Centre for Research-based Innovation

The Research Council of Norway

SMART MARITIME

Annual Report 2015

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Norwegian Centre for improved energy efficiency and reduced harmful emissions

Summary

The Centre started formally 1. July 2015 but in practice the main activity in the Work Packages started in September with three PhD candidates. All WP's are in good progress, five journal papers are registered. Kick Off and network meeting was arranged in November with all partners discussing the proposed work and the two Sub-Project (Fuel and Hybrid). The Sub-Project have good involvement from relevant industrial partners. One result in the Fuel project is a promising solution to meet existing IMO emission limits running on Heavy Fuel Oil (HFO) in a cost efficient manner using Scrubbing and Exhaust Gas Recirculation (EGR).
Smart Maritime has developed an active web page www.smartmaritime.no with at least monthly updated information and news. The web page has an open public access and a closed member access. We are using this platform for public information and for internal member communication.

Vision

The purpose of Smart Maritime is to establish a Norwegian Centre for improved energy-efficiency and reduced harmful emissions from the maritime sector.

Our vision is greening maritime transport, i.e. enable the Norwegian maritime cluster to be world leading in environmentally friendly shipping. This position will be gained through innovative use, improvement and combination of technologies which are not only cost, energy and emission efficient, but which also could increase the revenues for the maritime industry.

Our mission is to create innovations securing sustainability and competitiveness of the maritime transport sector. By developing new knowledge, methods and technologies and educating students (PhD, MSc), Smart Maritime will contribute to strengthen the Norwegian maritime industry's international competitiveness. The Centre will collaborate closely with global industry players, national and international research communities, maritime centers, networks and clusters.

After the eight-year SFI period, the Centre will become a permanent part of the planned Ocean Space Centre in Trondheim.

Research plan and Strategy

Our research strategy is the foundation for the structuring of the work packages. Improvements in full-scale measurements are fundamental to learn to utilize the growing access to real-time operational data to be used in ship and ship technology design, as well as ship operation. The underlying hypothesis is that this will become the 'big-data' parallel in the maritime industry – which in this SFI will be applied to enable improved energy efficiency and reduced emission in the design and operation of ships and ship technology. In addition, the framework for simulation-based design shall be further refined to enable fast, effective and reliable assessment of design in early-phase feasibility studies. This will enable designers to assess a larger set of designs in

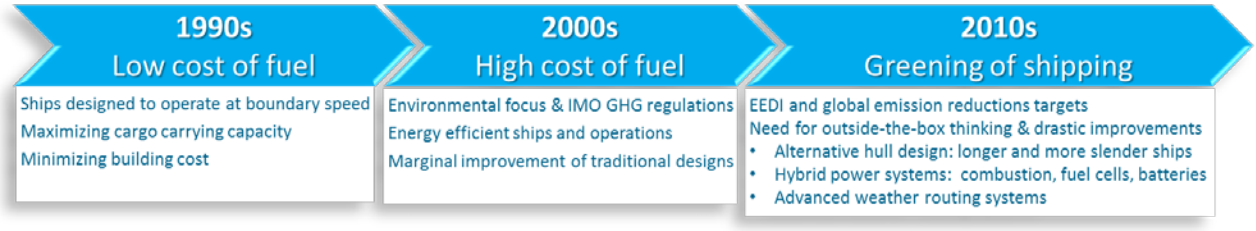
a feasibility phase (WP 1), before entering a detailed design phase with the most promising design alternatives with respect to energy and competitive performance (WP 5). This is a game-changer compared to the contemporary practice of reusing or alternate old designs.
In summary, the Centre will develop a holistic system-centered ship design method using a modular simulation and analysis framework for accurate performance assessment for ship and ship systems under realistic full-scale operational conditions (WP 4), to assess the effect of energy efficiency improving measures developed for hull and propeller (WP 2) and power systems and fuels (WP 3). Hybrid LCA methods will be used in combination with profit and opportunity cost models to verify environmental and economic benefits (WP 5). The proposed Centre partners comprise research institutes, academic institutions and key industry players in the Norwegian ship and ship equipment value chain where the key stakeholders from the maritime sector will be involved from day one through their business cases (Sub-Projects).

Research Plan - Work Packages 2015

Our vision: Greening maritime transport, enabling the Norwegian maritime cluster to be world leading in environmentally friendly shipping by 2025. This position shall be gained through innovative use, improvement and combination of technologies which are not only cost, energy and emission efficient, but which also could increase the revenues for the maritime industry.

Work Package 1 – Feasibility Studies

The main purpose of feasibility studies is to enable investigation of alternative concepts early in the project to identify the most promising options



Objectives (Overall):

Develop and test assessment models that enable ship designers and innovators to investigate a number of alternative designs at an early stage.

Background:

The main purpose of feasibility studies is to enable investigation of alternative concepts early in the project to identify the most promising options. There is a lack of assessment methods and tools that 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.

Scope of work (Activities 2015-2017):

(1) Identification of the areas largest potential for energy efficiency and emission reductions.
- State-of-the-art and current research frontier to be published as a review paper.
- Work to be based on Lindstad's Doctoral thesis on Strategies and measures for reducing maritime CO2 emissions (2013); current state of knowledge and review of previous studies presented in the state-of-the-art of the Smart-Maritime project description; and the study for DG Clima on GHG emission reduction potential of EU-related maritime transport and on its impacts (Lindstad et al., 2015).

(2) Development of a methodology and simplified versions of analytical and numerical models enabling identification and comparison of a number of alternative designs.
- First version of the Feasibility study methodology to be published in methodology paper.
- Work to be based on literature review of innovation process and approaches to conceptual design, as well as on previous studies conducted by MARINTEK and Lindstad on measures to reduce emission and increase efficiency in maritime transport.
- Development of analytical models for detailed analysis of the alternative solutions and concepts retained in the business cases.

(3) Test and use the methodology and models in the business cases.
- Feasibility study methodology to be tested in the initial phase of the business cases (2016), to support identification of alternative measures for emission reductions.
- Analytical models to be tested in the second phase of the business cases (2017)

Dependencies, critical factors, assumptions:

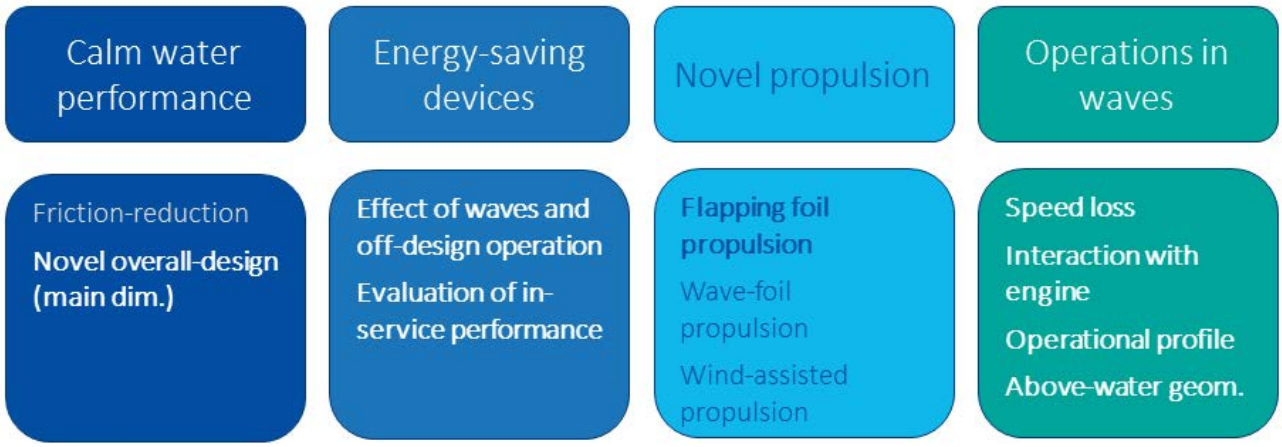
Close interdependency WP1 – WP5.
W1 to prepare methodology and analytical models to be tested in business cases.

WP1 to interact with WP2-3-4 regarding identification potential for energy and emission reductions.

Activities/Milestones:	Deadline	Deliverables
Start research work	01-sept-2015	
draft feasibility study methodology for efficient and environmentally-friendly maritime systems	15-nov-2015	
State of the art on technologies and measures for improved energy efficiency and reduced emissions	18-Dec-2015	Paper
Feasibility study methodology first version	15-Feb-2016	Paper
Fesibility study methodology tested in business cases	15 dec 2016	Case reports
Analytical models / tools tested in business cases	15 dec 2017	Case reports

Work Package 2 - Hull and propeller optimization

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 maneuvering-related aspects, but it has not found its way into practical design work yet. In design of offshore vessels, sea-keeping and positioning ability is taken into account to a larger extent



Objectives (Overall):

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

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 maneuvering-related aspects, but it has not found its way into practical design work yet. In design of offshore vessels, sea-keeping and positioning ability is taken into account to a larger extent. 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 of ships and propulsion systems, with special emphasis on operation in waves, will be specially addressed in WP 2.

Scope of work (Activities current year 2015):

P2.1 Novel propulsion system – flapping hydrofoil propulsion

1 PhD – John Martin Kleven Godø

Coursework. Planning of PhD project. Further model tests and CFD studies of flapping foil(s) (one and/or a pair of foils)

WP2.3 Propulsion performance in waves

The activity of 2015 is start-up of a Post doc project, utilizing “big data” approaches, as well as conventional prediction methods. We are working on an application for a MSCA-IF scholarship that if it is successful will “unload” most of the cost of the post doc from SMART Maritime.

WP2.2 Prediction of added resistance due to waves

Pre-project thesis, supervised by Prof. Steen, exploring different tools, including non-viscous CFD utilizing VOF free surface treatment and course grids.

State-of-the-art study (MARINTEK)

Dependencies, critical factors, assumptions:

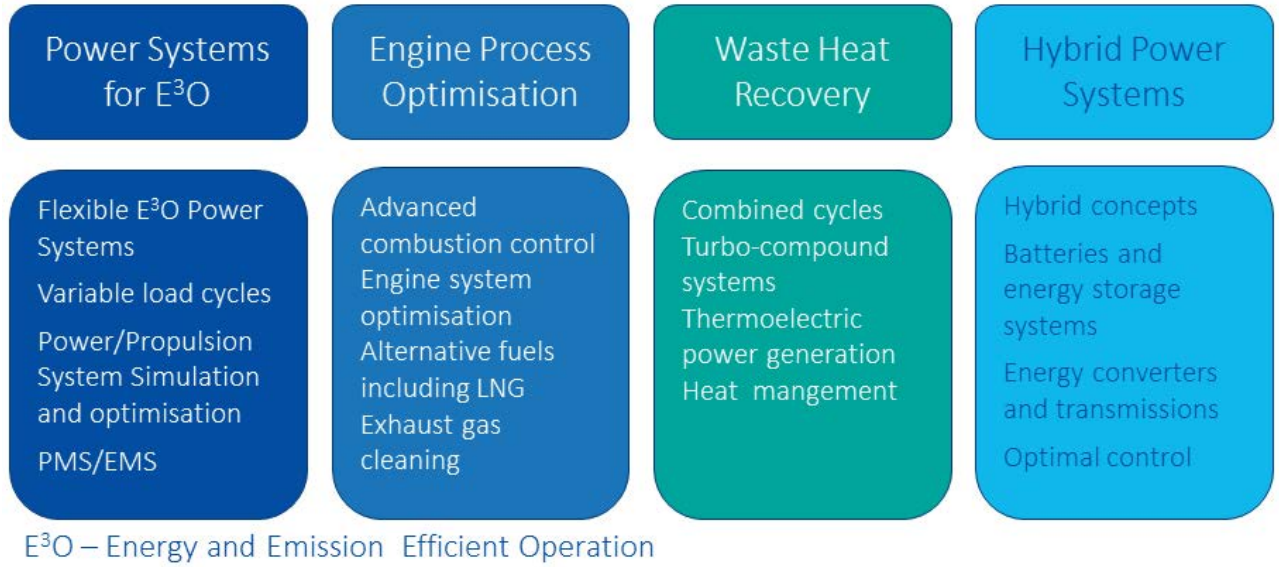
The start-up time of the post doc, and whether he will be financed by EU not this project is uncertain.

The details of involvement of MARINTEK researchers is not decided.

Activities/Milestones:	Deadline	Deliverables
Delivery of pre-project thesis (WP2.2)	**18.12.2015**	**thesis**
Project plan for PhD project of Godø	**15.09.2015**	**Project plan**
Working paper of CFD-study and model tests on flapping foils	**18.12.2015**	**Working paper**
State-of-the art study report (MARINTEK)	18.12.2015	Working paper

Work Package 3 - Power systems and fuel

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.



Objectives (Overall):

Improve current designs and explore novel technologies, systems and solutions for power generation which are energy and emission efficient.

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. Possible solutions are expected to be found using power systems that are much more flexible relative to fuel, power sources, system configuration, hybridization, WHR (waste heat recovery), HRS (energy harvesting, recovery and storage) and with a high level of integrated total power-, energy- and heat management control systems. This work package will concentrate on exploring options for integration of novel technologies into current and new designs, for more flexible energy and emission efficient power systems, engine system process optimization using advanced combustion control, waste heat heat recovery options and hybrid power systems utilizing batteries and advanced power management and control

Scope of work (Activities current year):

P3.1 Advanced Combustion control for alternative fuels

1 Phd - Vladimir Krivipolanski - starts 1st Sept 2015.

His work will focus on injection dynamics and combustion characteristics of alternative fuels including natural gas under varying applied scenarios. His approach is experimental and will for validation of simulation results perform experiments within our Constant Volume Pre-combustion cell (CVPC). Development of methodology for characterization of alternative fuels will be focused.

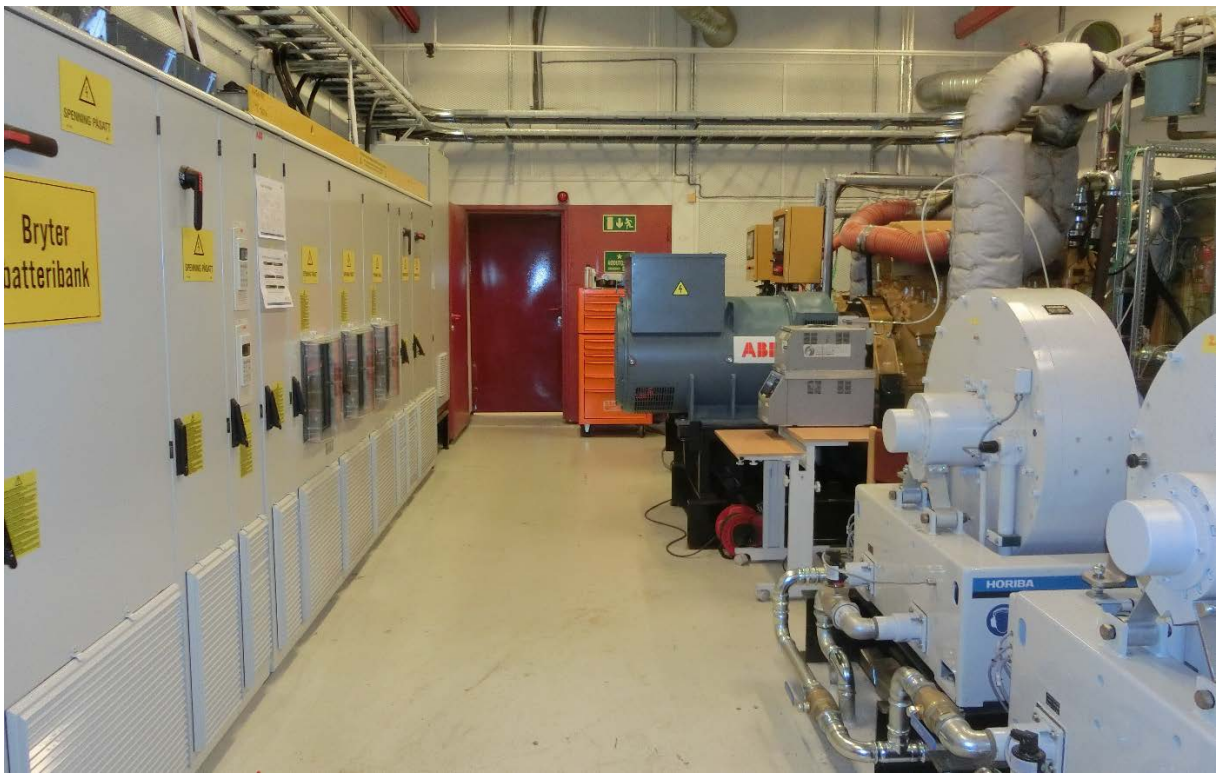
WP3.1 Engine Process Optimisation
State of the art report to be established for engine process optimization taking into account the new options for exhaust gas cleaning and hybridization options currently available. Marintek researchers, associated phd- and master-students, international collaboration.

WP3.1 Hybrid Power Systems
1 Post doc – Torstein Ingebrigtsen Bø – starts approximately 1st of January 2016.
Hybrid Power Systems, although actually installed in some ships, is still in its infancy. The potential for batteries or capacitors in different ship types are to be investigated using both experimental and theoretical simulation approaches. Combining advanced high fidelity simulators of typical power plants with proper vessel dynamic calculations are to be used for studying both current and new more futuristic options for hybridization. Cooperation with WP4 and associated projects (ViProMa) and other PhD-student projects (D2V). Verification of models and case results using Hybrid Power Lab.

WP3.2 Waste Heat Recovery
1 PhD –Jørgen B Nielsen
State of the art and future options for WHR and EHR to be established. Cooperation with partners, associated phd-projects and master projects. Development of simulation models for WHR to be able to assess current and future technologies. Cooperation with WP4.

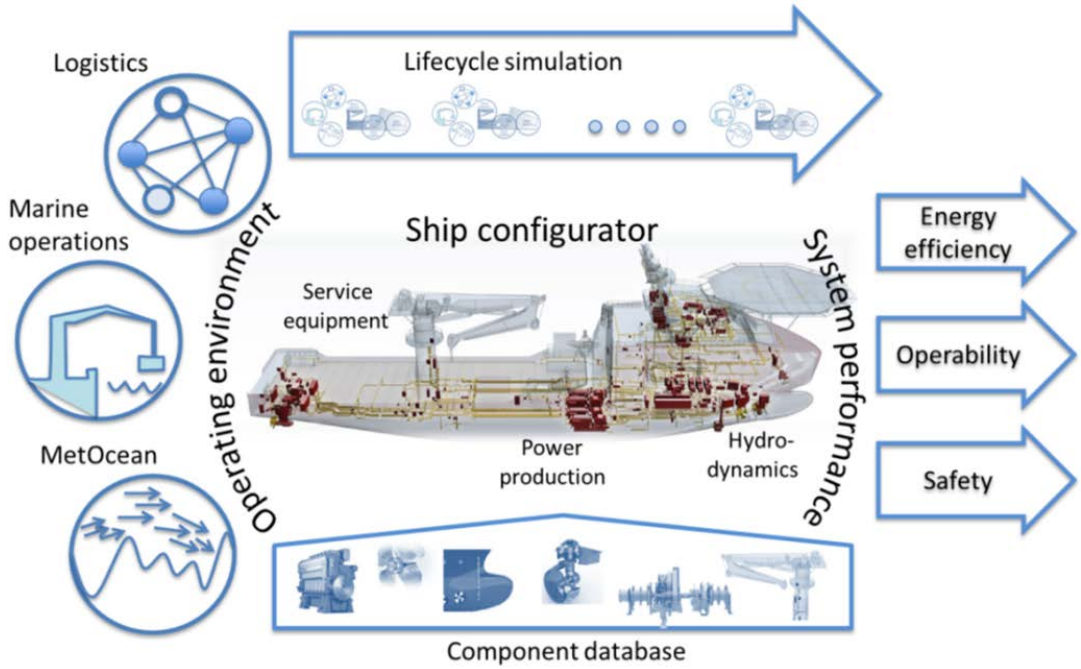
Dependencies, critical factors, assumptions:
Recruitment of PhD and Post Doc.
Results from the ViProMa KPN project.

Activities/Milestones:	Deadline	Deliverables
Start PhD #1 and #2	01-Sep-2015	



Work Package 4 - Ship system integration and validation

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.



Objectives (Overall):

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, and validate the results through laboratory and full-scale tests.

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. Optimal choice and performance of next generation low-emission ships need to be based on improved analytical and numerical models integrated in a system analysis and simulation framework, verified by laboratory and field tests. In addition, continuous optimization of these systems can be achieved by the combination of real-time monitoring and appropriate system simulations.

Scope of work (Activities current year 2015):

- 1 Phd candidate (Jørgen Bremnes Nielsen) starts 1st Sept 2015. His work will be on system simulation, specially focusing on integration of power system sub-models.
- Simulation framework development, building on the ViProMa project results:
- Connect the different physical domains and modeling regimes of hydrodynamics, power

systems and marine operations in one open framework.
- Develop a visual interface for configuring the components of the ship's power generation, distribution and propulsion system with the vessel's hydrodynamic characteristics.
- Develop a library database for efficient use and re-use of component models and product data, e.g. diesel engines, electrical switchboards, gearboxes and propellers.
- Develop methods for describing system operation, in the form of operational profiles and usage scenarios.
- Create an adequate representation of different operation modes (e.g. transport/transit; port operations; dynamic positioning close to rigs/vessels) and combine this with the influence of the environment using historical research weather data.
- Outline methods for assessing system performance against operational profiles and scenarios. Develop some standard measures for the performance of a system, in the form of KPIs.
- Develop methodologies for collection, filtering and use of full-scale measurement data in order to validate and calibrate the ship system simulations.

Dependencies, critical factors, assumptions:

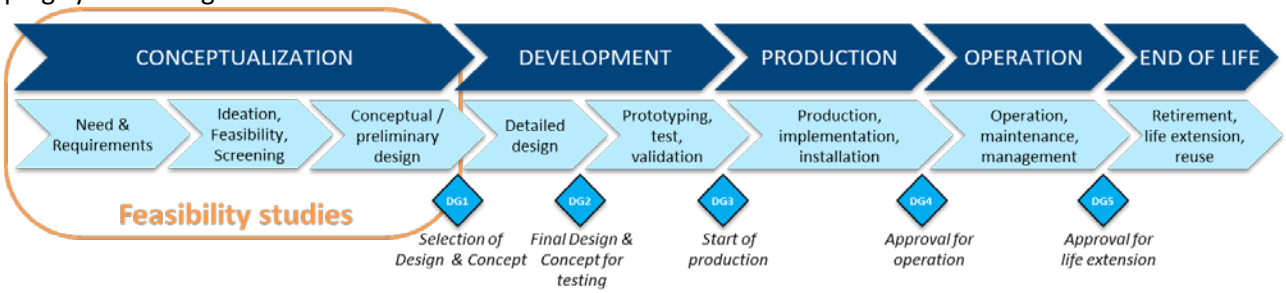
Recruitment of PhD.
Results from the ViProMa KPN project.

Work Package 5 - Environmental and economic due diligence

This work package will integrate state of the art methods for detailed environmental and economic analyses, to systematically assess, compare, and benchmark ships and shipping system designs

Objectives (Overall):

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



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 CO2 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 need for integration of such assessments in the environmentally conscious design of ships. The WP will integrate state-of-the-art methods for detailed environmental and economic analysis to perform due diligence in such a way that current and future ship types and shipping system designs can be systematically assessed, compared, and benchmarked.

Scope of work (Activities current year):

Evert Bouman researcher started 1st Sept 2015

- Defining the general scope of Environmental and Economic Due Diligence (EEDD) framework
- Exploring and defining the interface of WP5 with other work packages in the project.
- Design an initial EEDD framework architecture. For example, key environmental and economic indicators need to be identified in collaboration with the project partners.
- Explore options and approaches of how the framework can be integrated in ship design and engineering workflows.
- For further use in the project business cases (notably Fuels and Hybrid), provide an initial estimation of life-cycle fuel chain emissions for key substances: Examples are SOx, NOx, PM, CO2, CH4, and Black Carbon. Fuel chains to investigate: i) Well-to-tank, ii) tank-to-propeller, iii) and well-to-propeller. ii) and iii) require emissions estimates for the operation of ‘typical’ drivetrains.

Dependencies, critical factors, assumptions:

An essential part of the project will be to establish and uncover the interdepencies between different work packages. The successfulness of the project depends on a clear understanding of the potential outputs and necessary inputs of the framework, and division of labour between partners.

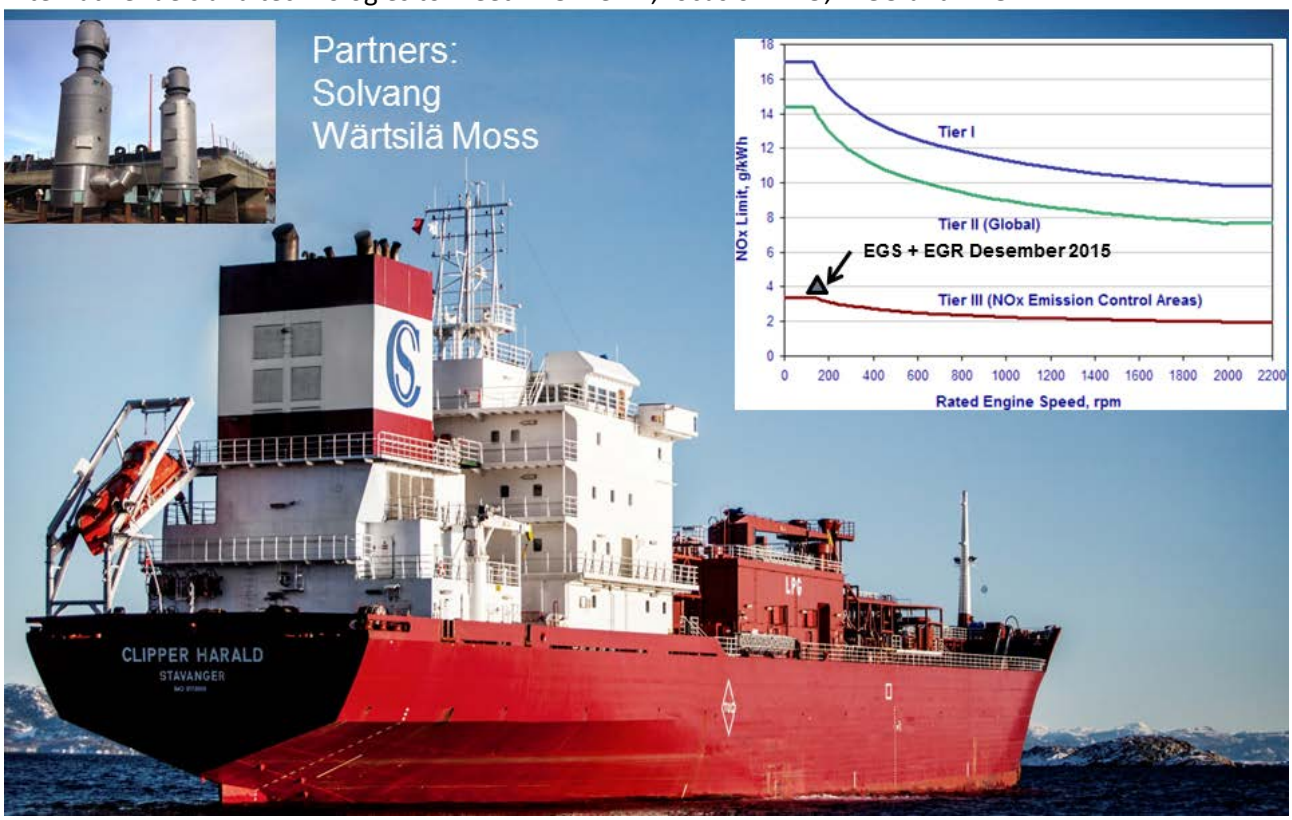
Activities/Milestones:	Deadline	Deliverables
Start Research Engineer	01-Sep-2015	
Scoping of the EEDD framework	15-Nov-2015	Initial scoping document
Design initial EEDD framework architecture	18-Dec-2015	Initial architecture description document
Provide fuel chain emissions estimate to internal project partners	15-Dec-2015	Emissions table

Research Plan - Sub-Projects 2015

Two sub-project were started in 2015

Sub Project 1 Fuels

Alternative fuels and technologies to meet IMO Tier III, focus on HFO, MGO and LNG



Objective:

The main objective of this study is to perform a full economic, technical and environmental due diligence of the alternative fuels and abatements technologies. This also includes assessment of technology trends and future legislation development.

Background and motivation

Requirement of 0.1% sulphur in the SECA's were put into force 1st of January 2015 and requirement of stricter limits on NOx emission for new built ships will come (1st of January 2016 in USA and Canada and later in European waters)

The known emission limits might be met by alternative fuels like LNG, low sulphur fuel oil with SCR or by HFO applying scrubbing technology and means to reduce NOx. There is a focus of Green House Gas (GHG) emission from ships even though there are no limits for the shipping industry. To make an objective comparison between different fuels and machinery systems, energy consumption and analysis form well to propeller will be included.

This study will perform a full economic and environmental due diligence of the different alterative solutions. The study will be supported with data and experience form ships in operation

Tasks and activities

1. Perform energy analysis for the different fuels (from well to propeller)
2. Perform cost and energy analysis for abatement technologies
3. Feedback for ships in operation in different market segments: a) Short sea b) Deep sea
4. A case study on a ship operating in SECA area on HFO with scrubbing system for shulphur reduction and combined with EGR to meet NOx Tier III will be performed
5. Comparison between ships with different technology level for stating the validity of the case results
6. A case study on a ship in short sea operation on Dual Fuel with LNG as the main fuel. A complete measurement program of exhaust emissions and fuel efficiency will be performed
7. Perform a full economic and environmental due diligence for the chosen cases.

Deliverables:

1. Well to Propeller analysis
2. Measurement report from ship case study
3. Journal papers
4. Conference presentations
5. Main report summarizing the project

WP – involvement

WP 3 Power Systems and Fuel: Power system simulation modelling

WP 4 Ship system integration, validation and monitoring: Integration of simulation models and validation of virtual prototypes against full-scale data
WP5 Environment and economic due diligence

Schedule:

Duration: 2 years. Start July 2015

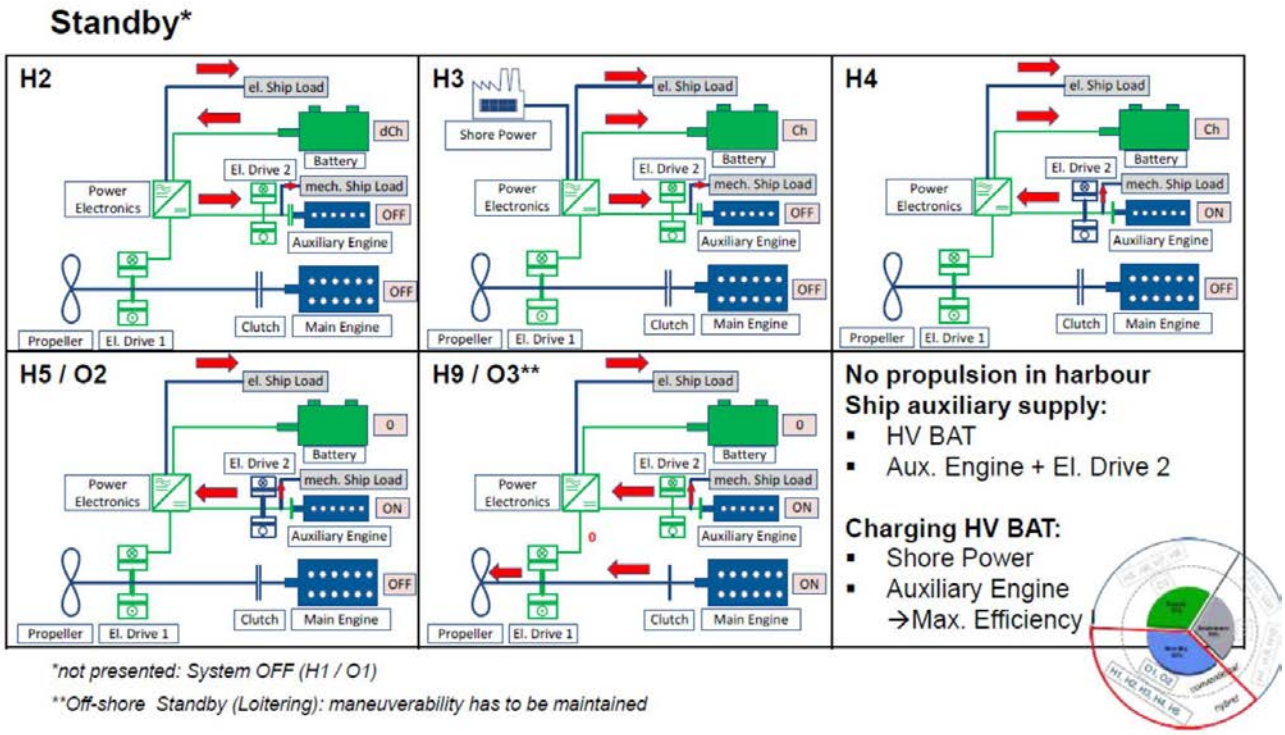
Participants and resources

Research: MARINTEK, NTNU

Relevant industry partners: Solvang Shipping, Wärtsilä Moss, Wihl Wilhelmsen, Kristian Gerhard Jebsen Skipsrederi, Grieg Star, DNV GL

Sub Project 2 Hybrid propulsion – project plan 2015 -2016

Marine Hybrid propulsion and batteries



Objective:

Identify and quantify the potential for reduction of cost and emissions in a maritime setting. Further, establish objective knowledge regarding technology potential for battery capacity, lifetime and cost

Background and motivation

The interest in using batteries in maritime applications has grown rapidly the latest years, mainly due to the success in road transport (private cars). We believe there is a need for a study determine the applicability for maritime applications of batteries, and to perform a full economic and environmental due diligence.

Hybrid technologies will include; battery storage of energy to take peak power requirements, engine power arrangements, cold ironing in port by vessel batteries, propulsion at sea by electricity from batteries only, and power management systems

Tasks and activities

- Battery technology – a technology review, possibilities and promises
- Marine hybrid power systems – a technology review, possibilities and promises
- Pure electrical marine propulsion – possible operating profile
- Marine propulsion configurations using hybrid technologies
- Potential of using power from batteries in harbor operations
- Perform a full economic and environmental due diligence of battery applications.

Deliverables:

- State of the art report of battery technology and possibilities and promises
- State of the art report of marine hybrid power systems and possibilities and promises
- Journal papers
- Conference presentations
- Main report summarizing the project

WP – involvement

WP 1 Feasibility studies
WP 3 Power Systems and Fuel: Power system simulation modelling
WP 4 Ship system integration, validation and monitoring: Integration of simulation models and validation of virtual prototypes against full-scale data
WP5 Environment and economic due diligence

Schedule:

Duration: 2 years. Start July 2015

Participants and resources

Research: MARINTEK, NTNU
Industry partners: ABB, SIEMENS, Rolls-Royce Marine, Grieg Star, NES, DNV GL

Organization

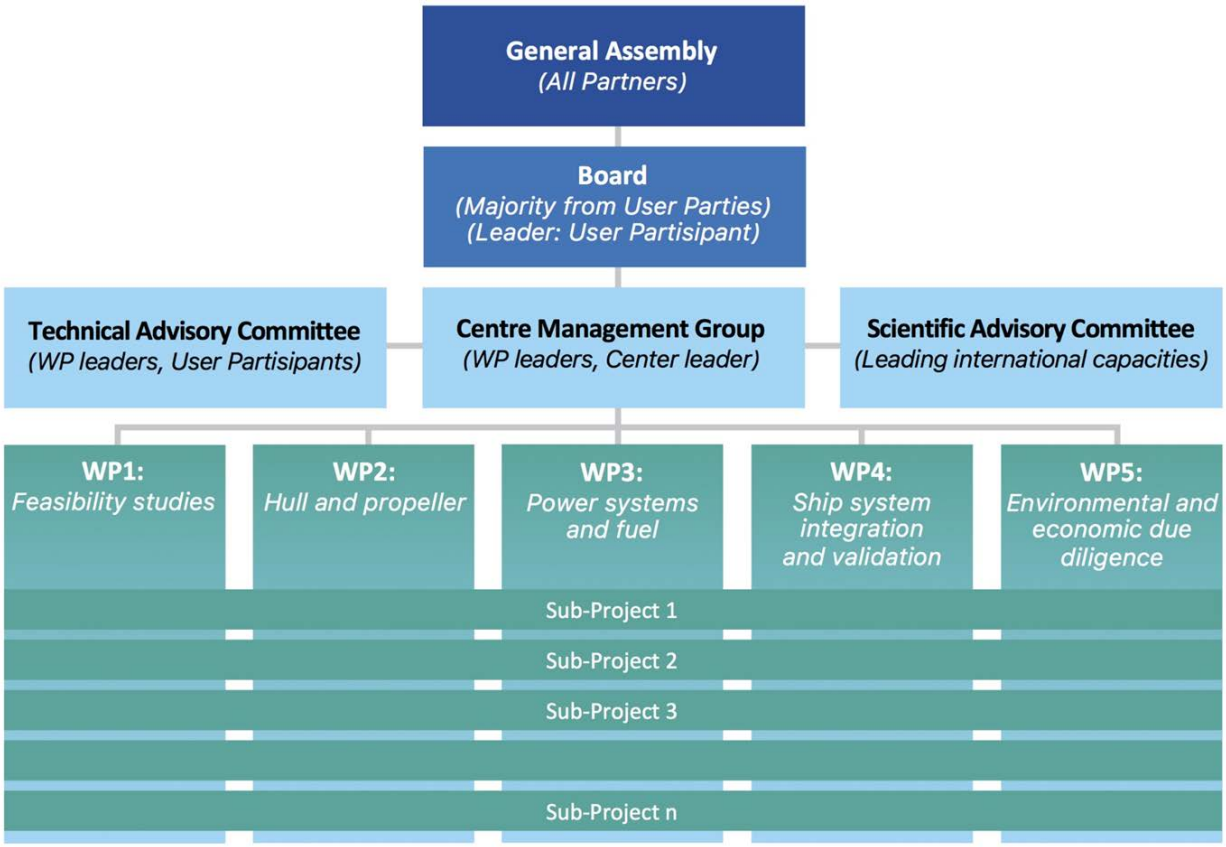
The Centre is using a matrix organization where the long-term research with the PhD programs performed in Work Packages (WP). Across of the WP's are Sub-Projects (SP) involving two WP's as a minimum. The SP's are relevant to actual topics for the industrial partners and are short-term activities, typically 2 years.

General assembly consist of all partners and a Centre Board with 7 members, industry partners in majority. The Centre management team consist of the WP'leaders, Centre Director and a Deputy Centre Director.

The Technical Advisory Committee (TAC) is formed to create a meeting place for all partners in the Centre to discuss and suggest activities in the WP's and SP's. The TAC is arranged with two network meeting a year. TAC will advise the Centre Management on prioritized R&D activities to be performed in the Centre.

The Scientific Advisory Committee will consist of leading international capacities auditing and advising the research activities in the Centre.

Organisation Structure



Board Members:	
Jan Øyvind Svardal, (Chairman of the Board)	Grieg Star
Per Brinchmann	Wilh. Wilhelmsen
Per Ingeberg	Rolls-Royce Marine
Henning Borgen,	Vard Design
Jan Fredrik Hansen	ABB
Ingrid Schjølberg	NTNU
Beate Kvamstad-Lervold	MARINTEK
Observer	
Sigurd Falch	Norwegian Research Council

Centre Management Group:	
Centre Director	Per Magne Einang
Deputy Centre Director	Anders Valland
Economy Controller	Jan Andre Almåsbakk
Adm. secretary	Inger Gudmundsen
WP1 Feasibility studies	Haakon Lindstad, MARINTEK
WP2 Hull and Propeller	Sverre Steen, NTNU
WP3 Power systems and Fuel	Eilif Pedersen, NTNU
WP4 Ship system Integration	Trond Johnsen, MARINTEK
WP5 Environment and economy	Anders Strømman, NTNU

Research partners:
MARINTEK (Host institution)
NTNU o Department of Marine Technology o Industrial Ecology Programme o NTNU in Ålesund Faculty of Maritime Technology and Operations

Industrial Partners:
DNV GL AS
Rolls-Royce Marine AS
Bergen Engines AS
ABB AS
SIEMENS AS avd corporate centre & real estate
Vard Design AS
Havyard Group ASA
Norwegian Electric System AS (NES)
Jotun AS
Wärtsilä Moss AS
Wilh. Wilhelmsen ASA
Solvang ASA
Grieg Star AS
Kristian Gerhard Jebsen Skipsrederi AS
Norges Rederiforbund
Fraktefartøyenes Rederiforening
Sjøfartsdirektoratet

Cooperation between partners

Smart Maritime organize an informal network meeting twice a year, Technical Advisory Committee. The purpose is to make a meeting place for the partners to discuss and express interest to the activities in the WP's and Sub-Project. We will also use this meeting place for discussing and suggestions for new research activities.

The industrial partners the main involvement will be in Sub-Projects, which are addressing actual and more short-term R&D topics.

Activities and Results

The SFI Smart Maritime is an important contribution to rebuild Norwegian maritime R&D. The research topics will still cover the traditional areas like hydrodynamic (hull and propellers) and machinery system (energy optimization, exhaust emissions and fuels). The focus of the ship as a system will be of great importance. This means a numerical simulation model of all components in a ship, which again constitute the ship as a system. The focus of the ship as a system will guide which components are most important for adding up to an optimized ship for the purpose it is built for. Such an approach will make it possible design and optimize the ship numerically before it is actually built. Some case ship with adequate instrumentation will be selected for feedback data in

real operation for adjustments and further developing of the numerical models. Another issue is life cycle analysis of some of the vital components concerning economic viability and environmental impact.

Sub Project 1 Alternative fuels and technologies to meet IMO Tier III, focus on HFO, MGO and LNG.
This sub-project has already performed the first test on board a ship in operation (Clipper Harald) with installation of exhaust gas scrubber and Exhaust Gas Recirculation (EGR). The preliminary results shows the potential of meeting the existing emission limits (IMO Tier III) when running on Heavy Fuel Oil (HFO). These results gives a promising possibility to ship operators for an energy and cost efficient solution to meet the coming emission limits in the Emission Controlled Areas (USA/Canada, European Waters)

International Cooperation

The Maritime Industry with Shipping, Equipment Industry, Ship Building and Design are in its nature an international industry and several of the members are multinational companies.

We are in the process of establishing cooperation with several international Univerities like:

- DTU – Technical University of Denmark
- Techn. Univ. of Hamburg-Hamburg

We are on an early stage of this process and the Centre need to establish formal contracts.
We are also in process in application to EU H2020 program, including several of our members as potential partners.

Recruitement

At the start-up in 1st of July there were already several candidates for PhD and Post Doc. This work started as the Smart Maritime was awarded the SFI Centre. Three PhD were employed by 1st of September as well as on Post Doc. Recruiting to these positions are according the progress plan of Smart Maritime. New announcements of PhD and Post Doc are displaced on www.smartmaritime.no as well as the normal channels for NTNU. We are happy to note an increased interested from Norwegian applicants. We are urging for female applicants.

Evert Bouman - Researcher, WP5

Area of work

- Contributing to Environment & Economic Due Diligence for SFI Smart Maritime
- Focus on environmental friendly ship design, by assessing environmental and economic perfomance parameters of selected ships and shipping systems.
- Analysis of fleet-wide implications of individual shipping designs for meeting overall climate change mitigation targets.

Previous and other work

- Focus on understanding environmental impacts and resource requirements of low-carbon energy technologies
- Working with both present and future energy systems scenarios
- Method development in the area of LCA and IO-analysis

Skills and expertise

- Life Cycle Assessment (LCA)
- Input-Output Analysis (IOA)
- Environmental systems analysis

Background

Education

- MSc Industrial Ecology Leiden University/Delft University of Technology (2011)
- MSc Chemical Engineering Delft University of Technology (2012)

Work experience

- Teaching assistant, Delft University of Technology. Teaching Introduction Chemical Process Technology (fall 2008)
- Project Engineer, Versatec Energy. Contributed to digitalization of Piping & Instrumentation Diagrams for oil platforms (2008)

Torstein Ingebrigtsen Bø

Postdoc Smart Maritime WP4 - Hybrid propulsion, Integrating new power sources for marine power plants.

Torstein I. Bø holds a Master of Science degree in marine technology from NTNU with specialization in marine cybernetics and a PhD in Engineering Cybernetics from NTNU with the title "**Scenario- and Optimization-based Control of Marine Electric Power Systems**".

He will contribute with his modelling and control expertise into the power systems and fuel project (WP3). The first milestone will be to establish a model of the hybrid power lab at NTNU, which is a joint laboratory of NTNU, Marintek, and ABB.

This model will be thoroughly verified with data from the lab. The models will be used to investigate the potential in fuel and emission re-

duction by different hybrid power system solutions. This can be combination of diesel electric and diesel mechanic propulsion, AC and DC distribution, and combinations including energy storage such as batteries.

The models will also be used to establish model based controllers, for optimal load and energy management of hybrid marine electric power plants.

This postdoc is supervised by Associated Professor Eilif Pedersen at NTNU department of marine technology

John Martin Kleven Godø

PhD Candidate WP2

Biomimetic Propulsion Systems for Increased Propulsive Efficiency

John Martin K. Godø holds a Master of Science degree in marine technology from NTNU with specialization in marine hydrodynamics. His master thesis involved design and experimental and theoretical studies of a biomimetic ship propulsion system attempting to replicate swimming motions found in nature.

Through his PhD thesis work, John Martin will continue the development of such a propulsion system with the aim of achieving significantly higher propulsive efficiencies than what is possible with today's propeller solutions. The first milestones will comprise experimental studies of a series of different motion patterns of a fish-tail-like propulsive device, validation of theoretical models for describing forces on such a system and studies of live creatures exhibiting efficient swimming.

Main supervisor for the PhD is Professor Sverre Steen at NTNU Department of Marine Technology, and co-supervisor is Research Scientist Luca Savio at MARINTEK.

Vladimir Krivopolianskii

PhD Candidate WP5

MSc from Høgskolen i Ålesund, working experience from Marintek.

High demand on low-emission marine engines due to strict environmental regulations stimulate development of technology related to injection and combustion processes. This PhD project is aiming to elaborate a research tool for further investigation of sprays of different fuels with help of optical and thermodynamic techniques. Unique big volume combustion rig is to allow to experimentally assess marine injection valves performance at relatively wide operation range. Thorough and multidisciplinary analysis of in-chamber processes is to contribute to precisely estimate conditions for injection, ignition and combustion activities in different gas engine concepts.

The actual research work will start with scrupulous literature survey to get confidence that the current study can contribute to the society and to

get hints and tips about ways to solve problems within particular topic. Significant attention in this PhD will be paid to investigation of injector's performance for dual-fuel applications. Here some work is assigned to study the injectors and spray geometries, their influence on the combustion process. Work towards the development high-pressure gas engine concept is additionally planed and it is mainly connected to investigation of autoignition of the low cetane fuel like LNG. This work comprises several stages such as: study of gas qualities and introduction of additives if needed. For validation of the results obtained from combustion rig experiments, the full-scale tests with help of available engine facilities are to be executed.

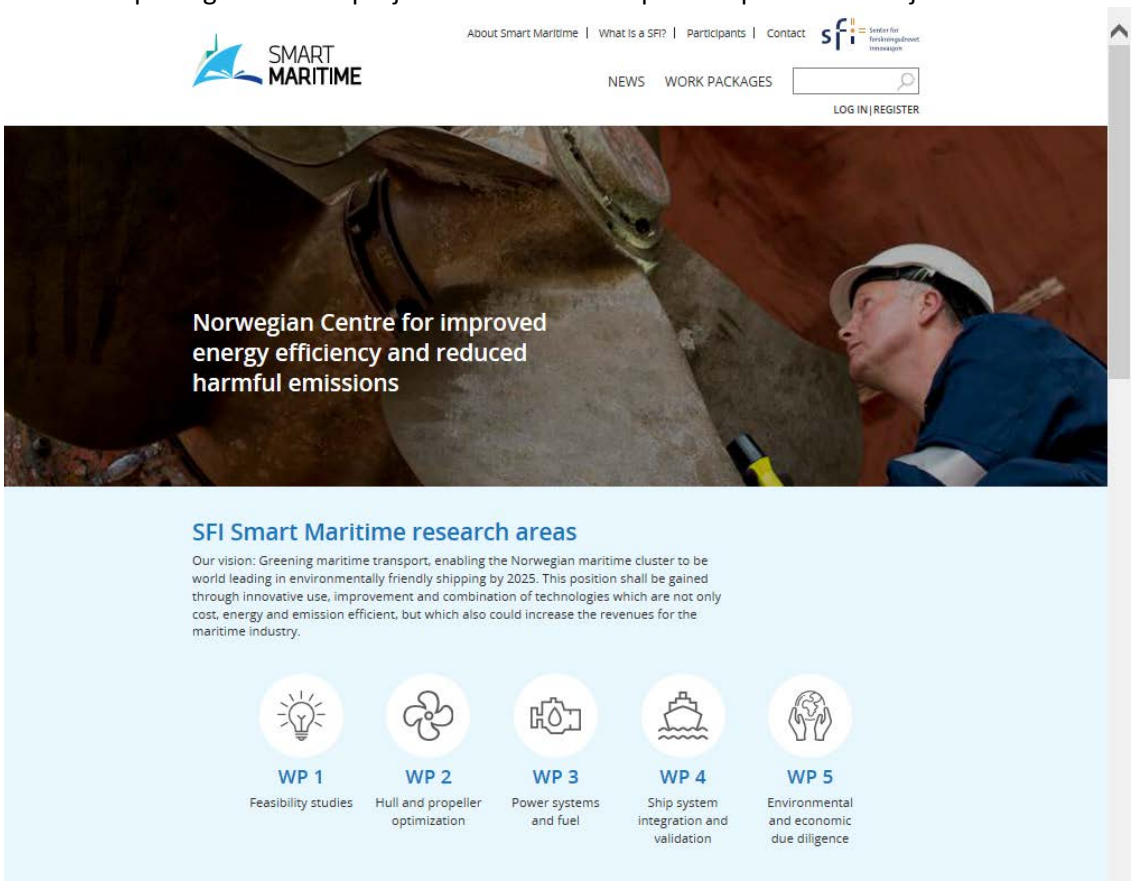
By the end of the project it is expected to develop recommendations and best practices for engine manufactures and ship-owners within SFI SmartMaritime.

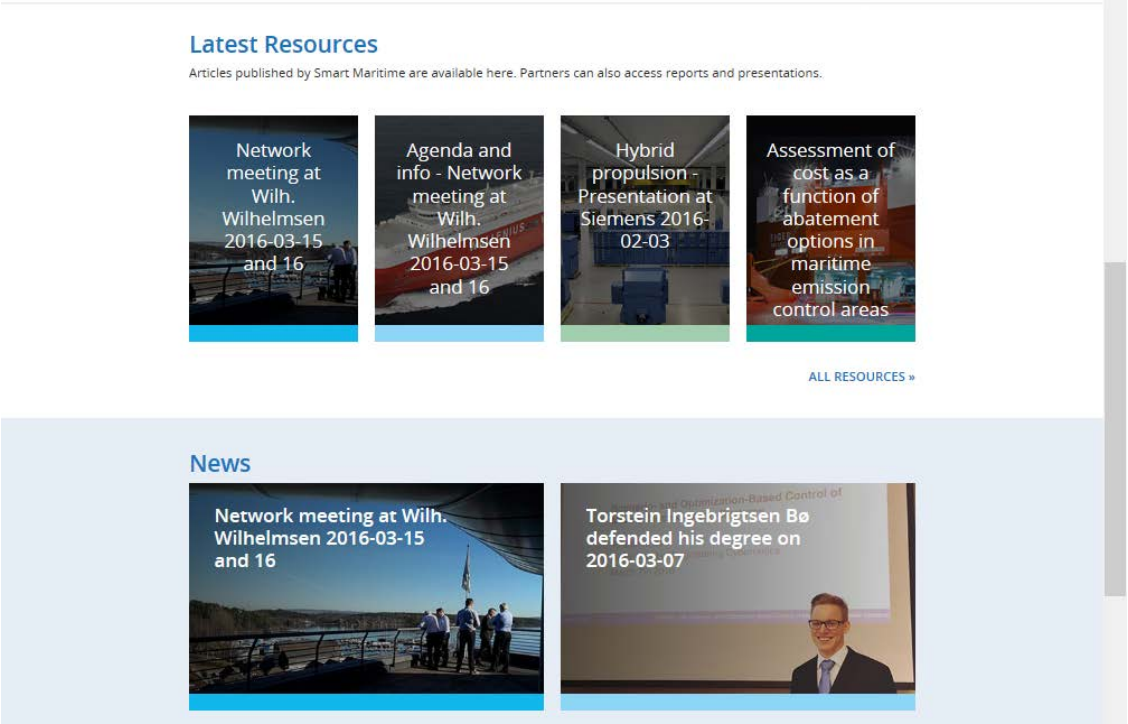
The PhD is supervised by Associate Professor Eilif Pedersen from Department of Marine Technology NTNU and co-supervised by Professor Vilmar Æsøy from NTNU i Ålesund

Dissemination

The Smart Maritime Centre has chosen to develop an active web page www.smartmaritime.no with at least monthly updated information and news. The web page has an open public access and a closed member access. We are using this platform for public information and for internal member communication.

Each work packages and sub-projects have their own plan for publication in journals and conferences.





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Statement of Accounts

Name	Funding		Cost
Research council	5 754	(49%)	
The Host Institution (MARINTEK)	2 258	(19%)	7 236
Research Partners*	694	(6%)	2 457
Industry partners	3 134	(26%)	1 962
Equipment			184
Total	11 839		11 839

Partners

MARINTEK NTNU

DESIGN, EQUIPMENT, SHIP BUILDERS

Rolls-Royce ABB HAVYARD Improving life at sea JOTUN WÄRTSILÄ

SIEMENS norwegian electric systems VARD a Fincantieri company

SHIP OPERATORS

Wilh. Wilhelmsen Solvang ASA GRIEG STAR KRISTIAN GERHARD JEBSEN SKIPSREDERI PART OF THE KRISTIAN GERHARD JEBSEN GROUP

OTHER PARTNERS

DNV·GL SJØFARTSDIREKTORATET Norwegian Maritime Directorate Norges Rederiforbund Norwegian Shipowners' Association FRAKTEFARTØYENES REDERIFORENING