SMART MARITIME

sfi Centre for Research-based Innovation

The Research Council of Norway

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

FINAL REPORT 2023

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FOREWORD

After 8 years of exciting research and innovation, hard work and a lot of enjoyable networking and collaboration, the time has now come to wrap up SFI Smart Maritime with this final report. Here you will find some key facts about the centre and it's activities, as well as a summary of our achievements within education, research and innovation. We reflect on the centre's impact for the partners and society, and also look forward towards a continuation of the Smart Martime collaboration. As this final report only provides an overview, you should look to the annual reports of the centre and the published papers and reports for more details.

Looking back at the journey from 2015 till where we are today, I am extremely proud of what the SFI Smart Maritime consortium has achieved. Great candidates have been educated, so many high-level scientific papers has been published and numerous innovations within the industry partners have resulted in proven reductions of emission from shipping. Thanks to all centre partners for your huge engagement and contribution over all these years, and a special thanks to present and previous centre management team members.

Trond Johnsen
Director of SFI Smart Maritime

SFI Smart Maritime has worked with pushing the state-of-the-art within maritime research disciplines, provided insight on potential emission reduction from ships, tested out novel technology solutions, developed prediction models for hydrodynamics and power systems simulation, simulation tools for performance evaluation and benchmarking of ship designs. There is no doubt about the Norwegian Maritime Cluster's dedication to reduce GHG emissions from shipping and achieve IMO Goals, as testifies the number of spin-off research and innovation activities from the SFI Smart Maritime collaboration.

The Centre has been a core driver for the maritime research and innovation in SINTEF, and has resulted in a significant increase in our maritime R&D activity and number of researchers since 2015. It has also been important for the development and realization of The Norwegian Ocean Technology Centre that is now under construction. We have learned that hosting a SFI puts us in a strong position for recruitment, market development and political influence, and we are very grateful that the Research Council of Norway trusted us with funding for SFI Smart Maritime.

Vegar Johansen
CEO of host institution SINTEF Ocean

SUMMARY

40 Research scientists
50 Industry Experts

23 Partners

13 PhD students, 4 PostDocs

95 Peer-reviewed journal & conference articles

125 Conference and academic lectures

29 software tools applied by industry

16 Network Meetings

30 Webinars

Contribution to EU & IMO regulations

34 associated projects

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

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

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

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

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

The need for research within the topics of SFI Smart Maritime will remain and even increase in the coming years. The vision of a climate neutral maritime industry will drive research towards 2050, and further development of the results of the centre should be part of this picture.

NORSK SAMMENDRAG

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SFI Smart Maritime er dedikert til forbedring av energieffektivitet og reduksjon av skadelige utslipp fra skip. Senteret bidrar til å forbedre konkurransekraften til Norsk Maritime industri og hjelpen den til å nå IMOs mål gjennom ny teknologi, verktøy og effektive løsninger. Smart Maritime jobber med utvikling av systemorienterte verktøy som analyserer effekten av energieffektiviserende løsninger og tiltak for skrog og propell, propulsjonssystem, fremdriftsmaskineri og drivstoff under realistiske fullskalaforhold. Målet er å kunne simulere og optimalisere skipet numerisk før det bygges. 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, Jotun, Kongsberg Maritime, HAV Design, Norwegian Electric Systems, Siemens-Energy, Vard Design, og Wärtsilä Moss, samt 8 av de største norske deepsea rederiene Wallenius Wilhelmsen, Solvang, Grieg Star, Kristian Gerhard Jebsen Skipsrederi, BW LNG, Höegh Autoliners, Odfjell Tankers, Torvald Klaveness, og Norges Rederiforbund, Kystrederiene og Sjøfartsdirektoratet.

Senterets styrke er vårt nettverk og den jevnlige og konstruktive dialogen mellom forsknings- og industripartnerne. SFI 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 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. Dette bekreftes av antall assosierte prosjekter og innovasjonsvirksomher som har kommet fra samabeidet SFI Smart Maritimer.

Behovet for forskning innenfor temaene SFI Smart Maritime vil øke i årene som kommer. Visjonen om en klimanøytral maritim næring vil drive forskningen mot 2050, og videreutvikling av resultatene til senteret bør være en del av dette bildet.

VISION AND OBJECTIVES

Our vision is

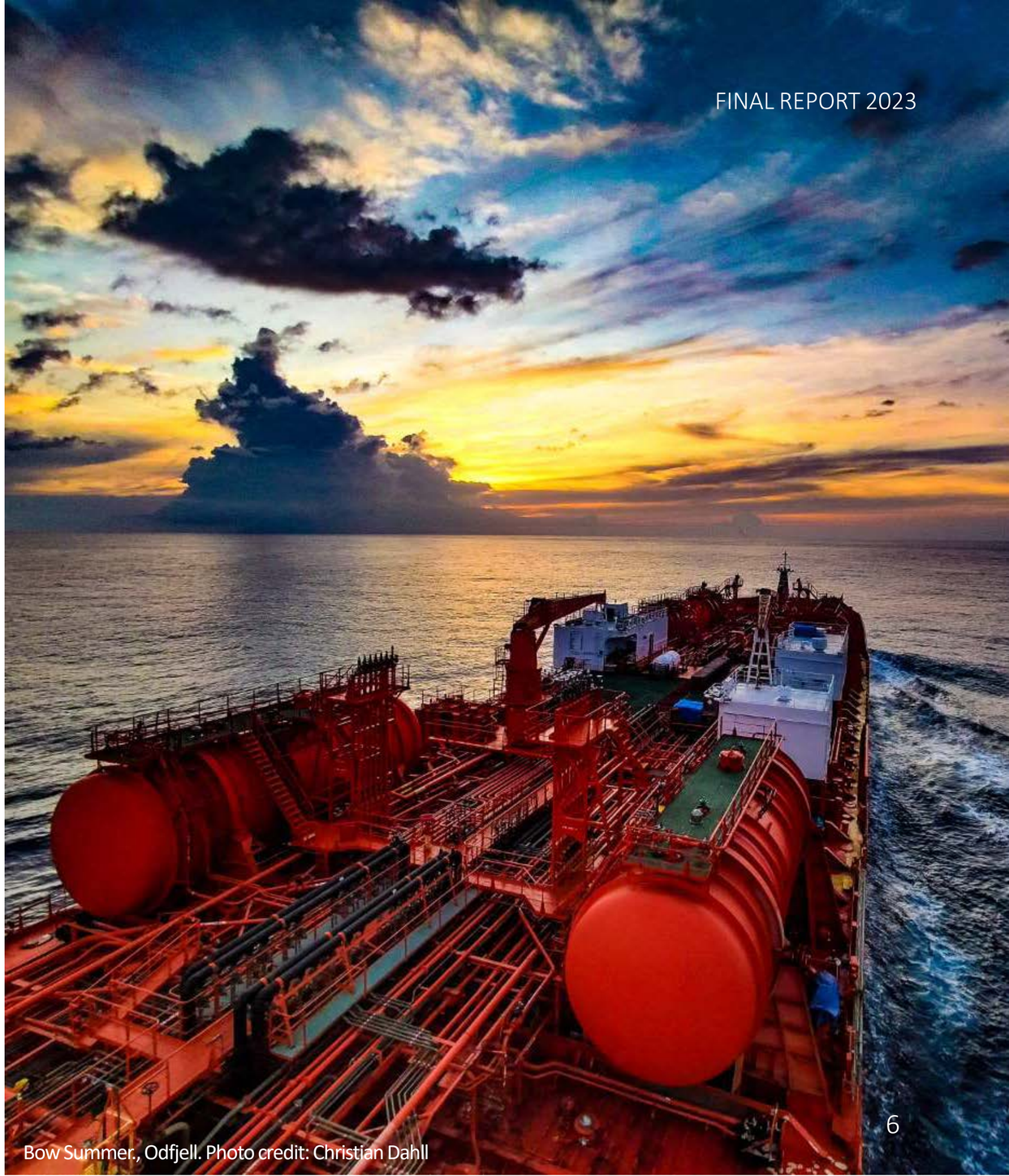
the greening of maritime transport, and by that enabling the Norwegian maritime cluster to be world leading in environmentally friendly shipping by 2025.

Our mission is

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

to contribute to

- increased competitiveness of the Norwegian maritime cluster,
- increased energy efficiency in shipping
- reduced harmful and GHG emissions from ships



Bow Summer., Odfjell. Photo credit: Christian Dahll

SFI Smart Maritime has reached the expected outcomes defined in 2015:

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

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

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

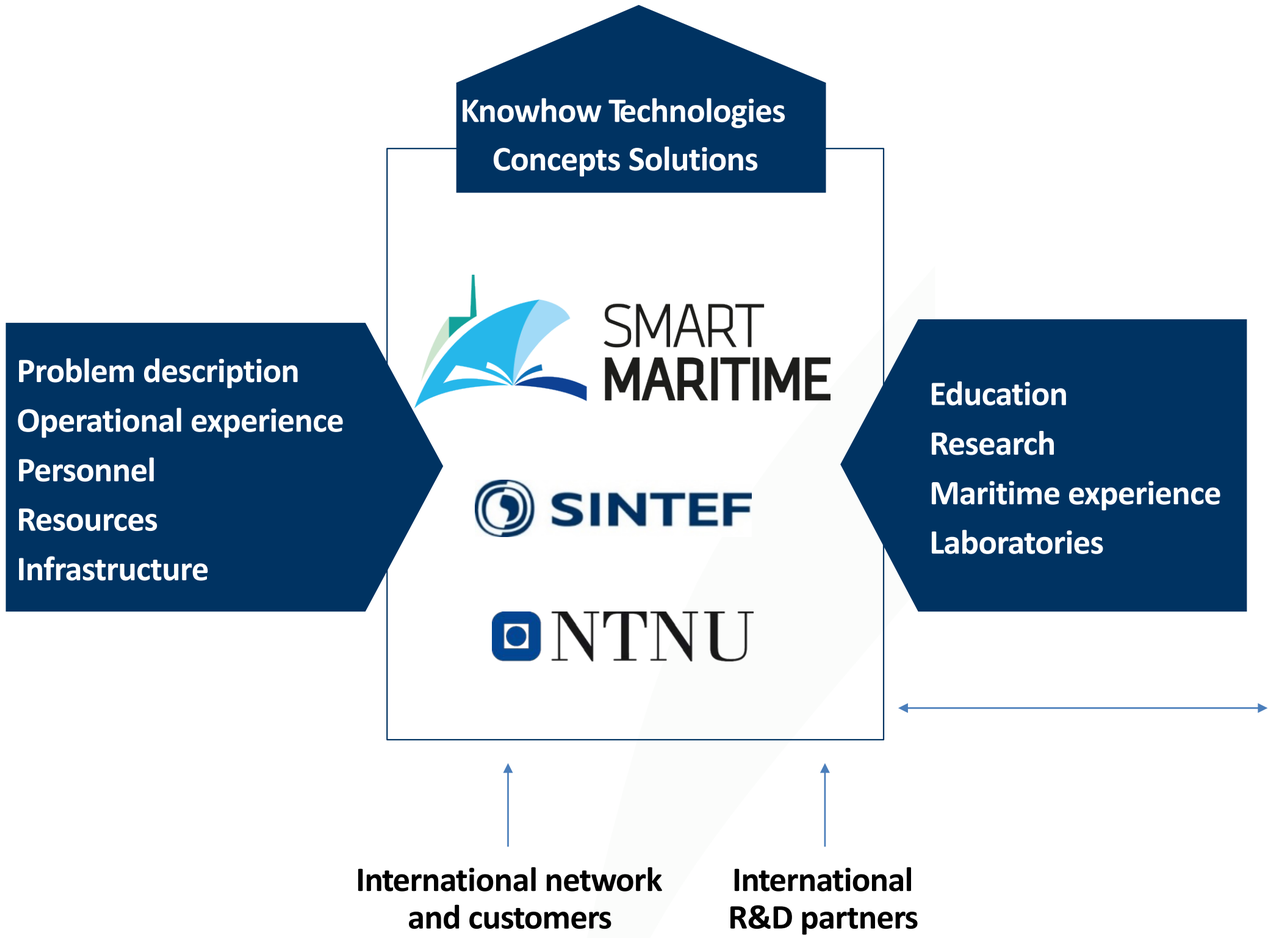
PARTNERS

INDUSTRY PARTNERS

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

Ship Owners & Operators
BW Group
Grieg Star
KG Jebsen Skipsrederi
Höegh Autoliners
Odfjell
Solvang
Klaveness
Wallenius Wilhelmsen

Other
DNV
Rederiforbundet
Sjøfartsdirektorat
Kystrederiene



RESEARCH PARTNERS

SINTEF Ocean (host)

NTNU
Dept. for Maritime Technology
Industrial Ecology Programme

NTNU – Ålesund
Faculty of Maritime Technology and Operations

OCEAN SPACE CENTRE

Norsk havteknologisenter
SFI Scope aligned with Ocean Space Centre's strategy.

RESSEARCH & INTEREST ORGANISATIONS

SINTEF

NTNU

DNV

Norges Rederiforbund
Norwegian Shipowners' Association

Kystrederiene

Sjøfartsdirektoratet
Norwegian Maritime Authority

SHIP OWNERS

GRIEG STAR

Grieg Star AS

Open Hatch general cargo, conventional Bulk / appr. 40 vessels.

SOLVANG ASA

Solvang ASA

LPG, petrochemical gases / appr. 27 vessels.

BW Group

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

KRISTIAN GERHARD JEBSEN SKIPSREDERI
PART OF THE KRISTIAN GERHARD JEBSEN GROUP

Kristian Gerhard Jebsen Skipsrederi AS

Tanker, dry cargo, cement / appr. 50 vessels

Torvald Klaveness

Torvald Klaveness

Dry bulk, Container / appr. 23 vessels

Wallenius Wilhelmsen

Wallenius Wilhelmsen ASA

RoRo shipping and vehicle logistics / appr. 125 vessels.

HÖEGH AUTOLINERS

Höegh Autoliners AS

PCTCs 2 300-8 500 ceu/ appr. 45 vessels

ODFJELL

Odfjell

Chemical tanker / appr. 120 vessels

SHIP DESIGN & SHIP BUILDING

HAV Design AS
(formerly Havyard group). Ship design, part of the HAV Group (founded 2021).

Vard Design AS
Ship design and Ship building. of specialized vessels.

Kongsberg Maritime
Development and delivery of integrated vessel concept (replaces Rolls-Royce Marine, fully integrated part of Kongsberg Maritime since 2019)

EQUIPMENT AND SYSTEM SUPPLIERS

ABB AS
Electric power and propulsion systems for ships.

Bergen Engines AS
;Medium speed gas and liquid fuel engines for marine power generation applications.

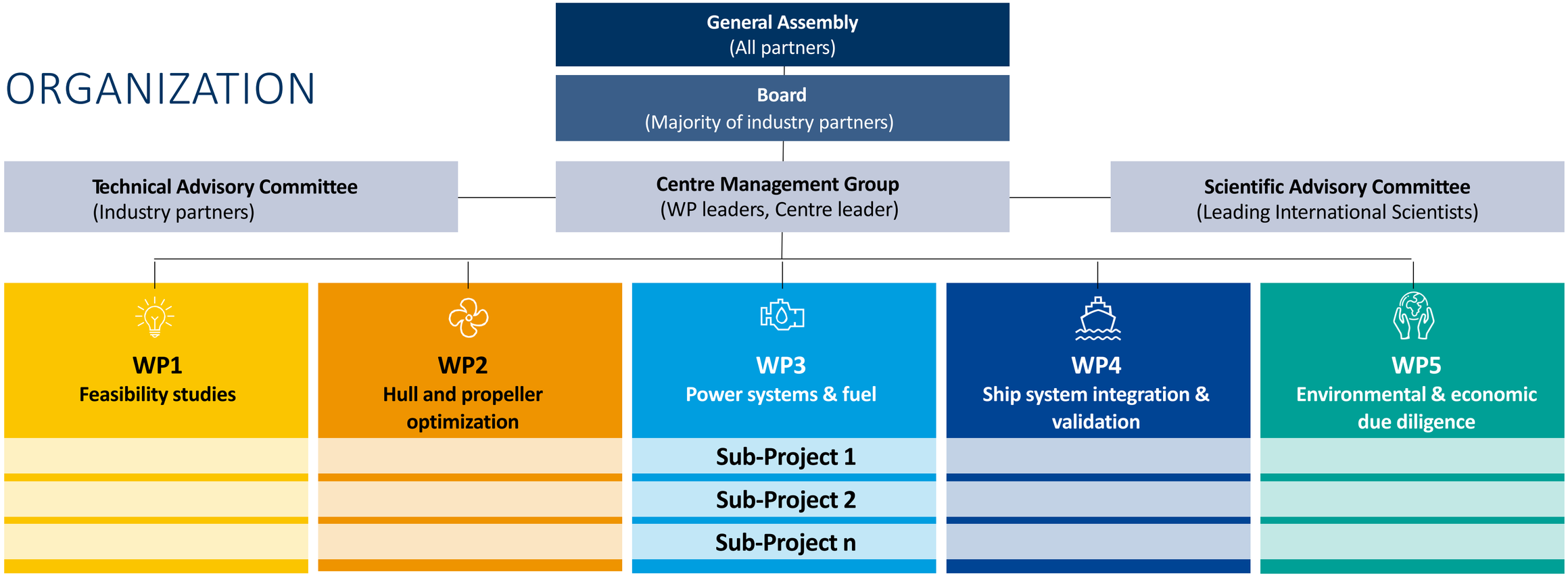
Jotun AS
Provider of paint systems and marine coatings for the newbuilding and dry-dock and maintenance markets.

Norwegian Electric Systems AS
Smart control systems and energy designs. HAV Design is part of the HAV

SIEMENS AS
Suppliers of diesel-electric propulsion systems.

Wärtsilä Moss AS
Solutions for ship machinery, propulsion, automation, ship design, automation systems and liquid cargo solutions.

ORGANIZATION



SINTEF Ocean hosts the Centre in collaboration with research partner NTNU. The industry partners form the Technical Advisory Committee, covering major parts of the maritime value chain. The Centre's long-term research activity is organised in five **Work Packages** (WP).

Board: operative decision-making body (7 members)

General assembly: representant from each Consortium partner.

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

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

Board Members	Affiliation
Jan Øivind Svardal *(Chairman)*	Grieg Star
Jan Fredrik Hansen	ABB
Sverre Torben (2020-2023)	Kongsberg Maritime
Per Ingeberg (2015-2019)	
Håvard Lien Vollset (2022-2023)	‚VARD Design
Ove Bjørneseth (2020-2021)	
Kjell Morten Urke (2017-2019)	
Henning Borgen (2015-2016)	
Lars Dessen	Wallenius Wilhelmsen
Beate Kvamstad-Lervold	SINTEF Ocean
Bjørn Egil Asbjørnslett	NTNU
Sigurd Falch (observer)	Norwegian Research Council


Jan Øivind Svardal


Jan Fredrik Hansen


Sverre Torben


Per Ingeberg


Håvard Lien Vollset


Ove Bjørneseth


Kjell Morten Urke


Henning Borgen


Lars Dessen


Beate Kvamstad-Lervold


Bjørn Egil Asbjørnslett


Sigurd Falch

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 (2019-2023) Per Magne Einang (2015-2018)	SINTEF Ocean	Centre Director
Anders Valland	SINTEF Ocean	Deputy Director
Elizabeth Lindstad	SINTEF Ocean	WP1 Feasibility studies
Sverre Steen Sverre Anders Alterskjær		WP2 Hull & Propeller
Mehdi Zadeh (2019-2023) Sergey Ushakov (2017-2018) Eilif Pedersen (2015-2016)	NTNU	WP3 Power systems & Fuel
Jon Dæhlen (2019-2023) Trond Johnsen (2015-2018)	SINTEF Ocean	WP4 Ship system
Anders Strømman Helene Muri (2018-2023) Evert Bouman (2015-2017)	NTNU	WP5 Environment & economy

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


Trond Johnsen


Per Magne Einang


Anders Valland


Stein Ove Erikstad


Elizabeth Lindstad


Sverre Steen


Anders Alterskjær


Jon Dæhlen


Mehdi Zadeh


Sergey Ushakov


Anders Strømman


Helene Muri


Eilif Pedersen


Evert Bouman


Agathe Rialland


Jan Andre Almåsbakk

RESEARCH TEAM:

CONTRIBUTION OF OVER 60 RESEARCHERS FROM 2015 TO 2023

SINTEF Ocean

Agathe Rialland
Anders Valland
Anders Östman
Anders Alterskjær
Andrew Ross
Beate Kvamstad
Dag Stenersen
Dariusz Fathi
Elizabeth Lindstad
Per Magne Einang
Endre Sandvik
Gunnar Gamlem
Henning Borgen
Inge Sandaas
Ingebrigt Valberg
Jon S. Dæhlen
Kevin Koosup Yum
Kristian Steinsvik
Kourosh Koushan
Martin Rindarøy
Renato Skejic
Torstein Bø
Trond Johnsen
Anne Bruyat
Edvard Ringen
Hans Jørgen Rambech
Jørgen Nielsen
Kristoffer Eide
Martin Gutsch
Ole Thonstad
Sadi Tavakoli
Thomas Sauder
Tor Einar Berg

NTNU

Anders Strømman
Benjamin Lagemann
Bjørn Egil Asbjørnslett
David Emberson
Diogo Kramel
Drazen Polic
Ehsan Esmailian
Eilif Pedersen
Florian Parebo
Helene Muri
Holmedal Lars Erik
Hyungjun Jeon
Jarle Kramer
John Martin Godø
Kamyar Maleki
Marius Ulla Hatlehol
Mehdi Zadeh
Namireddy P. Reddy
Nastaran Shakeri
Prateek Gupta
Siamak Karimi
Stein Ove Erikstad
Stian Skjong
Sverre Steen
YoungRong Kim
Yuan Tian
Vilmar Æsøy

With valuable support from:

FORSKNINGSRÅDET
Liv Jorunn Jenssen
Sigurd Falch
Marianne Nereng

INDUSTRY EXPERTS:

A NETWORK OF OVER 150 PEOPLE

ABB
Børre Gundersen
Espen Olsen
Henrik Gjemdal
Jan-Fredrik Hansen

BERGEN ENGINES
Erlend Vaktskjold
Isak Stamnes
Jan Eikefet
Leif Arne Skarbø
Matthew Bloss

BW
Borge Mokleiv
Olav Lyngstad

DNV
Binjie Guo
Christos Chryssakis
Edwin Aalders
Hans Anton Tvete
Hendrik Brinks
Liang Qin
Olav Rognebakke
Sverre Eriksen
Øystein Å Alnes

GRIEG STAR
Jan Øivind Svardal
John Gabriel Östling
Ragnhild Farstad Høvik
Roar Fanebust

HAV GROUP
Arve Nedreberg
Jan-Magne Goksøyr
Kay Lorgen
Kjetil Myren
Kristian Osnes
Stig Endre Moe

HØEGH AUTOLINERS
Adrian Lim
Christian Dahl
Eirik Austad
Henrik Andersson
Sondre Nilsen
Thea Valvatne

JOTUN
Kim Andreassen
Manolis Levantis
Andreas Krapp
Angelika Brink
Stein Kjølberg
Zakari Midjiyawa

KLAVENESS
Anders M Sørheim
Audun Eriksen
Christian Skjelbred
Ernst A Meyer
Martin Wattum

KONGSBERG MARITIME
Are Folkestad
Birgit Lynge
Bjørn Erik Osmark
Bjørnar Vik
Einar Vegsund
Eirik Mathisen
Erling Johannesen
Gaute A Augestad
H.M.Hjørungnes
Harald O Myrlund
Henrik A Sjøblom
Karl A Wirén
Krishna Nagalingam
Leif Vartdal
Mark Callaway
Markus Heimdal
Martijn de Jongh
Robert Eriksson
Rune van Ravens
Svein Kleven
Sverre Torben
Torbjørn Hals
Vidar Smines

KRISTIAN GERHARD JEBSEN SKIPSREDERI
Jan Berntzen
Stein Håvard Sunnevåg
Rune Sylta
Ståle Torsvik
Ole-Johan Haahjem (OSM)
Øyvind Monsen (OSM)
Øyvind Vindenes (OSM)

KYSTREDERIENE
Tor Arne Borge

REDERIFORBUND
Helene Tofte
Jahn Viggo Rønningen

NORWEGIAN ELECTRIC SYSTEMS
Daniel Aaro
Geir Larsen
Håvard Hellvik
Johannes Tveit
Kåre Vistnes
Oddvar Sandtorv
Ole Georg Rørhus
Stein Ruben Larsen
Torbjørn Haugland
Tore Havsø

ODFJELL
Erik Hjortland
Jan A. Opedal
Vegard Marken
Veine Huth

SIEMENS ENERGY
Furunes Arne
Arne-Gunnar Brandvold
Kenneth P Tjong
Lars Barstad
Mona Khorasani
Odd Moen
Stig-Olav Settemsdal
Tor Ove Haugan
Vemund Kårstad

SJØFARTSDIREKTORAT
Berge Kolbjørn
Mildal Simen Diserud
Lasse Karlsen

SOLVANG ASA
Jone Ask
Tor Øyvind Ask

VARD DESIGN
Andreas Hjellbakk
Henrik Burvang
Håvard Vollset Lien
Ulrik Havnsund
Kjell Morten Urke
Kåre Nerland
Martin Skaar Vadset
Ove Bjørneseth
Tim Mak
Tor Arne Myklebust
Andreas Buskop
Bjørn Bjerke

WALLENIUS WILHELMSEN
Lars Dessen
Lars Ekren
Sergey Ushakov

WÄRTSILÄ MOSS
Heidi Paulsrud
Jan Gannefors
Sergio R Palencia
Sigurd Jenssen

COOPERATION
INDUSTRY - RESEARCH - ACADEMIA

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

Industry participation includes the following:

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

NETWORK MEETINGS

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

NETWORK MEETINGS: SPRING

Dialog on new research and innovation initiatives

February 2016
Oslo – Host: Wallenius Whilhelmsen

Mars 2017
Ålesund – Host: Rolls Royce Marine

April 2018
Bergen – Host: Grieg Star

April 2019
Oslo – Host: Rederiforbundet

June 2022
Havila Castor – Host: Havila

June 023 – Final Conference
Trondheim – Host: SINTEF Ocean

MAY 2020 & 2021
Online

NETWORK MEETINGS: AUTUMN

Presentation of results and Planning of future activities

Trondheim, Host: SINTEF Ocean

October 2015 (Kick-off meeting)

October 2016

October 2017

October 2018

October 2019

October 2020

November 2021

November 2022

NATIONAL COOPERATION

National research and expertise centres

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

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

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

Smart Maritime is represented in

- NCE Maritime CleanTech
- Grønnkystfartprogram
- Kompetanseforum for krevende marinoperasjoner

University collaboration

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

Associated projects

Associated projects are the most important forms of collaboration with user partners generated by the centre.

New opportunities are explored every year by partners of Smart Maritime for further research or commercialisation activity.

Through the Centre's life-time, based on active collaboration among the Centre partners, no less than **34 associated projects involving at least two of SFI Smart Maritime Partners have been launched.**

ASSOCIATED PROJECTS

Project title	Period	Funding	Smart Maritime Partners
HOLISHIP - HOLIstic optimisation of SHIP design and operation for life cycle	(2016-2020)	EU H2020	Kongsberg Maritime, DNVGL, SINTEF
Hybrid testing - Real-Time Hybrid Model Testing	(2016-2020)	MAROFF, KPN	NTNU, SINTEF
SATS - Analytics for ship performance monitoring in autonomous vessel	(2018-2020)	MAROFF, KPN	NTNU, SINTEF
Open simulation platform	(2018-2020)	JIP	DNV GL, Kongsberg Maritime, SINTEF, NTNU
Digital twin for lifecycle operations	(2018-2022)	MAROFF	DNV GL, Kongsberg Maritime, SINTEF, NTNU
CLIMMS - Climate change mitigation in the maritime sector	(2019-2023)	MAROFF, KPN	NTNU, SINTEF, Rederiforbund + all 8 ship owners SFI-partners
SmartShipRouting	(2019-2021)	MAROFF, IPN	NCS, NES, Havila, Havyard, SINTEF
RuteSim: Simuleringsbasert Ruteplanlegging	(2019-2020)	MAROFF, IPN	Grieg Star, WWO, KGJS, SINTEF, Nansen
Digital twin yard	(2019-2021)	MAROFF, IPN	DNVGL, Rolls-Royce, NTNU, SINTEF
FreeCO2ast	(2019-2022)	PILOT E	Havyard, Havila , SINTEF
Extension of Hybrid Lab	(2019-2019)	ABB	ABB, SINTEF
Autoship	(2019-2022)	EU H2020	Kongsberg, SINTEF
RedRes - Innovative surface structures to reduce friction	(2020-2023)	MAROFF, KPN	JOTUN, SINTEF, NTNTU, Grieg Star
IPIRIS - Improving Performance in Real Sea	(2020-2023)	MAROFF, KPN	VARD, Havyard, Kongsberg, SINTEF, NTNU
CruiseZero – Zero-emission expedition cruise	(2020-2022)	MAROFF, IPN	VARD, ABB, SINTEF
PEZOS - Plug-In Electric Zero-emission Offshore-ship	(2020-2022)	MAROFF, IPN	VARD, SINTEF
Bio4-7seas - Biofuels in deep sea shipping for climate change mitigation	(2020-2023)	ENERGIX, KPN	NTNU, SINTEF
ZeroCoaster - Zero-emission coastal bulk shipping	(2020-2022)	MAROFF, IPN	VARD, ABB, DNV GL, SINTEF
Air-lubrication	(2020-2022)	MAROFF, IPN	Jotun, SINTEF
Gaters - Gate Rudders	(2020-2022)	EU H2020	Strathclyde, SINTEF
Aegis	(2020-2023)	EU H2020	SINTEF
VesselAI	(2021-2024)	EU H2020	Kongsberg, SINTEF
CCShip – Carbon Capture and Storage onboard ships	(2021-2024)	MAROFF, KSP	Klaveness, Wärtsila, NCCS, Calix,SINTEF, NTNU
AMAZE - Ammonia zero emission	(2021-2023)	MAROFF, IPN	Bergen Engines, SINTEF, NTNU
SEA-Co - Safer, easier and more accurate Co-simulations	(2021-2025)	MAROFF, KSP	DNV, Kongsberg, SINTEF, NTNU
ISTS - Intelligent ship transport systems	(2021-2024)	MAROFF, KSP	SINTEF, Kongsberg, DNV, Grieg, Kystverket, Sjøfartsdirektoratet
ZeroKyst – Decarbonization of ships for seafood sector	(2021-2024)	Green Platform	Siemens, SINTEF, NTNU
ProfSea - Ship Operational Performance in Following Sea	(2021-2024)	NFR, KSP	Kongsberg, SINTEF, NTNU
Ecorouter - Route optimization integrating low-carbon technologies	(2022-2024)	MAROFF, IPN	KGJS, OSM, Odfjell, SINTEF
SeaWorthy	(2022-2026)	MAROFF KSP	SINTEF, NTNU, DNV, HAV, Kongsberg, Kystrederiene,Rederiforbundet
GreenPlatform SeaZero (Hurtigruten)	2023-2026	NFR,IN,SIVA	Vard, DNV, Jotun, SINTEF
WIND - Enabling Zero-Emission shipping with wind-assisted propulsion	2023-2026	NFR, KSP	Kongsberg M, KGJS, Grieg Star, Odfjell, Klaveness, Solvang
Air Lubrication	2023-2026	NFR, KSP	Kongsberg, Jotun, KGJS, Klaveness, Grieg Star
DYNAPORT - Dynamic navigation and port call optimisation in real time	2023-2026	EU Horizon Europe	Grieg Star, SINTEF Ocean

FINANCING THROUGH THE LIFE OF THE CENTRE (NOK MILLION)

Contributor	Cash	In-kind	Total
The Host Institution (SINTEF ocean)		41,9	41,9
Research Partner (NTNU)		28,2	28,2
Industry partners	17,2	45,2	62,4
Public partners	1,2	0,5	1,7
Reseach Council of Norway	96,0		96,0
Total	**114,4**	**115,8**	**230,2**

DISTRIBUTION OF RESOURCES (NOK MILLION)

Type of activity	NOK million
Research projects	199,8
Common centre activities*	8,0
Administration	22,4
Total	**230,2**

* activities to enhance cohesiveness at the centre (meetings, seminars, workshops and centre-internal communication).

Foto: Sjøfartsdirektoratet

RESULTS - KEY FIGURES

	2015	2016	2017	2018	2019	2020	2021	2022	2023	Total
Scientific publications (peer reviewed)	4	17	12	8	12	8	11	14	9	**95**
Dissemination measures for users	0	9	14	15	17	33	24	10	3	**125**
Dissemination measures for the general public	7	5	7	9	20	2	6	4	1	**61**
PhD degrees completed		1			3			3	2	**9**
Master degrees	1	2	12	7	2	1		17	3	**45**
Number of new/improved methods / models / prototypes finalised		5	6	6		7	9	4	4	**40**
Number of new/improved products / processes / services finalised			1	3		2	6		4	**15**
Patents registered			1							**1**
New business activity				1		1		2		**4**

SMART MARITIME

DISSEMINATION

71 Peer-reviewed journal articles

23 Conference articles, Academic chapters

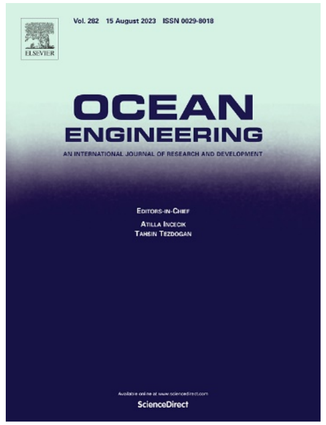
68 Conference lectures

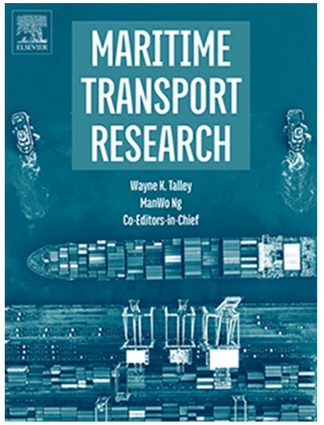
50 Academic lectures

12 Popular science lectures

12 Popular science articles

50 Media contributions & others





INDUSTRIAL INNOVATION

Skal løse skipsfartens klimagassproblem med multifuel brenselcelle

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

Modulbygde skip skal gjøre det lettere å bytte til utslippsfritt

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

Solvang-skip får karbonfangst og lagring om bord

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

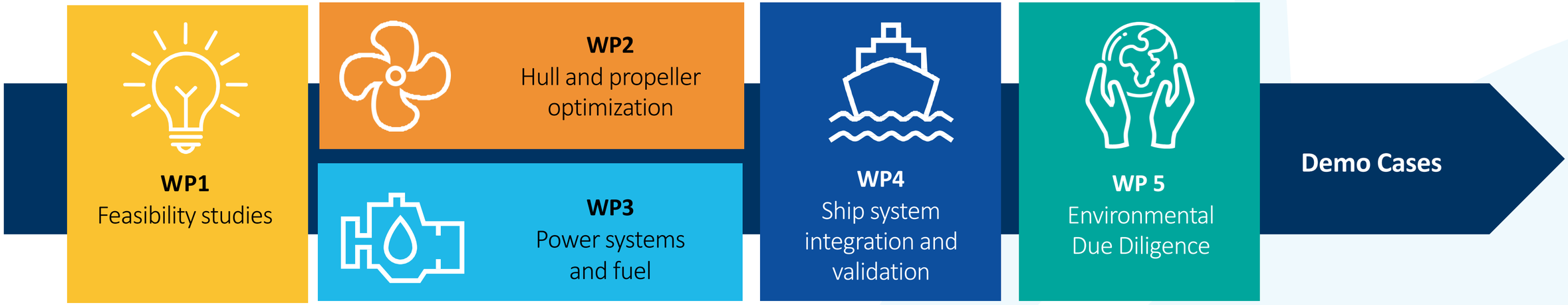
Source: Teknisk Ukeblad

RESEARCH

Original plan and Research Achievement

STAR HARMONIA, Photo: Grieg Star

WORK PACKAGES / RESEARCH AREAS



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

WP1: Feasibility studies

Objective

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

Research need and background

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

Main Achievement

Feasibility studies method & tool	GHG emissions reduction potential	Feasibility studies
• Power setups, fuels and hull designs to fulfill EEDI requirements • Assessing Alternative Fuel pathways considering GHG emissions, Energy usage and Cost, in a Well-to-Wake perspective	• Potential for GHG reduction from shipping – technical and operational measures • The potential role of E-fuels • Assessing LNG as a Transition Fuel • Energy efficiency measures	• Shipping decarbonization scenarios • Wise use of renewable energy in transport • Slender dry-bulker with wind assisted propulsion • Batteries in offshore support vessels • EEDI to Include a threshold for Performance in Waves to Achieve the Desired GHG Reductions

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.

Main Achievement

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

WP3: Power systems and fuel

Objective

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

Research need and background

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

Main Achievement

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

WP4: Ship System Integration and Validation

Objective

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

Research need and background

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

Main Achievement

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

WP5: Environmental Due Diligence

Objective

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

Research need and background:

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

Main Achievement

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

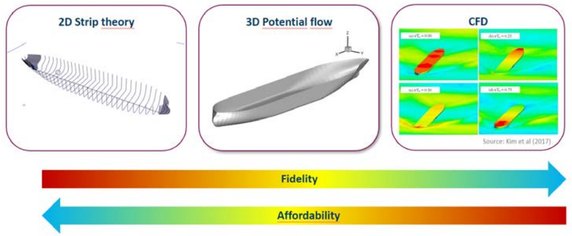
SMART MARITIME

SCIENTIFIC RESULTS - HIGHLIGHTS

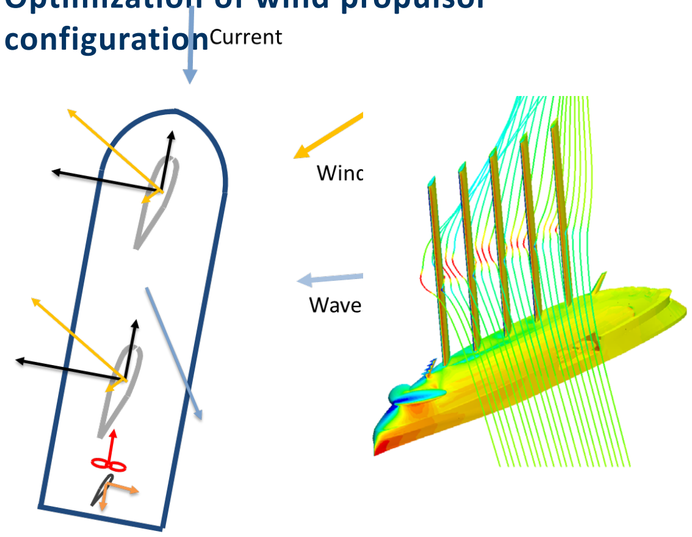
Clipper Quito. Photo: Solvang.

SMART MARITIME ANALYSIS AND SIMULATION TOOLS

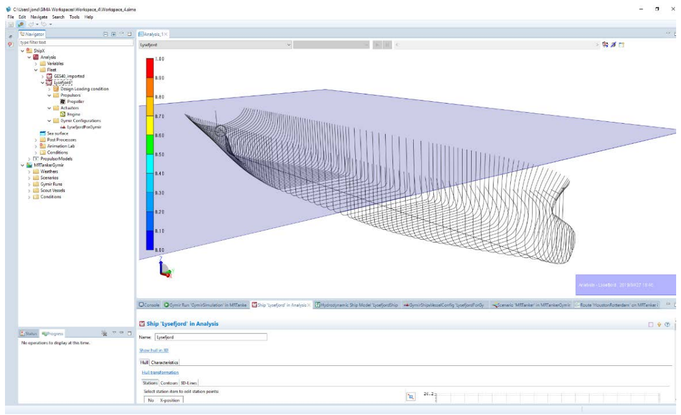
VERES3D:
Added resistance in waves



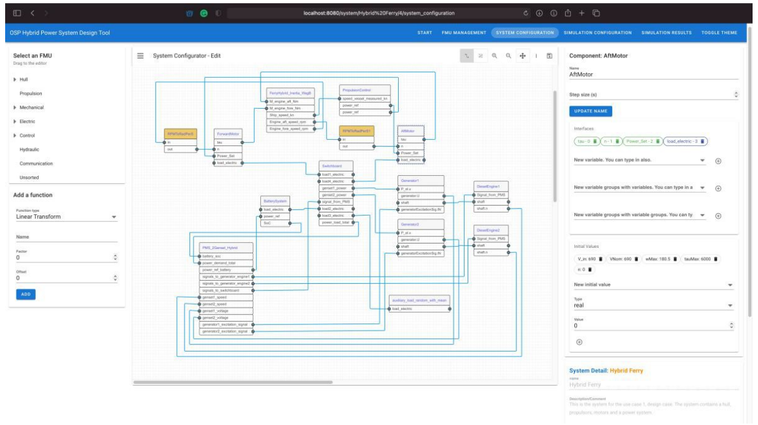
Steady sail
Optimization of wind propulsor configuration



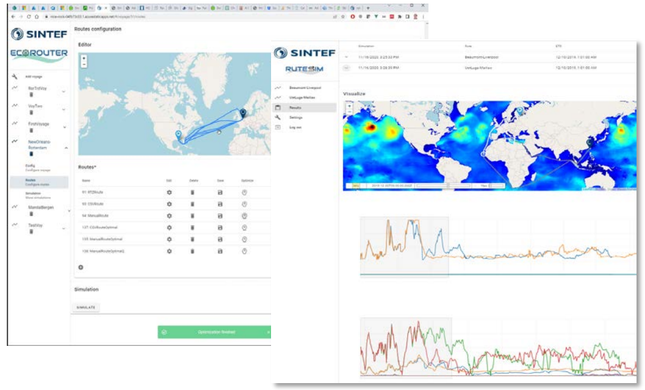
Gymir Simulation Framework: Ship Models



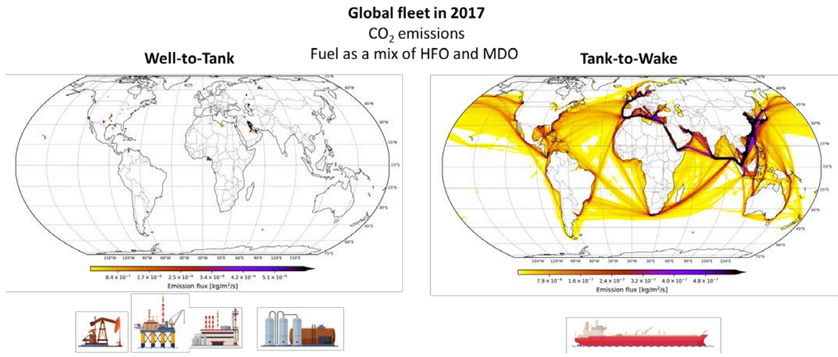
Gymir Simulation Framework: Power Plant



Ecorouter / Rutesim:
Ship Model-basert Route Simulation & Optimization



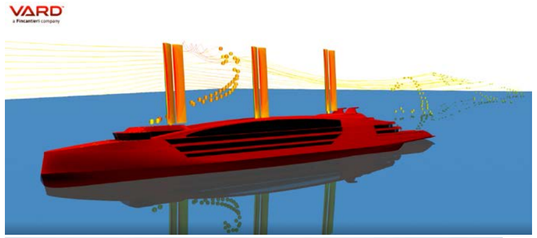
MAriTEAM
Maritime Transport Environmental Assessment Model

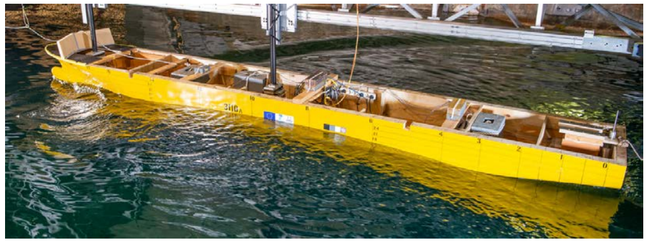


CASE STUDIES

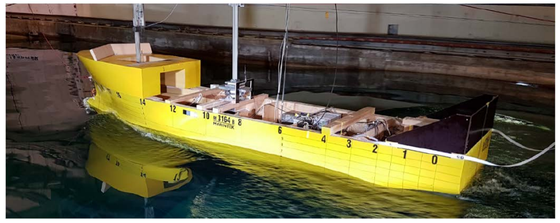
- Exploring new ideas and concepts
- Testing methods and analytical tools

Zero emission expedition cruise.

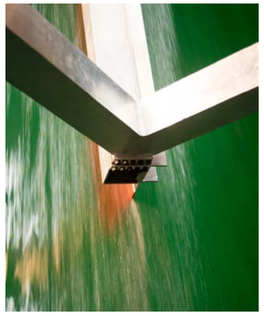




Energy Saving Devices (ESD)



Frictional resistance



Ferry

Open hatch bulk carrier concept

Ro-Ro ship concept

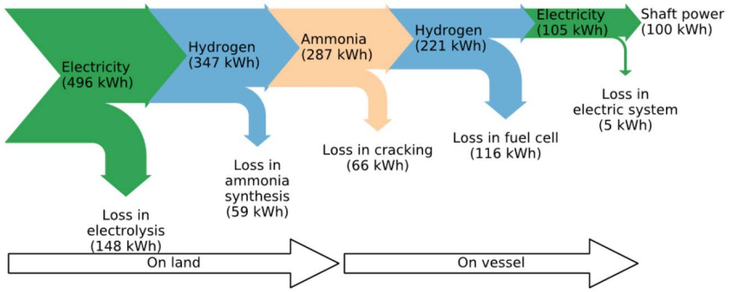
Kystruten

POWER SYSTEMS AND FUELS

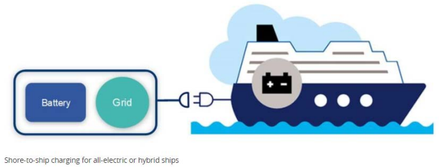
Hybrid Lab
Extension with Fuel Cells

METHANE SLIP FROM GAS FUELLED ENGINES

Hydrogen propulsion

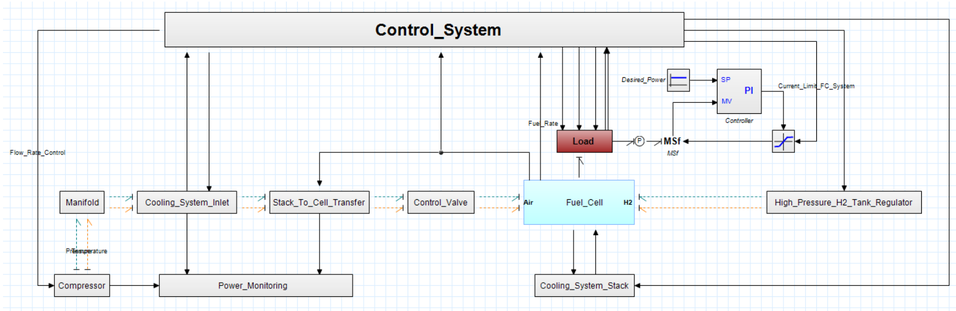


Shore to ship charging



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

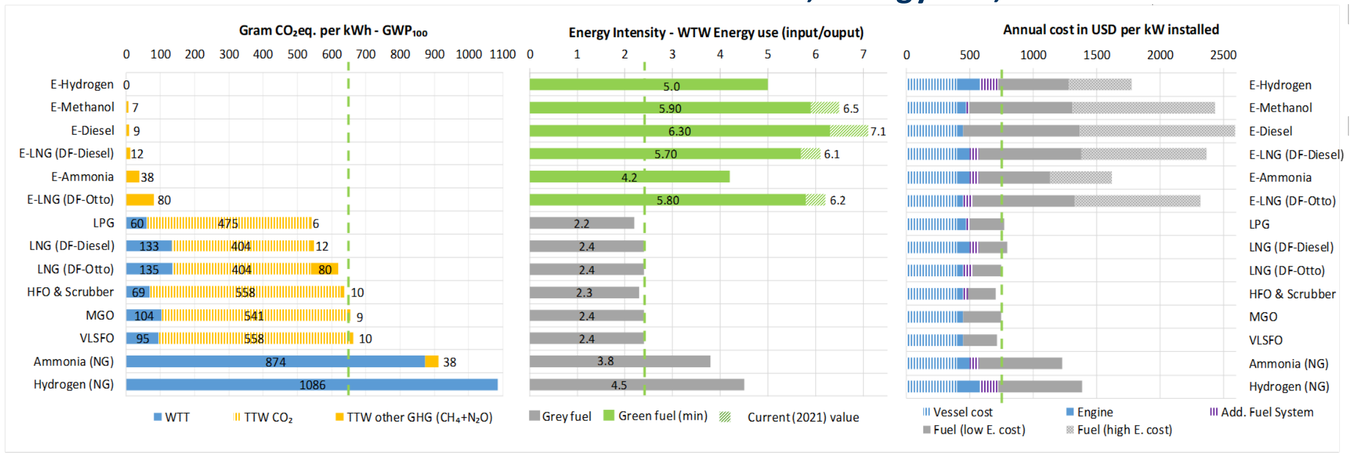
CFD modelling of fuel cell



ABATEMENT TECHNOLOGIES

A test on improved EGR quality showed a reduced need for turbine and heat-exchanger washing.

Assessment of fuels based on GHG emissions, Energy use, Annual vessel cost



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. From 2015 to 2023, SINTEF Ocean and Smart Maritime partners have been involved in 5 H2020 projects with high relevance and synergy with Smart Maritime in terms of scientific activity or industrial challenges.

Academic and research cooperation

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

International cooperation on policy development

- IPCC International Panel on Climate Change: Prof. Strømman and Dr. Muri (NTNU) co-author of the IPCC's Sixth Assessment Report.
- ESSF: European Shipping Sustainability Forum: Dr Lindstad expert advisor and task-lead for working groups: Alternative Fuels and Ship Energy Efficiency, coordinating submissions to IMO and ISO.
- Dr. Lindstad, one of three external experts in BIMCO's WG on Alternative Fuels which started autumn 2021
- IMO / MEPC: SFI Smart Maritime participants actively involved in IMO consultations.
- UNCTAD: contribution to UNCTAD expert assessment for IMO.
- MAREFORUM. Dr. Lindstad regular panel speak at one of the most global and influential forums for the maritime and shipping industry.
- SNAME fellowship attributed to Dr Elizabeth Lindstad in 2017
- WSA – Wind Ship Association: SINTEF Ocean associated member
- ITTC – SINTEF Ocean Technical committee member
- HLPOCC: High Level Panel for a Sustainable Ocean Economy. 2019: Dr Lindstad invited to co-author the report The Ocean as a Solution to Climate Change.

TRAINING OF RESEARCHERS

Smart Maritime is a scientific and industrial network of 100 people. The research team has over time involved over 40 research scientists from two institutions NTNU and SINTEF Ocean, and financed (fully or partially) **13 PhDs** and **4 PostDocs**.

Gender Balance:

The maritime technology sector has traditionally a low percentage of woman. The Centre has puts efforts on mobilising at Master level, in order to increase the interest for the field, and increase the pool of potential PhD candidates, researchers or professional in the medium and long-term.

Through the SFI Smart Maritime lifetime, the gender balance among MSc Students, Researchers, as well as Industrial Experts involved in the Technical Advisory board and research activity together with NTNU and SINTEF, has improved.

Contribution to development of educational programmes:

The centre contributes to strengthen the aspect of research-based education in courses concerning maritime transport. The Centre members contribute to the teaching at Master level, applying knowledge gained through the wide and active centre activities.

PHD STUDENTS AND POSTDOCTORAL RESEARCHERS

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.

Employment of PhD candidates (number)							
By centre company	By other companies	By public organisations	By university	By research institute	Outside Norway	Other	Total
			13				13

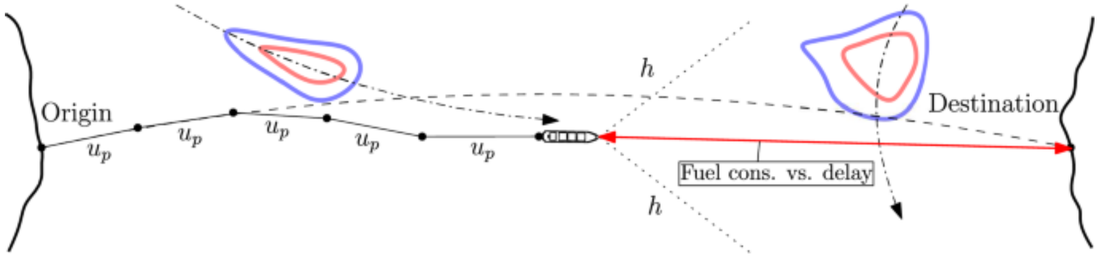
Name	Nationality	Period	Topic
Postdoctoral researchers SFI Smart Maritime			
L.Prasad Perera	LK	2015 – 2017	Data handeling and analysis
Torstein I. Bø	NO	2015 – 2018	Hybrid propulsion
Renato Skejic	HR	2016 - 2018	Computation of added resistance due to waves
Dražen Polić	HR	2020 - 2022	Impact of wind propulsion on the propeller and power system. (WP3)
PhD students SFI Smart Maritime - WP2 Hull and propeller optimization			
John Martin Godø	NO	2015-2018	Hydrodynamics
Jon Coll Mossige	NO	2017-2020	Added resistance on ships due to hull roughness
Prateek Gupta	IN	2018–2022	Ship performance monitoring using in-service measurements & big data analysis
Ehsan Esmailian	IR	2019-2022	Optimization of ships for operation in real sea states
Jarle Kramer	NO	2020-2022	Hydrodynamic modelling of wind-powered merchant vessels
PhD students SFI Smart Maritime - WP3 Power systems and fuels			
Jørgen Nielsen	NO	2015-2018	System simulation
Vladimir Krivopolianskii	UA	2015-2018	Fuel injection and combustion
Kamyar Maleki	IR	2019-2022	A Simulator Approach to Concept Analysis and Optimization of marine Power Plants
Yuan Tian	CN	2020-2023	Modelling and simulation of ship exhaust gas cleaning system
Siamak Karimi	IR	2019-2022	Modelling and optimal design of marine hybrid electric power systems
Marius Ulla Hatlehol	NO	2021-2024	Modelling, Design and Control of Hybrid Electric Power and Propulsion
PhD students SFI Smart Maritime - WP4 Ship System Integration and Validation			
Endre Sandvik	NO	2016-2019	Simulation Based Design of Ships
Benjamin Lagemann	GE	2019-2022	Concept Ship Design for Future Low-Emission Shipping Technology

Endre Sandvik

PhD student WP4 (2016–2019)

Simulation Based Design of Ships With Regards to System Performance

Using simulations to virtually test designs in operational scenarios
Routing vessels taking future sea states into consideration



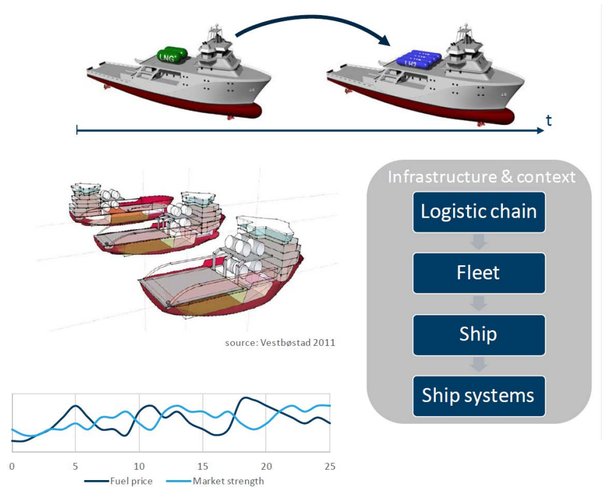
Supervisor: Professor Bjørn Egil Asbjørnslett, NTNU IMT
Co-supervisor: Professor Sverre Steen, NTNU IMT
Professor 2 Stein Ove Erikstad, IMT (FEDEM)
Associate professor Eilif Pedersen, NTNU IMT

Benjamin Lagemann

PhD student WP4 (2019-2022)

Concept Ship Design for Future Low-Emission Shipping Technology

Optimal ship lifetime fuel and power system selection
Reduction of maritime GHG emissions and the potential role of E-fuels

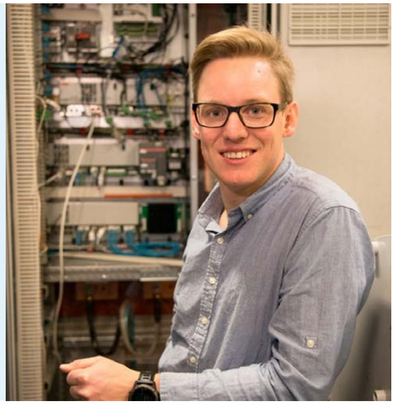


Supervisors
Supervisor: Prof. Stein Ove Erikstad
Co-supervisors: Prof. Bjørn Egil Asbjørnslett; Prof. Sverre Steen

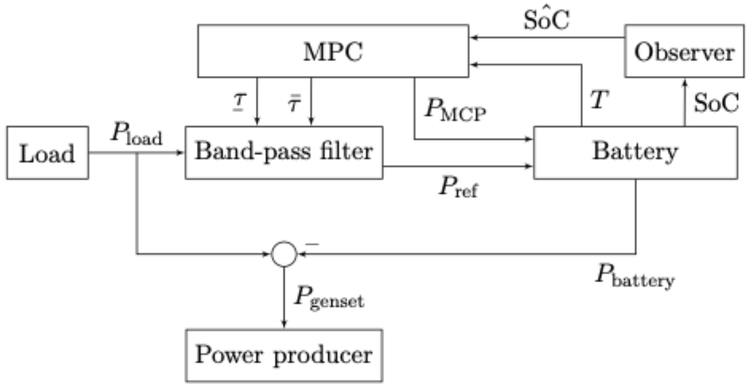
Torstein Ingebrigtsen Bø

Postdoc WP3 (2015-2018)

Hybrid propulsion, integrating new power sources for marine power plants



Models of marine electric power plants suitable for design and optimisation of propulsion systems
A scenario-based model predictive controller (MPC)
A method to control peak-shaving
The vessel itself as energy storage during DP operation

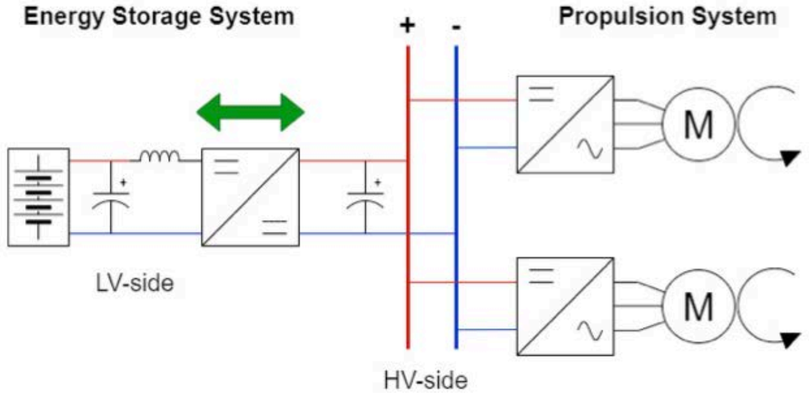


Supervisor: Professor Eilif Pedersen (IMT, NTNU)

Marius Ulla Hatlehol

PhD student WP3 (2021-2024)

Modeling, Design and Control of Hybrid Electric Power and Propulsion for Future Low-Emission and Autonomous Vessels

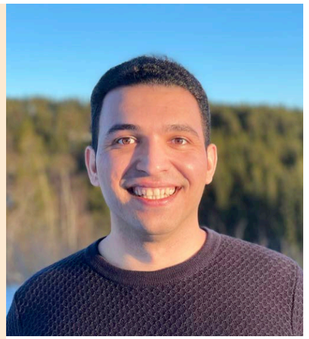


Supervisor: Associate Professor Mehdi Zadeh (NTNU)
Co-supervisors: Prof. Roger Skjetne (NTNU)
Associate Prof. Gilbert Bergna-Diaz (NTNU)

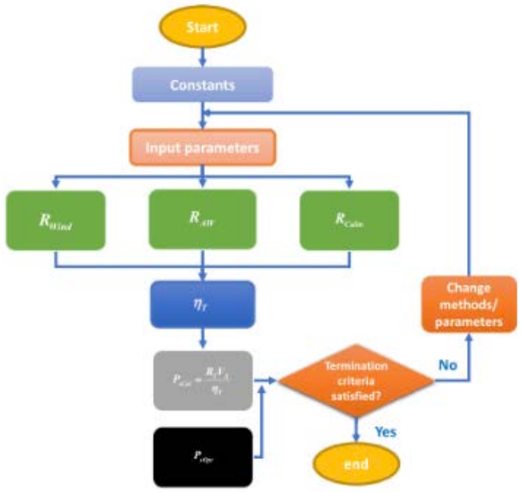
Eshan Esmailian

PhD student WP2 (2019–2022)

Optimization of Ships for Operation in Real Sea States



More practical, accurate and efficient methods for ship design and optimization in real seaways



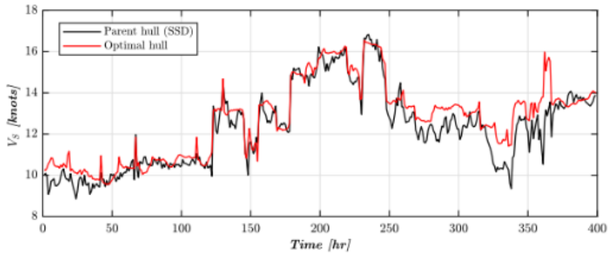


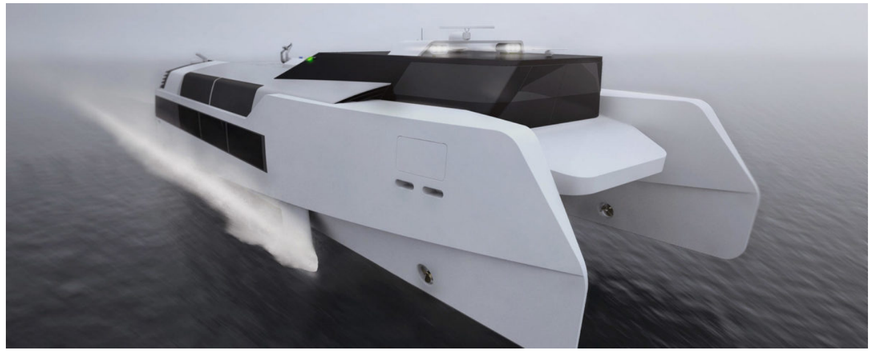
Fig. 18. Comparison of the attainable ship speed across different cases.

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

John Martin Kleven Godø *PhD student WP2 (2015–2018)*

Hydrodynamics of hydrofoil vessels

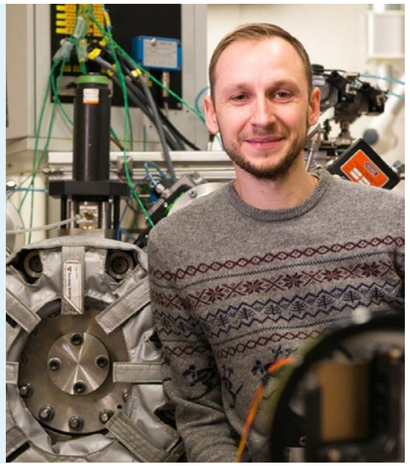
Flying Foil - develop and commercialize a new generation of hydrofoil vessels for use in passenger transport. is a start-up project aiming to develop and commercialize a new generation of hydrofoil vessels for use in passenger transport



Vladimir Krivopolianskii

PhD student WP3 (2015–2018)

Development of a constant volume combustion rig for experimental investigation of combustion and emission characteristics of alternative fuels



Develop an experimental setup for fundamental study of the emission from alternative fuels' combustion
Develop facility and experimental research methods for marine engine injection valves and combustion process of both liquid and gaseous fuels

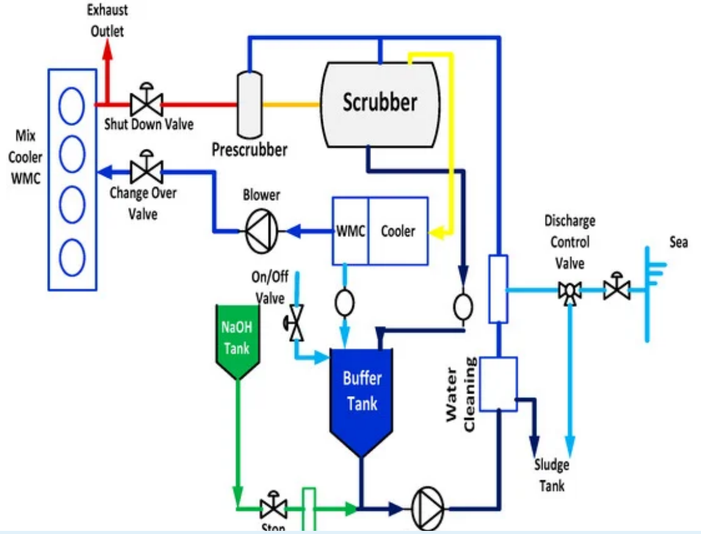
Supervisor: Professor Sergey Ushakov (IMT, NTNU)
Co-supervisor: Professor Eilif Pedersen (IMT, NTNU)

Yuan Tian

PhD student WP3 (2021-2023)

Modelling and simulation of ship exhaust gas cleaning system

How to reduce ship emissions more effectively by investigating ship exhaust gas cleaning systems



Supervisor: Professor Eilif Pedersen, NTNU IMT.
Co-supervisor: Jørgen B. Nielsen, SINTEF Ocean.

Lokukaluge Prasad Perera

Postdoc WP2/WP3 (2015–2017)

Data handling framework for ship performance and navigation monitoring

A machine learning-based data handling framework for ship performance and navigation monitoring

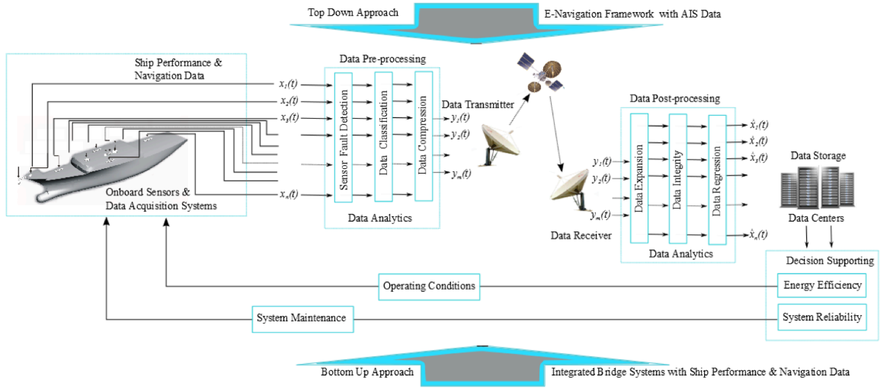


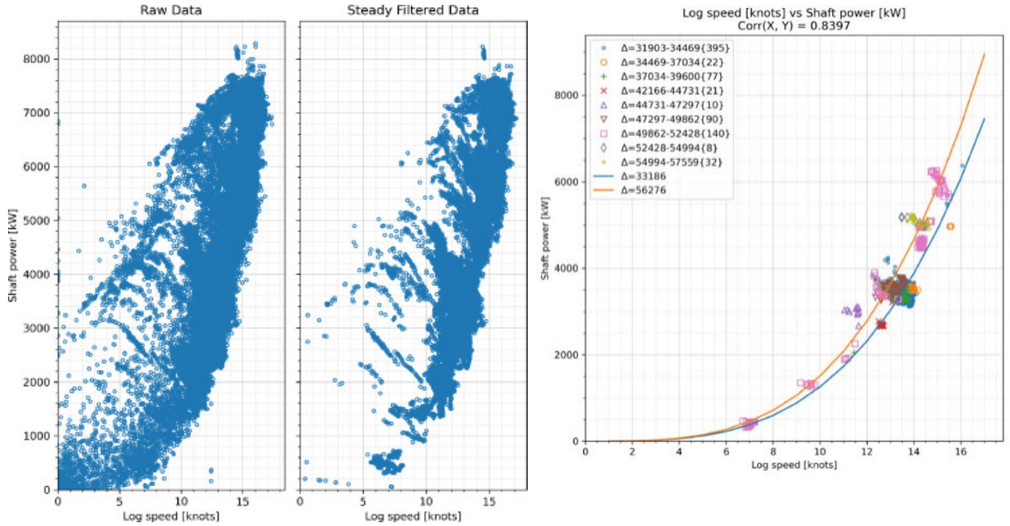
Figure 1. Data handling framework

Prateek Gupta

PhD student WP2 (2018–2021)

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

Convert the highly dimensional in-service measurement data recorded onboard a ship into meaningful information

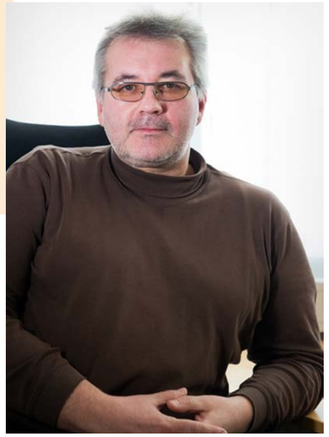


Supervisor: Prof. Sverre Steen (NTNU)
Co-supervisor: Prof. Adil Rasheed (NTNU, SINTEF)

Renato Skejic

Postdoc WP2 (2016–2018)

Computation of added resistance due to waves



Medium-fidelity computational methods for added resistance due to waves
Potential flow methods that are less complicated, faster and more robust than full 3-D non-linear panel methods

Jon Coll Mossige

PhD student WP2 (2017–2020)

Added resistance on ships due to hull roughness

Numerical investigation of roughness effects on the turbulent boundary layer for a flat plate

Improve prediction methods for power requirement and fuel consumption of full scale ships
Design of new hull coating technologies with better performance

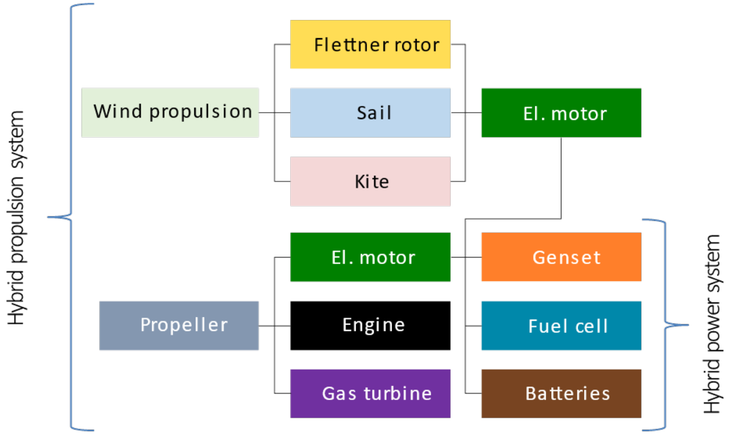
Supervisor:	Lars Erik Holmedal (NTNU)
Co-supervisor:	Kourosh Koushan (SINTEF)

Dražen Polić

Postdoc WP3 (2020-2022)

Impact of wind propulsion on the propeller and power system

Impact of wind propulsion on the propeller and power system



Supervisor: Prof. Eilif Pedersen (NTNU)

Jarle Vinje Kramer

PhD student WP2 (2014–2017 and 2020 - 2021)

Hydrodynamic modelling of wind-powered merchant vessels

- Sails models in a route simulation framework using both a discrete lifting line method and a Vortex Lattice Method.
- Modelling wing-to-wing interaction which are seen to strongly affect both the thrust and the side force from sails

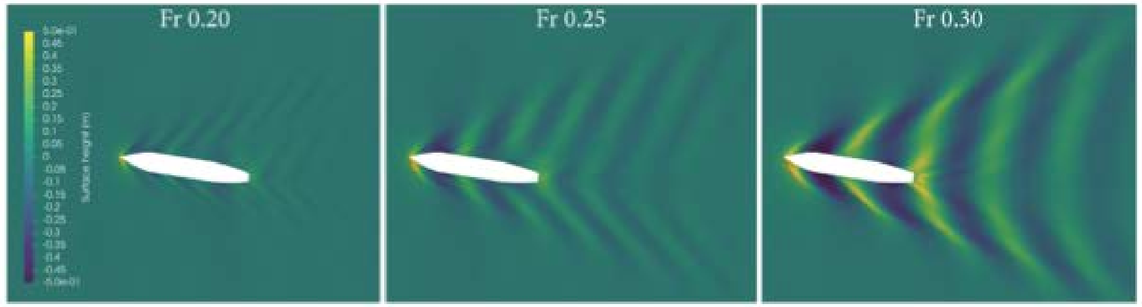


Fig. 13. Waves generated by the ship while moving with 9 degrees drift, for different Froude numbers. Model scale 1:4.

Supervisor: Prof. Sverre Steen (NTNU)
Co-supervisor: Luca Savio (NTNU, SINTEF)

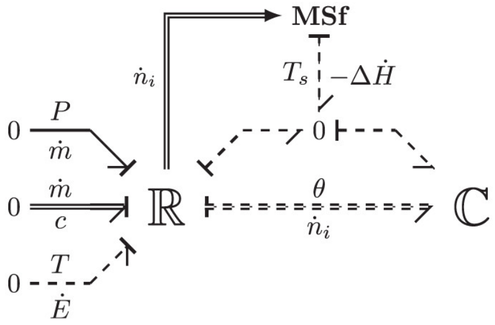
Jørgen Nielsen

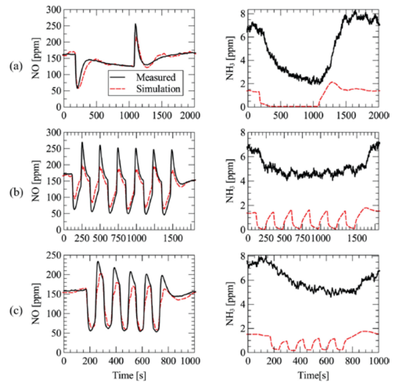
PhD Student WP3/WP4 (2015–2018)

Virtual Prototyping of Complex Marine Power Systems

Improve energy utilization in marine power systems with hybrid power technology and energy harvesting

•A system approach to modelling heat exchanger and heat exchanger network dynamics using bond graphs.





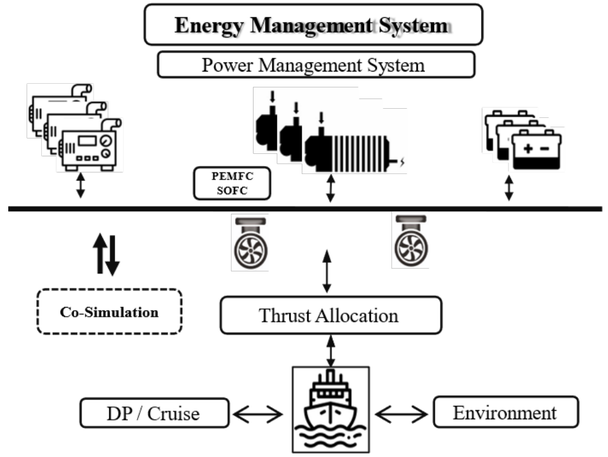
Supervisor: Professor Eilif Pedersen (IMT, NTNU)

Kamyar Maleki

PhD student WP3 (2019-2022)

Simulator Approach to Concept Analysis and Optimization of Marine Power Plants

- Fuel cell system models for the marine sector
- Bond Graph of Proton Exchange Membrane Fuel Cell System
- Dynamic Modelling of PEM Fuel Cell System for Simulation
- System-Level Modeling of Plant with PEMFC System and Battery
- Co-simulation of Hybrid Power Plant for an Offshore Vessel
- Simulation of Ammonia SOFC for Offshore Supply Vessel



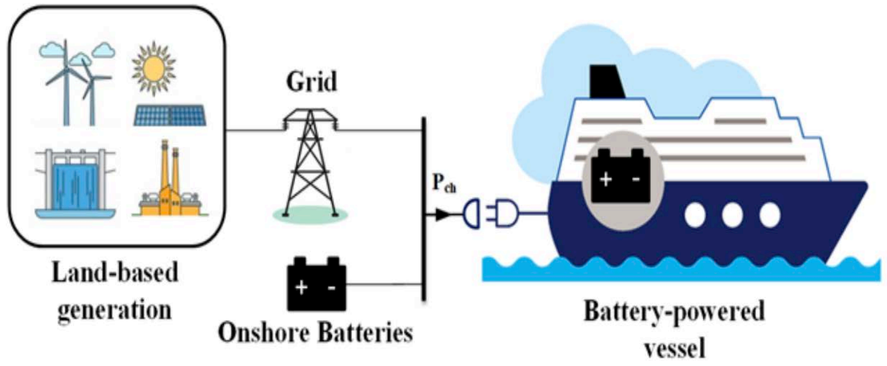
Supervisor: Prof. Eilif Pedersen (NTNU)

Siamak Karimi

PhD student WP3 (2019-2022)

Design and optimization of shore to ship charging systems for all-electric and plug-in hybrid ships

- Power system architecture for shore-to-ship charging systems (S2SCS)
- Energy efficiency
- Reliability
- Control and operation management



Supervisor: Associate Professor Mehdi Zadeh (NTNU)

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

COMMUNICATION AND DISSEMINATION

Photo: Siemens

COMMUNICATION

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

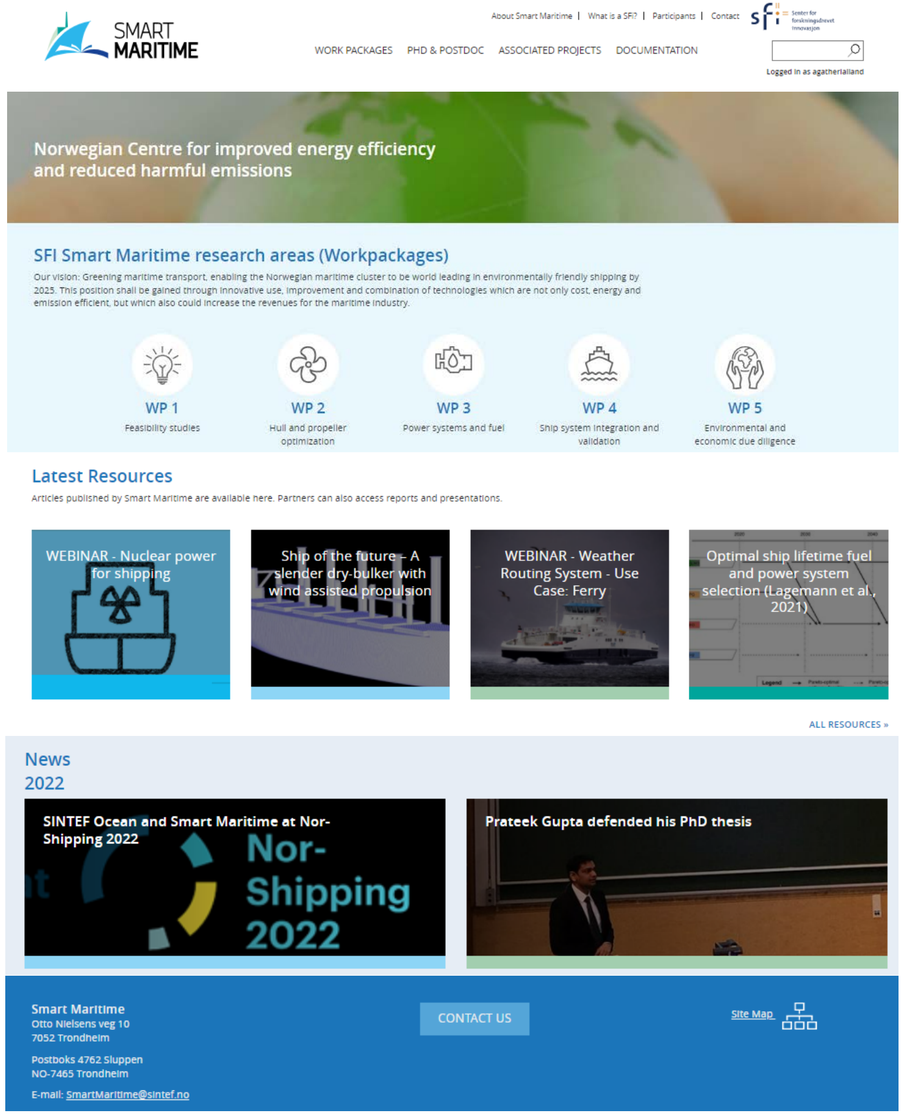
Our main communication channels are:

Website

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

Webinars

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



WEBINARS

2020	2021	2022
IMO's work on GHG emission reduction strategy and regulations	Carbon Intensity Indicator	Open Simulation Platform Conference 2022
Sustainable Alternative Marine FuelsAlternative Fuels, Engines and Design to reach IMO 2030 and 2050 GHG targets	Maritime emissions estimation model (W/ CLIMMS)	Added resistance in waves
Wind assisted propulsion	Hybrid Power Systems	Updates on IMO and EU work on Maritime GHG Regulations
IMO - EEDI achievements so far and EEDI phase 4	Maritime Policy updates	Alternative Fuels Selection
Carbon Capture and Storage onboard	Big data application in the maritime sector	Krevende nødslepoperasjoner:Kompetanseforum for krevende fartøysoperasjoner inviterer til nytt diskusjonsmøte
IMO - GHG Studies and short term measures	Ship design optimization – live from towing tank	Ship performance monitoring using machine-learning
Sustainable Alternative Marine Fuels	Network meeting	Decarbonization of shipping combining ship design and alternative power
Hydrodynamic Energy Saving Measures	Håndtering av skip i dårlig vær	Nuclear Power for Shipping
Maritime Policies EU & IMO updates	Energy Efficiency on-board	Weather routing system
Alternative Fuels and Flexible Technology Solutions	Alternative fuels	
Simulation platform - Gymir-ShipX plug-in release	To-ship power transfer for sustainable propulsion	
CLIMMS - Reducing Maritime GHG Emissions		

DISSEMINATION > Smart Maritime in the media

TU

Havila Capella: Nå er første kystruteskip levert

Havila Kystrutens nye skip er spekket med norske nyvinninger.

Modulbygde skip skal gjøre det lettere å bytte til utslippsfritt

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

Solvang-skip får karbonfangst og lagring om bord

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

Skal løse skipsfartens klimagassproblem med multifuel brenselcelle

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

Source: Teknisk Ukeblad

DISSEMINATION > International arena

SNAME
THE INTERNATIONAL COMMUNITY FOR MARITIME AND OCEAN PROFESSIONALS

MARE FORUM
• EST 1999 •

IMO

ISO

IWSA International Windship Association

European Commission

EFFECTS OF CENTRE FOR THE HOST INSTITUTION

In terms of knowledge, competence and capability development, Smart Maritime has played a highly important role for strengthening SINTEF Ocean's expertise within energy efficient and environment-friendly ship design and operations. Furthermore, the Centre's close dialog with its industry partners has contributed to increasing our insight on trends and challenges in the maritime sector, and provides real opportunities for new projects and cooperation with maritime actors.
In addition to scientific competence and a series of innovative analytical tools, SINTEF Ocean has benefited positively from the associated projects established in cooperation with the Centre partners. Furthermore, SINTEF Ocean has gained enormous knowledge from management of a long-term research centre, cooperation and networking activities.

Several of Smart Maritime PhD students and PostDoctoral researchers have chosen to pursue their scientist carrier at SINTEF Ocean, which demonstrate of the success of the Centre. Industrial experts from the Centre's partners have also joined SINTEF Ocean during the course of the Centre lifetime.

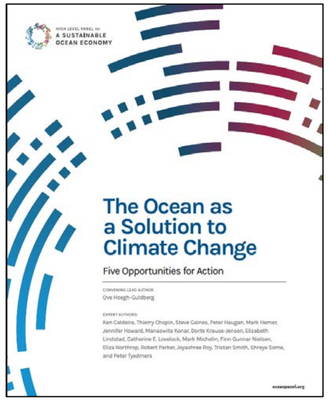
SINTEF Ocean also expects a long-term positive impact of SFI Smart Maritime. In order to continue the joint effort between SINTEF Ocean, NTNU and the Norwegian maritime industry, SINTEF Ocean is planning to carry on Smart Maritime activity and maintain the consortium as a formalized knowledge centre. This step is of strategic importance for the ongoing process of building the Norwegian Ocean Technology Centre.

SFI Smart Maritime will contribute strongly to the development the Norwegian Ocean Technology Centre's machinery and seakeeping laboratories, 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.

Strategic impact

- Leading working groups in both Martim21 iterations
- Board member in EU public private partnership for Waterborne Transport
- Providing feedback on several government propositions and strategy documents (e.g. Maritim stortingsmelding, Regjeringens strategi for grønn skipsfart)
- Impacting IMO regulation developments
- Contribution to High Level Panel for a Sustainable Ocean Economy. 2019

MARITIM 21



EFFECTS OF THE CENTRE FOR THE CENTRE PARTNERS

Throughout the whole centre period, the industrial partners have focused on utilization of the research results through innovation. The main categories of innovations taken into use by the industry are:

- New technology and products for green ship power systems and emission abatement
- New methods for ship and system design
- Software tools for vessel design simulation and evaluation
- Innovative and energy-efficient ship designs built for several ship owners
- Improved business services based on simulation-based design processes
- Testing and verification of new green ship technology
- Establishment of spin-off projects and companies

Industry partners within ship design and equipment manufacturing report very high value creation (billons of NOK) in terms of revenues and activity related to product and services that are based on, or impacted by, results from the centre and the associated projects. Furthermore, the ship owning partners of the centre report substantial reduction in emissions, both of greenhouse gases (up to 40%) and local pollutant (up to 100%) during the centre period.

Simulation-based **design tool (GYMIR and VESIM)**

Verification of Havila Kystruten design og HAV Design

NTNU Spin-off company Flying Foil AS

EFFECTS OF THE CENTRE FOR THE SOCIETY AT LARGE

The first goal of Smart Maritime is to strengthen the competitiveness of the Norwegian maritime cluster. Maintaining technology leadership and international competitiveness is imperative for securing future employment in maritime industry and other sectors supplying it with knowhow, services and equipment (2nd and 3rd order effects). The results of the center will have positive impact on value creation and activity also for companies that are not partners. Furthermore, Smart Maritime addresses major societal challenges such as climate change, GHG emissions from shipping, increased regulations on harmful emissions, and the continuous need for increased energy efficiency.

On a global scale, Smart Maritime contributes to 4 of the UN Sustainable Development Goals in the following way:

- **Climate action**: Efforts to reducing GHG emissions from ships, and ensure adequate regulations are development at international level.
- **Life below water:** Efforts to reduce ship pollution and emissions to sea.
- **Industry, innovation and infrastructure**: Contribution to promoting sustainable industrialisation and innovation in the maritime sectors.
- **Partnerships for the goals**: The center strengthens cooperation between public, private and research communities towards green shipping.

FUTURE PROSPECTS

The need for research within the topics of SFI Smart Maritime will remain and even increase in the coming years. The vision of a climate neutral maritime industry will drive research towards 2050, and further development of the results of the centre should be part of this picture. This will require a number of efforts beyond 2023, such as:

- Continuation of the Smart Maritime consortium as a formalized knowledge centre (FME proposal to be submitted to RCN in November 2023).
- Development of a portfolio of new research and innovation projects within the consortium, and together with other national and international partners.
- Dissemination and implementation of Smart Maritime knowledge and methods, not only within the consortium, but throughout the maritime industry.
- Commercialization of simulation models and decision support tools for improved ship designs and operations.
- Further contribution towards national and international maritime policy-making and regulations.
- Continuous Master and Phd education within Smart Maritime topics at NTNU.
- Establishment of Smart Maritime as an important part of the strategy for utilizing the Norwegian Ocean Technology Centre (under construction)

CONCLUSIONS AND RECOMMANDATIONS FOR FUTURE CENTRES

The research centre status and funding of SFI Smart Maritime has provided a long-term perspective on research activities and collaboration that is rare in todays R&D environment. The fact that the partners have been onboard the same boat for 8 years has developed relationships and trust among the partners, which is crucial for successful collaborative efforts towards challenging problems.

Engagement of industry partners relies on results that are relevant for their commercial business. Defining the right research tasks based on understanding of industrial needs is key. Thus, it has been important for the centre management and the researchers to close-up to the industry partners through visits, discussions and business process mapping.

It has been important for us to facilitate networking, discussions and research across organizations and disciplines. This has been done by addressing complex and cross-cutting user cases and projects, which requires contributions from all technical work packages and partners. Also, it has been important to have sufficient flexibility in the annual work planning in order to cope with the challenges emerging during the life-time of the centre.

For the Phd students and young researchers is has been important with close collaboration with each other and the industry partners. Joint office location has made this easier for most of the researchers and is strongly recommended. Recruitment of female candidates for maritime research has proven difficult and has been lifted as a critical challenge for NTNU/SINTEF.

SFI Smart Maritime has made successful investments in dissemination and communication, both to the scientific community and the public. This has paid off in different ways such as recruitment, market development and political influence. A research centre offers opportunities for strategic and comprehensive communication that individual projects cannot manage.

Trond Johnsen
Director of SFI Smart Maritime

APPENDICES

SKS SINNI. Photo: Mastership/Kristian Gerhard Jebsen Skipsrederi.

APPENDIX 1: STATEMENT OF ACCOUNTS FOR THE COMPLETE PERIOD OF CENTRE FINANCING

Funding

Activity/Item	RCN	Host institution - SINTEF Ocean	Research partner 1 NTNU	ABB	SIEMENS	Kongsberg Maritime	Bergen Engines	VARD	Havyard	Norwegian Electric System (NES)	Wärstilä Moss	DNV-GL	Wihl Wilhelsen	Solvang ASA	Grieg Star	Kristian Gerhard Jebsen	Jotun	BW Gas	Höegh Autoliners	Klaveness	Odfjell	Sjøfartsdirektoratet	Norges Rederiforbund	Kystrederiene	Total
WP1 Feasibility studies	8 361	3 873	1 800	203	202	502	116	277	135	29	185	183	659	796	529	306	90	37	291	118	27	29	42	28	18 818
WP2 Hull and propeller	21 204	7 444	8 766	529	502	2 096	786	1 312	1 038	334	488	444	1 080	1 505	688	824	889	126	844	402	86	69	84	57	51 596
WP3 Power systems and fuel	31 842	9 653	8 409	2 161	964	1 200	978	654	338	152	2 254	762	1 061	4 121	477	483	263	151	1 413	447	111	67	84	57	68 101
WP4 Ship system integration, validation and monitoring	13 976	9 470	6 731	1 282	958	1 498	378	1 704	1 155	120	407	1 062	951	1 096	814	515	187	85	591	303	55	56	84	57	43 535
WP5 Environmental and economical due dilligence	12 690	4 192	2 536	539	334	577	161	303	146	92	507	636	401	848	465	324	101	45	368	146	33	237	42	28	25 751
SFI Administration	7 928	7 297	-	351	588	1 174	218	594	486	116	247	328	360	334	1 366	238	160	-	-	-	-	213	214	230	22 442
Sum	96 000	41 929	28 243	5 065	3 549	7 047	2 637	4 843	3 297	843	4 087	3 415	4 511	8 701	4 340	2 690	1 690	444	3 507	1 416	312	670	550	457	230 243

Cost

Activity/Item	Host institution - SINTEF Ocean	Research partner 1 NTNU	ABB	SIEMENS	Kongsberg Maritime	Bergen Engines	VARD	Havyard	Norwegian Electric System (NES)	Wärstilä Moss	DNV-GL	Wihl Wilhelsen	Solvang ASA	Grieg Star	Kristian Gerhard Jebsen	Jotun	BW Gas	Höegh Autoliners	Klaveness	Odfjell	Sjøfartsdirektoratet	Norges Rederiforbund	Kystrederiene	Total
WP1 Feasibility studies	9 621	5 802	73	71	343	13	211	77	12	118	43	496	746	447	223	28	37	291	118	27	5	15	3	18 818
WP2 Hull and propeller	17 726	22 865	265	284	1 874	311	1 247	786	283	381	125	902	1 389	547	616	451	126	844	402	86	18	57	10	51 596
WP3 Power systems and fuel	21 230	31 282	1 811	488	1 164	520	650	315	83	2 147	309	890	4 163	355	405	102	151	1 413	447	111	12	47	7	68 101
WP4 Ship system integration, validation and monitoring	20 676	13 777	1 045	517	1 138	63	1 284	792	52	233	419	637	740	638	375	64	85	591	303	55	10	37	6	43 535
WP5 Environmental and economical due dilligence	11 813	9 076	358	127	450	106	261	97	40	409	343	344	921	371	244	35	45	368	146	33	142	19	3	25 751
SFI Administration	20 707	-	44	62	77	-	66	105	24	-	-	-	-	1 182	28	35	-	-	-	-	84	-	28	22 442
Sum	101 773	82 802	3 597	1 549	5 047	1 012	3 718	2 172	493	3 287	1 240	3 268	7 959	3 540	1 890	715	444	3 507	1 416	312	270	175	57	230 243

Postdoctoral researchers with financial support from the Centre budget

Name	Sex M/F	Nationality	Scientific Area	Period	Topic	Contact
Prasad Perera	Male	Sri Lanka	WP2 Hull and propeller optimization	2015 - 2017	Data handling and analysis	
Torstein Ingebriktsen Bø	Male	Norwegian	WP3 Power systems and fuels	2015 - 2018	Hybrid propulsion	
Renato Skejic	Male	Croatia	WP2 Hull and propeller optimization	2016-2018	Computation of added resistance due to waves	
Dražen Polić	Male	Croatia	WP3 Power systems and fuels	2020-2022	Impact of wind propulsion on the propeller and power system	

PhD students who have completed with financial support from the Centre budget

Name	Sex M/F	Nationality	Scientific Area	Period	Thesis Title	Supervisor
John Martin Godø*	M	NO	WP2 Hull and propeller optimization	2015-2018	Hydrodynamics	Professor Sverre Steen
Jørgen B. Nielsen	Male	Norwegian	WP3 Power systems and fuels	2015-2018	System simulation (WP3/4)	Professor Sverre Steen
Vladimir Krivopolianskii	Male	Ukraine	WP3 Power systems and fuels	2015-2018	Fuel injection and combustion (WP3)	Professor Sergey Ushakov
Endre Sandvik	Male	Norwegian	WP4 Ship System Integration and Validation	2016-2019	Simulation based design of ships with regards to system performance (WP4)	Professor Eilif Pedersen
Espen Krogh*	Male	Norwegian		2018-2018	Hybrid propulsion machinery optimisation	Professor Sverre Steen
Prateek Gupta	Male	India	WP2 Hull and propeller optimization	2018-2021	Ship performance monitoring and optimization using in-service measurements and big data analysis methods (WP2)	Professor Sverre Steen
Benjamin Lagemann	Male	German	WP4 Ship System Integration and Validation	2019-2022	Concept Ship Design for Future Low-Emission Shipping Technology (WP4)	Professe Bjørn Egil Asbjørnslett
Siamak Karimi	Male	Iran	WP3 Power systems and fuels	2019-2022	modeling and optimal design of marine hybrid electric power systems (WP3)	Professeor Mehdi Zadeh
Ehsan Esmailian	Male	Iran	WP2 Hull and propeller optimization	2019-2022	Optimization of ships for operation in real sea states (WP2)	Professor Sverre Steen
Jarle Kramer	Male	Norway	WP2 Hull and propeller optimization	2020-2021	Hydrodynamic modelling of wind-powered merchant vessels	Professor Sverre Steen

PhD students with financial support from the centre budget who still are in the process of finishing studies

Name	Sex M/F	Nationality	Scientific Area	Period	Thesis Title	Supervisor
Kamyar Maleki	Male	Iran	WP3 Power systems and fuels	2019-2022	A Simulator Approach to Concept Analysis and Optimization of marine Power Plants (WP3)	Professor Eilif Pedersen
Marius Ulla Hatlehol	Male	Norway	WP3 Power systems and fuels	2021-2024	Modeling, Design and Control of Hybrid Electric Power and Propulsion for Future Low-Emission and Autonomous Vessels	Professor Eilif Pedersen
Yuan Tian	Female	China	WP3 Power systems and fuels	2021-2023	Modelling and simulation of ship exhaust gas cleaning system	Professor Eilif Pedersen
Jon Coll Mossige	Male	Norwegian	WP2 Hull and propeller optimization	2017-2019	Calm water performance - Friction reduction (WP2)	Lars Erik Holmedal

PhD students working on projects in the centre with financial support from other sources

Name	Sex M/F	Funding	Nationality		Period
Pramod Ghimire	M	Kongsberg Maritime	SR	A Simulator Approach for Ship Hybrid Power Plant Concept Studies	2019-2021
Espen Krogh	M	NTNU in-kind to Smart Maritime	Norway	Hydrodynamics	2018-2020
Sadi Tavakoli	M	NTNU	IR	Marine machinery	2017-2020
Simone Saettone	M	NTNU	IT	Hydrodyna Simulation based designmics	2017-2020
Diogo Kramel	M	NTNU	BR	LCA marine fuels	2019-2022
YoungRong Kim	M	NTNU	CH	Efficient fleetwide modelling	2019-2022
Kevin Koosup Yum	M	NTNU	South Korea	Simulation Machinery	2012-2017
Øyvind Ø. Dahlheim	M	Rolls-Royce UTC	Norway	Hydrodynamics	2015-2018
Anna Swider	F	Rolls-Royce Ind. PhD	Polen	Hydrodynamics	2015-2018
Sabah Alwan	M	KPN LEEDS	Australia	Simulation based design	2013-2017
Dig Vijay Singh	M	KPN LEEDS	UK	Machinery	2012-2016
Bhushan Taskar	M	KPN LEEDS	India	Hydodynamic	2013-2016
Jarle Kramer	M	KPN LEEDS	Norway	Hydrodynamics	2013-2018
Stian Sjong	M	KPN ViProma	Norway	System Simulation	2013-2017
Espen Krogh	M	NTNU in-kind to Smart Maritime	Norway	Hydrodynamics	2018-2020
Sadi Tavakoli	M	NTNU and DTU Denmark	Iran	Ship propulsion dynamics and emissions	2017-2020
Simone Saettone	M	NTNU and DTU Denmark	Italy	Hydrodynamics	2017-2020
Diogo Kramel	M	NTNU	Brasil	LCA marine fuels	2019-2022
YoungRong Kim	M	NTNU	Kina	Efficient fleetwide modelling	2019-2022
Sotiria Lagouvardou	F	DTU	Greece	Marked-based measures	2019-2022

MSc candidates with thesis related to the centre research agenda and an advisor from the centre staff

Name	M/F	Nationality	Institution	year	MSc thesis
Mats William Snåre; Jon Halfdanarson	M	NO	NTNU, Energy and Process Engineering	2015	Implementation and application of an integrated framework for economic and environmental assessment of maritime transport vessels
Jørgen Rørvik	M	NO	NTNU, Marine Technology	2016	Application of Inviscid Flow CFD for prediction of Motions and Added Resistance of Ships
Haakon Utby	M	NO	NTNU, Marine Technology	2016	Hydrodynamics optimization of bulk and tank ship hulls
Anna Karina Magnussen	F	NO	NTNU, Marine Technology	2017	Rational calculation of sea margin
Jens Christoffer Gjølme	M	NO	NTNU, Marine Technology	2017	Estimation of Speed Loss due to Current, Wind and Waves
Sigbjørn Wiik	M	NO	NTNU, Marine Technology	2017	Voluntary speed loss
Fredrik Gyberg	M	NO	NTNU, Marine Technology	2017	Design, modelling and control of a generic crane for marine application
Thomas Haraldsen Evang	M	NO	NTNU, Marine Technology	2017	Marine Crane Dynamics Lab - Modelling and experimental validation
Jan Olav Øksnes	M	NO	NTNU, Marine Technology	2017	Regeneration in Crane Operation
Anna Ringvold	F	NO	NTNU, Industrial Ecology	2017	Prospective life cycle assessment of container shipping
Mafalda Silva	F	PT	NTNU, Industrial Ecology	2017	Life cycle assessment of marine fuel production
Martin Øksdal Bakke; Peter Slinning Tenfjord	M	NO	NTNU, Marine Technology	2017	Simulation-Based Analysis of Vessel Performance During Sailing - Describing a simulation platform applied in early stage ship design
Andrea Aarseth Langli	M	NO	NTNU, Marine Technology	2017	Exhaust Gas Cleaning Systems - Selecting the Best EGCS Option Using the Analytic Hierarchy Process and Cost Benefit Analysis
Jon Hovem Leonhardsen	M	NO	NTNU, Marine Technology	2017	Estimation of Fuel Savings from Rapidly Reconfigurable Bulbous Bows Exemplifying the Value of Agility in Marine Systems Design
Jon-Erik Hvidsten Remme	M	NO	NTNU, Marine Technology	2017	Multivariate Data Analysis in Conceptual Vessel Design – A Study of Offshore Construction Vessels
Joakim Tveiten Vigsnes	M	NO	NTNU, Marine Technology / WP2	2018	Comparison of seakeeping analyses
Mario Delgado	M	ES	NTNU, Industrial Ecology / WP5	2018	Reconciling Big Data on Trade Statistics and Ship Traffic: A Case Study
Jens Bredahl	M	NO	NTNU, Marine Technology / WP3	2018	Modification of CVCR for gas fuel operation – modelling and experiments
Ole Johan Lønnum	M	NO	NTNU, Marine Technology / WP4	2018	Fall of the Machines: A Deep Stochastic Autoregressive LSTM Neural Network for Wave Simulation and its Applications in Marine Simulation-based Design
Jens Berg Ildstad	M	NO	NTNU, Marine Technology / WP2	2018	Use of turbulence stimulation on ship models
Even Wollebæk Førrisdal	M	NO	NTNU, Marine Technology / WP2	2018	Empirical prediction of resistance of fast catamarans
Benjamin Vist Hagen	M	NO	NTNU, Marine Technology / WP2	2018	Influence of a wavefoil on the wave pattern resistance of a ship
Kristian Olof Ejdfors	M	NO	NTNU, Marine Technology	2019	Use of in-service data to determine the added power of a ship due to fouling
Jonas Munch Wahl	M	NO	NTNU, Marine Technology	2019	Prediction of Fuel Consumption of a Ship in Transit Using Machine Learning
Julie Sandnes Galaaen	F	NO	NTNU, Industrial Ecology	2020	Comparative Life cycle assessment of a diesel electric and a battery electric ferry.
Tone Dale	F	NO	NTNU, Industrial Ecology	2020	Development of simplified methods for ship powering performance calculations.
Anna Spedo	F	NO	NTNU, Industrial Ecology	2020	Integrated Assessment Model of the International Maritime Sector
Maria Kristine Munkvold	F	NO	NTNU, Industrial Ecology	2020	Comparative Life Cycle Assessment of a hydrogen fuel cell and diesel-powered high-speed passenger catamaran
William Hyggen Viken	M	NO	NTNU, Marine Technology	2022	The effects of wind assisted propulsion on a fleet basis
Ludvik Sjåvåg	M	NO	NTNU, Marine Technology	2022	Redesigning and retrofitting existing service vessels towards new missions
Anna Sophia Hüllein	F	NO	NTNU, Marine Technology	2022	Transport system logistics impact of windassisted ship propulsion
Dorthe Alida A. Slotvik	F	NO	NTNU, Marine Technology	2022	Availability of Zero-Emission Fuel for Operation at Deep Sea
Gaute Aanesland Jørgensen	M	NO	NTNU, Marine Technology	2022	Cruise ship design and operation after Covid 19
Andreas Isaksen	M	NO	NTNU, Marine Technology	2022	Retrofitting hydrogen as fuel for existing OSVs
Tiril Amundsen Urban	F	NO	NTNU, Marine Technology	2022	water transport system for combined passengers and cargo
Finn Lorange	M	NO	NTNU, Marine Technology	2022	Redesigning operations for wind assisted propulsion
Eirik Eikeland Haahjem	M	NO	NTNU, Marine Technology	2022	Location optimization for deep sea shipping refueling stations
Marit Solheim Thériault	F	NO	NTNU, Marine Technology	2022	Optimal location of reception points for shipboard carbon capture
Magnus Rønningen	M	NO	NTNU, Marine Technology	2022	Design re-engineering and modularization in shipbuilding (DREAMS)
Sigurd Nygård Rimereit	M	NO	NTNU, Marine Technology	2022	Design of newbuilds with flexible power solutions
Elias Ødegaard	M	NO	NTNU, Marine Technology	2022	Comparative study of zero emission high speed sea transport systems
Petter Sletten	M	NO	NTNU, Marine Technology	2022	Sustainable marine power system with alternative fuels; a case study of energy efficiency and cost
Juyoung Lee	M	ROC	NTNU, Marine Technology	2022	Zero-emission propulsion with fuel cells and batteries
Christoffer Helgesen	M	NO	NTNU, Marine Technology	2022	DC grid for trawlers
Ziwen Wang	M	ROC	NTNU, Marine Technology	2022	Reliability analysis of onboard hybrid power systems

APPENDIX 3: LIST OF PUBLICATIONS

Journal publication
Academic article
Guo, Bingjie; Gupta, Prateek; Steen, Sverre; Tvete, Hans Anton. Evaluating vessel technical performance index using physics-based and data-driven approach. Ocean Engineering 2023 ;Volume 286.
Gupta, Prateek; Kim, YoungRong; Steen, Sverre; Rasheed, Adil. Streamlined Semi-automatic Data Processing Framework for Ship Performance Analysis. International Journal of Naval Architecture and Ocean Engineering 2023
Karimi, Siamak; Zadeh, Mehdi; Suul, Jon Are Wold. Operation-based Reliability Assessment of Shore-to-Ship Charging Systems Including On-Shore Batteries. IEEE transactions on industry applications 2023 ;Volume 59.(4) p. 4752-4763
Lagemann, Benjamin; Lagouvardou, Sotiria; Lindstad, Elizabeth; Fagerholt, Kjetil; Psaraftis, Harilaos; Erikstad, Stein Ove. Optimal ship lifetime fuel and power system selection under uncertainty. Transportation Research Part D: Transport and Environment 2023 ;Volume 119.
Lindstad, Elizabeth; Alterskjær, Sverre Anders; Sandaas, Inge; Solheim, Astrid Vamråk; Vigsnes, Joakim Tveiten.
Open Hatch Carriers – Future Vessel Designs & Operations. *Transactions - Society of Naval Architects and Marine Engineers* 2023 ;Volume 125. p. 39-56
Lindstad, Elizabeth; Ask, Tor Øyvind; Cariou, Pierre; Eskeland, Gunnar; Rialland, Agathe Isabelle. Wise use of renewable energy in transport. Transportation Research Part D: Transport and Environment 2023 ;Volume 119.
Lindstad, Elizabeth; Polic, Drazen; Rialland, Agathe Isabelle; Sandaas, Inge; Stokke, Tor.Reaching IMO 2050 GHG Targets Exclusively through Energy efficiency measures. Journal of Ship Production and Design 2023
Malekibagherabadi, Kamyar; Skjong, Stian; Bruinsma, Jogchum; Pedersen, Eilif. Investigation of hybrid power plant configurations for an offshore vessel with co-simulation approach. Applied Energy 2023 ;Volume 343.
Esmailian, Ehsan; Steen, Sverre. A new method for optimal ship design in real sea states using the ship power profile. Ocean Engineering 2022 ;Volume 259. p. -
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Ghimire, Pramod; Karimi, Siamak; Zadeh, Mehdi; Nagalingam, Krishna Kumar; Pedersen, Eilif. Model-based efficiency and emissions evaluation of a marine hybrid power system with load profile. Electric power systems research 2022 ;Volume 212. p. -
Gupta, Prateek; Rasheed, Adil; Steen, Sverre. Ship performance monitoring using machine-learning. Ocean Engineering 2022 ;Volume 254. p. -
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Kim, YoungRong; Esmailian, Ehsan; Steen, Sverre. A meta-model for added resistance in waves. Ocean Engineering 2022 ;Volume 266.(2) p. -
Kramer, Jarle Vinje; Steen, Sverre. Sail-induced resistance on a wind-powered cargo ship. Ocean Engineering 2022 ;Volume 261. p. -
Lindstad, Elizabeth; Polic, Drazen; Rialland, Agathe Isabelle; Sandaas, Inge; Stokke, Tor. Decarbonizing bulk shipping combining ship design and alternative power. Ocean Engineering 2022 ;Volume 266.(2) p. -
Lindstad, Elizabeth; Stokke, Tor; Alterskjær, Anders; Borgen, Henning; Sandaas, Inge. Ship of the future – A slender dry-bulker with wind assisted propulsion. Maritime Transport Research 2022 ;Volume 3. p. 1-11
Malekibagherabadi, Kamyar; Skjong, Stian; Bruinsma, Jogchum; Pedersen, Eilif. System-level modeling of marine power plant with PEMFC system and battery. International Journal of Naval Architecture and Ocean Engineering 2022 ;Volume 14. p. -
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Lindstad, Elizabeth; Rialland, Agathe Isabelle. LNG and cruise ships, an easy way to fulfil regulations-versus the need for reducing GHG emissions. Sustainability 2020 ;Volum 12.(5) s. 1-15

Sandvik, Endre; Nielsen, Jørgen Bremnes; Asbjørnslett, Bjørn Egil; Pedersen, Eilif; Fagerholt, Kjetil. Operational sea passage scenario generation for virtual testing of ships using an optimization for simulation approach. Journal of Marine Science and Technology 2020

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Muri, Helene. Alternativ til utslippskutt monner ikke. Dagens næringsliv 2018

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FINAL REPORT 2023

Sea of Heaven, Grieg Star. Photo: Reanmer Baldoza

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