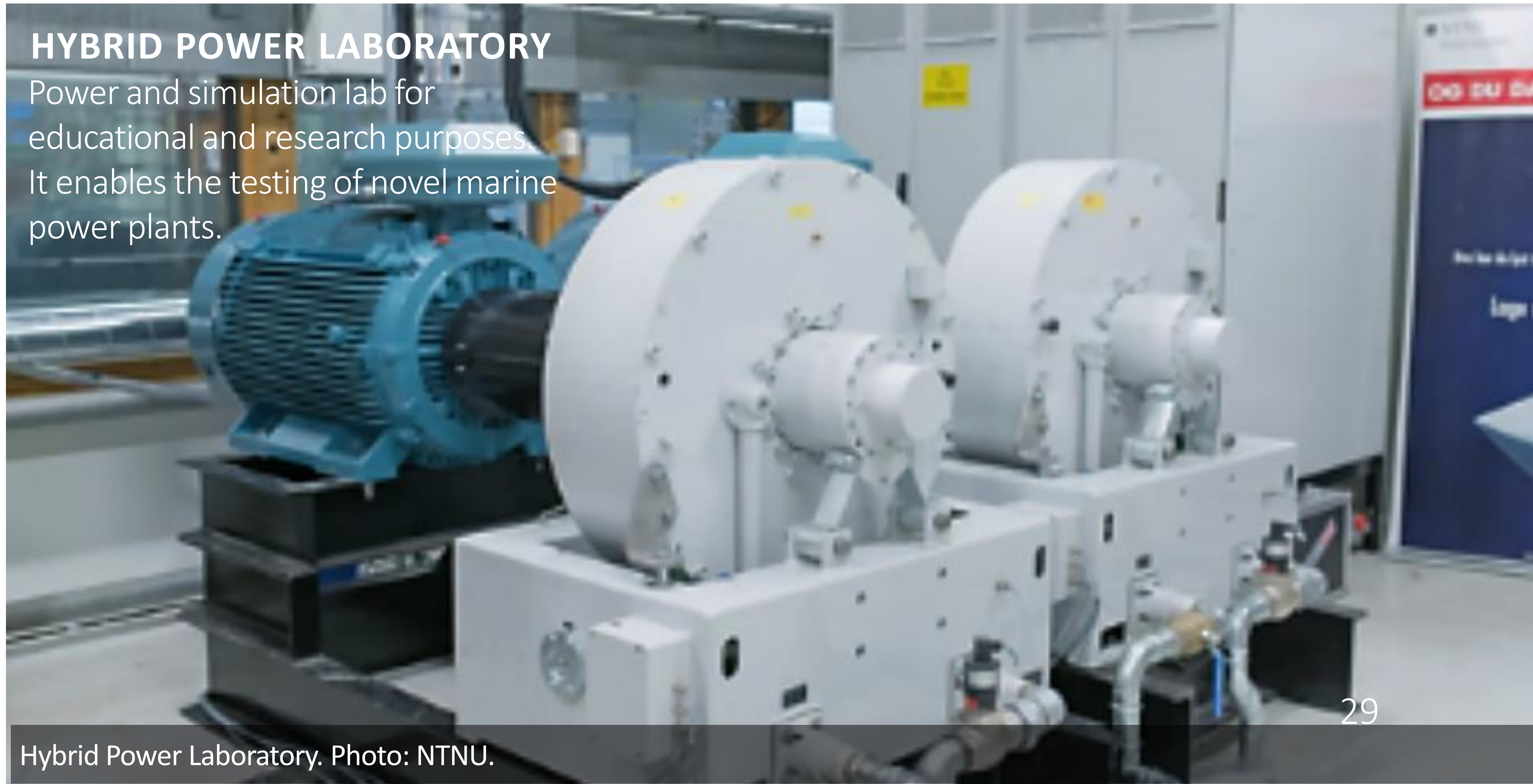
Combustion rig for ignition and combustion studies.

Energy and Machinery Laboratory. Photo: NTNU/Sintef Ocean



FUEL CELL & HYDROGEN HYBRID LABORATORY

Energy and Machinery Laboratory.

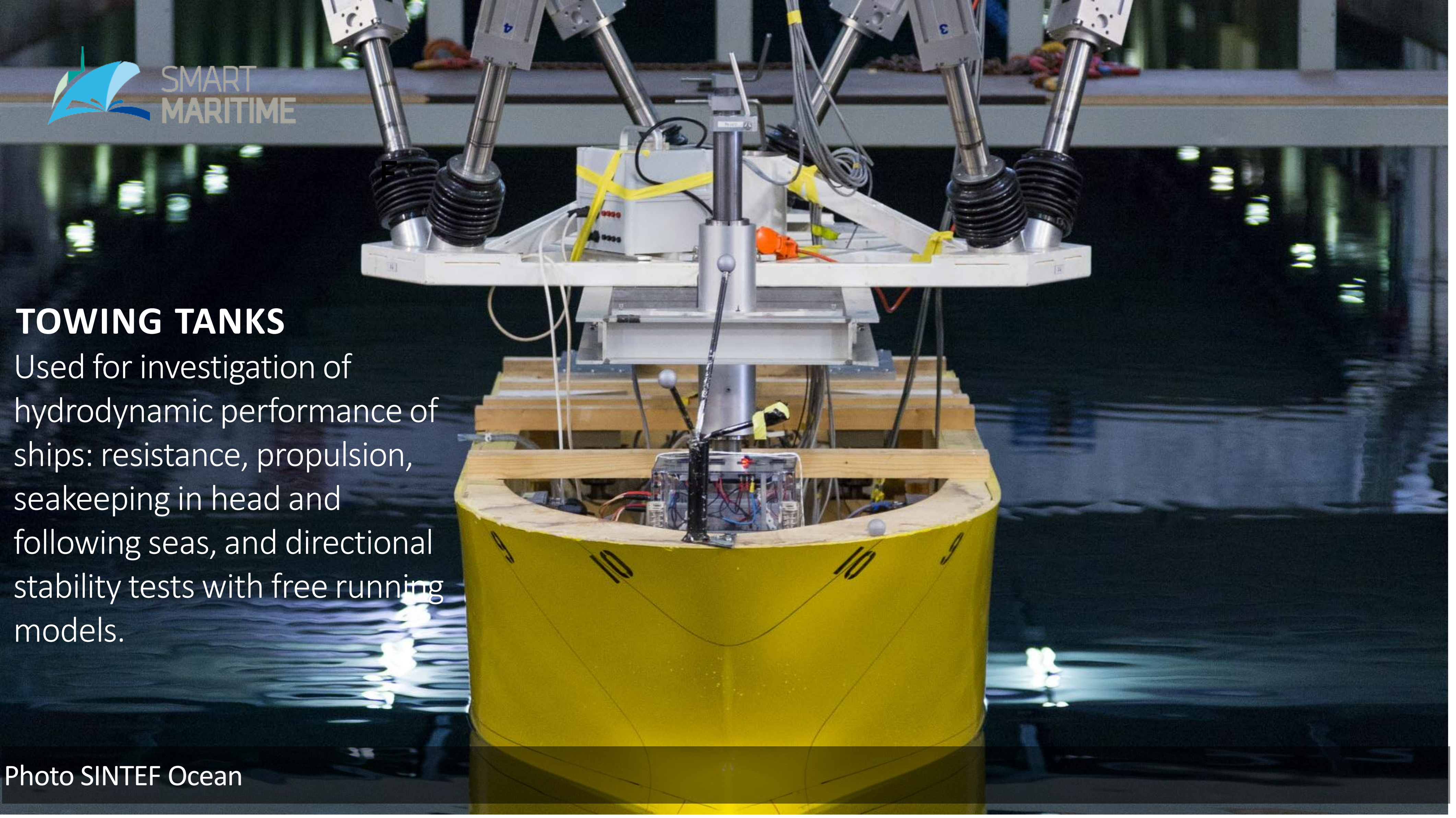


HYBRID POWER LABORATORY

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

Hybrid Power Laboratory. Photo: NTNU.

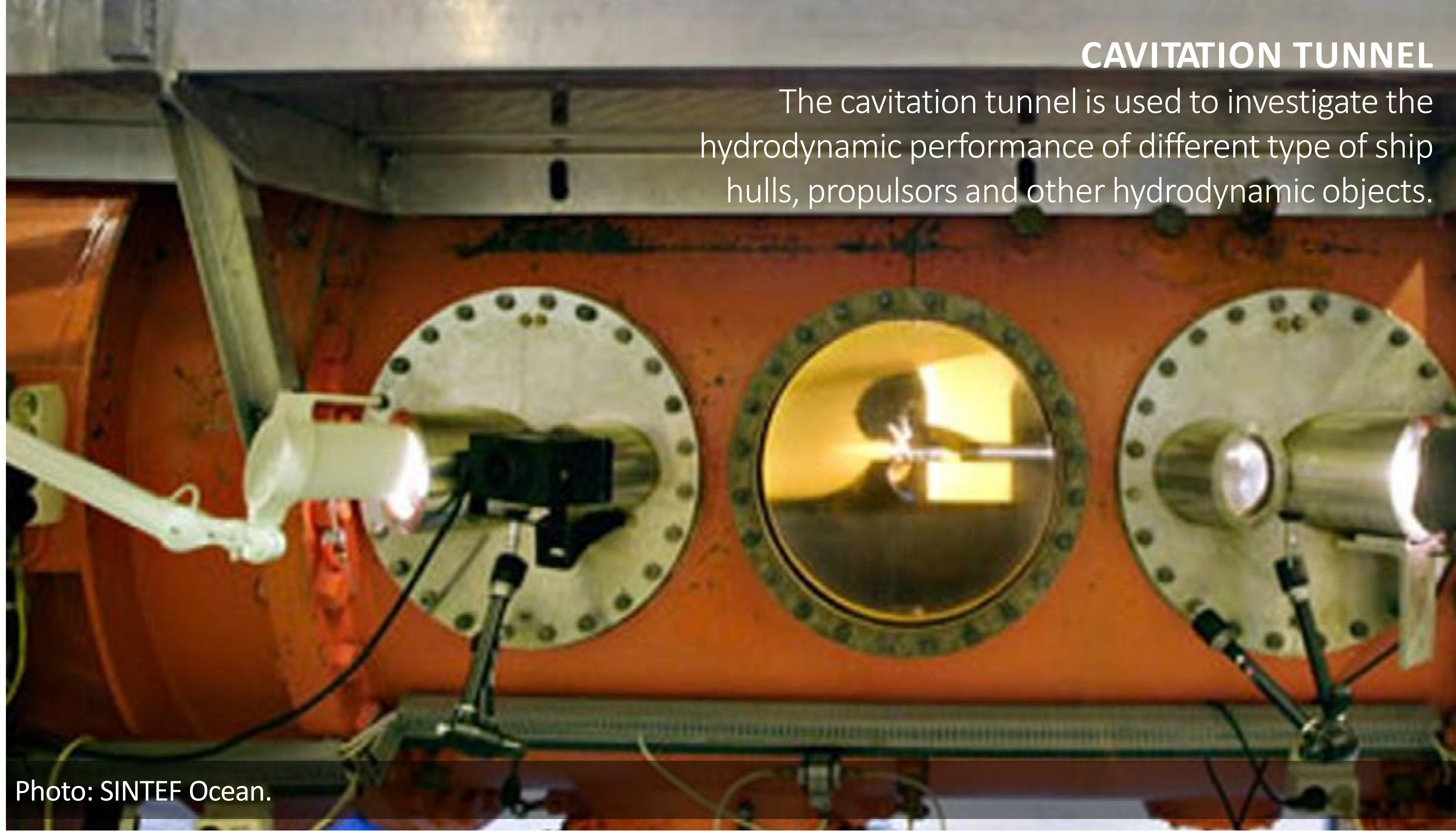
SMART MARITIME



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.

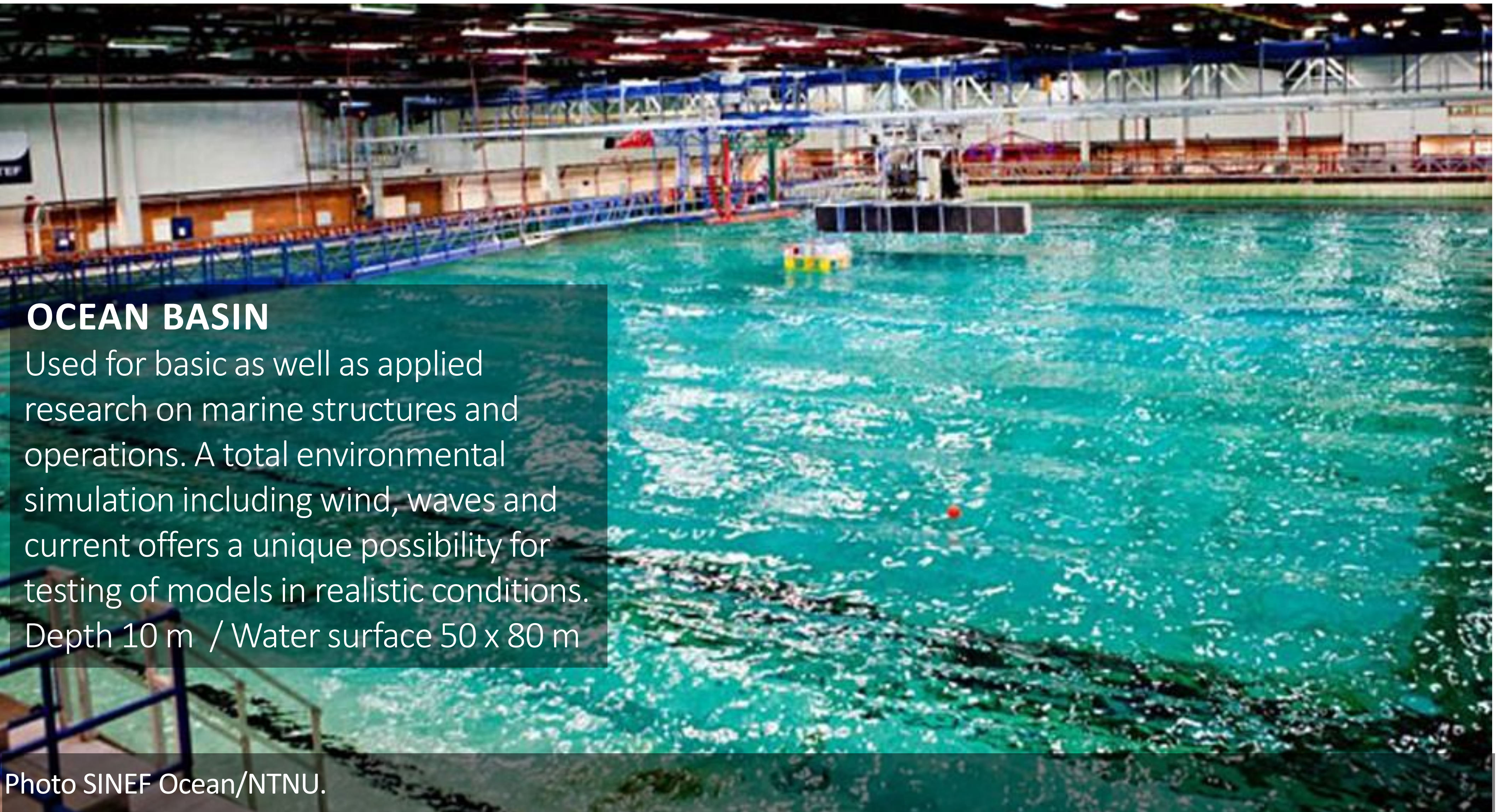
Photo SINTEF Ocean



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 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

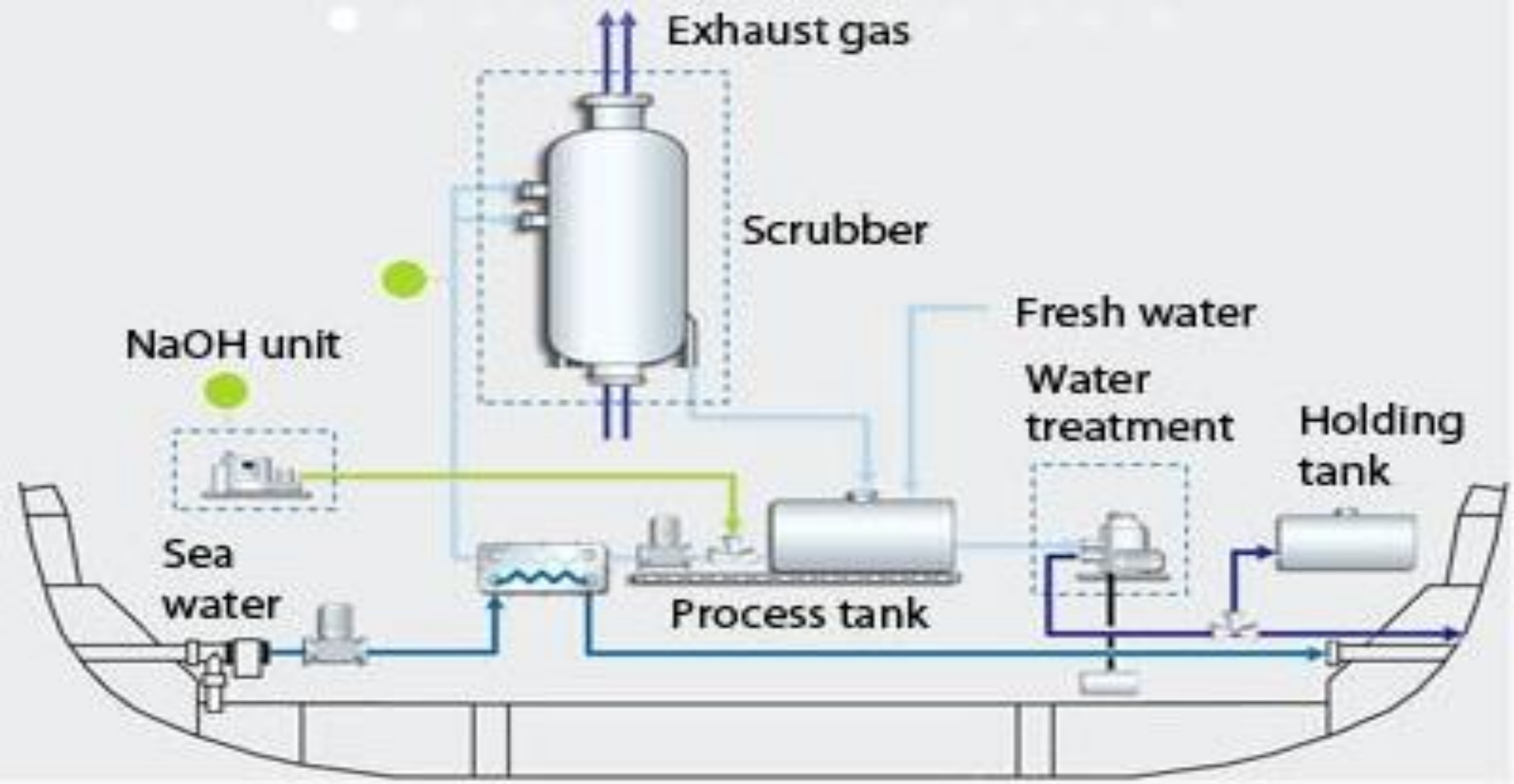
Test facility dedicated to optical measurement techniques and flow visualization.

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 Marine -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 (owner: Solvang). Photo: Solvang.

POWER SYSTEM LABORATORY (NORWEGIAN ELECTRIC SYSTEMS)

Photo: Norwegian Electric Systems

INTERACTION ACADEMIA – INDUSTRY – RESEARCH

Project cooperation

Smart Maritime enjoys a network of highly motivated industry representatives, striving for knowledge and excellence. The participation of user partners in research is generally high and is crucial for the good progress of our projects. In-kind participation lies around 20% of the annual budget.

Industry participation includes the following:

- Sharing of operational data
- Participation in measurement and tests experiments
- Laboratory or test ship made available for research
- Direct involvement in research work
- Cooperation on model and tool development
- Participation at workshops and webinars
- Scientific discussion, knowledge sharing, competence development
- Associated projects, joint initiatives for spin-off projects
- Co-supervision of and support to Master theses
- Dissemination, cooperation on scientific publication

Network meetings

Smart Maritime organizes a network meeting twice a year when the research team and the industry partners (functioning as the Technical Advisory Committee) gather for two days. The purpose is to provide a meeting place for the partners to exchange ideas and experience, receive updates and scientific lectures from the research team, discuss new challenges and launch new initiatives, and help prioritize R&D activities.

Webinars

Online seminars are offered to the Centre members for providing update on ongoing research, short presentations of selected topics and scientific discussion with meeting participants. Webinars enable the participations of a wider audience and effective dissemination of scientific activity.

NETWORK MEETINGS

OSLO, 29-30 April
Host: Norges Rederiforbund
Participants: 38

VÆRNES, 26-27 November
Host: SINTEF Ocean
Participants: 50

Photos: Rjølland.

SMART MARITIME

SCIENTIFIC ACTIVITIES AND RESULTS 2019

Bow Clipper. Photo: Odfjell

SCIENTIFIC RESULTS

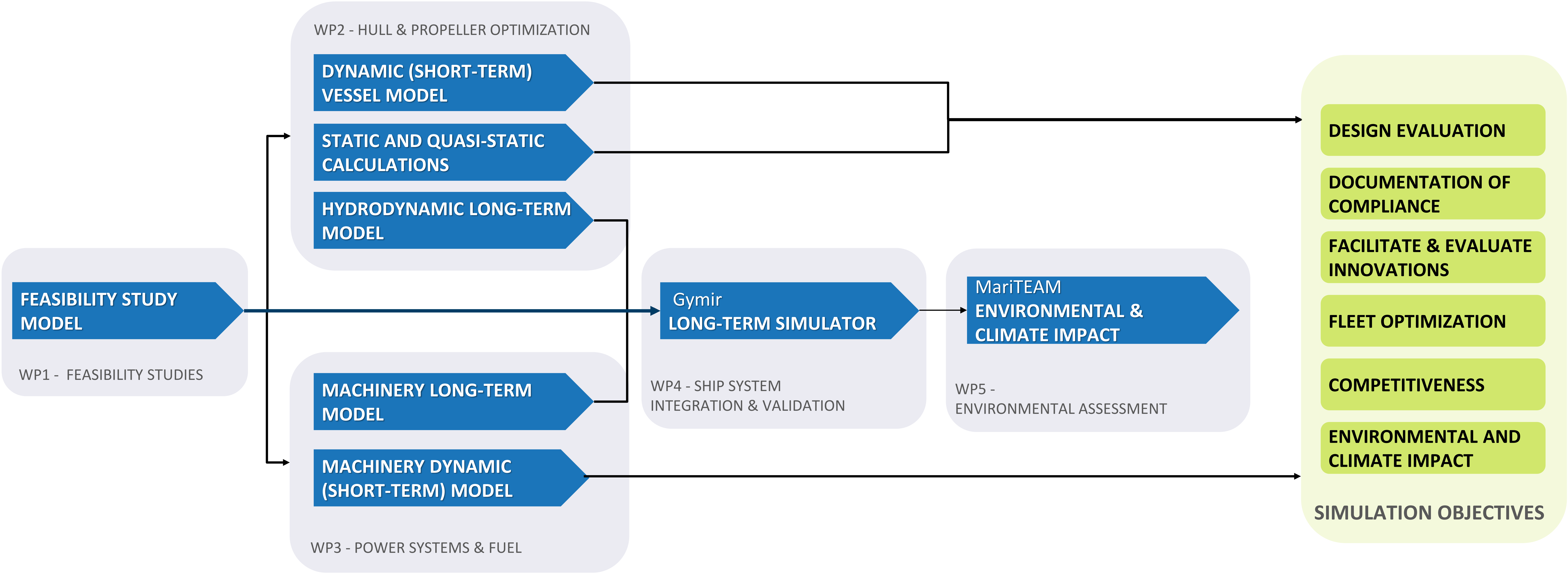
SIMULATION

Photo: Wallenius Wilhelmsen Group

Smart Maritime simulation tools

Smart Maritime works continuously with the development of a system-oriented analysis platform, whihc utility is to assess the effect of energy savings solutions and measures for hull and propeller, power systems and fuels, under realistic operation- and weather conditions.
The purpose of this analysis platform is to support the efficient and effective simulation and optimization of a ship, virtually and in an early design phase.

Simulations tools are available as stand-alone tools, as well as integrated through the Long-Term Ship Performance Simulation tool Gymir.
2019: finalisation of the integration of the machinery model into the Gymir simulation tool and carried out several validation studies, a.o. of a Medium Range Tanker and through a set of Demo Cases for low to zero GHG emission vessel concepts.



Gymir – ship performance simulation tool

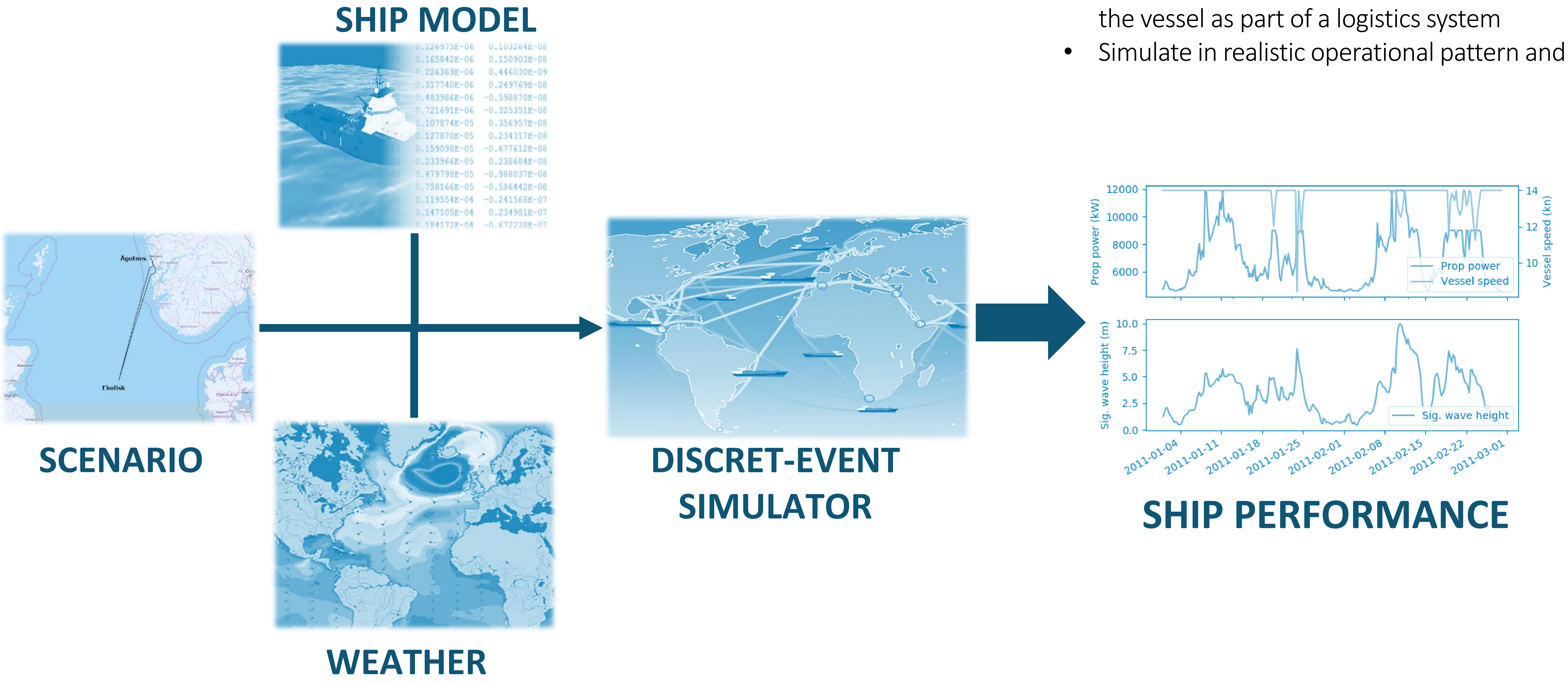
GYMIR is developed as a tool for virtual testing of ship design solutions, providing insight that improve early stage design decisions.

Goal:

- Improved early-stage ship designs
- More efficient and robust design process

Principle:

- Holistic design simulations: consider the vessels sub-systems as a whole, and the vessel as part of a logistics system
- Simulate in realistic operational pattern and weather conditions



OUTPUT

- Weather statistics
- Vessel performance: Operational profile & Predicted sea margin.
- Machinery working point & fuel/power consumption

DEMO-CASE Low Emissions Deep Sea Vessel

Objective

Reduce the carbon intensity of ships through implementation of further phases of the energy efficiency design index (EEDI) for new ships.

Reduce CO2 emissions per transport work by at least 40% by 2030, pursuing efforts to reducing them by 70% by 2050 (compared with 2008)

To peak GHG emissions from international shipping as soon as possible and to reduce annual GHG emissions by at least 50% by 2050 (compared to 2008).

Activities

- Hull form: Simulation of 83m Standard MR tanker vs. 200 m Slender MR tanker with same capacity.
- Fuels: Comparison and analysis of conventional fuels wiht focus on well-to-tank-to-wake.
- Cost benefit analysis covering Capex, Opex, fuel savings, IMO requirements (SOx, NOx, EEDI, GHG)
- Proposed ship concept for fulfilling IMO 2030 goal and prepare for IMO 2050

Findings

Cost of abatetment options for MR-tanker to meet IMO 2025 and for the amonia option IMO 2050	Legis-lation	Cost	Fuel redu-ction	GHG redu-ction	Total Capex	Annual fuel
		MUSD			MUSD	
Standard MR tanker - 183 meter		35			35	6000
Slender MR tanker - 200 meter		3	7 %	7 %	38	5580
Slender MR tanker - 200 meter with Hybrid Scrubber & EGR	IMO 2025	8	7 %	7 %	43	5580
Low Pressure (Otto) dual fuel LNG - Diesel	IMO 2025	5	+5%	0 %	40	6300
High Pressure (Diesel) dual fuel LNG - Diesel	IMO 2025	9	0 %	20 %	44	6000
Slender MR tanker with HP dual fuel	IMO 2025	12	7 %	26 %	47	5580
Slender & Improved & HP (diesel) LNG dual fuel	IMO 2030	21	15 %	32 %	56	5100
Adding Amonnia ready	IMO 2030	24	15 %	32 %	59	5100
Slender & Improved HP (diesel) running on renewable Amonia	IMO 2050	30	15 %	>70%	65	5100

DEMO-CASE Zero emission expedition cruise

Background

Although far from being the largest contributor to global emissions, the cruise industry is under public and politic scrutiny.

In addition to IMO's target of a 50% cut in emissions by 2050, local zero-emission requirements is expected for vulnerable areas.

The target group for the expedition cruise market is typically environmentally aware.

Technology considered

- Hull optimization (monohull / trimaran)
- Sail-assisted propulsion (sail / flettner rotor)
- Power plant optimization (Hydrogen fuel cells, batteries, backup power source alternatives)
- other relevant technologies
    - Wave Foil
    - Regenerative propellers
    - Solar panels
    - Air lubrication
    - Maximized utilization of waste heat
    - Circular resource economy (waste handling)

Cruise ship initial concept

Zero emission expedition cruise. Illustration: Vard

Model Predictive Control of Marine Power Plants With Gas Engines and Battery.

The electric load demand on marine vessels is constantly changing during some operational modes, such as in harsh weather or complex operations. Therefore, diesel engines are typically used to handle these variations. Gas engines reduce the CO2 due to lower carbon content in LNG compared with diesel oil. However, they may not be able to handle the load variations of a marine power plant. There are multiple other energy sources with strict rate constraints, such as slow speed diesel engines and fuel cells. In such cases, a battery may be used to take care of the variations, while the generator set produces a slowly varying power. In this paper, a common power flow controller for the battery and the generator set is proposed. It utilizes the rotating inertia in the generator set as energy storage, in addition to a battery. This is done by allowing a small excursion in the speed of the generator set; the speed change will change the kinetic energy of the generator set and this is used analogously to energy storage. The controller is compared with a baseline controller based on virtual inertia and speed droop. A simulation study is included to demonstrate the performance of the control methods. The simulation study shows that the gas engine (with strict constraints) is not able to handle the given load series. Nonetheless, it can be used in combination with a battery to handle the variations. The power plant can handle a measured load series from an offshore vessel when either speed-droop control or model predictive control is used. However, the study indicates that by using MPC, the aging of the batteries and fuel rate variations can be reduced.

Reference: Bø, T. I., Vaktskjold, E., Pedersen, E. & Mo, O. 2019. Model Predictive Control of Marine Power Plants with Gas Engines and Battery. IEEE Access, 7, 15706-15721.

Mode	Cycles after 10 years	Energy loss	RMS $\dot{u}$ [%/s]
Frequency barrier, baseline	18,684	0.2%	0.77
Stiff frequency, baseline	38,968	0.5%	30
Frequency barrier, perfect prediction	10,920	0.04%	0.28
Frequency barrier, low/high prediction	28,032	0.3%	0.37
Stiff frequency, perfect prediction	29,136	0.3%	0.32
Stiff frequency, low/high prediction	39,672	0.5%	0.75
Stiff frequency, low/high predictions, 10 Hz	39,000	0.5%	0.28

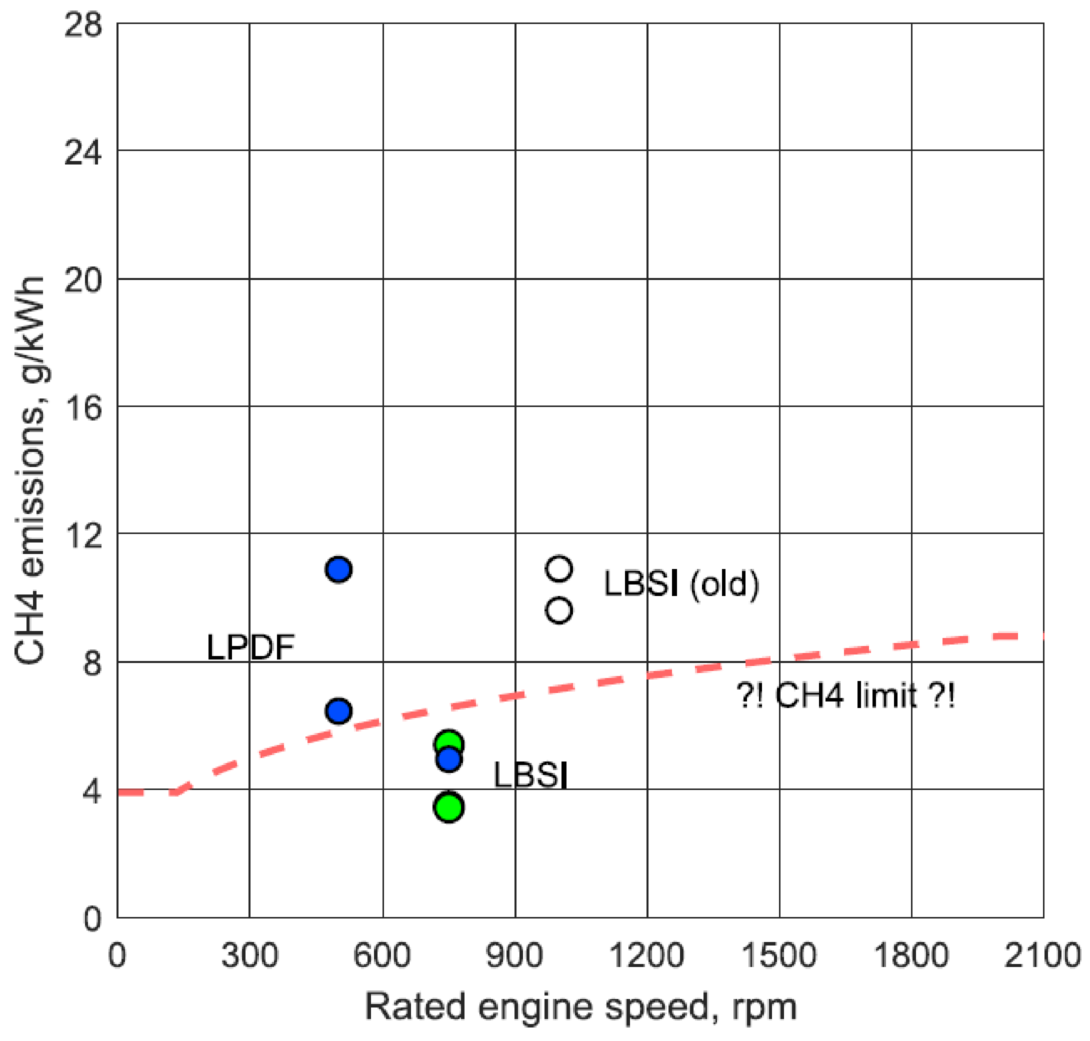
The table shows the number of equivalent full cycles the battery is cycled if the load series is repeated for 10 years. The batteries are expected to last for 10 years, and withstand 12,000 cycles. The energy loss in the battery is also included in the table. It is given as the ratio between lost energy in the battery due to ohmic losses and the total consumed energy by the consumers. The root mean square of Pu is shown in the right-hand column.
Source: Bø et al. (2019)

Methane Slip Summarized: Lab vs. Field Data

As more and more experience is gained by the operators using different marine gas engines, more and more understanding of what that can and need to be improved is also acquired. Not considering purely technical issues often related to durability or non-optimal operation of a certain engine component(s), the major concern is often poor efficiency of lean burn spark ignited (LBSI) and lowpressure dual-fuel (LPDF) engines at low loads. These types of gas engines comprise the majority of currently operated gas engines and the shipowners are often concerned with the increased fuel consumption at low loads resulting in higher operational costs of the vessel. At the same time, engine (environmental) researchers are often much more concerned with high emissions of unburned methane (i.e. unburned fuel), which typically are called methane slip. Emissions of methane are not regulated in international maritime transport, so from regulatory perspective can be ignored by vessel operators. It should be noted that it is widely known that methane has a rather strong greenhouse gas effect and normally is controlled in all on-shore applications.

Norway is one of the leading nations in terms of acceptance of gas-engine technology for shipping with dozens of gas-driven ships operated by Norwegian companies. At the same time, Norway has one of the strictest emission regulations set for shipping and is constantly investing in development and testing of different emission reduction technologies allowing even further reduction of harmful emissions. Methane slip is not an exception to this rule.

Current article deals with the analysis and comparison of gaseous emission data measured from ship engines in field (on board) with similar data from the laboratory measurements. The main emphasis is paid to methane slip and the data is also compared with that available from the measurements done by the engine manufacturer. Both LBSI and LPDF engines are covered by the study. The reasons for the agreement and (or) disagreement between the collected data sets are transparently discussed, providing the reader with ideas of how the methane slip emissions from marine diesel engines can be further reduced not affecting compliance of the engines with Tier III emission standards.

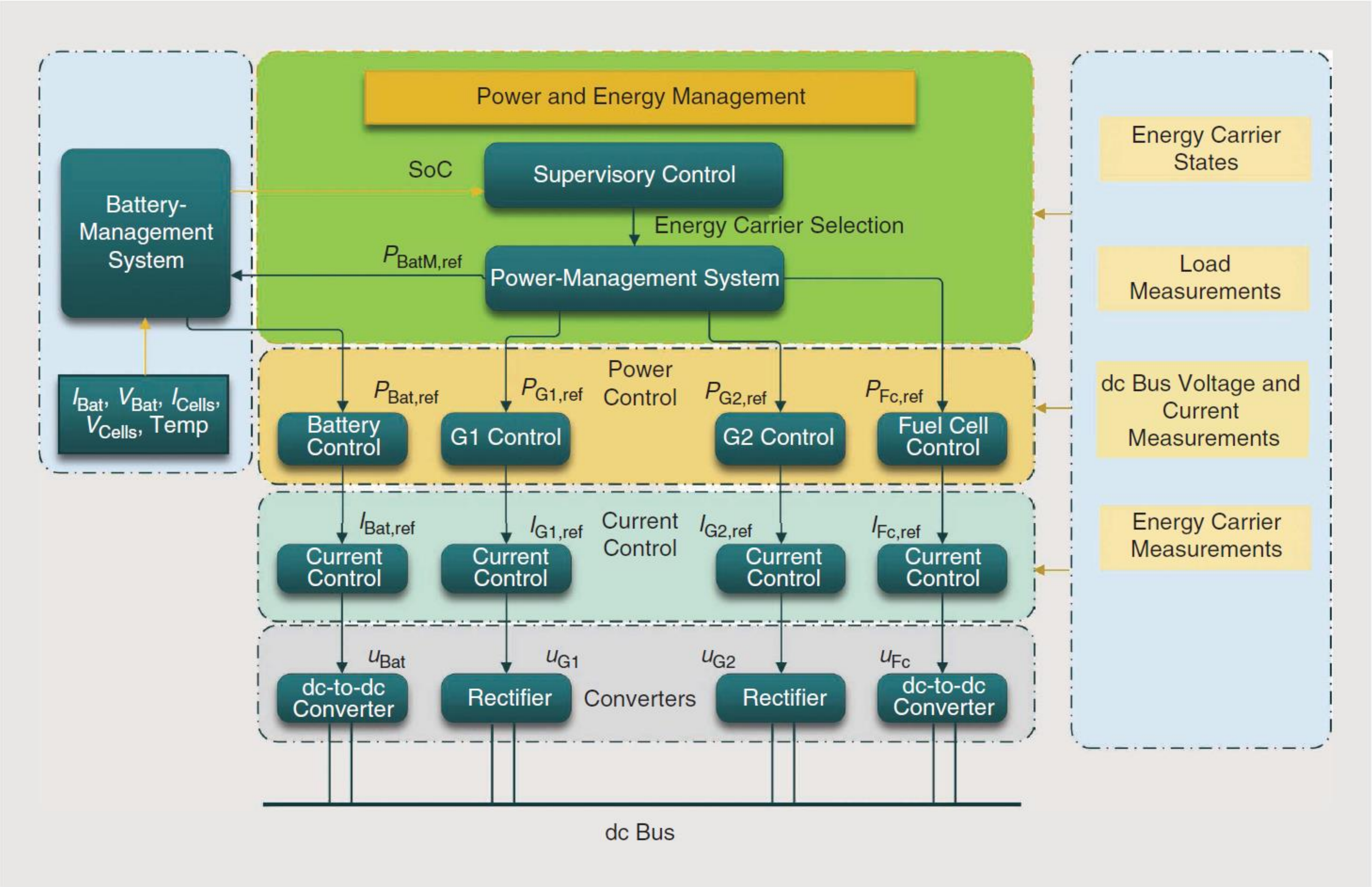


Cycle-averaged methane slip summarized for all tested engines. Source: Ushakov et al. (2019)

Reference: Ushakov, S.; Stenersen, D.; Einang, P. M. 2019. Methane Slip Summarized: Lab vs. Field Data. CIMAC Congress 2019. Vancouver.

Shipboard Electric Power Conversion: System Architecture, Applications, Control, and Challenges

In this article, developments in the evolution and design of ship electrification, with a focus on onboard power conversion, were reviewed and discussed. Ship electrification is growing fast, and many vessels are being retrofitted to hybrid electric propulsion as a transitional step before the field of marine electric power and propulsion matures. On the other hand, many marine engineers are not famifiar with the emerging concepts in the marine industry, such as onboard power electronics, hybrid power systems, and the associated controllers in the different power system levels. Therefore, this article provided an extensive overview of shipboard systems, including power electronic converters, power system architecture, different control levels and methods for converter based systems, and design and operating challenges.

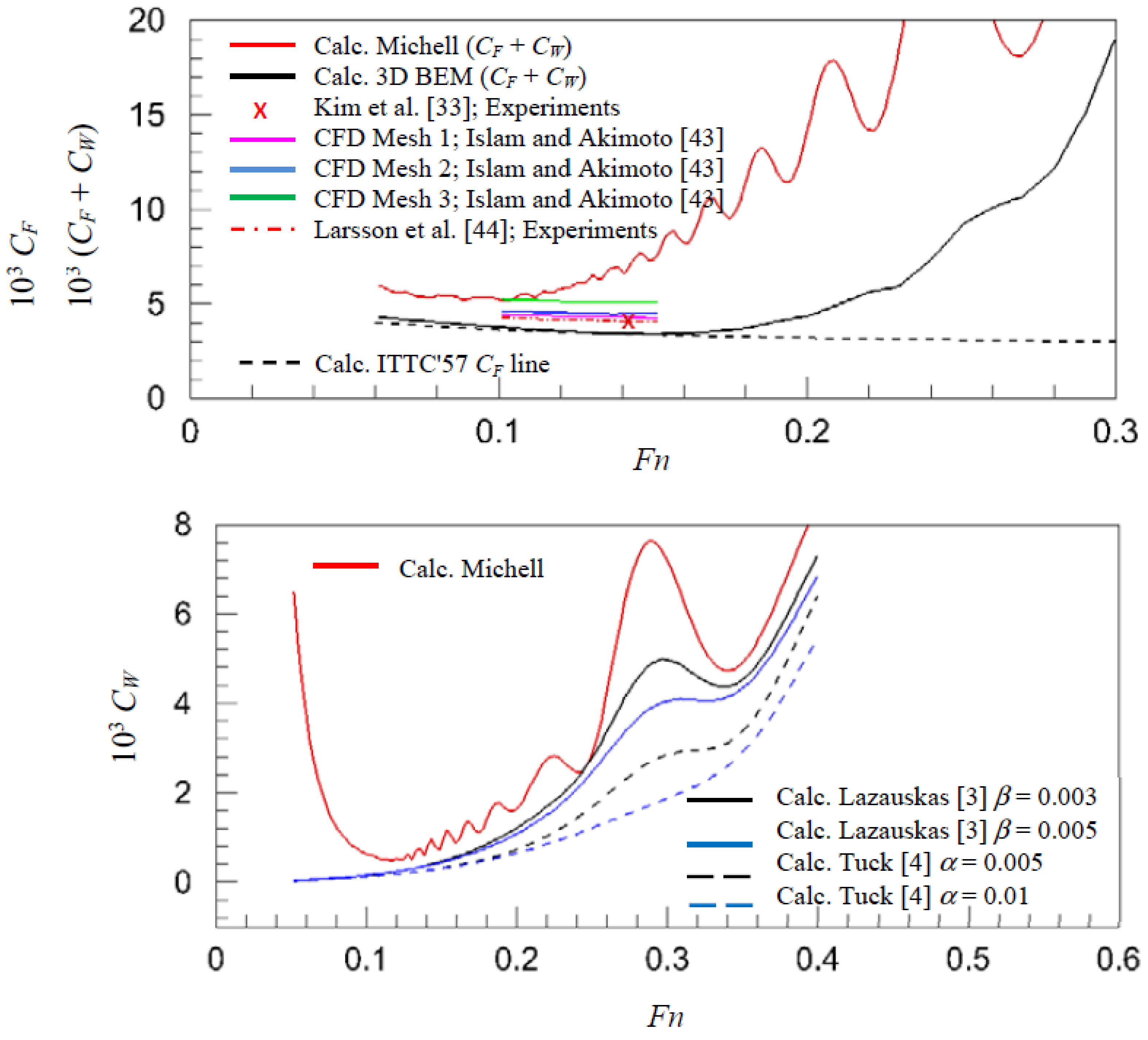


The complete control structure for the onboard dc power grid. (Source: Ghimire et al. 2019)

Reference: Ghimire, P.; Park, D.; Zadeh, M.; Thorstensen, J.; Pedersen, E. 2019. Shipboard Electric Power Conversion: System Architecture, Applications, Control, and Challenges. IEEE Electrification Magazine. vol. 7 (4).

On Total Resistance of Ships in a Seaway

Abstract:
To ensure successful ship operations it is important to be able to predict, reliably and effectively, ship performance in a seaway. This study investigate estimation of the ship total resistance in deep water through utilization of different theoretical models based on potential fluid flow theory with partial inclusion of viscous effects. The complexity of the models and therefore their difficulty in practical application from the perspective of the theoretical studies is varied.
To exempliy and compare the studied theoretiacal calculation methods, two modern and distinctively different ship hull forms have been studied. The obtained calculation results were compare with published experimental and theoretical results and found to be in good agreement.

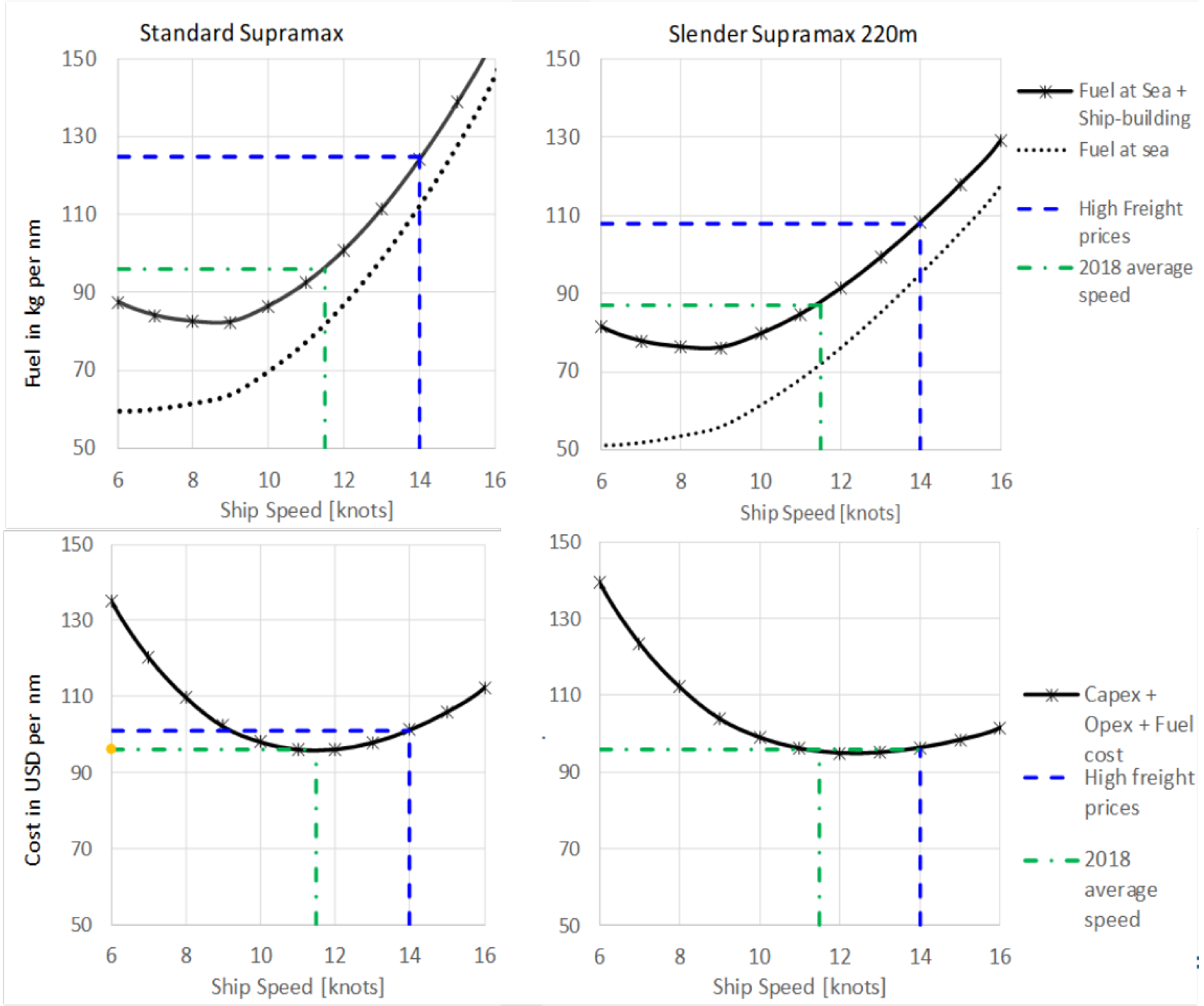


Nondimensional friction resistance CF and total resistance (Cf + Cw), in calm and deep water for KLVCC2 (upper figure) and KCS (bottom figure) hulls versus Froude numbers Fn. Source: Skejic and Steen, 2019:9,15)

Reference: Skejic, Renato; Steen, Sverre. 2019. On total resistance of ships in a seaway. PRADS 2019; 2019-09-22 - 2019-09-26

Length and hull shape importance to reach IMO's GHG target

In April 2018 at the 72nd session of IMO’s Marine Environment Protection Committee, a GHG strategy consistent with the Paris Agreement temperature goals was adopted. The main target set was to reduce absolute GHG emissions from shipping in 2050 by 50% compared to 2008. To reduce GHG emissions there are five main technical and operational measures: hull design; power and propulsion; alternative fuels; alternative energy sources; and operations. In this paper we focus on the potential reductions through hull design, i.e. length and hull shapes in relation to speed and sea states. Our findings indicate that moderate increases of length and reduction of block to enable better hull shapes give 10 – 20 % reduction of annual fuel consumption and hence emissions for a low or even negative abatement cost. Achieving these reductions will require that national and international authorities stop penalizing energy efficient ships with increased length compared to standard tonnage through higher port and fairway fees; pilotage rules; and artificial sailing restrictions.

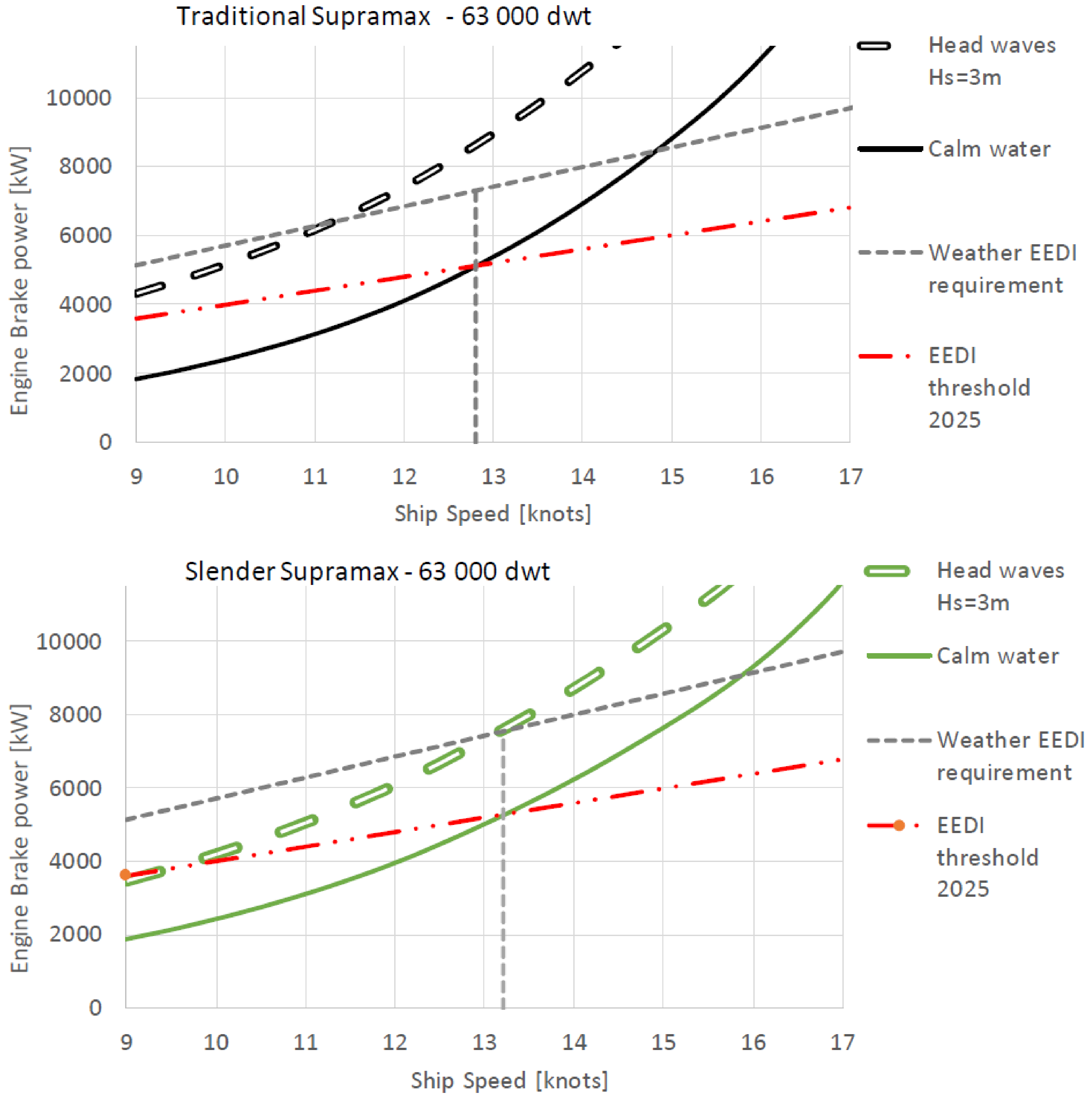


Reference: Lindstad, E., Sandaas, I. & Borgen, H. 2019. Length and hull shape importance to Reach IMO's GHG target SMC-075-2019. SNAME Maritime Conference - SMC 2019. Tacoma - Washington.

IMO's EEDI:
the need to include performance in wave) to Achieve the Desired GHG Reductions

Abstract:
The International Maritime Organization (IMO) has established the Energy Efficiency Design Index (EEDI) as the most important policy measure to reduce greenhouse gas (GHG) emissions from shipping.
A vessel's EEDI is based on sea trials at delivery, and vessels cannot exceed a threshold for emitted CO 2 per ton-mile, depending on vessel type and size. From other industries such as cars we have learnt that testing methods must reflect realistic operating conditions to deliver the desired emission reductions. Present sea-trial procedures for EEDI adjust to 'calm water conditions' only, as a comparative basis, despite calm sea being the exception at sea. We find that this adjustment procedure excessively rewards full bodied 'bulky' hulls which perform well in calm water conditions. In contrast, hull forms optimized with respect to performance in realistic sea-conditions are not rewarded with the current EEDI procedures.
Our results indicate that without adjusting the testing cycle requirements to also include a threshold for performance in waves (real sea), the desired reductions will be short on targets and GHG emissions could potentially increase.

Reference: Elizabeth Lindstad & Henning Borgen & Gunnar S. Eskeland & Christopher Paalson & Harilaos Psaraftis & Osman Turan, 2019. "The Need to Amend IMO's EEDI to Include a Threshold for Performance in Waves (Realistic Sea Conditions) to Achieve the Desired GHG Reductions," Sustainability, MDPI, Open Access Journal, vol. 11(13), pages 1-17, July.



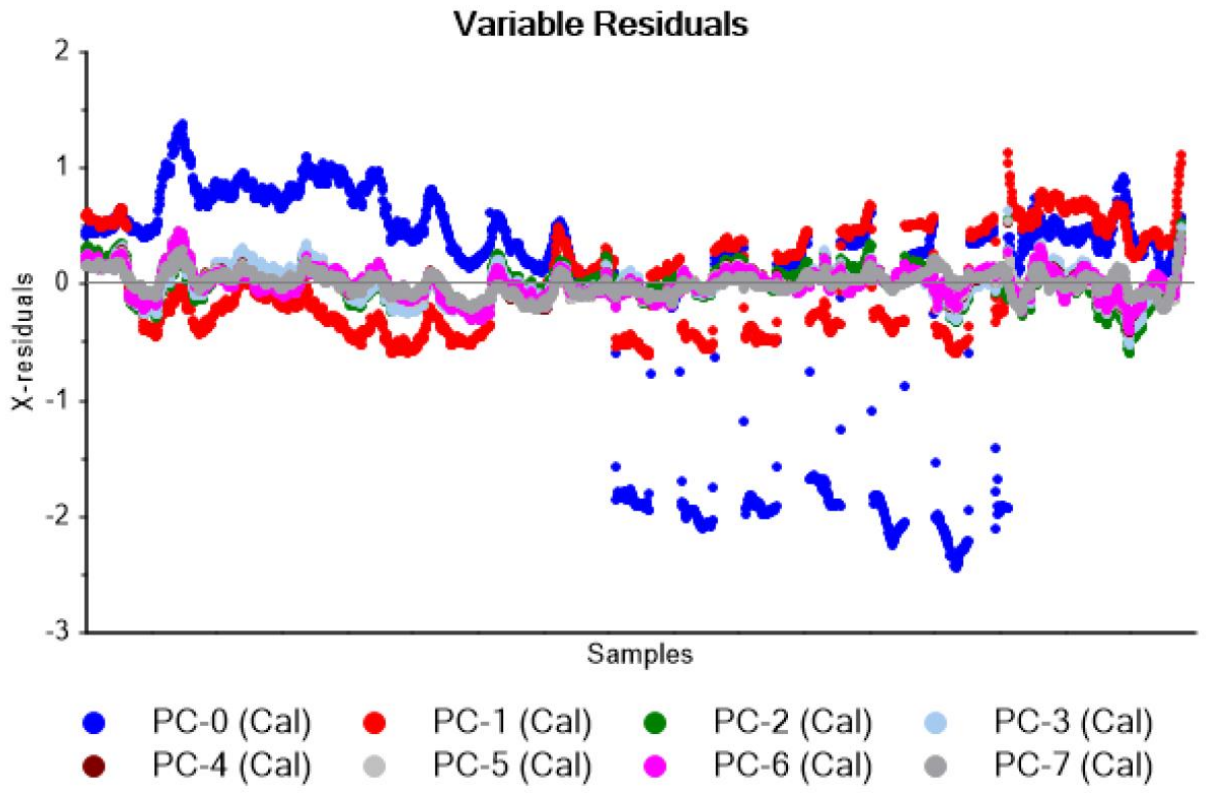
Impact of introducing a weather EEDI in addition to a calm water EEDI
Source: Lindstad et al. (2019)

Big Data Analytics As a Tool to Monitor Hydrodynamic Performance of a Ship

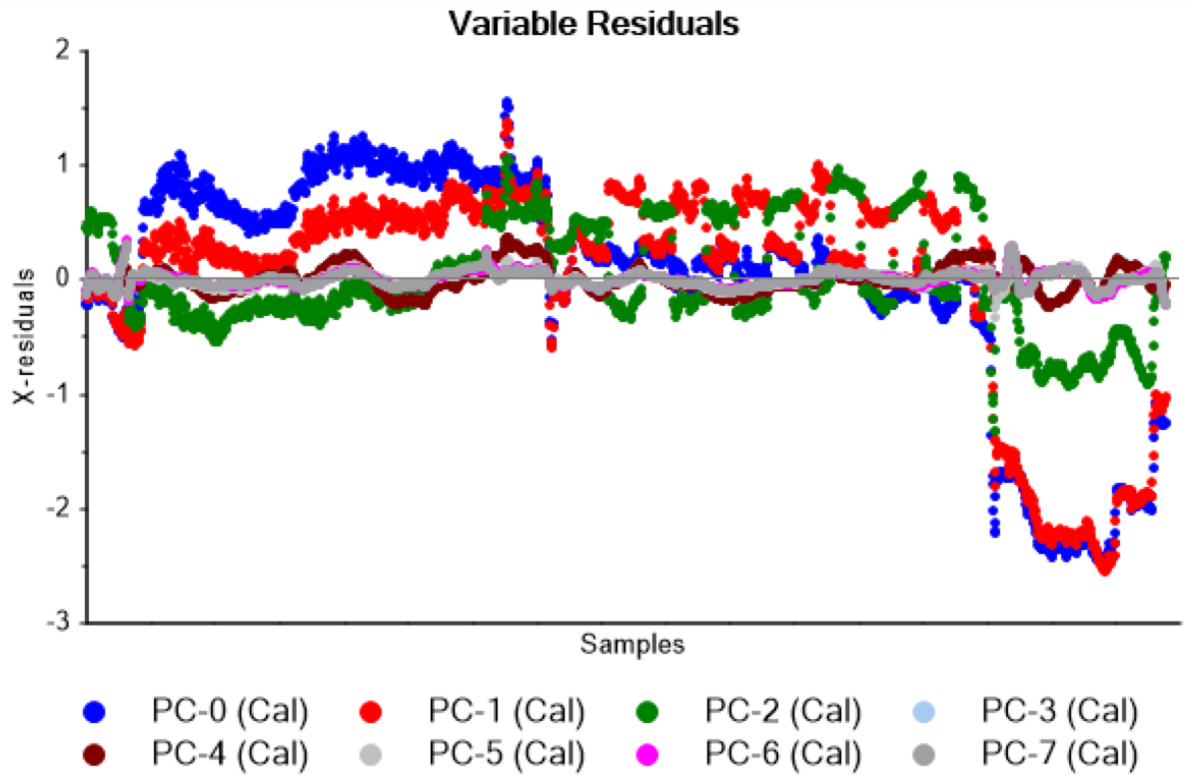
The amount and quality of in-service collected data concerning ship performance is increasing rapidly. This data is potentially very valuable, and many uses is seen, like hull condition monitoring, machine-learning based performance prediction and ship routing, and performance optimization of various kinds. For scientists, this type of data represent a unique opportunity to get access to full scale data – until now one has mainly had to rely on model scale ship performance data. However, the full scale data sets are large, heterogeneous and of unknown and sometimes poor quality. Thus, data collection, data cleaning and data processing of this type of data are still areas of research and development.

In Gupta et al. (2019), a modern ship is fitted with numerous sensors and Data Acquisition Systems (DAQs) each of which can be viewed as a data collection source node. These source nodes transfer data to one another and to one or many centralized systems. The centralized systems or data interpreter nodes can be physically located onboard the vessel or onshore at the shipping data control center. The main purpose of a data interpreter node is to assimilate the collected data and present or relay it in a concise manner. The interpreted data can further be visualized and used as an integral part of a monitoring and decision support system. This paper presents a simple data processing framework based on big data analytics. The framework uses Principal Component Analysis (PCA) as a tool to process data gathered through in-service measurements onboard a ship during various operational conditions. Weather hindcast data is obtained from various sources to account for environmental loads on the ship. The proposed framework reduces the dimensionality of high dimensional data and determines the correlation between data variables. The accuracy of the model is evaluated based on the data recorded during the voyage of a ship.

Gupta, Prateek; Steen, Sverre; Rasheed, Adil. Big Data Analytics As a Tool to Monitor Hydrodynamic Performance of a Ship. I: ASME 2019 38th International Conference on Ocean, Offshore and Arctic Engineering. Volume 7A: Ocean Engineering.



Final PCA model: shaft power residuals. Showing the variance in shaft power absorbed by consecutive pcs. First 2 pcs explaining most of the variance in shaft power.



Final PCA model: trim-by-aft residuals. Showing the variance in trim-by-aft absorbed by consecutive pcs. First 3 pcs explaining most of the variance in trim-by-aft.

COOPERATION

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

NATIONAL COOPERATION

Cross-SFI research cooperation

Cooperation on simulation methods and tools among SFI Smart Maritime, MOVE and EXPOSED is also coordinated through the Joint Industry Project Open Simulation Platform launched in 2017.

SFI Forum

SFI Smart Maritime participated at the SFI-forum organised by the Norwegian Research Council in May 2019, gathering 90 participants. The focus this year was on sharing information and experience in preparation of the midway evaluation process for SFI.

Spin-off and associated projects

Additional funding is seeked every year by partners of Smart Maritime for further research or commercialisation activity. Funding sources include:

- Research projects (RCN, EU)
- Commercialisation: Innovation Norge, NTNU TTO

In 2019, based on active collaboration among the Centre partners, 3 project applications received approval from the Norwegian Research Council to be launched in 2020.

- **RedRes**: Firction Reduction, development of new coating; testing on Grieg Star ship (Industry partners Jotun).
- **IPIRIS**: Improving Performance in Real Sea. Numerical calculation of added resistance in wind and waves (Industry partners Vard, Havyard, Kongsberg Maritime)
- **CruiZero:** spin-off of Zero-Emission Cruise demo case; further analysis of sail and rotor solution and energy use for hotel section (Industry partners VARD, ABB

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. SINTEF Ocean is currently participating in 6 H2020 projects with relevance for Smart Maritime in terms of scientific activity or industrial challenges.

International cooperation on policy making:

- Prof. A. H. Strømman (NTNU) designated as co-author of the IPCC's Sixth Assessment Report (chap. 10 Transport) due in 2021. Dr. Helene Muri (NTNU) is also contributing to chapters on Short-lived climate forcers and Transport.
- Dialog and cooperation with Norwegian Shipowner Association and Sjøfartsdirektorat for contribution to IMO environmental strategy.

Academic and research cooperation

- Scientific advisory committee, consisting of 5 Professors with expertise covering research area of the Centre. These are important knowledge partners. Through annual meeting, the Committee audits and advice on the research activity of the Centre.
- 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).

International conferences and forums

- Contribution to conferences: SNAME Maritime convention; IMDC International Marine Design Conference; SOME Ship operations, Management & Economics; IMSF International Maritime Statistics Forum;
- SNAME fellowship attributed to Dr Elizabeth Lindstad in 2017
- Membership in ESSF the European Sustainable Shipping Forum: Dr Lindstad.

ASSOCIATED PROJECTS - ONGOING 2019

Project name and time period	Funding	Smart Maritime Partners	Synergy with Smart Maritime
HOLISHIP - HOLIstic optimisation of SHIP design and operation for life cycle (2016-2020)	EU H2020 MG-4.3-2015	Kongsberg Maritime	WP4, SP3 Virtual prototyping
Hybrid testing - Real-Time Hybrid Model Testing for Extreme Marine Environments (2016-2020)	MAROFF, RCN		WP3 Power systems WP4 Ship system integration
SATS - Analytics for ship performance monitoring in autonomous vessel (2018-2020)	MAROFF, RCN		WP1 Feasibility studies WP4 Ship system integration
Open simulation platform (2018-2020)	JIP	DNV GL, Kongsberg Maritime, SINTEF Ocean, NTNU	WP2, WP3, WP4 Ship system simulations
Digital twin for lifecycle operations (2018-2022)	MAROFF	DNV GL, Kongsberg Maritime, SINTEF Ocean, NTNU	WP2, WP3, WP4 Ship system simulations
CLIMMS: Climate change mitigation in the maritime sector (2019-2023)	MAROFF	NTNU, SINTEF Ocean, Rederiforbund, Solvang, Grieg Star, KGJS, WW, BW Gas, Höegh Autoliners, Klaveness, Odfjell, Sjøfartsdirektorat.	SFI models and tools. Connection ship design simulation and climate models. GHG reduction demo cases.
SmartShipRouting (2019-2020)	MAROFF	NCS, NES, Havila, Havyard, SINTEF Ocean	Simulation, use of in-service data
RuteSim: Simuleringsbasert Ruteplanlegging (2019-2020)	MAROFF	Grieg Star, WWO, KGJS SINTEF Ocean, Nansen	Gymir: ship routing modul
Digital twin yard (2019-2021)	MAROFF	DNVGL, Rolls-Royce, NTNU, SINTEF Ocean	Digital twin, simulation
FreeCO2ast (2018-2022)	PILOT E	Havyard, Havila SINTEF Ocean	Gymir og hybridlab
Extension of Hybrid Lab (2018-2019)	ABB	ABB, SINTEF Ocean	WP3; Hybrid lab (Installation of Fuel Cell and H2)

RECRUITEMENT

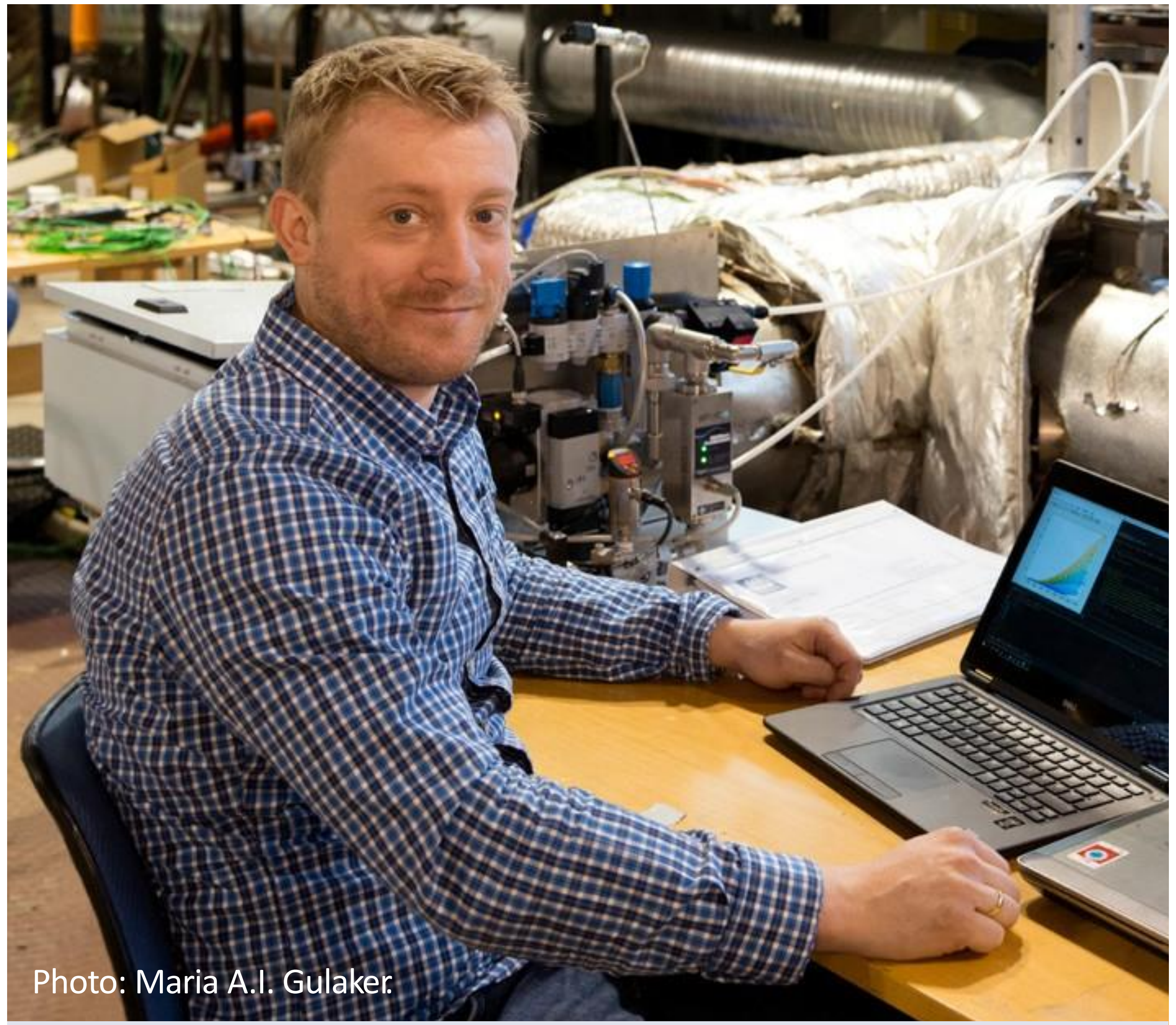
Smart Maritime is a scientific and industrial network of 100 people. The research team consists of over 20 research scientists from two institutions NTNU and SINTEF Ocean, including 7 PhD students financed by the Centre in 2019.

Photo: Siemens

PHD AND POSTDOC RESEARCH PROJECTS

Research training:
The doctoral education programme combines academics with methodological schooling and hands on experience. A PhD programme is composed of one semester of coursework / research training, and 2.5 years of dissertation work and research. The supervisor assists in preparing the project plan, training component, plan for internationalization and an application for admission. The faculty is responsible for the required coursework and academic training based on the supervisor's recommendation and offers training in research ethics and scientific methods.

Star Harmonia. Photo: Grieg Star



Jørgen Nielsen

PhD Student WP3/WP4 (2015–2018)

Virtual Prototyping of Complex Marine Power Systems

Doctoral Thesis:
Modeling and Simulation for Design Evaluation of Marine Machinery Systems

Supervisor
Eilif Pedersen (IMT, NTNU)

Research topic

The maritime industry is facing significant changes in how marine power plants have to be designed due to stricter regulation on emission of air pollutants and greenhouse gases and the need for increased energy efficiency. Due to the geographic application of regulation, there are reasons to believe that a more diverse set of system solutions will appear suited to fit the trade, operation profile and area of operation. Moving from a standardised design to selecting between multiple viable designs or developing custom designs, poses a significant challenge for marine power plant designers. Designers need methods for evaluating suggested designs and for building confidence in novel systems before system realization. System modelling and simulation is considered an important methodology for our ability to develop these novel systems. Successful use of system modelling and simulation increases our ability to tackle systems related problems such as complexity due interaction between components and sub-systems and provides designers with a methodology to evaluate concepts using virtual prototyping.

Achievements:

- Models development
  - Heat exchanger and heat exchanger network models
  - SCR system models
- Model validation
  - SCR system models
- System design suggestion
  - SCR system and marine two stroke engine integration

Publications

Nielsen et al. (2019) A system approach to selective catalytic reduction deNOx monolithic reactor modelling using bond graphs. *Journal of Engineering for the Maritime Environment (Part M)* 2019, vol 233.

Nielsen et al. (2019) Impact of simulation model fidelity and simulation method on ship operational performance evaluation in sea passage scenarios. *Ocean Engineering*. vol. 188.

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Nielsen et al. (2019). Improving pre-turbine selective catalytic reduction systems in marine two-stroke diesel engines using hybrid turbocharging: A numerical study of selective catalytic reduction operation range and system fuel efficiency. *Proceedings of the Institution of Mechanical Engineers, Part M: Journal of Engineering for the Maritime Environment*.

Nielsen & Pedersen (2018) On the modelling of heat exchangers and heat exchanger network dynamics using bond graphs, *Mathematical and Computer Modelling of Dynamical Systems*, 24:6.

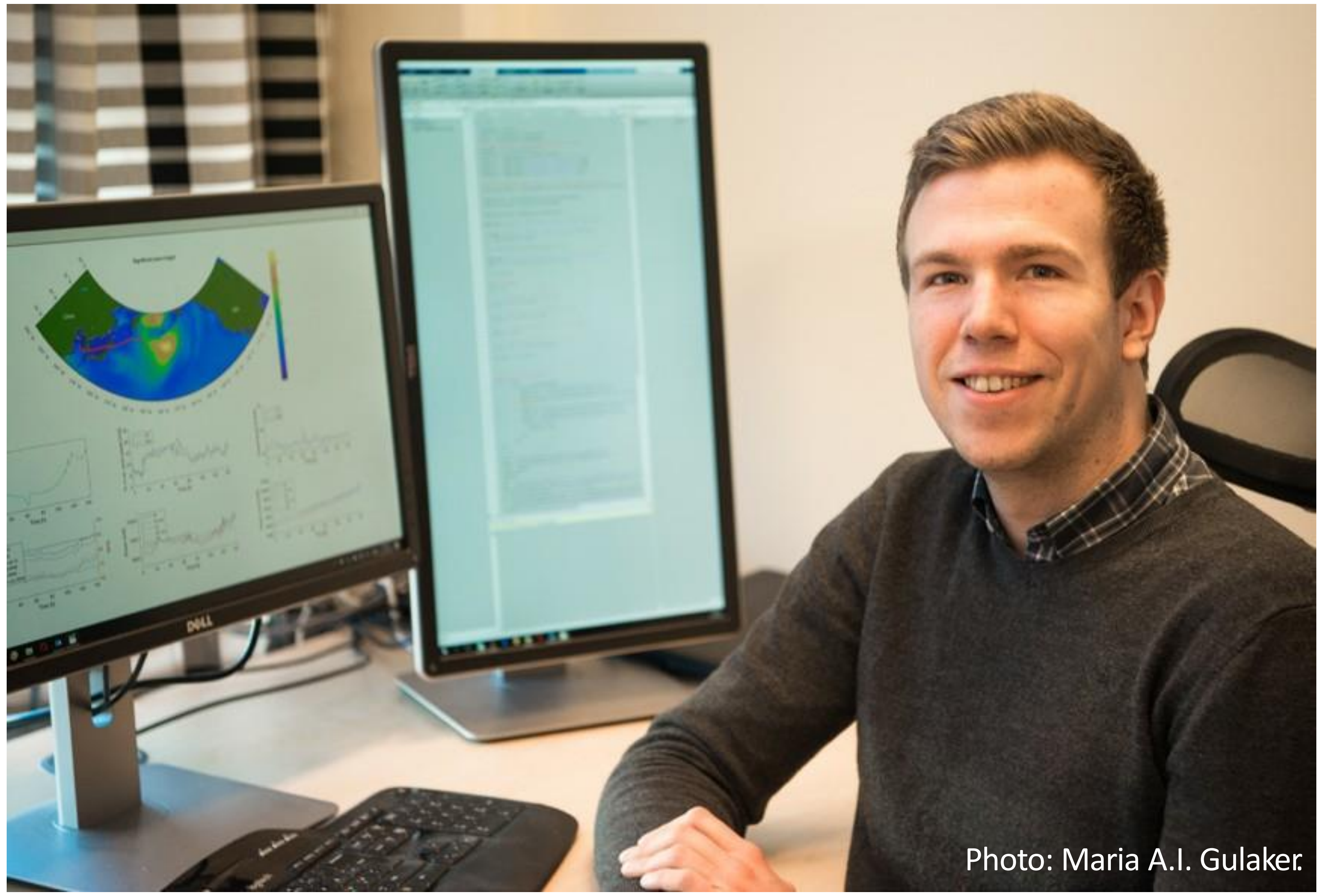


Photo: Maria A.I. Gulaker.

Endre Sandvik

PhD student WP4 (2016–2019)

Simulation Based Design of Ships With Regards to System Performance

Research topic

The purpose of the PhD research was to provide knowledge regarding the validity of simulation models for application in ship design. The research focuses on simulation techniques for implementing relevant operational scenarios for virtual testing of design concepts.

Achievements

Several validation studies of Smart Maritime's Ship performance simulation tool Gymir. The analyses were performed based on operational data and vessel profiles from Smart Maritime ship owners, . towards estimation of fuel consumption and operational profile using GYMIR was conducted in 2017. The methodology and results are presented in a conference paper for the International Marine Design Conference in Helsinki June 2018.

Defence and Trial Lecture

Endre Sandvik submitted the Thesis entitled «Sea Passage Scenario Simulation for Ship System Performance Evaluation», and gave a trial lecture in September 2019 on the subject: «How to Design a Research Project to Solve Contemporary Maritime Problems».

Publications:

Sandvik et al. (2018) A simulation-based ship design methodology for evaluating susceptibility to weather-induced delays during marine operations. Ship Technology Research 2018 ;Volum 65(3)

Sandvik et al. (2019) Stochastic bivariate time series models of waves in the North Sea and their application in simulation-based design. Applied Ocean Research 2019 ;Vol 82.

Sandvik et al. (2018) Estimation of fuel consumption using discrete-event simulation - a validation study. In: Marine Design XIII. Taylor & Francis 2018.

Supervisors

Main supervisor:

- Professor Bjørn Egil Asbjørnslett, NTNU IMT

Co-supervisors:

- Professor Sverre Steen, NTNU IMT
- Professor 2 Stein Ove Erikstad, IMT (FEDEM)
- Associate professor Eilif Pedersen, NTNU IMT

Prateek Gupta
PhD student WP2
(2018–2021)

Ship Performance Monitoring & Optimization using in-service measurements & Bigdata Analysis methods

Main achievements 2019

- Developed a variety of data-driven mathematical regression models, namely PCR, PLSR and ANN, to predict the hydrodynamic state of the propulsion system of a ship during a sea voyage. The model accuracies were evaluated based on the in-service data recorded onboard a sea going ship.
- Non-linear transformations were used, based on the physical knowledge of the system, to implement simplistic as well as highly interpretable linear regression methods (PCR & PLSR) while solving a non-linear problem.
- Used a probabilistic approach to quantify the model predictive confidence or uncertainty in predictions of a mathematical model.

Results presented at OMAE2019:
Gupta, et al. (2019) Big Data Analytics As a Tool to Monitor Hydrodynamic Performance of a Ship. ASME 2019 38th International Conference on Ocean, Offshore and Arctic Engineering. Volume 7A: Ocean Engineering.

Research topics

The focus of the project would be to convert the highly dimensional in-service measurement data recorded onboard a ship into meaningful information. Initially, data integrity and quality assurance procedures must be implemented and applied on the data set(s). The cleaned data will be further used to quantify the hydrodynamic performance of the ship. The project will apply big data analysis, data science, and machine learning for data processing.

The in-service data will be linked with environmental data from open sources, like for instance NorKyst800 and ECMWF to improve the ability to detect the environmental condition.

Topics like prediction of ship speed loss, speed-powering variation, hull-propeller performance, seakeeping performance, influence of environmental factors will be covered under the hydrodynamics aspect of the project.

Industrial goal

- Monitor and optimize the hydrodynamic performance of a ship using in-service measurements from onboard installed sensors.
- Estimation of frictional resistance of the ship from total engine power consumption and ship motions using in-service measurements.
- Estimation of added wave resistance using weather hind-cast data, ship motions and total engine power consumption during voyage.

Scientific questions

- How to quantitatively represent the hydrodynamic performance of a ship using in-service measurement data?
- How to separate calm water resistance from the total resistance?
- How to convert large amount of sensor data into small number of meaningful hydrodynamic performance parameters?
- How to identify the frictional resistance from the measured total engine power consumption?
- How to estimate sea state and speed-through-water in real time?

Supervisor: Prof. Sverre Steen (NTNU)
Co-supervisor: Prof. Adil Rasheed (NTNU, SINTEF)


Photo: Private

Eshan Esmailian

PhD student WP2 (2019–2022)

Optimization of Ships for Operation in Real Sea States

Research topics

Optimization of ship designs has been a focus of research and development for a long time, but mostly optimum performance in calm water has been the issue. However, ships should be designed for operation in real sea states, meaning that performance in representative conditions with respect to time-varying components such as wind, waves and current, as well as loading conditions and transit speed should be taken into account. Moreover, there are typically uncertainties needed to be considered in the design phase. To make a design optimization method involves many aspects; proper design approaches for the optimization and tools to enhance the accuracy of design methods must be selected (or developed). Finding reliable and practical methods to ensure optimal energy efficiency of ships in real sea states that are both sufficiently accurate and robust and at the same time sufficiently computationally effective is expected to be a major task. Another research question concerns developing frameworks to be able to evaluate the performance of the suggested approaches for different case studies.

Industrial goals

• Improve the design methods for ships operating in real sea states and harsh sea conditions.
• Ensure high performance of designed ships in various scenarios such as routs, loading, and varying weather conditions etc.
• Improve the energy efficiency of ships
• Enhance Gymir capabilities
• Proposed solutions can be also useful for the following applications:
- Modern ship design
- Passenger comforts
- Offshore operations
- Autonomous ships

Main achievements 2019

Firstly, a comprehensive literature review was conducted. Then, a tool was provided to estimate different parts of a ship design problem and calculate the fuel consumption in seaways. The code was also verified through the previous research. We also studied the performances of various optimization approaches in a ship design problem and an article is under preparation in this topic. Now, our next objectives are improving the capabilities of the tool and propose approaches to enhance energy efficacies of ships in seaways that are both sufficiently accurate and computationally effective.

Faculty / Supervisor

Supervisor: Prof. Sverre Steen (NTNU)
Co-supervisor: Prof. Kourosh Koushan(SINTEF Ocean), Prof. Stein Ove Erikstad (NTNU)

Kamyar Maleki

PhD student WP3 (2019-2022)

Simulator Approach to Concept Analysis and Optimization of Marine Power Plants

Supervisor: Prof. Eilif Pedersen (NTNU)

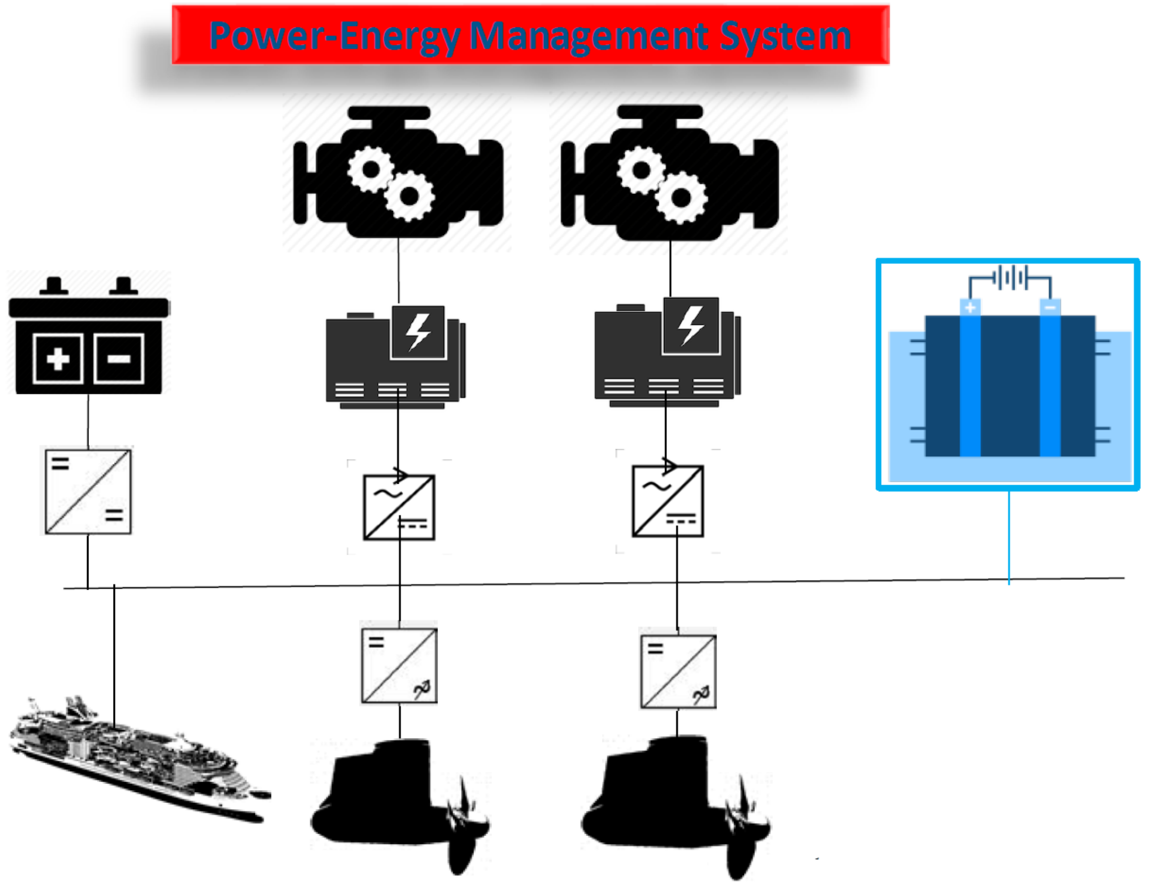
Objective

In this PhD project, the main goal is reaching a package and methods of suggesting optimum hybrid power systems with flexibility in sizing, components configuration, system integration, and operations. Indeed, Multidisciplinary Design Optimization (MDO) is the fundamental optimization method that will be implemented in this project. The main objective in the first stage is developing a package of high-fidelity model of Fuel Cells (FC) with the ability to suggest optimum size and construction. After defining the main parameters of FCs, the model will provide the specific FC operation in power system with an emphasis on dynamic response and control-oriented approach. The second stage, that will be developed in parallel, is implementing the optimum algorithm of energy management decision making. This algorithm will permit the system components such as generators, batteries and fuel cells to operate in an efficient way for reaching the goal of reducing fuel consumption and emission.

Research topics

Increasing strict regulations on emitted pollution of maritime operations directed the energy efficiency practical approaches toward hybrid solutions. Moreover, modeling and simulation have a significant role in the investigation of systems behavior for the aim of developing, enhancing and optimizations. Furthermore, numerical modeling and optimization methods enhance the approach of designers for obtaining the most efficient point of system configuration for specific goals and constraints. Since, for the aim of reaching the optimum state of the hybrid system configuration, the primary step is providing a high-fidelity model with flexibility in parameters and considering a control-oriented approach.

In previous PhD projects, the main components of hybrid power systems, such as generators, batteries and other mechanical and electrical devices have been accomplished. However, there are two research gaps, the first is a model of fuel cells package by flexibility in design, size and operation. The second is optimum decision-making strategy of the energy management system. As a result, developing these two areas facilitates investigating operation state of each component in way of minimizing the consumed fuel and emission regarding the load requirements.



Expected results

- High Fidelity Modeling of various Fuel Cells
- Experimental Validation with Hybrid Power Systems Laboratory (HPS)
- Optimization of PMS in Operation
- Optimization in Sizing and Design by Multidisciplinary Design optimization

Photo: Private

Siamak Karimi

PhD Student WP3 (2019–2022)

Optimization and design of shore to ship charging Systems for all-electric and plug-in hybrid ferries

Research goal and strategy

Electrification of marine vessels has become an important and efficient solution for moving toward the zero-emission sea transportation. Existing technologies for reducing emissions include diesel-electric, hybrid and fully battery-electric propulsion systems. While hybrid or plug-in hybrid propulsion systems can reduce the consumption of fossil fuels, fully battery-electric solutions can eliminate all emissions from regular operation. Indeed, hybrid propulsion systems allows for onboard batteries to be recharged by diesel generators or discharged to supply loads . Furthermore, another way to recharge the onboard batteries is shore charging which can allow for sustainable energies, such as wind, solar and hydropower energies available in onshore power systems to be utilized for propulsion in the onboard power system. In many countries the electricity generated on land is also cheaper and more sustainable than the electricity generated by onboard diesel engines. For instance, in Norway, more than 90 percent of national electricity demand is produced by renewable energy such as hydropower energy.

Expected results

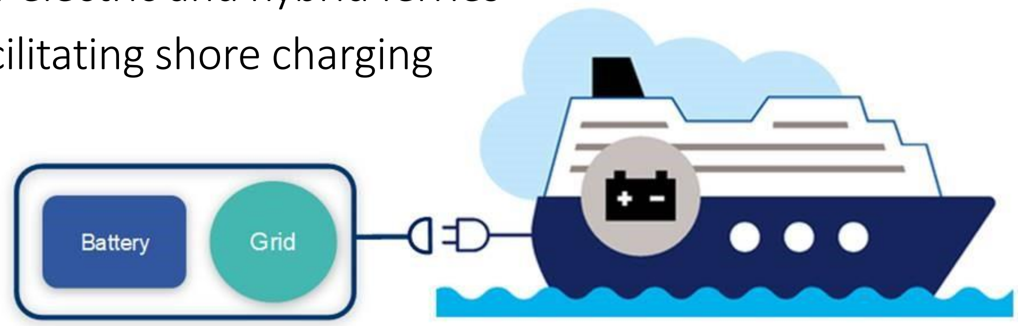
- A mathematical model for charging / discharging of onboard batteries which is required for energy efficiency, reliability and stability studies.
- A design Platform for charging infrastructures at ports concerning the power system architecture.
- An onshore power and energy management system compatible for generating an optimal charging regime with the highest energy efficiency, sharing the power between onshore batteries and the grid.

Supervisor: Associate Professor Mehdi Zadeh (NTNU)
Co-supervisor: Prof. Roger Skjetne (NTNU)

The main challenge of using batteries in maritime vessels is their low energy density. In other words, a marine battery pack which weighs about tens of tones and spaces hundreds of square meters cannot guarantee sailing for long distances. Thus, due to the current range limitations for fully electric ships, all-electric ships are not suitable for long distance transportation. With tight schedules for short-distanced ferries, it is important to take advantage of docking time efficiently, explaining the need for fast charging. Further, another challenge of shore-charging system for motor/car ferries is that usually the ports are located in remote areas with limited capacity in the local power grid. This means that the local grid may not be able to provide high power for fast charging loads, so using stationary energy storage systems, which act as energy buffers, is a proper solution for supporting the weak grid. However, using stationary battery introduces internal energy loss in the energy flow from shore to ship.

Applications

- For charging all-electric and hybrid ferries
- Smart ports facilitating shore charging



Shore-to-ship charging for all-electric or hybrid ships

Main achievements 2019

A technology and methodology survey has been carried out to fully understand the current unsolved challenges of shore to ship charging systems. Then an evaluation of energy efficiency for different charging topologies, wired and wireless solutions has been accomplished.

Benjamin Lagemann

PhD student WP4 (2019-2022)

Concept Ship Design for Future Low-Emission Shipping Technology

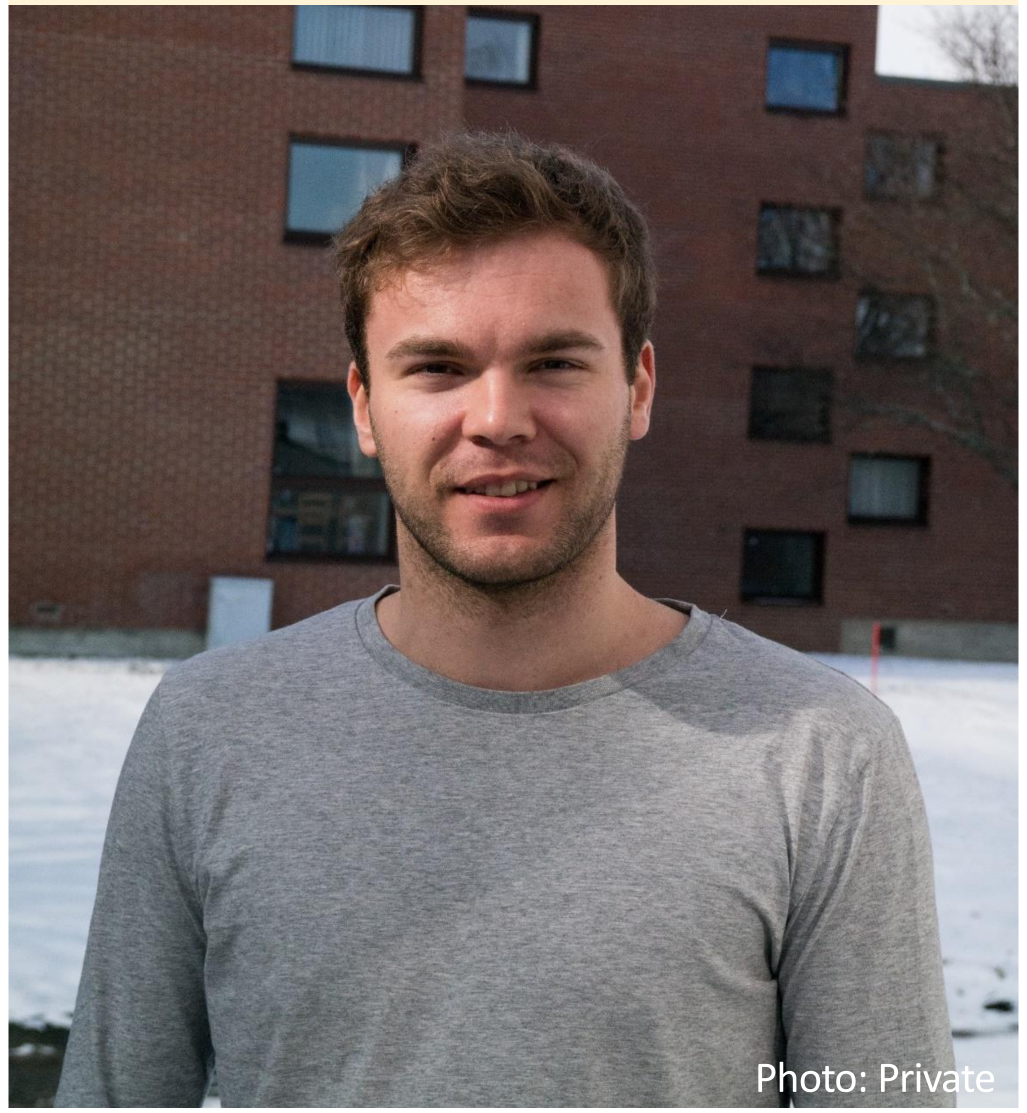


Photo: Private

Supervisors

Supervisor: Prof. Stein Ove Erikstad
Co-supervisors: Prof. Bjørn Egil Asbjørnslett
Prof. Sverre Steen

Research topic

The overarching research question for this project is
How to systematically design innovative, future-proof and low-emission ships at a conceptual level?

The main research question is divided into three sub-questions:

- How to rapidly explore different conceptual ship designs?

A large number of different systems and principles for lowering ship emissions are available today. The aim is to find out how these principles can be combined and assessed on a case basis for each new design.

- How to prepare for uncertain future contexts and operations?

While the focus of the first sub-question is on synthesizing ship systems, this question targets the system response to future contexts and operations. A life-cycle assessment accounting for different scenarios shall be set up and combined with the synthesis model.

- How to structure the design process?

With tools for synthesis and analysis in place, this question addresses the way to effectively engage and interact with all stakeholders in the conceptual design phase.

Main achievements 2019

The project builds upon precedent research both at NTNU and internationally. Thus, a large literature study has be conducted. This study serves as a basis for the synthesis and analysis models.

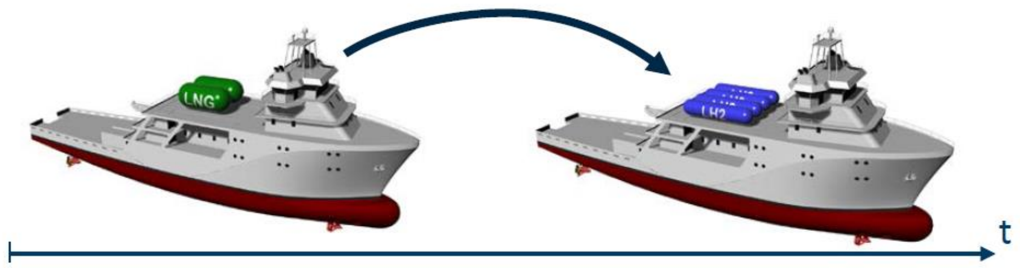
As for the first research question, ship system synthesis, work on a paper is currently in progress. The paper shall be submitted to the HIPER conference in fall 2020.

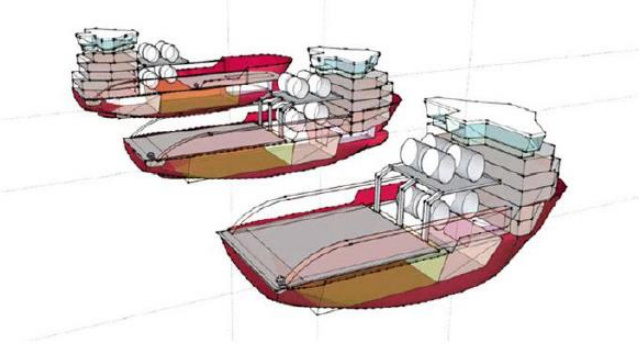
Industrial goals:

A large fraction of costs and ship life-time emissions are determined by decisions made during the preliminary ship design phase. Thus, the goal of this study is to support ship designers and ship owners in their decisions during this early design phase. An illustrative question to be supported would be: "Should the next newbuilt be prepared for a retrofit with, e.g. Hydrogen storage facilities, during its life-time?". Since the definite answer is likely to depend on certain scenarios for the future, these shall be effectively included in the design process.

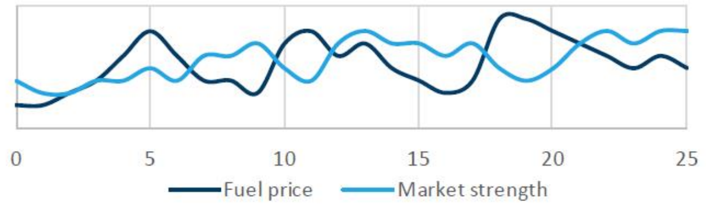
Expected results

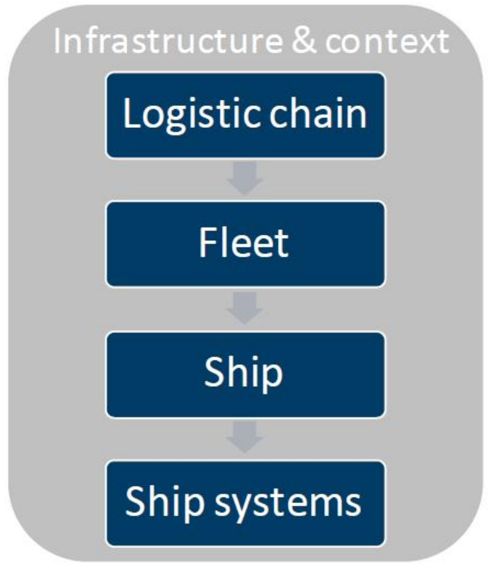
- Methodology and tool to investigate aspects such as flexibility, modularity, infrastructure, visualization, and uncertain future contexts on the ship design process and ship life cycle emissions.
- Prove the tool's performance in different case studies.





source: Vestbøstad 2011





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Ferry. Illustration: Havyard Group.

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* Primary contacts

RESEARCH TEAM

Name	Company	Position	Expertise area	Contribution to Smart Maritime
Sverre Anders Alterskjær	SINTEF Ocean	Research Scientist	Hull and propeller performance	WP2
Torstein Bø	SINTEF Ocean	Research Scientist	Hybrid propulsion	WP2, WP1
Jon S. Dæhlen	SINTEF Ocean	Research Scientist	Simulation-based concept design	WP4 leader (from Nov. 2018)
Dariusz Fathi	SINTEF Ocean	Research Manager	Data simulations and optimization	WP4
Trond Johnsen	SINTEF Ocean	Research Manager	Maritime logistics	WP4, Centre director (from Nov. 2018)
Kourosh Koushan	SINTEF Ocean	Senior Advisor	Hull and propeller performance	WP2
Kevin Koosup Yum	SINTEF Ocean	Research Scientist	Simulation, Machinery	WP3
Elizabeth Lindstad	SINTEF Ocean	Chief Scientist	Environment-friendly shipping	WP1 leader
Andrew Ross	SINTEF Ocean	Research Scientist	Hydrodynamics	WP2
Dag Stenersen	SINTEF Ocean	Senior Engineer	Power systems and fuel	WP3
Ole Thonstad	SINTEF Ocean	Senior Engineer	Full scale data harvesting	WP3
Anders Valland	SINTEF Ocean	Research Manager	Hybrid propulsion	WP3
Ingebrigt Valberg	SINTEF Ocean	Senior Engineer	systems and fuel	WP3
Henning Borgen	SINTEF Ålesund	CEO	Simulation based design	WP4
Bjørn Egil Asbjørnslett	NTNU Marine Technology	Professor	Ship design	WP4
Stein Ove Erikstad	NTNU Marine Technology	Professor	Hull and propeller hydrodynamics Data	WP4
Helene Muri	NTNU Indusrial Ecology	Senior Researcher	Climate and environmental impact	WP5, WP1
Sverre Steen	NTNU Marine Technology	Professor	Hydrodynamics	WP2 leader
Anders H. Strømman	NTNU Indusrial Ecology	Professor	Climate and environmental impact	WP5 leader
Mehdi Zadeh	NTNU Marine Technology	Professor	Exhaust emissions	WP3 leader
Vilmar Æsøy	NTNU Ålesund	Professor	Power systems and fuel	WP3

RESEARCH TEAM - SINTEF OCEAN


Sverre Anders Alterskjær


Torstein Bø


Jon Schonhovd Dæhlen


Dariusz Fathi


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Kourosh Koushan


Kevin Koosup Yum


Elizabeth Lindstad


Jørgen Nielsen


Agathe Rialland


Andrew Ross


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RESEARCH TEAM - NTNU

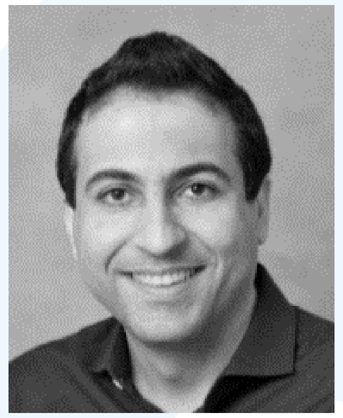

Bjørn Egil Asbjørnslett


Stein Ove Erikstad


Helene Muri


Sverre Steen


Anders H. Strømman


Mehdi Zadeh


Vilmar Æsøy

PHD STUDENTS AND POSTDOCTORAL RESEARCHERS

Name	Funding source	Nationality	Period	Topic
Postdoctoral researchers				
Renato Skejic	SFI Smart Maritime WP2	HR	2016–2018	Computation of added resistance due to waves
Torstein Ingebrigtsen Bø	SFI Smart Maritime WP3	NO	2015–2018	Hybrid propulsion, integrating new power sources for marine power plants
PhD students				
Prateek Gupta	SFI Smart Maritime WP2	IN	2018–2021	Ship performance monitoring and optimization using in-service measurements and big data analysis methods
Jon Coll Mossige	SFI Smart Maritime WP2	NO	2017–2020	Added resistance on ships due to hull roughness
John Martin Godø	NTNU in-kind to Smart Maritime	NO	2015–2018	Hydrodynamics of hydrofoil vessels
Espen Krogh	NTNU in-kind to Smart Maritime	NO	2018–2020	Hybrid propulsion machinery optimisation
Jørgen B. Nielsen	SFI Smart Maritime WP3/4	NO	2015–2018	Simulation of complex high efficiency maritime power systems
Vladimir Krivopolianskii	SFI Smart Maritime WP3	UA	2015–2018	Fuel injection and combustion
Endre Sandvik	SFI Smart Maritime WP4	NO	2016–2019	Simulation Based Design of Ships With Regards to System Performance
Benjamin Lagemann	SFI Smart Maritime WP4	GE	2019-2022	Concept Ship Design for Future Low-Emission Shipping Technology (WP4)
Siamak Karimi	SFI Smart Maritime WP3	IR	2019-2022	modeling and optimal design of marine hybrid electric power systems (WP3)
Kamyar Maleki	SFI Smart Maritime WP3	IR	2019-2022	A Simulator Approach to Concept Analysis and Optimization of marine Power Plants (WP3)
Ehsan Esmailian	SFI Smart Maritime WP2	IR	2019-2022	Optimization of ships for operation in real sea states (WP2)
Other funding				
Pramod Ghimire	Kongsberg Maritime		2019-2021	Simulator Approach for Ship Hybrid Power Plant Concept Studies
Sadi Tavakoli	Cotutelle NTNU / DTU	IR	2017–2020	Marine machinery
Simone Saettone	Cotutelle NTNU / DTU	IT	2017–2020	Hydrodynamics
Øyvind Øksnes Dahlheim	Rolls-Royce UTC	NO	2015–2018	Hydrodynamics
Anna Swider	Rolls-Royce Ind. PhD	PL	2015–2018	Hydrodynamics
Jarle Kramer	KPN LEEDS	NO	2013–2018	Hydrodynamics

COMMUNICATION AND DISSEMINATION

Rotor test – Fouling rate test. Photo: Jotun.

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.

e-mail newsletters

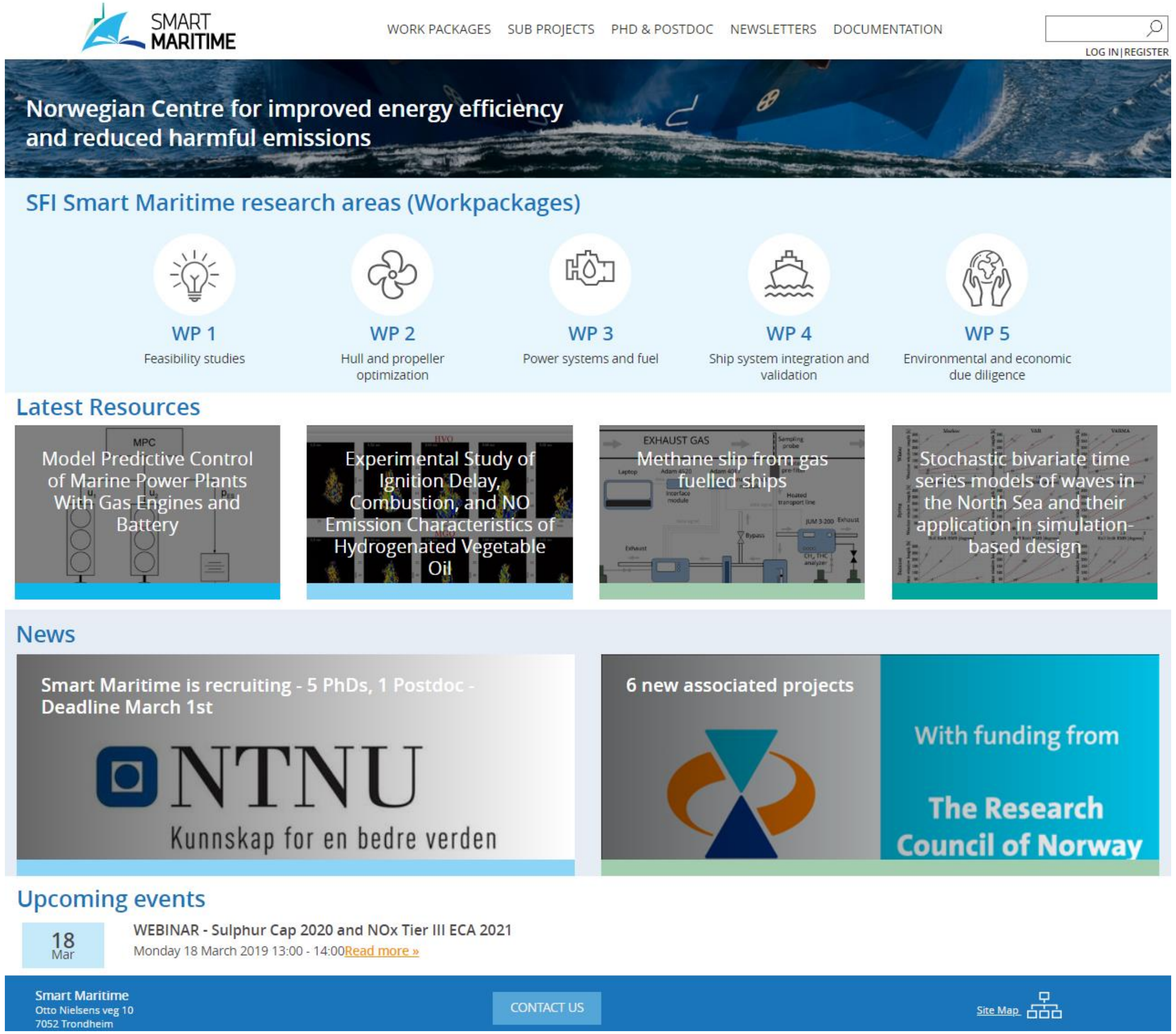
sent to Smart Maritime participants, with information about the research progress, achievements, upcoming events.

Workshops

Technical workshops and Bi-annual network meetings.

Webinars

Smart Maritime offers Webinars that contribute to more scientific discussion between research team and industry partners and a wider network.



PUBLICATIONS AND REPRESENTATIONS

Journal publication

Academic article

Bø, T. I., Vaktskjold, E., Pedersen, E. & Mo, O. 2019. Model Predictive Control of Marine Power Plants with Gas Engines and Battery. IEEE Access, 7, 15706-15721.

Lindstad, E., BORGEN, H., ESKELAND, G., PAALSON, C., PSARAFTIS, H. & TURAN, O. 2019a. The Need to Amend IMO's EEDI to Include a Threshold for Performance in Waves (Realistic Sea Conditions) to Achieve the Desired GHG Reductions. Sustainability, 11, 17.

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Nielsen, J. B. & Pedersen, E. 2019. A system approach to selective catalytic reduction deNOx monolithic reactor modelling using bond graphs. Journal of Engineering for the Maritime Environment (Part M), 233, 632-642.

Nielsen, Jørgen Bremnes; Sandvik, Endre; Pedersen, Eilif; Asbjørnslett, Bjørn Egil; Fagerholt, Kjetil. (2019) Impact of simulation model fidelity and simulation method on ship operational performance evaluation in sea passage scenarios. Ocean Engineering. vol. 188.

Nielsen, J. B., Yum, K. K., & Pedersen, E. (2019). Improving pre-turbine selective catalytic reduction systems in marine two-stroke diesel engines using hybrid turbocharging: A numerical study of selective catalytic reduction operation range and system fuel efficiency. Proceedings of the Institution of Mechanical Engineers, Part M: Journal of Engineering for the Maritime Environment.

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Ushakov, S., Stenersen, D., Einang, P. M. & Ask, T. Ø. 2019. Meeting future emission regulation at sea by combining low-pressure EGR and sea water scrubbing. Journal of Marine Science and Technology.

Ushakov, S., Stenersen, D., Einang, P. M. 2019. Methane slip from gas fuelled ships: a comprehensive summary based on measurement data. Journal of Marine Science and Technology, 24, 1308-1325.

Yum, K. K., Taskar, B. & Pedersen, E. 2019. Model Reduction through Machine Learning Tools Using Simulation Data with High Variance. ISOPE - International Offshore and Polar Engineering Conference. Proceedings.

Popular scientific article

Lindstad, E. Labour under an Assumption. Baltic Transport Journal. 2019, 30-32

Feature article

Muri, H. 2019. Vi kan kjøle ned kloden med ørsmå partikler i stratosfæren. Men er det lurt? Aftenposten (morgenutg. : trykt utg.). 2019-03-11

Part of a book/report

Academic chapter/article/Conference paper

Gupta, Prateek; Steen, Sverre; Rasheed, Adil. Big Data Analytics As a Tool to Monitor Hydrodynamic Performance of a Ship. I: ASME 2019 38th International Conference on Ocean, Offshore and Arctic Engineering. Volume 7A: Ocean Engineering.

PUBLICATIONS AND REPRESENTATIONS

Media contribution

Interview

Bartlett, P. W. & Lindstad, E. 2019. Ship Dimmensions - a key factor in todays's GHG reduction aims.

Lindstad, E. 2019. Dr Elizabeth Lindstad on why increased use of LNG might not reduce maritime GHG emissions at all, Transport & Environment, 2019-07-10

Lindstad, HFO and Scrubbers a positive effect on GHG emissions study, www.tankeroperator.com, 2019-08-21

Lindstad, E. 2019. HFO with EGCs better for global CO2 reduction, Clean Shipping Alliances, 2019-08-12

Lindstad, E. & Hartkopf-Mikkelsen, J. 2019. LNG er måske slet ikke en fordel for klimaet. Søfart, 2019-09-02

Lindstad, E. & Lipsith, G. 2019. LNG study dispute puts methane slip in the spotlight. fathom.world, 2019-08-08

Muri, H. 2019. Earth could warm by 14°C as growing emissions destroy crucial clouds. New Scientist, 2019-02-25

Muri, H. 2019. Innsikt: 500 har underskrevet på at det ikke er klimakrise. Dette sier klimaforskere om oppropet. Faktisk.no, 2019-10-17

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Muri, H. 2019. Our Planet's fluffy clouds are in danger, increasing CO2 is destroying them. The Smoking Earth, 2019-12-26

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Reports

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Conference lecture and academic presentation

Lecture

Lindstad, E. 2019. Are HFO & Scrubbers with its low abatement cost, also an efficient measure to reduce local pollution. 3rd Environment Day der Kreuzfahrtindustrie - 4. September 2019. Hamburg.

Muri, H. 2019. Climate change mitigation through technology. Climate change mitigation lecture. 19.11.19

Muri, H. 2019. Climate Extremes. Geoengineering the Climate: Impacts and the Developing World 2nd Summer School.

Muri, H. 2019. From ambition to action - what does IPCC tell us? Energy Transition Conference 2019.

Muri, H. 2019. Half a degree matters. Fridays for future - Student mobilisation for sustainability 20.09.19

Muri, H. 2019. Hvordan oppfylle Parisavtalen? Hovedfunn fra FNs klimapanels siste rapport. Mobilisering for grønn verdiskaping i Trøndelag. 13.05.19

Muri, H. 2019. Marine cloud brightening. Geoengineering the Climate: Impacts and the Developing World 2nd Summer School. Beijing Normal University. 12.08.19 - 16.08.19

Popular scientific lecture

Muri, H. 2019. Hvordan henter vi CO_2 fra atmosfæren? <2 grader rapport lansering. Byåsen VGS. 17.10.19

Muri, H. 2019. Slik arter klimaendringene seg i Trøndelag. Folkemøte - Trøndersk klimatoppmøte. Byscenen.

Poster

Muri, H., Strømman, A. H., Ringvold, A., Lonka, R., Lindstad, E. & Bouman, E. 2019. A new emission inventory of the global maritime fleet; the effect of weather. American Geophysical Union Fall Meeting.

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Ushakov, S.; Stenersen, D.; Einang, P. M. 2019. Methane Slip Summarized: Lab vs. Field Data. CIMAC Congress 2019. Vancouver.

SMART MARITIME

STATEMENT OF ACCOUNTS 2019

	Funding		Cost	
Research council	12 553	(39 %)		
The Host Institution (SINTEF ocean)	3 365	(11 %)	12 431	(39 %)
Research Partner (NTNU)	3 310	(10 %)	8 702	(27 %)
Industry partners	12 561	(40 %)	10 541	(33 %)
Equipment			116	(<1 %)
Total NOK ‘000	31 790		31 790	

Bow Summer. Photo credit: Christian Dahll / Odfjell

SMART MARITIME

SMART MARITIME IN BRIEF

- Norwegian centre for improved energy efficiency and reduced harmful emissions from the maritime sector
- Centre for research-based innovation (SFI) granted by the research council (SFI-III)
- Main goals:
  - Improve energy efficiency
  - Reduce harmful emissions
  - Strengthen the competitiveness of the Norwegian maritime industry
- 22 research scientists
- Technical advisory: 50 industry professionals
- 10 laboratories
- Duration: 2015–2023
- Budget: 24 mnok/year
- Financing:
  - 50 % research council of Norway
  - 25 % industry partners
  - 25 % research partners

sfi Senter for forskningsdrevet innovasjon

Norges forskningsråd

Photo: Norwegian Electric Systems.

Photo: KG Jebsen

SMART MARITIME

sfi = Centre for Research-based Innovation

The Research Council of Norway

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