Proceedings of the 3rd

Sustainability *in* Ship Design *and* Operations

Conference

November 6-7, 2023

Volume 1 Part 2: Presentations

Conference Information

The Sustainability in Ship Design and Operations conference aims to bring together industry and academia to discuss the concepts, technologies, case studies, and success stories related to sustainability in ship design and the greater maritime industry. Academic papers and technical presentations are shared by experts and practitioners, bringing innovative ideas and information to a wider audience. The papers and presentations are collected in these conference proceedings. Part 1 publishes submitted and reviewed technical papers while Part 2 gathers all presentation slide decks.

The ultimate goal of maritime sustainability is to create and operate ships and infrastructure that are more efficient and environmentally friendly, making the maritime industry more sustainable in the long term.

Disclaimer

The views and viewpoints expressed during the Sustainability in Ship Design and Operations conference and through the following papers and presentation slides are those of the authors and/or speakers and do not necessarily reflect the opinions, policies, or endorsements of the conference organizers, partner institutions, sponsor organizations, U.S. Government or of the non-Federal entities (NFE). References to NFEs, trade names, or commercial products do not constitute their endorsement by the U.S. Government and are meant for illustrative and educational purposes only.

Citation Information

Papers or presentations from this publication may be cited with the following information, adapted to the citation format of choice.

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MARIN
BETTER SHIPS, BLUE OCEANS

Sustainable Ships for our Blue Planet

Guilhem Gaillarde
Head of Ships Department

OUR BLUE PLANET

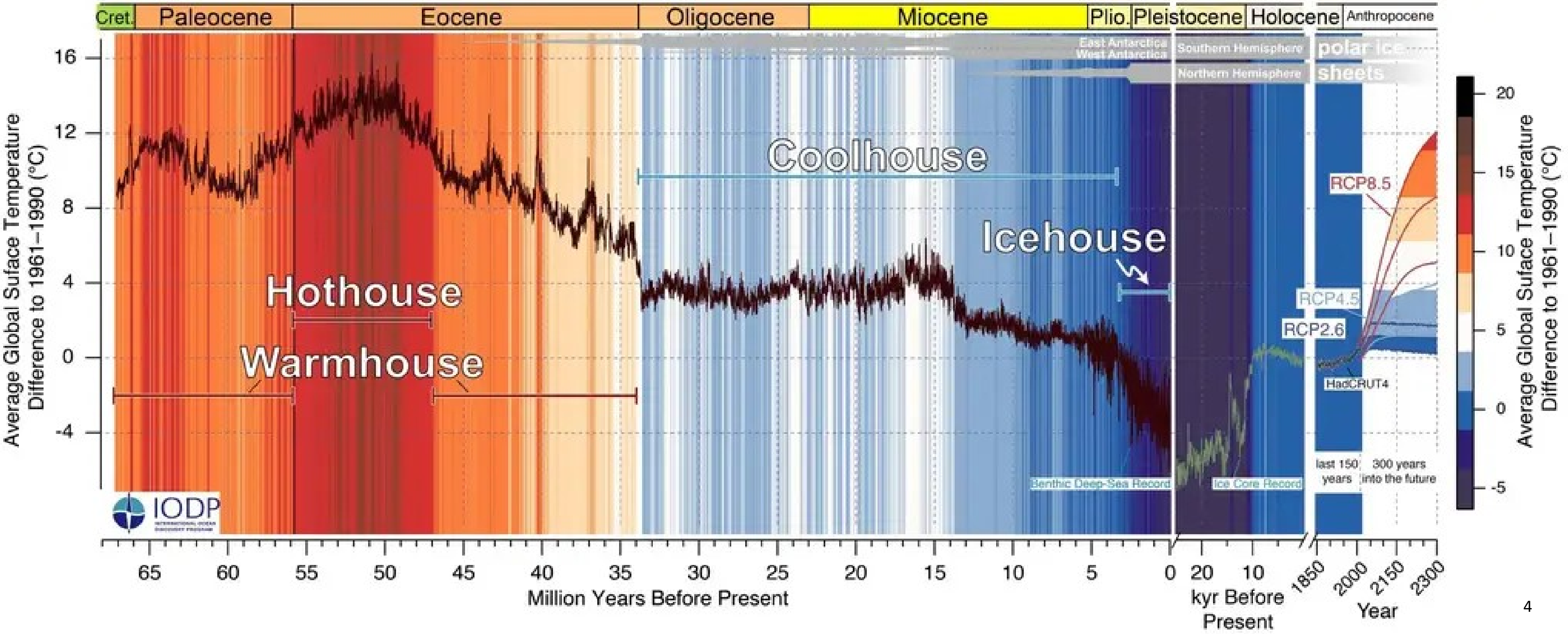
OUR BLUE PLANET

71% of its surface is covered by water
97.5% of water on earth is in the Oceans

90% of world trade is transported by seas
118.928 ships worldwide (>100 GT)
7.000 ships represent 51% of total GT

3% of annual GHG emission from shipping
expected to double in 2050 with same type of energy and power systems

OUR BLUE PLANET



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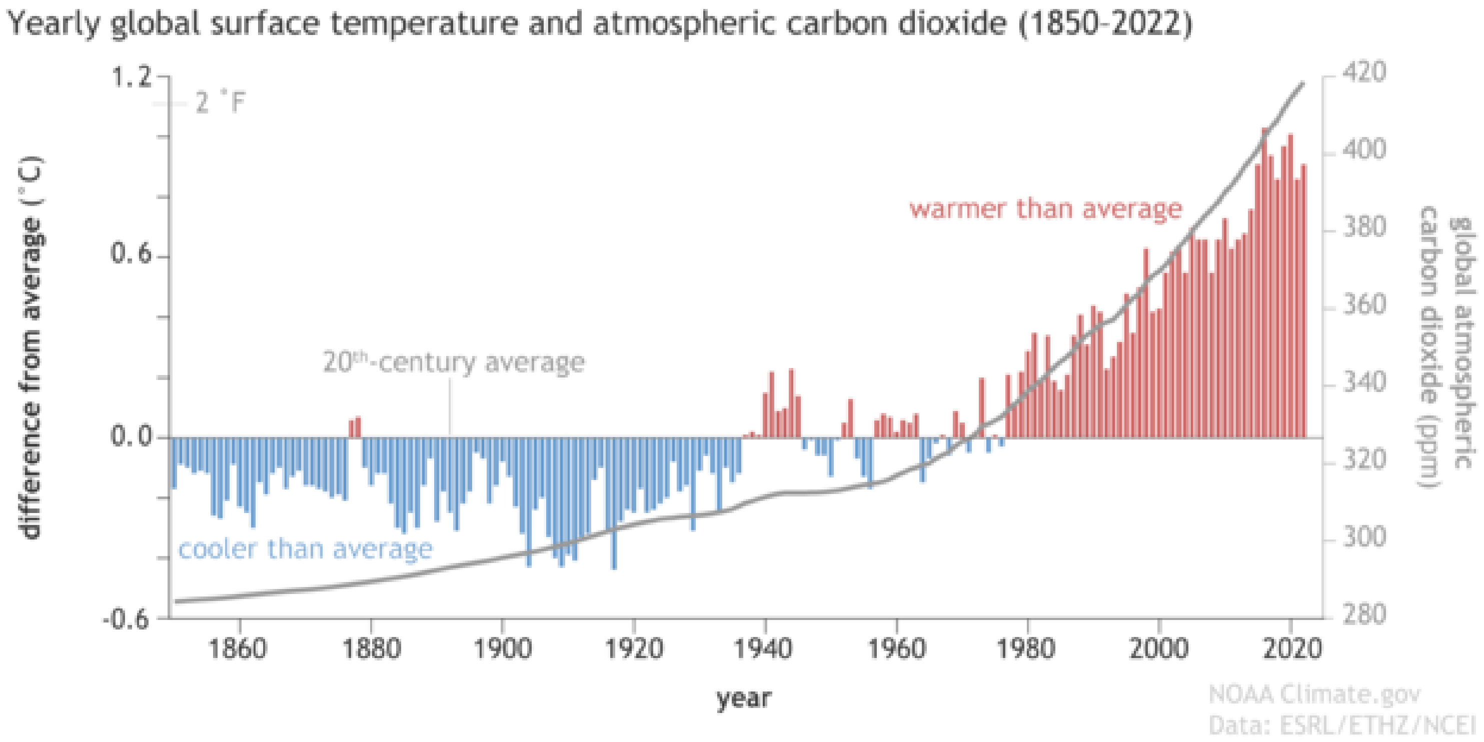
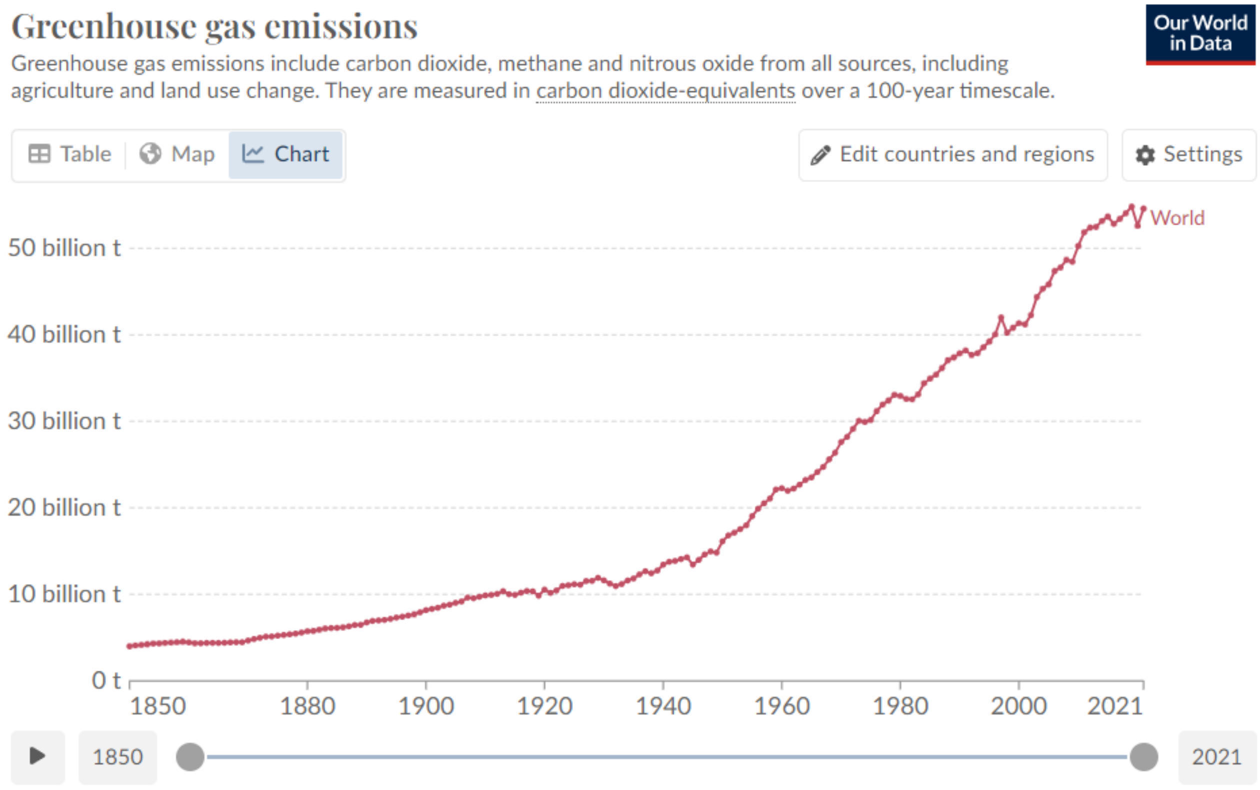


Greenhouse gas emissions

Greenhouse gas emissions include carbon dioxide, methane and nitrous oxide from all sources, including agriculture and land use change. They are measured in carbon dioxide-equivalents over a 100-year timescale.



Data source: Calculated by Our World in Data based on emissions data from Jones et al. (2023) - Learn more about this data

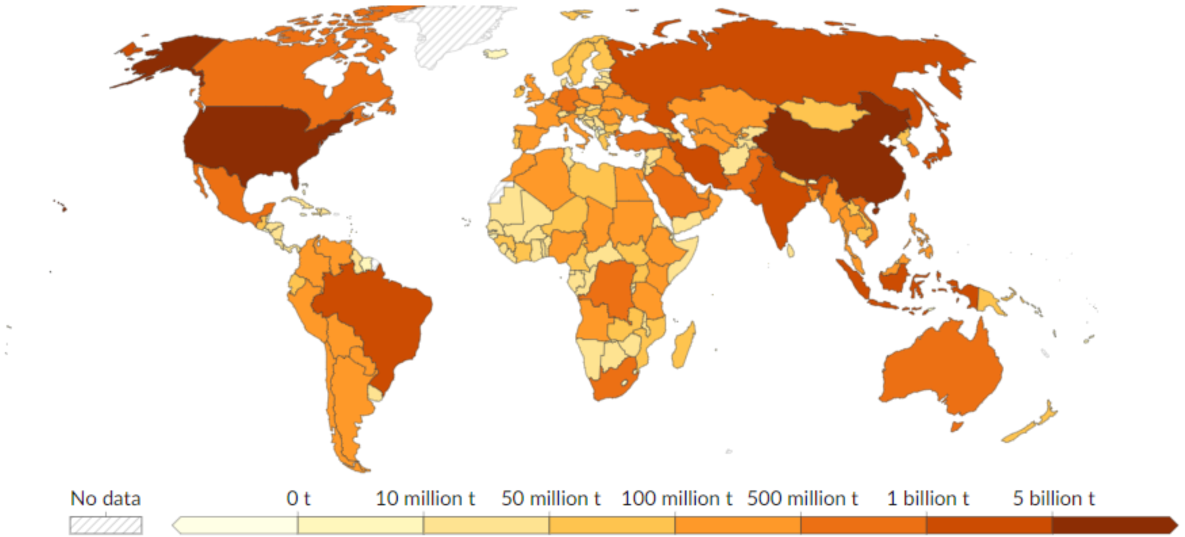
Greenhouse gas emissions, 2021

Our World in Data

Greenhouse gas emissions include carbon dioxide, methane and nitrous oxide from all sources, including agriculture and land use change. They are measured in carbon dioxide-equivalents over a 100-year timescale.

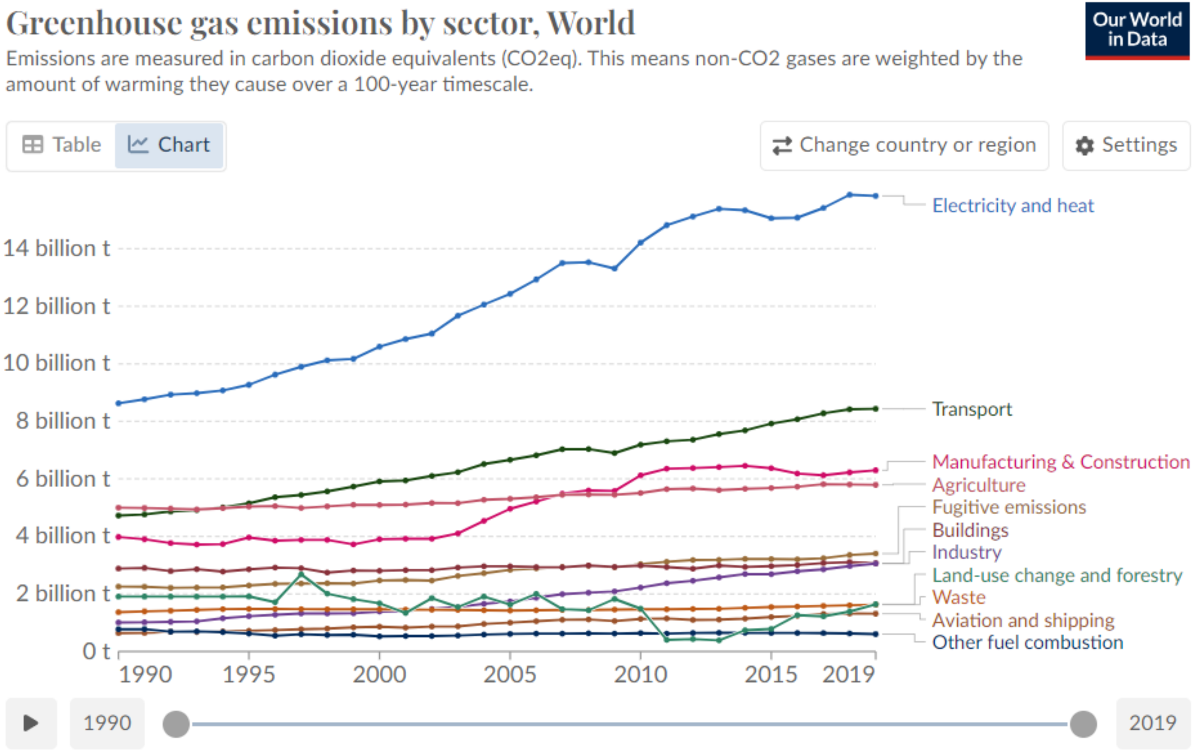
Table | Map | Chart

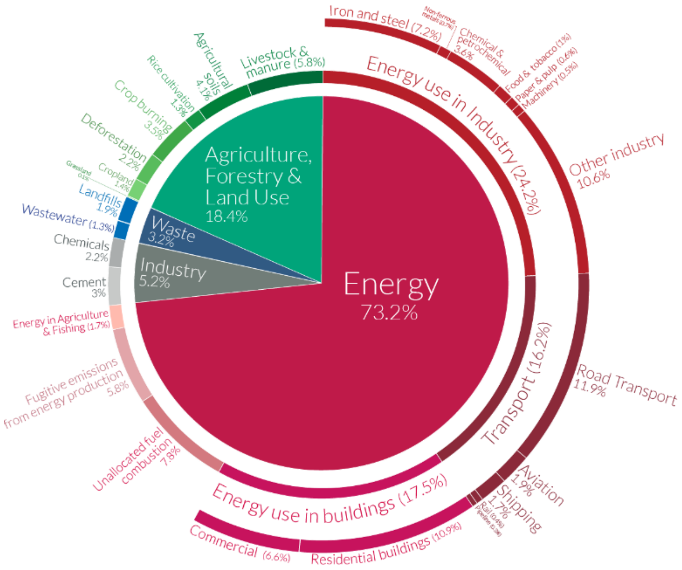
World

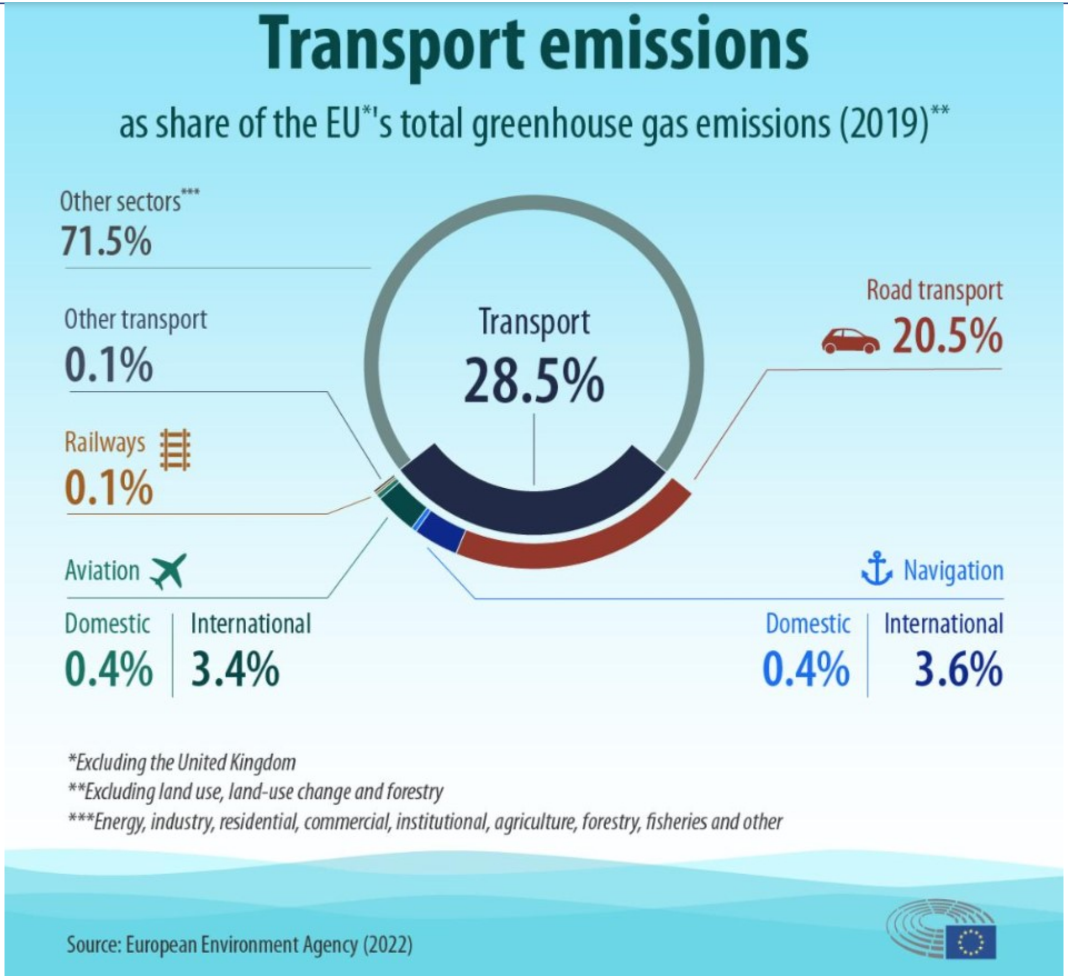


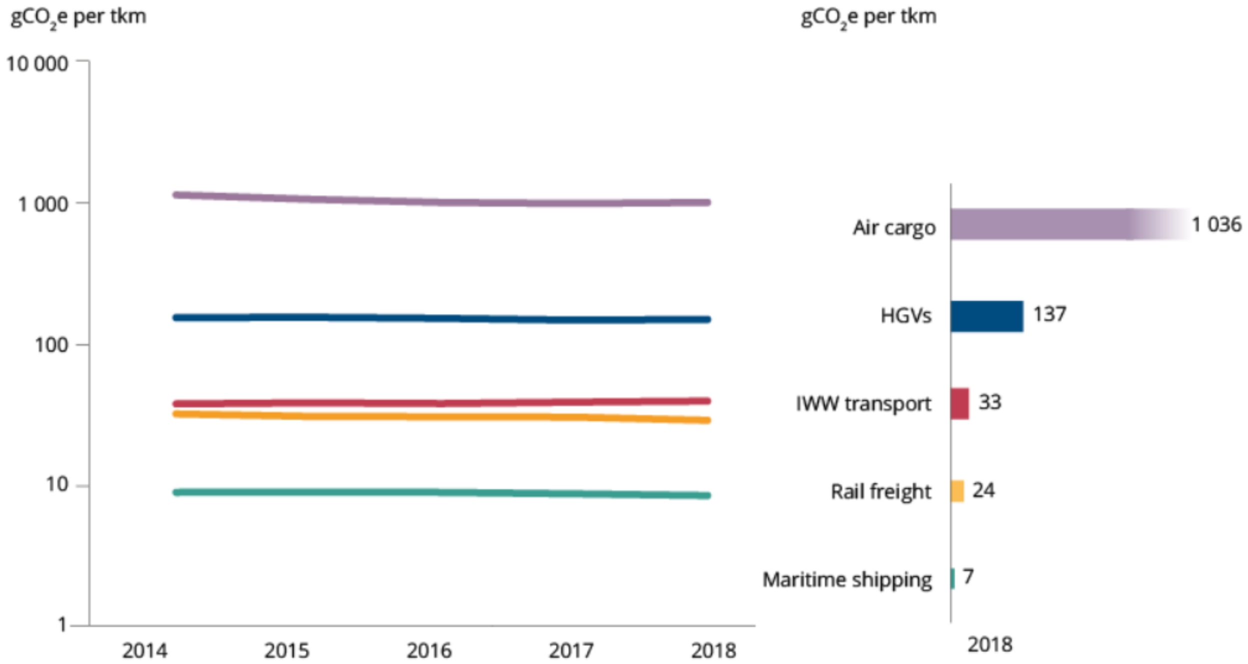
1850 2021

Data source: Calculated by Our World in Data based on emissions data from Jones et al. (2023) - Learn more about this data


Greenhouse gas emissions by sector, World
Emissions are measured in carbon dioxide equivalents (CO2eq). This means non-CO2 gases are weighted by the amount of warming they cause over a 100-year timescale.
Our World in Data
Table
Chart
Change country or region
Settings
14 billion t
12 billion t
10 billion t
8 billion t
6 billion t
4 billion t
2 billion t
0 t
1990
1995
2000
2005
2010
2015
2019
Electricity and heat
Transport
Manufacturing & Construction
Agriculture
Fugitive emissions
Buildings
Industry
Land-use change and forestry
Waste
Aviation and shipping
Other fuel combustion
1990
2019

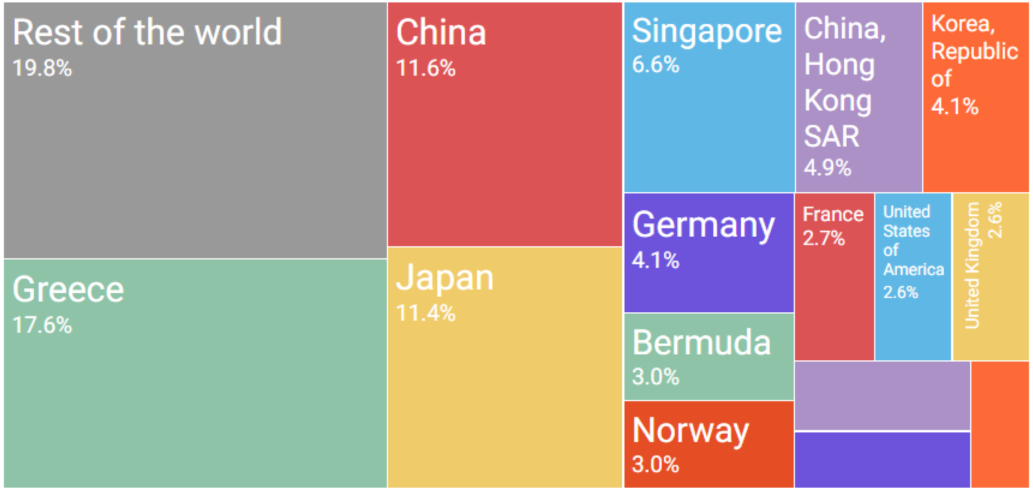

Energy
73.2%
Agriculture, Forestry & Land Use
18.4%
Waste
3.2%
Industry
5.2%
Energy use in Industry (24.2%)
Iron and steel (7.2%)
Other industry
10.6%
Transport (16.2%)
Road Transport
11.9%
Aviation
1.9%
Shipping
1.7%
Energy use in buildings (17.5%)
Residential buildings (10.9%)
Commercial (6.6%)
Unallocated fuel combustion
7.8%
Fugitive emissions from energy production
5.8%
Energy in Agriculture & Fishing (1.7%)
Cement
3%
Chemicals
2.2%
Wastewater (1.3%)
Landfills
1.9%
Cropland
1.4%
Deforestation
2.2%
Crop burning
3.5%
Rice cultivation
1.3%
Agricultural soils
4.1%
Livestock & manure (5.8%)


Transport emissions
as share of the EU*'s total greenhouse gas emissions (2019)**
Other sectors***
71.5%
Other transport
0.1%
Railways
0.1%
Aviation
Domestic
0.4%
International
3.4%
Transport
28.5%
Road transport
20.5%
Navigation
Domestic
0.4%
International
3.6%
*Excluding the United Kingdom
**Excluding land use, land-use change and forestry
***Energy, industry, residential, commercial, institutional, agriculture, forestry, fisheries and other
Source: European Environment Agency (2022)

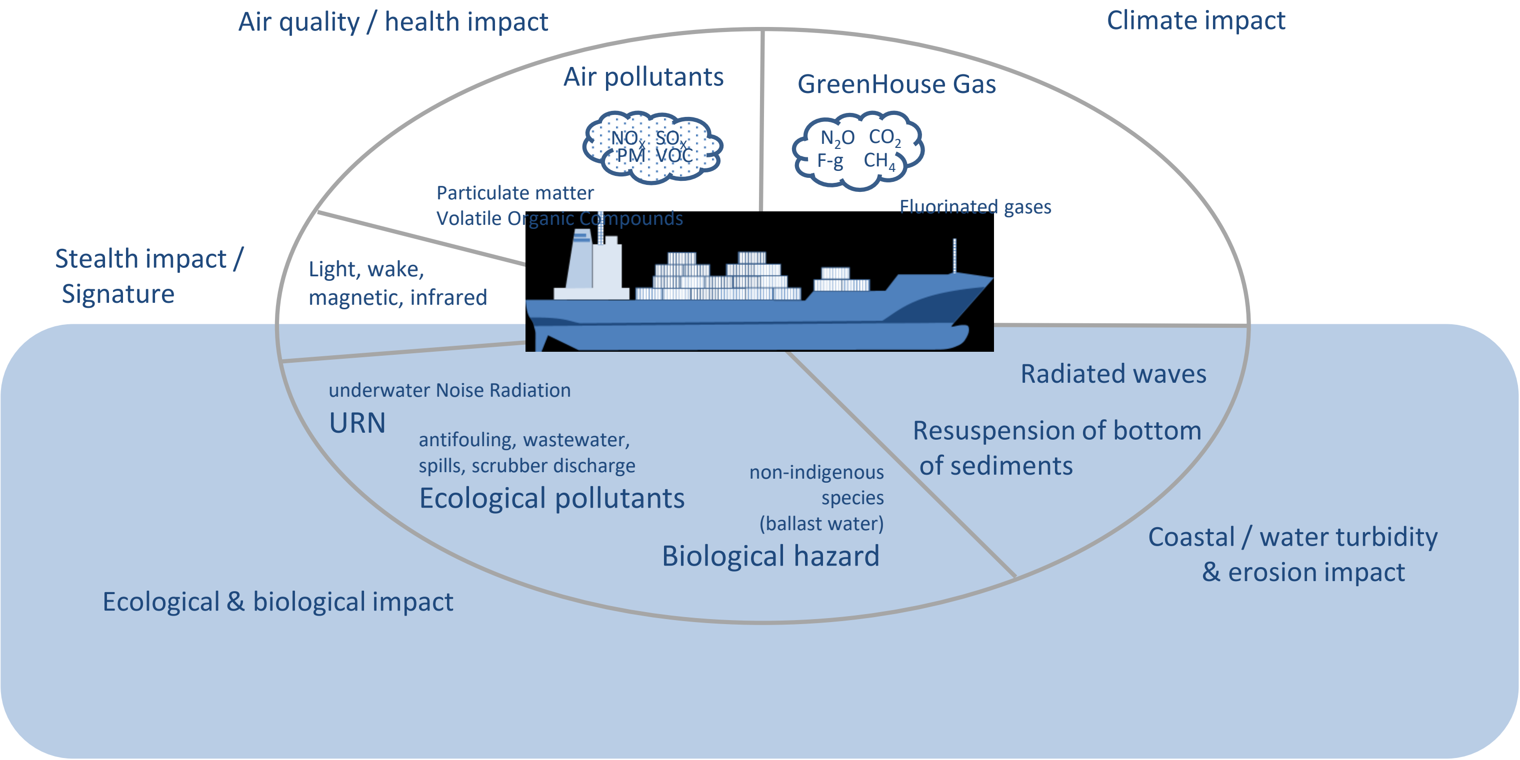


gCO2e per tkm
10 000
1 000
100
10
1
2014
2015
2016
2017
2018
gCO2e per tkm
Air cargo
1 036
HGVs
137
IWW transport
33
Rail freight
24
Maritime shipping
7
2018

Share of world fleet in % owned by top 15 countries in 2021 (> 5000GT)



Which emissions from ships?



theguardian.com/environment/2009/apr/09/shipping-pollution

This article is more than **14 years old**

Health risks of shipping pollution have been 'underestimated'

One giant container ship can emit almost the same amount of cancer and asthma-causing chemicals as 50m cars, study finds

newatlas.com/shipping-pollution/11526/

HOME LIFESTYLE SCIENCE TECHNOLOGY TRANSPORT

ENVIRONMENT

Big polluters: One massive container ship equals 50 million cars

April 23, 2009

lngtransfer.com/news/the-16-biggest-ships-produce-more-pollution-than-all-the-cars-in-the-world/

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21 Oct 2016

Home » News » The 16 biggest ships produce more pollution than all the cars in the World

The 16 biggest ships produce more pollution than all the cars in the World

Posted in News By Mark James On October 21, 2016

CO2 emissions: claims and fact checks

Claim:
"The 16 largest ships emit as much CO2 emissions as all the cars in the world" (NRC.nl, 2014).

Evaluation CE Delft study (2021)*:
16 of the largest ships […] emitted between 1 and 4 million tons of CO2 in 2015, while all the cars in the world emitted between 1,900 and 3,500 million tons of CO2

16 of the largest ships produced as much CO2 emission than 0,1% of all the cars in the world

* Source: https://cedelft.eu/wp-content/uploads/sites/2/2021/04/CE_Delft_7N59_The_basic_facts_Summary_and_Conclusions.pdf

SOx emissions: claims and fact checks

"The 17 largest ships in the world emit more sulfur than all the cars in the world combined" (D66, 2017).

Evaluation CE Delft study (2021)*:
17 of the largest ships emitted in 2015, depending on how you define "large," between around 10 and 45 kilotons of SOX. Around 947 million cars worldwide emitted between around 70 and 350 kilotons of SOX in 2015.

‘With an estimated 800 million cars driving around the planet, that means 16 super-ships **can** emit as much sulphur as the world fleet of cars’ (Daily Mail Online, 2009).

Evaluation CE Delft study (2021)*:
If you define a 'super-ship' as a cruise ship and assume that the 16 largest cruise ships only operated on HFO (with the maximum allowable sulfur content of 3.5%), then the statement is correct. However, because cruise ships often sail in Emission Control Areas, (and the average sulfur content of HFO in 2015 was already at 2.45%), this statement was accurate in 2015 only under unrealistic assumptions.

One large container ship with over 14,500 TEU emitted around 1 kiloton of SOX in 2015. This is equivalent to about 3 to 12 million cars in 2015.

NOx emissions: claims and fact checks

Claim:
"Container ship as polluting as up to 50 million cars" (Groen7.NL, 2015).

16 of the largest container ships (with over 14,500 TEU) emitted around 45 kilotons of NOX in total in 2015. 50% of the cars worldwide emitted around 5,900 kilotons of NOX in 2015, which is 130 times more.

1 large container vessel emits per year as much nitrous dioxide than about 250.000 cars

Designing sustainable ships and waterborne operations is technically possible but necessitates a holistic approach, full of challenges and requires making choices and accepting changes.

- Ship design
- Ship operations
- Fuel & Transport Infrastructures
- Fleet & Logistics

⟺

Three main drivers

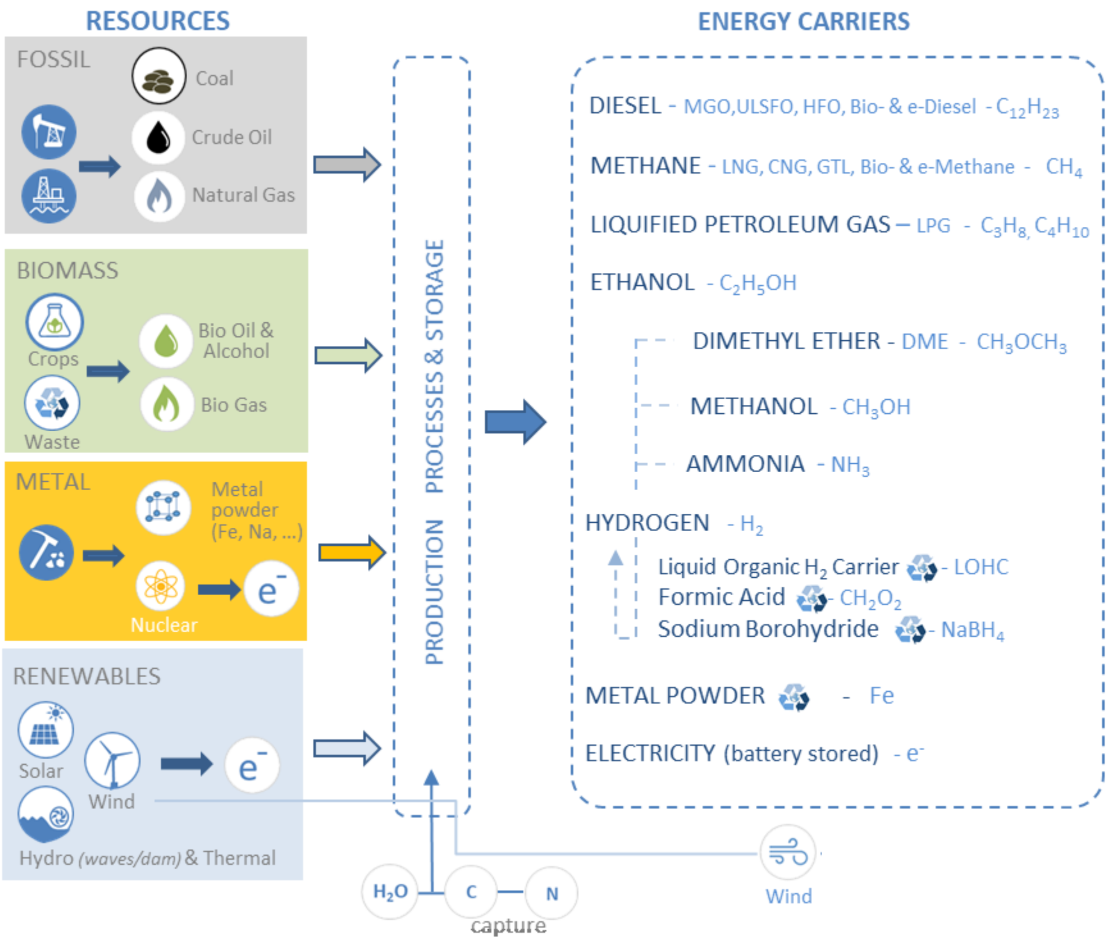
- **Use sustainable energy**
- **Design for operations**
- **Use less energy**

One ready to implement solution

- **Use freely available energy**

SUSTAINABLE ENERGY


RESOURCES
FOSSIL
Coal
Crude Oil
Natural Gas
BIOMASS
Crops
Waste
Bio Oil & Alcohol
Bio Gas
METAL
Metal powder (Fe, Na, ...)
Nuclear
e⁻
RENEWABLES
Solar
Wind
e⁻
Hydro (waves/dam) & Thermal



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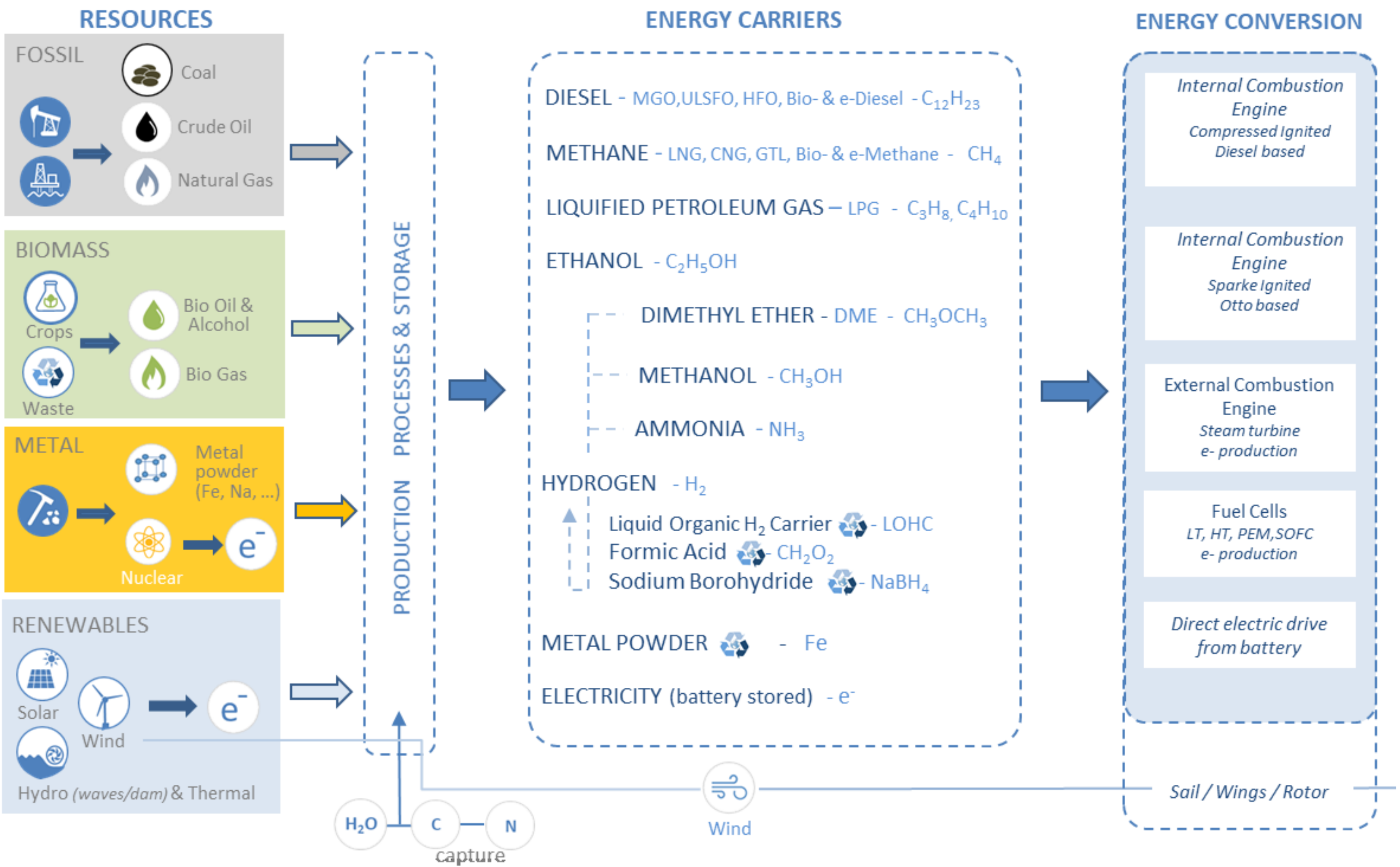
PRODUCTION PROCESSES & STORAGE
H_2O
C
N
capture
Wind
ENERGY CARRIERS
DIESEL - MGO,ULSFO, HFO, Bio- & e-Diesel - $C_{12}H_{23}$
METHANE - LNG, CNG, GTL, Bio- & e-Methane - CH_4
LIQUIFIED PETROLEUM GAS – LPG - C_3H_8, C_4H_{10}
ETHANOL - C_2H_5OH
DIMETHYL ETHER - DME - CH_3OCH_3
METHANOL - CH_3OH
AMMONIA - NH_3
HYDROGEN - H_2
Liquid Organic H_2 Carrier - LOHC
Formic Acid - CH_2O_2
Sodium Borohydride - $NaBH_4$
METAL POWDER - Fe
ELECTRICITY (battery stored) - e⁻



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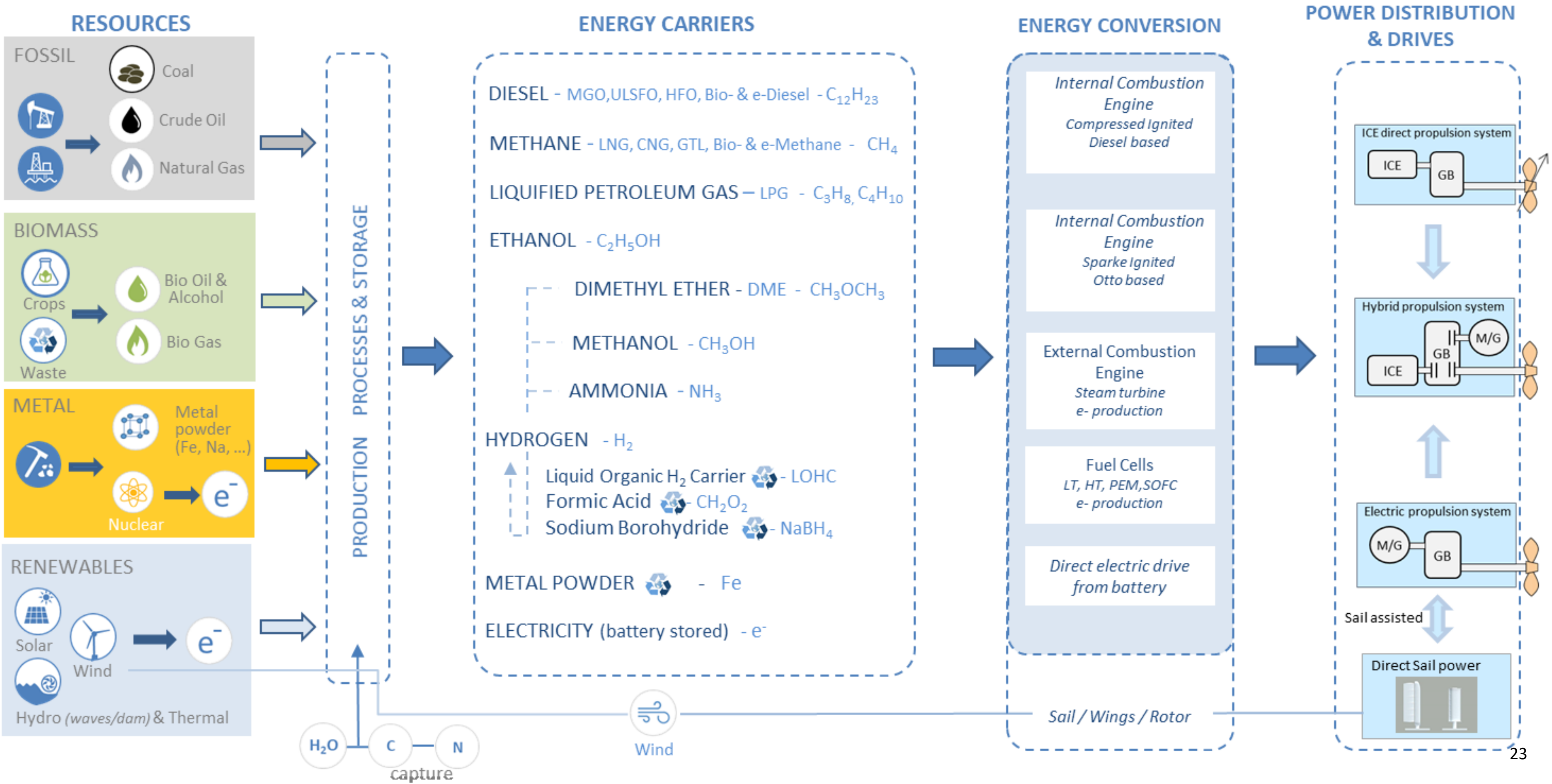

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Formic Acid - CH_2O_2
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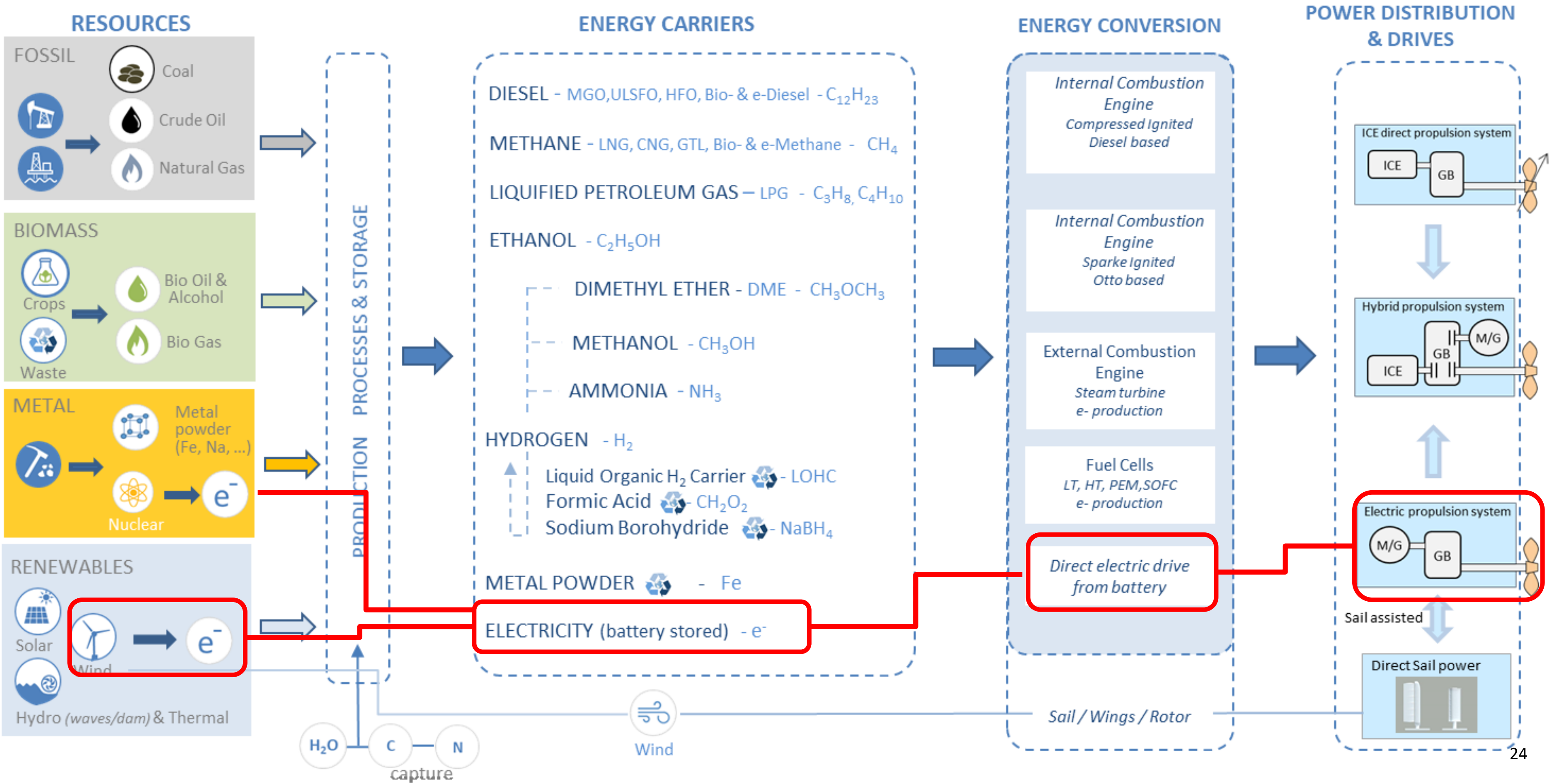
METAL POWDER - Fe
ELECTRICITY (battery stored) - e^-
Wind
ENERGY CONVERSION
Internal Combustion Engine
Compressed Ignited
Diesel based
Internal Combustion Engine
Sparke Ignited
Otto based
External Combustion Engine
Steam turbine
e- production
Fuel Cells
LT, HT, PEM,SOFC
e- production
Direct electric drive from battery
Sail / Wings / Rotor
POWER DISTRIBUTION & DRIVES
ICE direct propulsion system
ICE
GB
Hybrid propulsion system
M/G
GB
ICE
Electric propulsion system
M/G
GB
Sail assisted
Direct Sail power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METHANOL - CH3OH
AMMONIA - NH3
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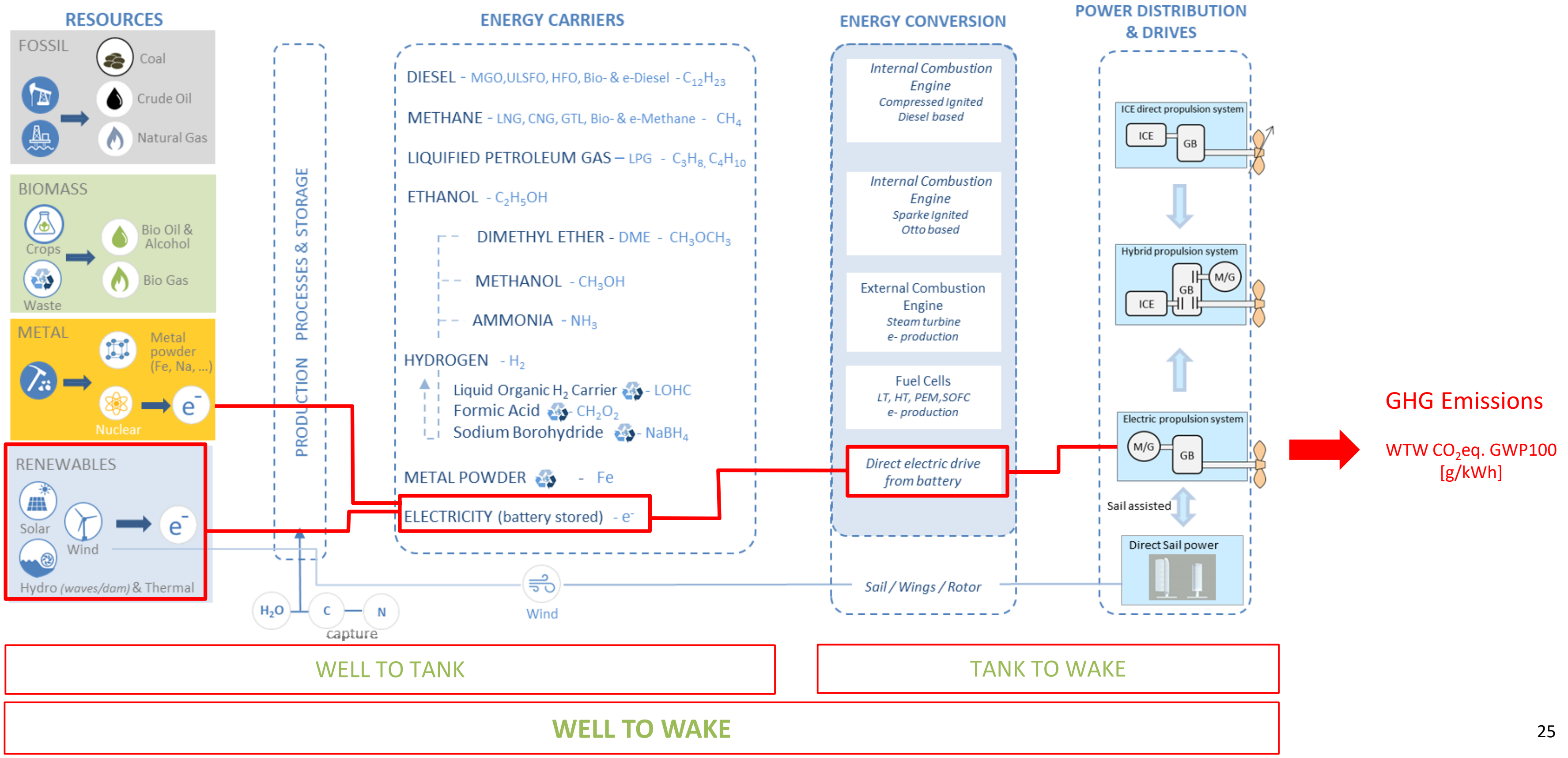

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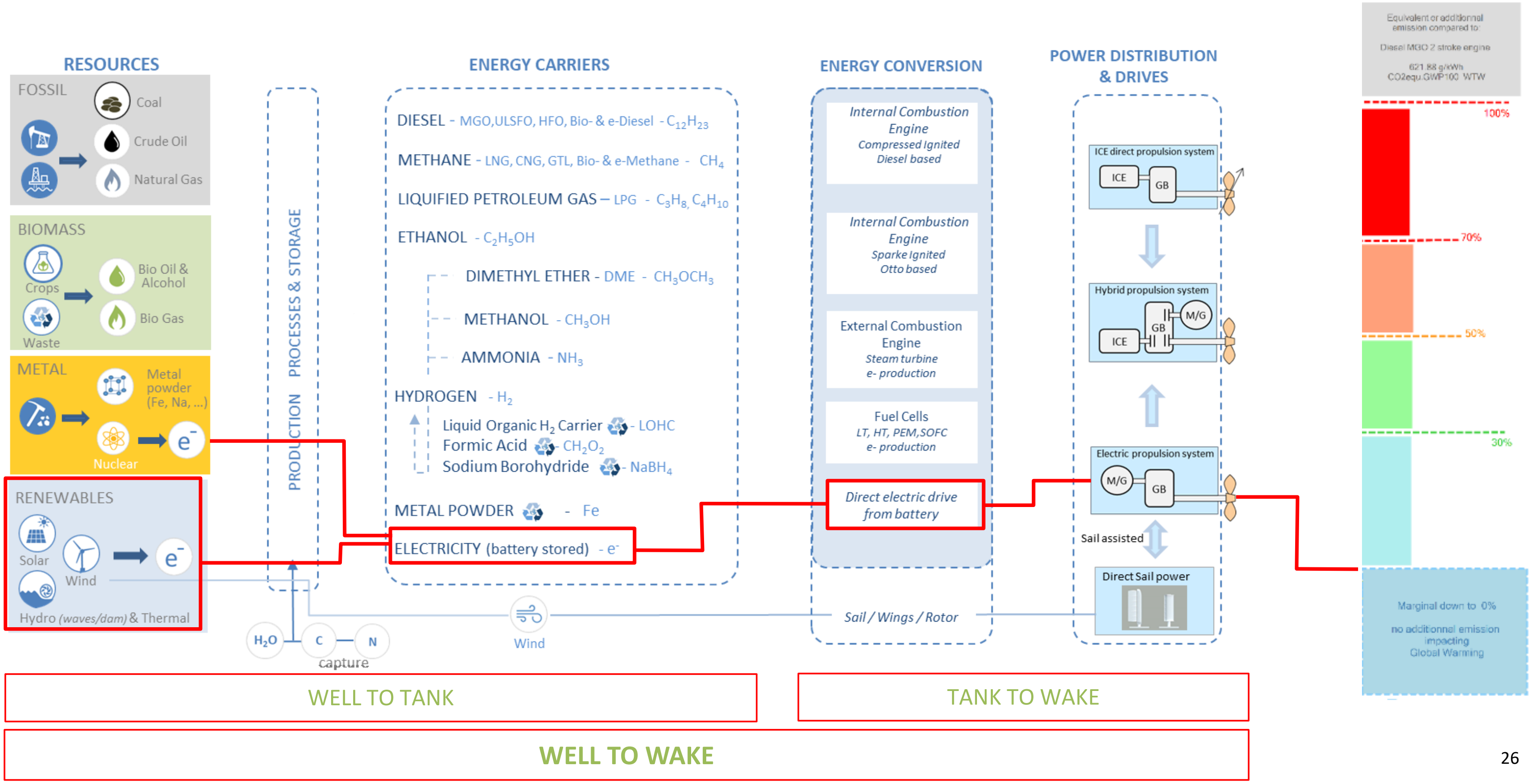
Direct Sail power
GHG Emissions
WTW CO_2eq. GWP100 [g/kWh]
WELL TO TANK
TANK TO WAKE
WELL TO WAKE



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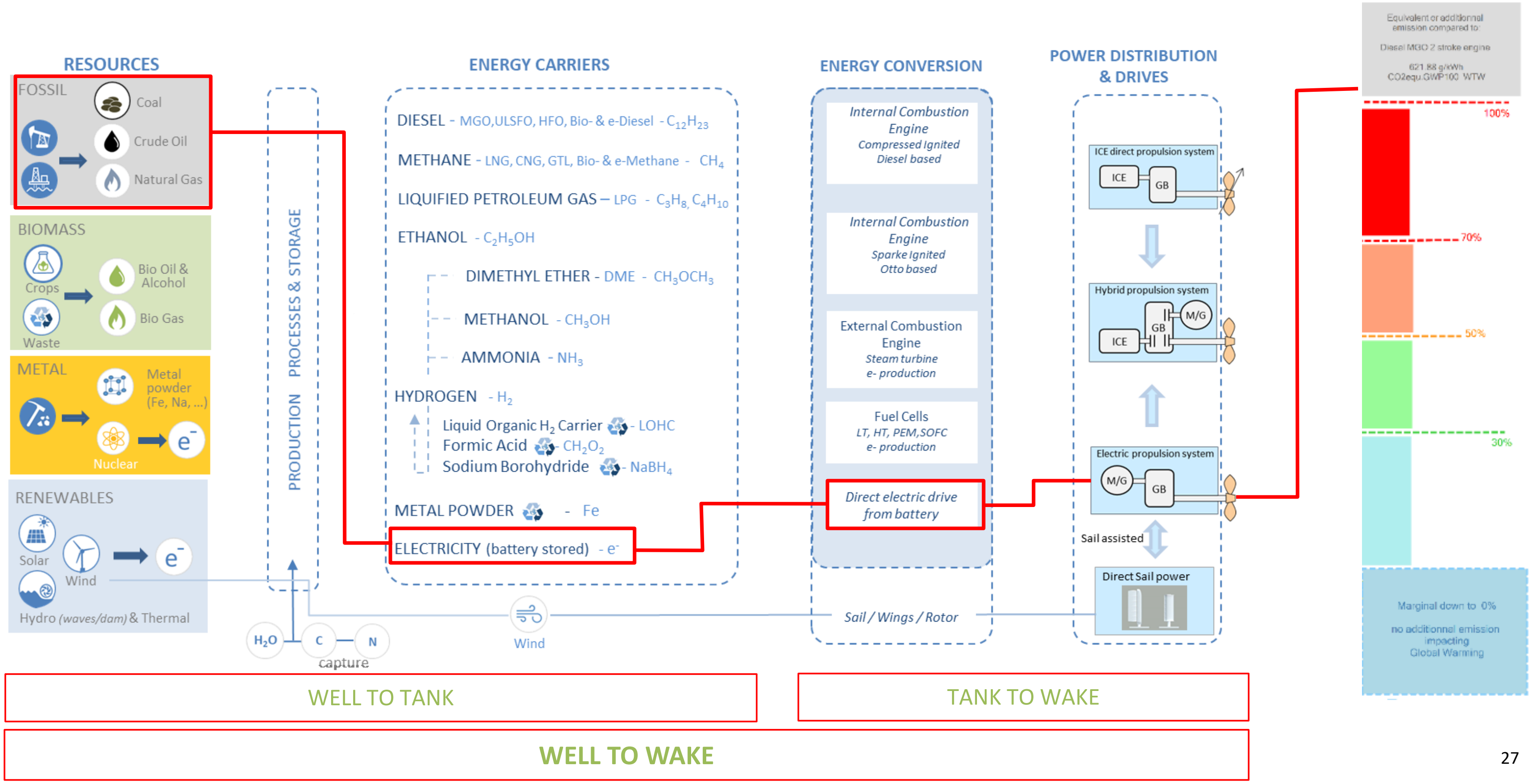
Equivalent or additionnal emission compared to:
Diesel MGO 2 stroke engine
621.88 g/kWh
CO2equ.GWP100 WTW
100%
70%
50%
30%
Marginal down to 0%
no additionnal emission impacting Global Warming
WELL TO TANK
TANK TO WAKE
WELL TO WAKE



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no additionnal emission impacting Global Warming
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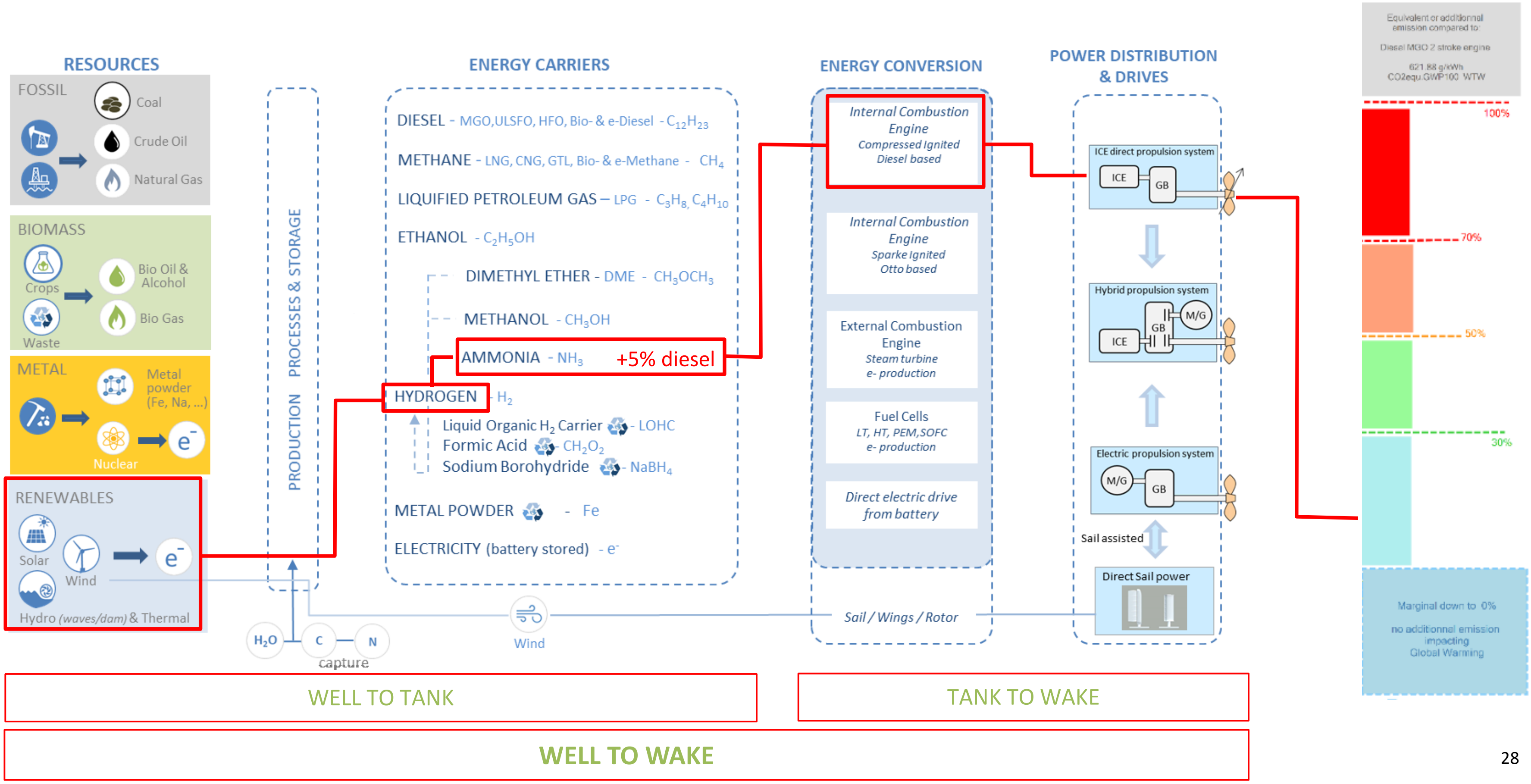
TANK TO WAKE
WELL TO WAKE



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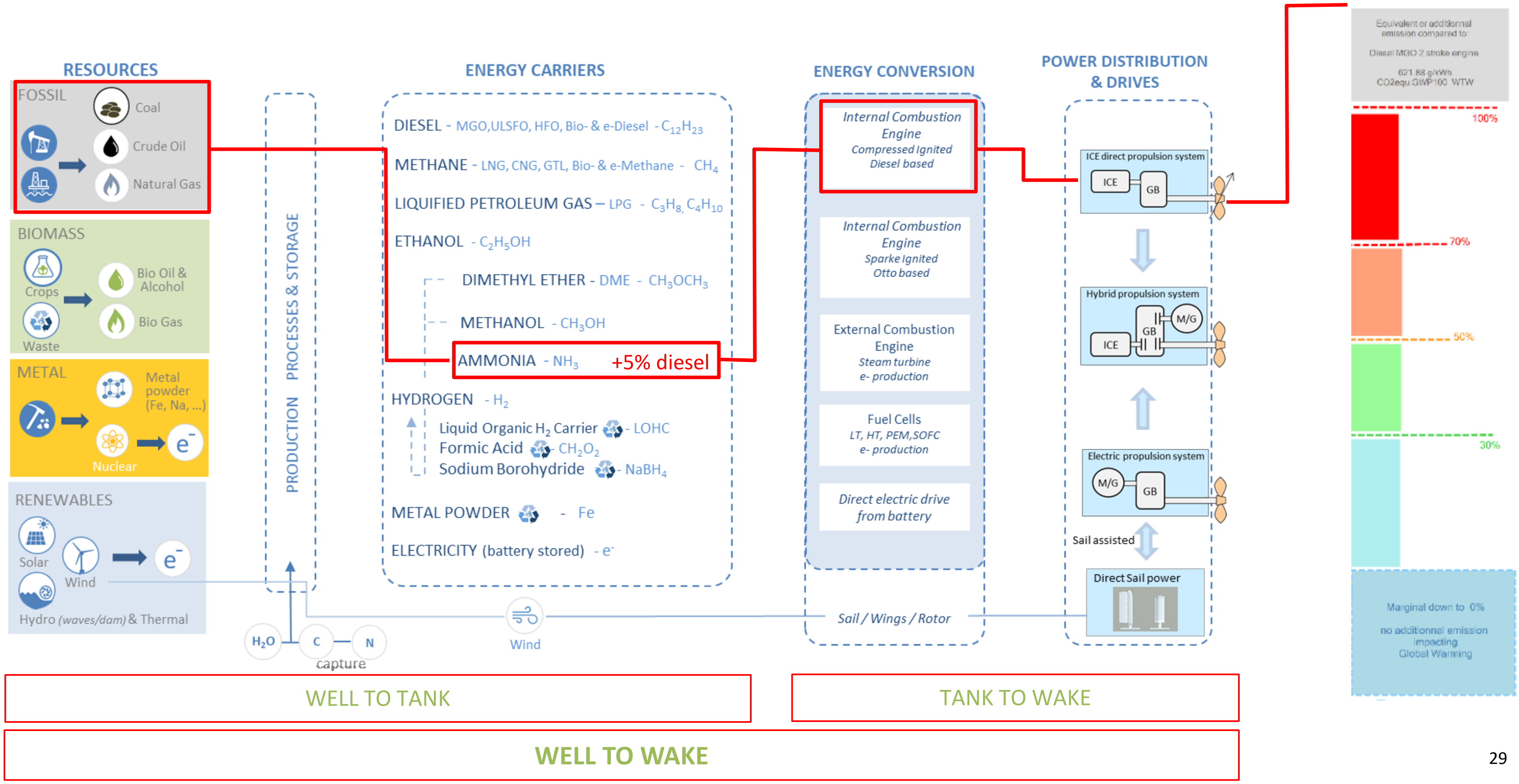
Wind
ENERGY CARRIERS
DIESEL - MGO,ULSFO, HFO, Bio- & e-Diesel - $C_{12}H_{23}$
METHANE - LNG, CNG, GTL, Bio- & e-Methane - CH_4
LIQUIFIED PETROLEUM GAS – LPG - C_3H_8, C_4H_{10}
ETHANOL - C_2H_5OH
DIMETHYL ETHER - DME - CH_3OCH_3
METHANOL - CH_3OH
AMMONIA - NH_3
+5% diesel
HYDROGEN - H_2
Liquid Organic H_2 Carrier - LOHC
Formic Acid - CH_2O_2
Sodium Borohydride - $NaBH_4$
METAL POWDER - Fe
ELECTRICITY (battery stored) - e-
ENERGY CONVERSION
Internal Combustion Engine
Compressed Ignited
Diesel based
Internal Combustion Engine
Sparke Ignited
Otto based
External Combustion Engine
Steam turbine
e- production
Fuel Cells
LT, HT, PEM,SOFC
e- production
Direct electric drive from battery
Sail / Wings / Rotor
POWER DISTRIBUTION & DRIVES
ICE direct propulsion system
ICE
GB
Hybrid propulsion system
ICE
GB
M/G
Electric propulsion system
M/G
GB
Sail assisted
Direct Sail power
Equivalent or additionnal emission compared to:
Diesel MGO 2 stroke engine
621.88 g/kWh
CO2equ.GWP100 WTW
100%
70%
50%
30%
Marginal down to 0%
no additionnal emission impacting Global Warming
WELL TO TANK
TANK TO WAKE
WELL TO WAKE



RESOURCES
FOSSIL
Coal
Crude Oil
Natural Gas
BIOMASS
Crops
Waste
Bio Oil & Alcohol
Bio Gas
METAL
Metal powder (Fe, Na, ...)
Nuclear
e⁻
RENEWABLES
Solar
Wind
e⁻
Hydro (waves/dam) & Thermal
PRODUCTION PROCESSES & STORAGE
H2O
C
N
capture
ENERGY CARRIERS
DIESEL - MGO,ULSFO, HFO, Bio- & e-Diesel - $C_{12}H_{23}$
METHANE - LNG, CNG, GTL, Bio- & e-Methane - CH_4
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Steam turbine
e- production
Fuel Cells
LT, HT, PEM,SOFC
e- production
Direct electric drive from battery
Sail / Wings / Rotor
POWER DISTRIBUTION & DRIVES
ICE direct propulsion system
ICE
GB
Hybrid propulsion system
GB
M/G
ICE
Electric propulsion system
M/G
GB
Sail assisted
Direct Sail power
Equivalent or additionnal emission compared to:
Diesel MGO 2 stroke engine
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CO2equ.GWP100 WTW
100%
70%
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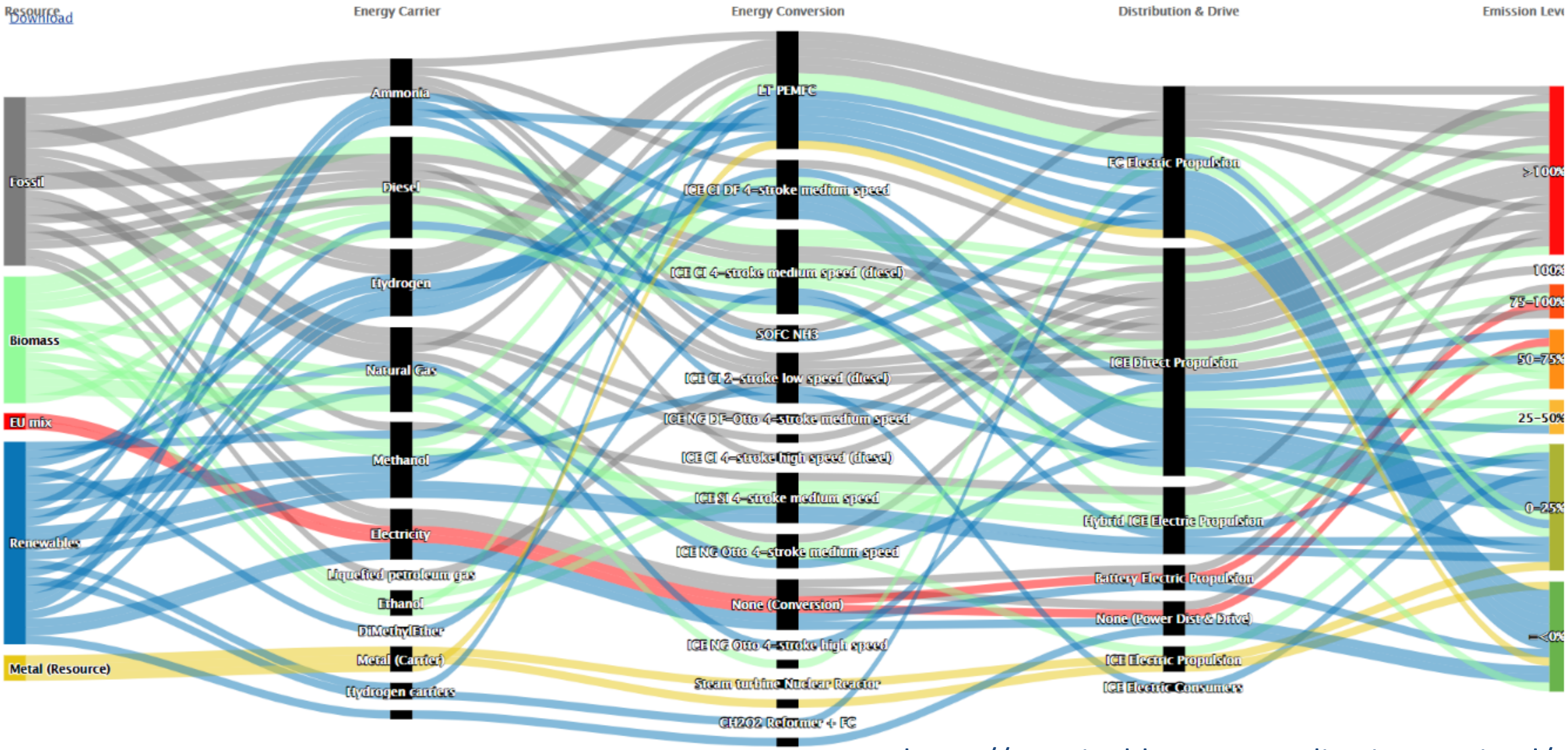
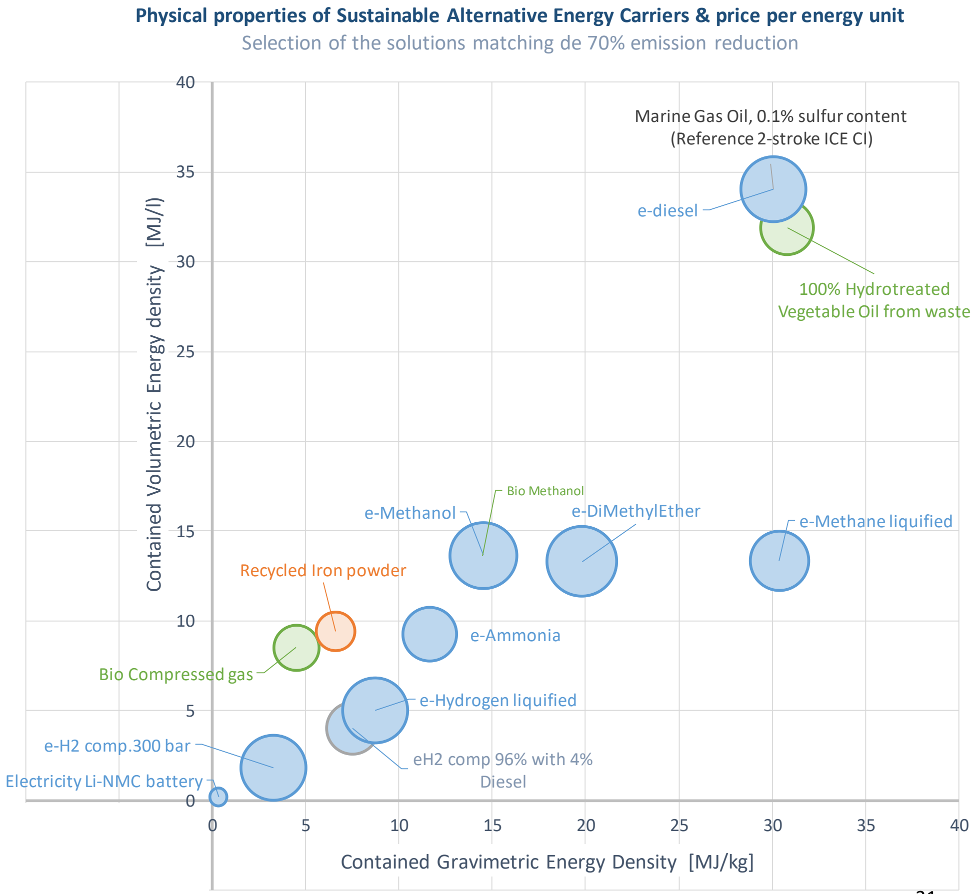
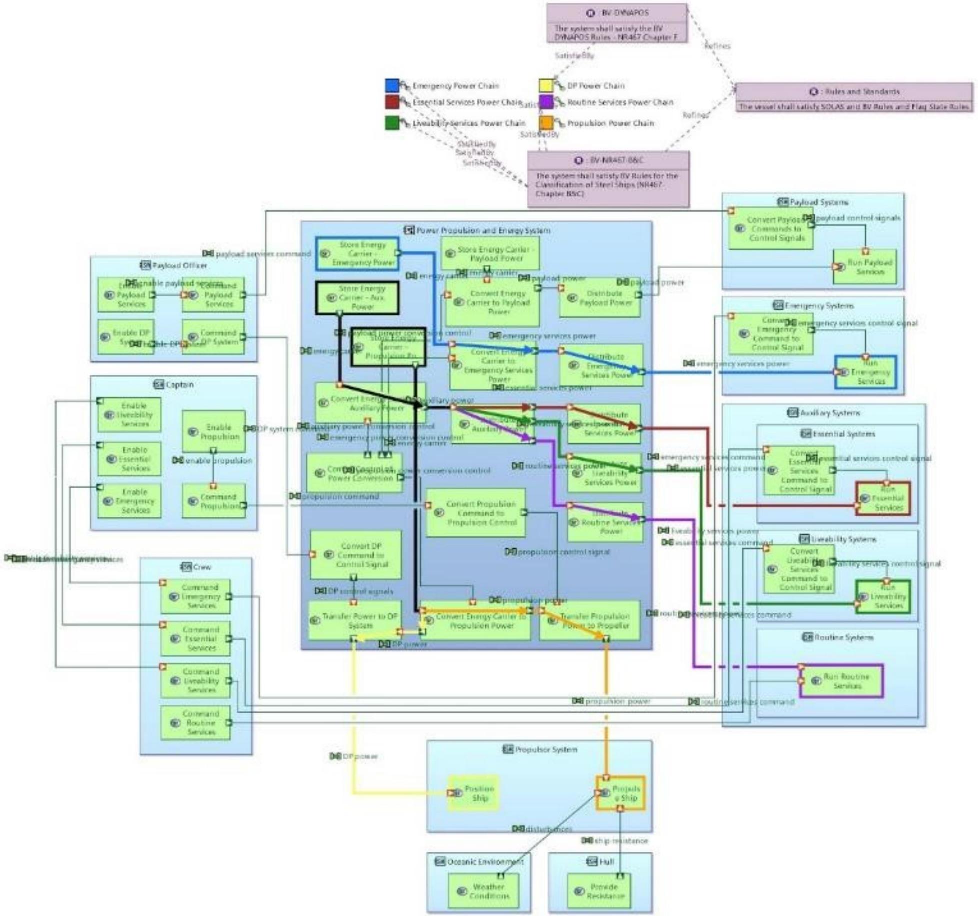
Marginal down to 0%
no additionnal emission impacting Global Warming
WELL TO TANK
TANK TO WAKE
WELL TO WAKE



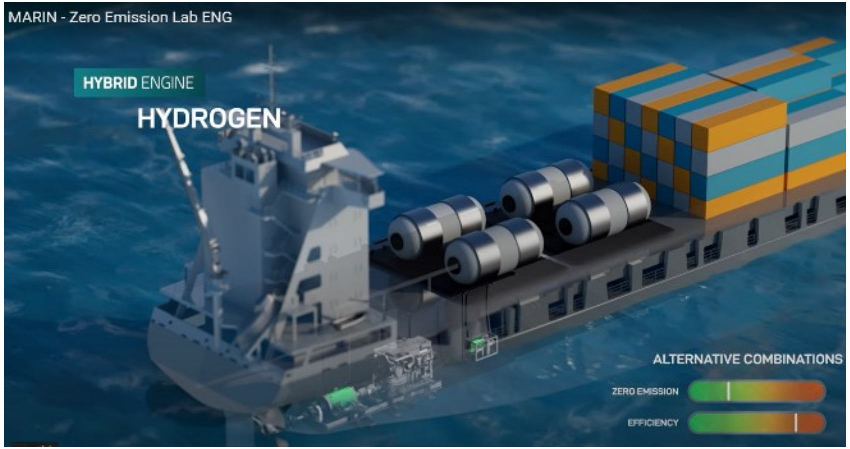
https://sustainablepower.application.marin.nl/

The energy density and energy storage challenge



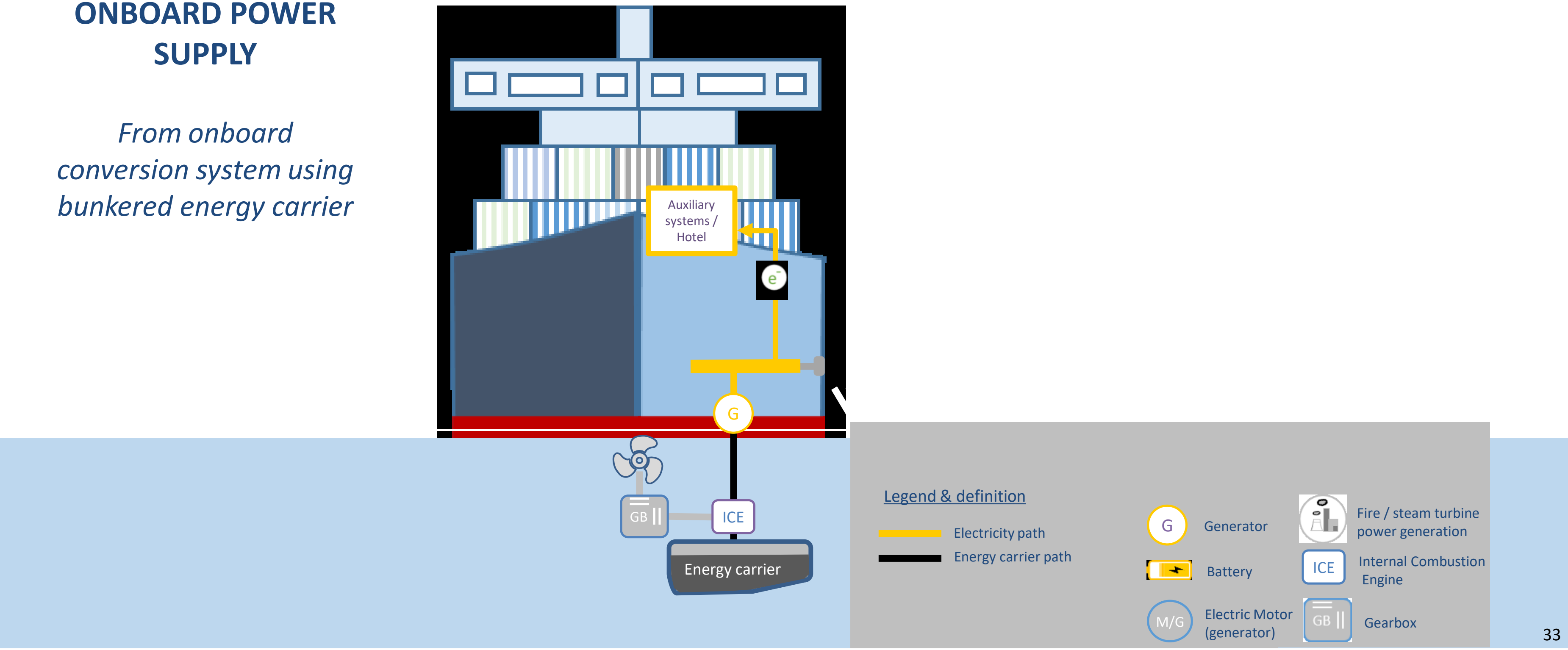

Power Propulsion and Energy System
Payload Systems
Emergency Systems
Auxiliary Systems
Essential Systems
Liveability Systems
Routine Systems
Payload Officer
Captain
Crew
Propulsor System
Oceanic Environment
Hull
Rules and Standards
Emergency Power Chain
Essential Services Power Chain
Liveability Services Power Chain
DP Power Chain
Routine Services Power Chain
Propulsion Power Chain


ELECTRIC ENGINE
NO STORAGE
ZERO EMISSION
EFFICIENCY


MARIN - Zero Emission Lab ENG
HYBRID ENGINE
HYDROGEN
ALTERNATIVE COMBINATIONS
ZERO EMISSION
EFFICIENCY

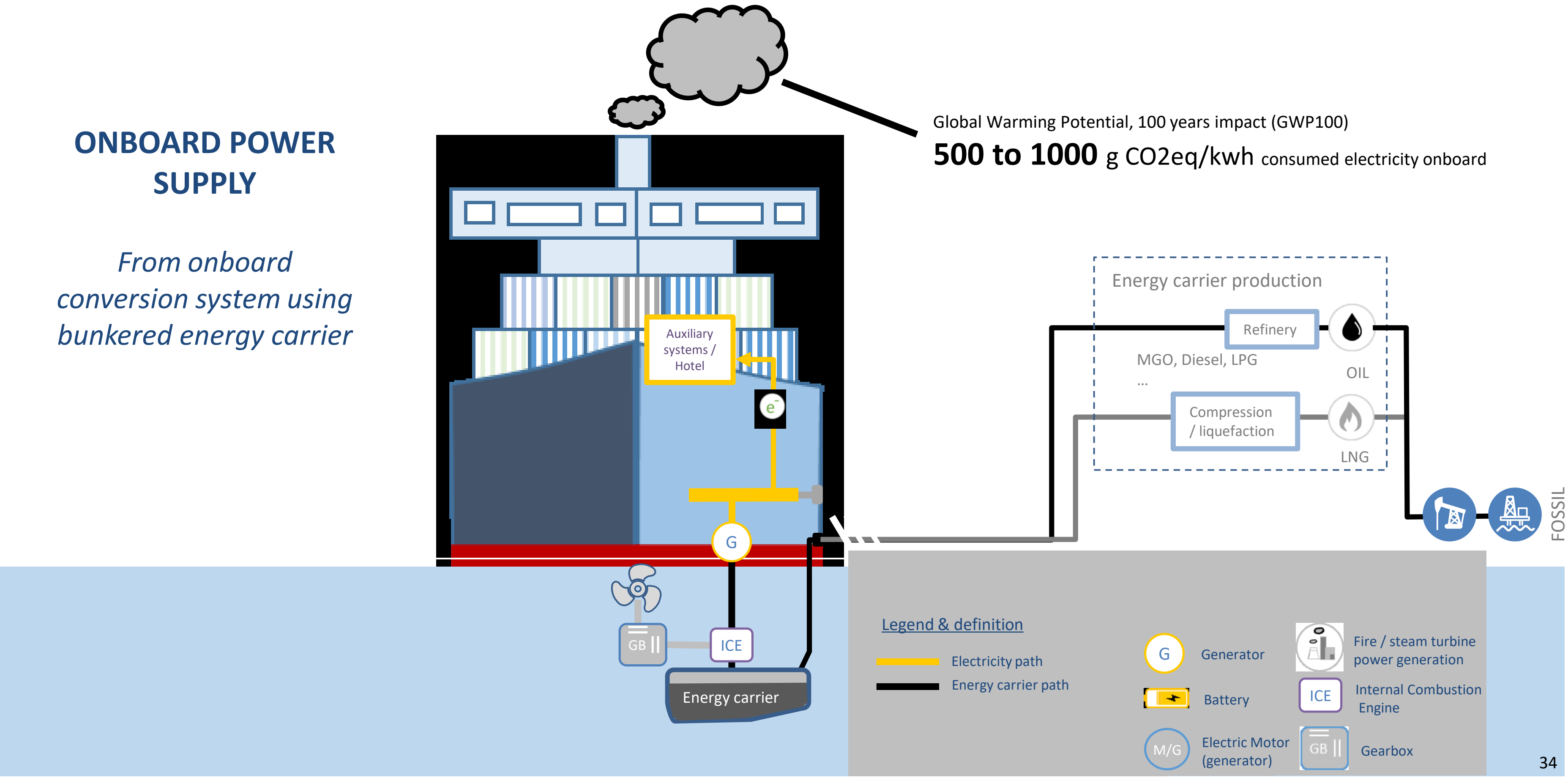
ONBOARD POWER SUPPLY

From onboard conversion system using bunkered energy carrier



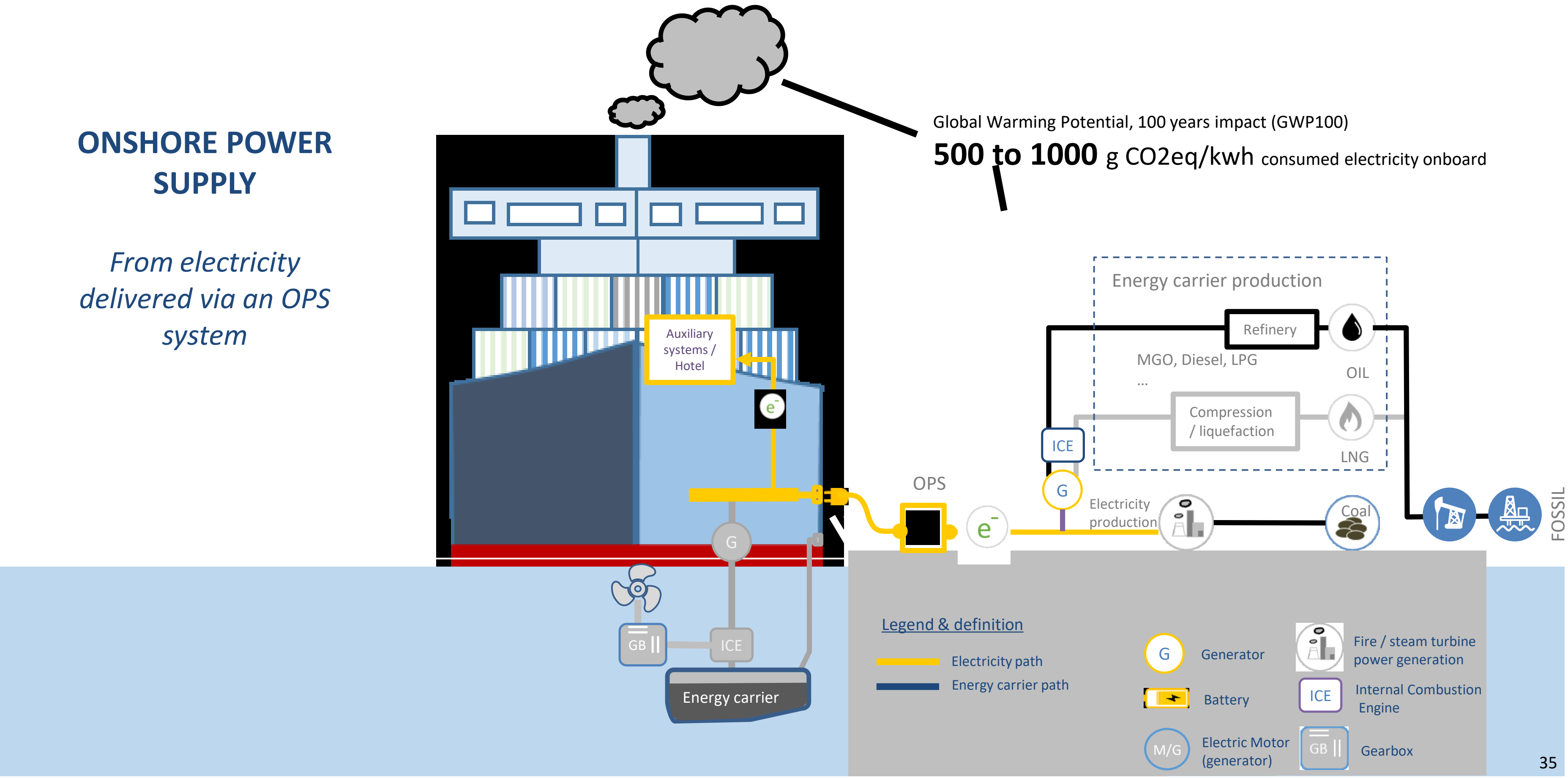
ONBOARD POWER SUPPLY

From onboard conversion system using bunkered energy carrier

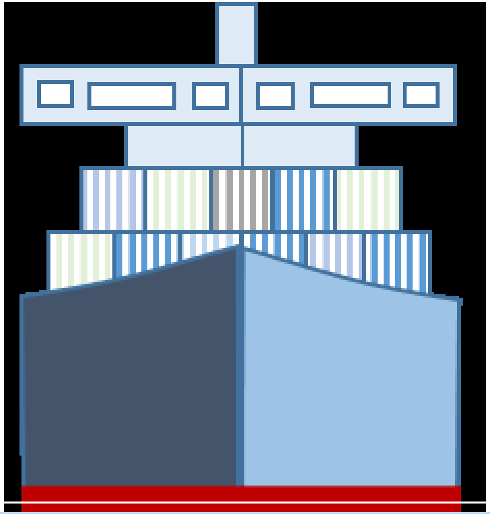


ONSHORE POWER SUPPLY

From electricity delivered via an OPS system



(auxiliary electric systems & hotel in harbor or at anchor)



Legend & definition

Electricity path

Energy carrier path

G Generator

Battery

ICE Internal Combustion Engine

M/G Electric Motor (generator)

GB Gearbox

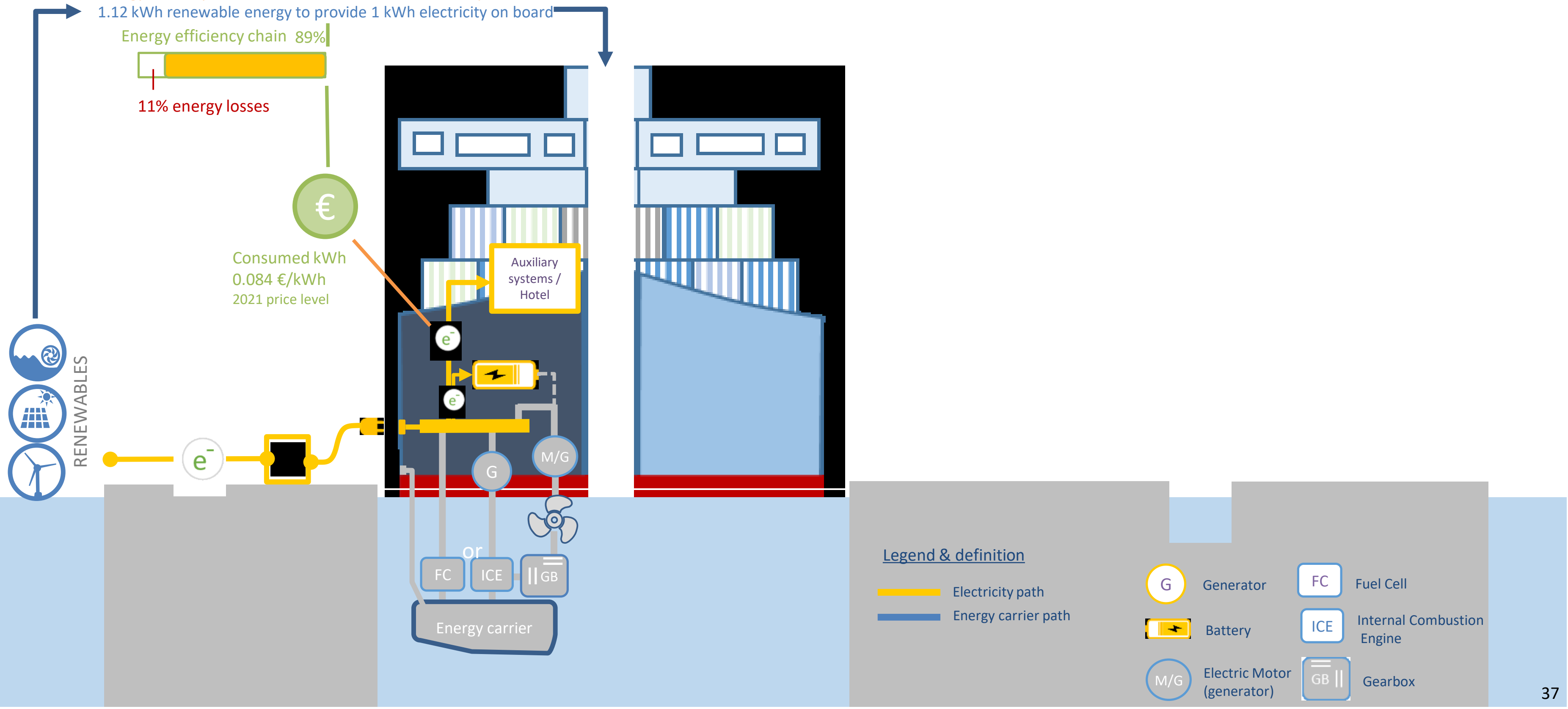
PATHWAY FROM ENERGY RESOURCE TO ONBOARD ENERGY CONSUMPTION
(auxiliary electric systems & hotel & battery charging in harbor or at anchor)

ONSHORE or OFFSHORE POWER SUPPLY

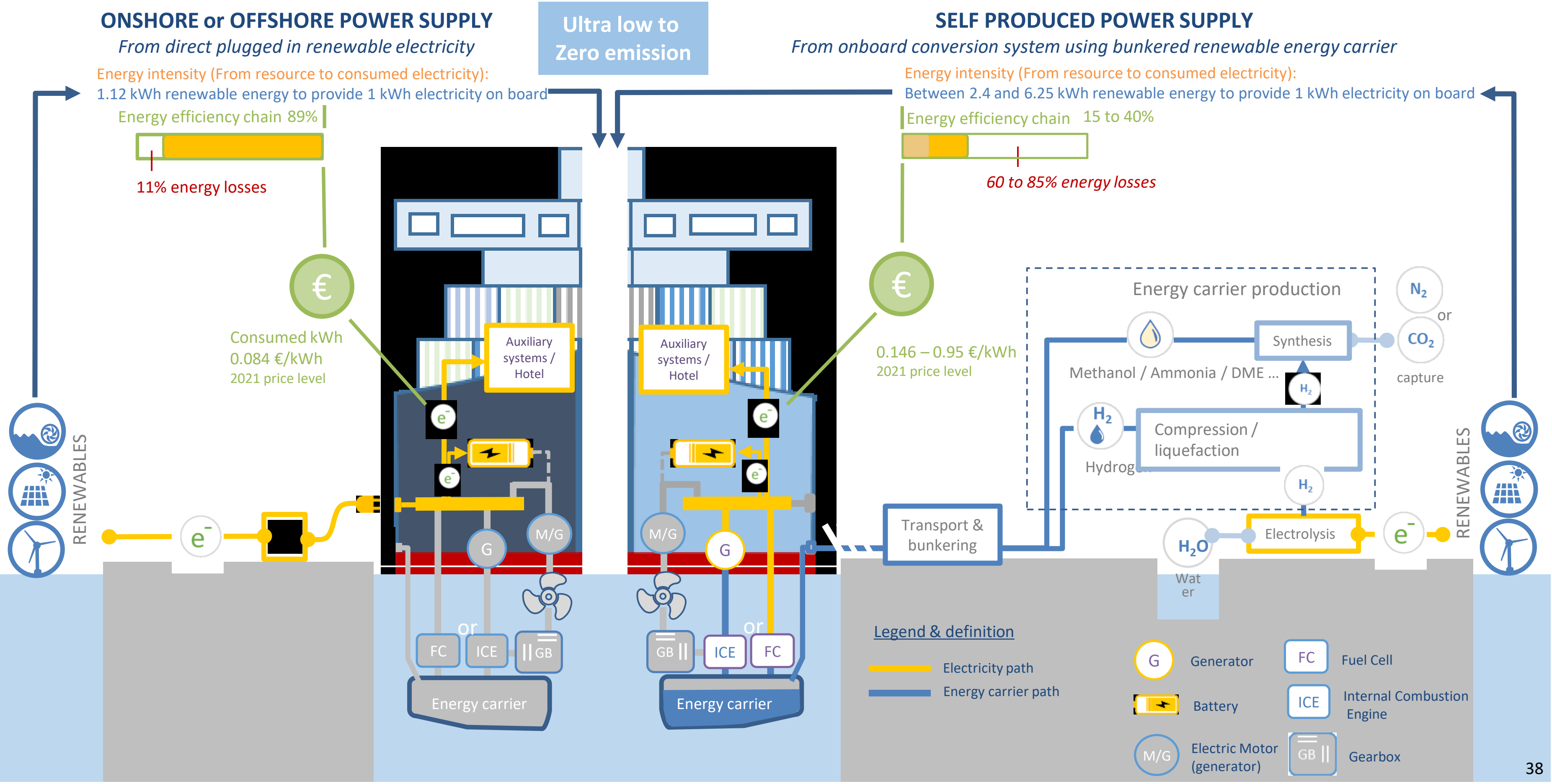
From direct plugged in renewable electricity

Ultra low to Zero emission

Energy intensity (From resource to consumed electricity):
1.12 kWh renewable energy to provide 1 kWh electricity on board



PATHWAY FROM ENERGY RESOURCE TO ONBOARD ENERGY CONSUMPTION
(auxiliary electric systems & hotel & battery charging in harbor or at anchor)



Engines off, Shore Power on!

Heerema's offshore vessels successfully plugged in at the largest shore power installation of Europe in Rotterdam

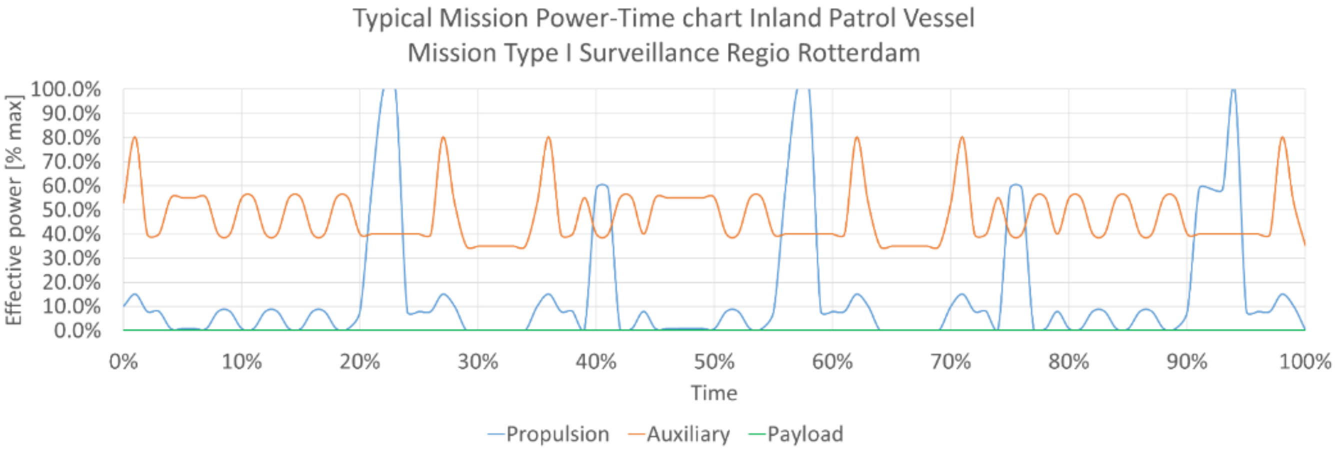
The Shore Power connection has a 20 MW capacity, which is the energy equivalent of around 15,000 homes. As the vessels turn off their engines when connected to Shore Power, virtually all emissions and particulate matter is prevented because no more marine gas oil or LNG in Sleipnir's case will be used. This action has direct benefits for local residents with air quality improvements and a reduction in CO2. Also, without the engines running there is a significant reduction in noise nuisance.

When Heerema's vessels turn off their engines when moored in the Port of Rotterdam for a standard repair and maintenance period there is a saving of 15,000 metric tons of CO2, 20 metric tons of particulate matter, 5 metric tons of sulfur, and a significant amount of nitrogen– comparable to the annual emissions of 5,000 diesel cars.

DESIGN FOR OPERATIONS

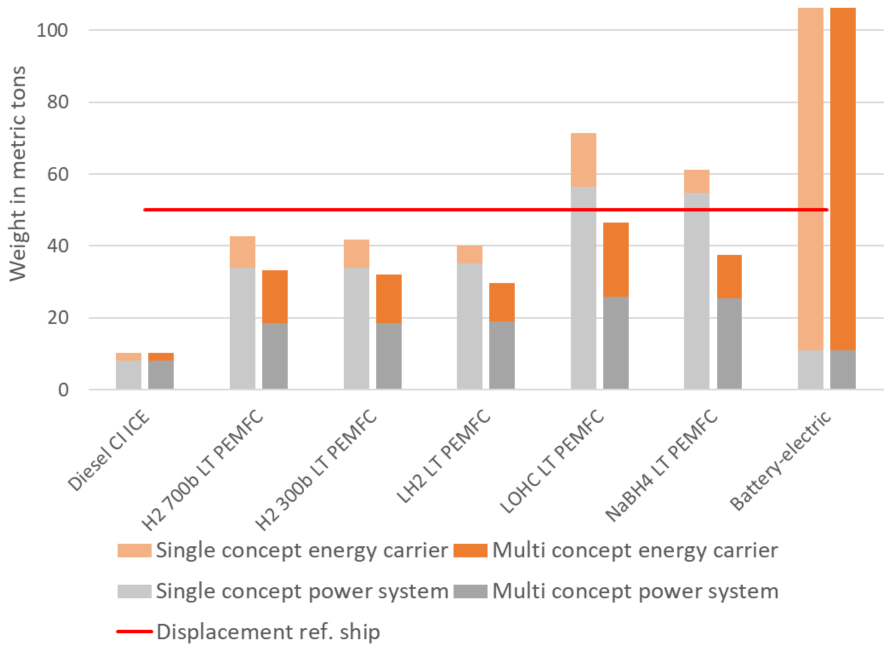
Ship design perspective

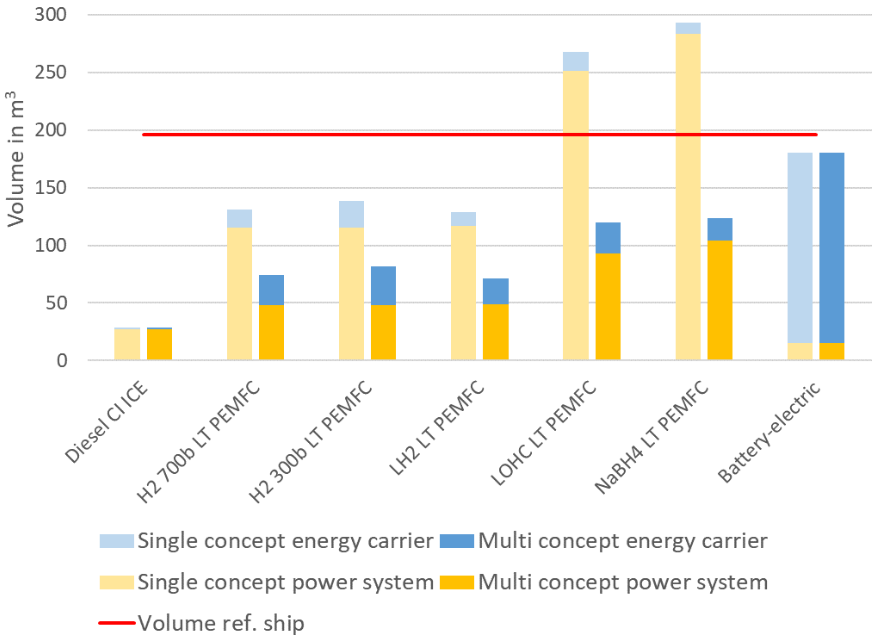
Mission reconstructions: combination of operational input and power performance evaluations



Note, propulsive and auxiliary maximum powers are different

Mission Type	Maximum total effective power & Effective Energy			Requirements
	Criterion	[kW]	[MWh]	GHG and Pollutants
I – Surveillance (Region Rotterdam)	Endurance: 24 hrs	1236	5,1	Zero Emission
II – Surveillance (Region Dordrecht)	Endurance: 16 hrs	1236	6,5	Zero Emission
III – Surveillance (Region Amsterdam)	Endurance: 16 hrs	1236	2,3	Zero Emission





System Abbreviations	Short description
Diesel CI ICE	Diesel in Compression ignited internal combustion engine
H2 700b LT PEMFC	Compressed hydrogen (700 bars) in Low Temperature PEM Fuel Cell
H2 300b LT PEMFC	Compressed hydrogen (300 bars) in a Low Temperature PEM Fuel Cell
LH2 LT PEMFC	Liquified (cryogenic) hydrogen in a Low Temperature PEM Fuel Cell
LOHC LT PEMFC	Liquid Organic Hydrogen Carrier in a Low Temperature PEM Fuel Cell
NaBH4 LT PEMFC	Sodium Borohydride in a Low Temperature PEM Fuel Cell
Battery-electric	Battery-electric

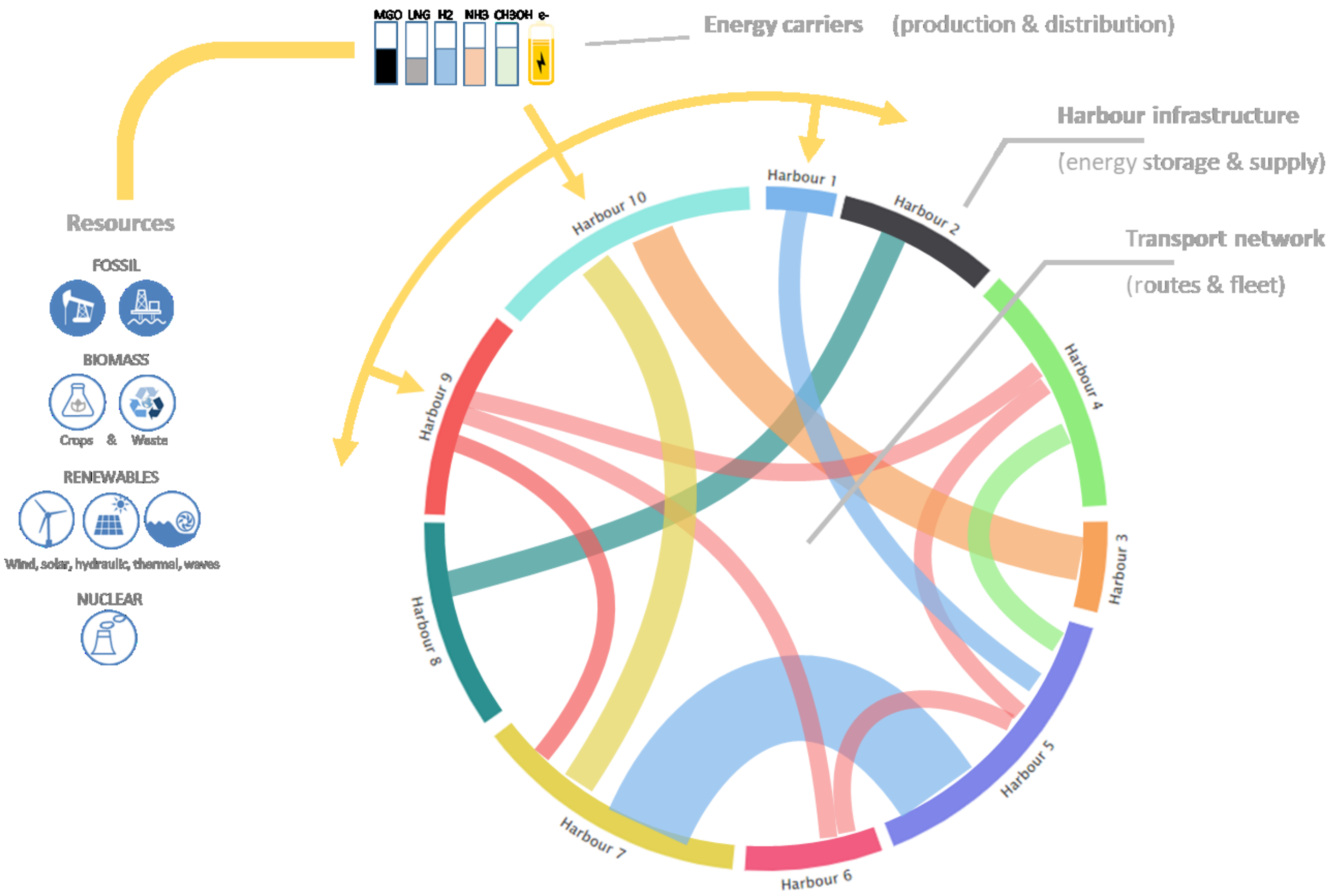
DESIGN FOR OPERATIONS

Macro perspective

DESIGN FOR OPERATIONS

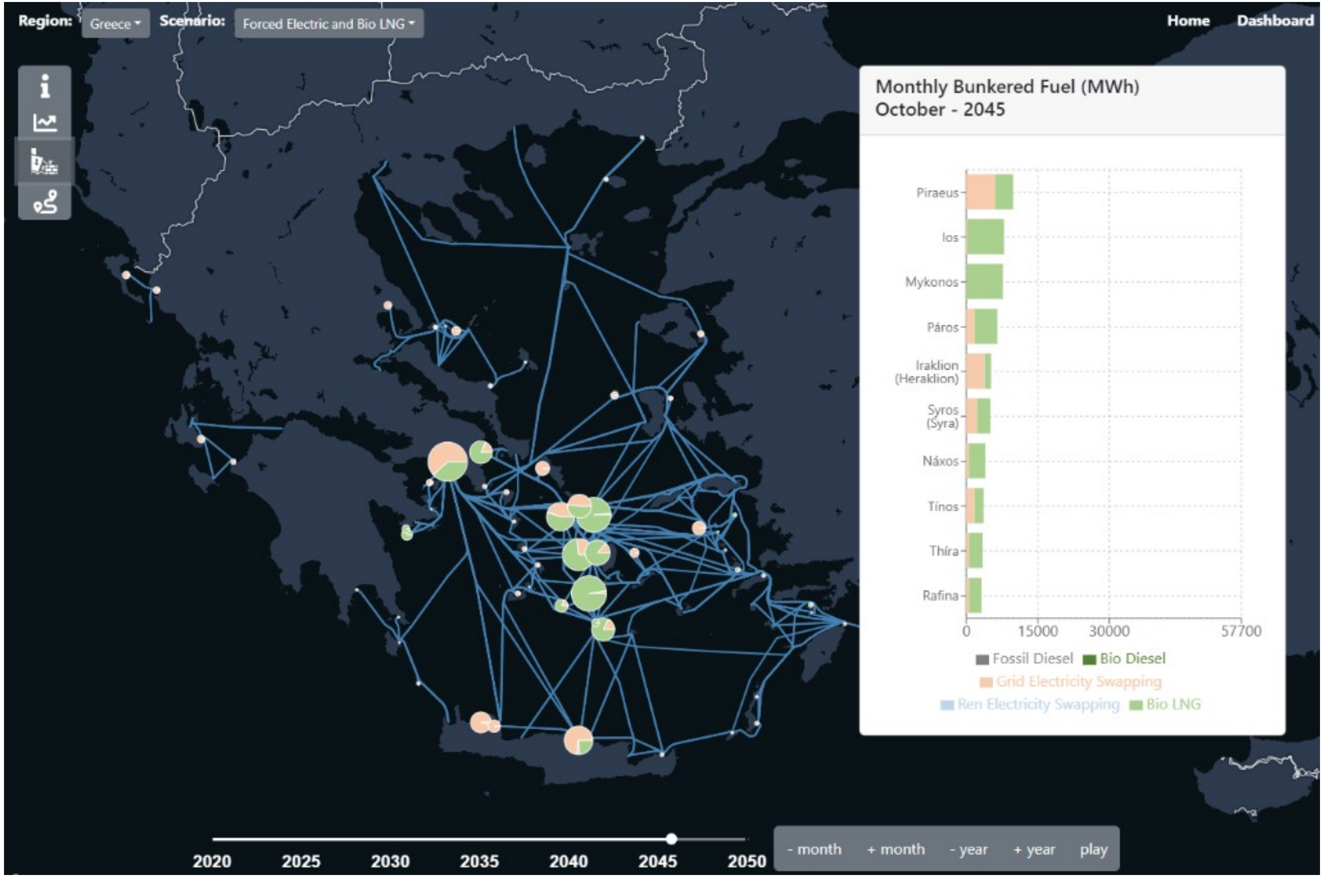
Macro perspective

ENERGY - INFRASTRUCTURE - SHIPS & OPERATIONS

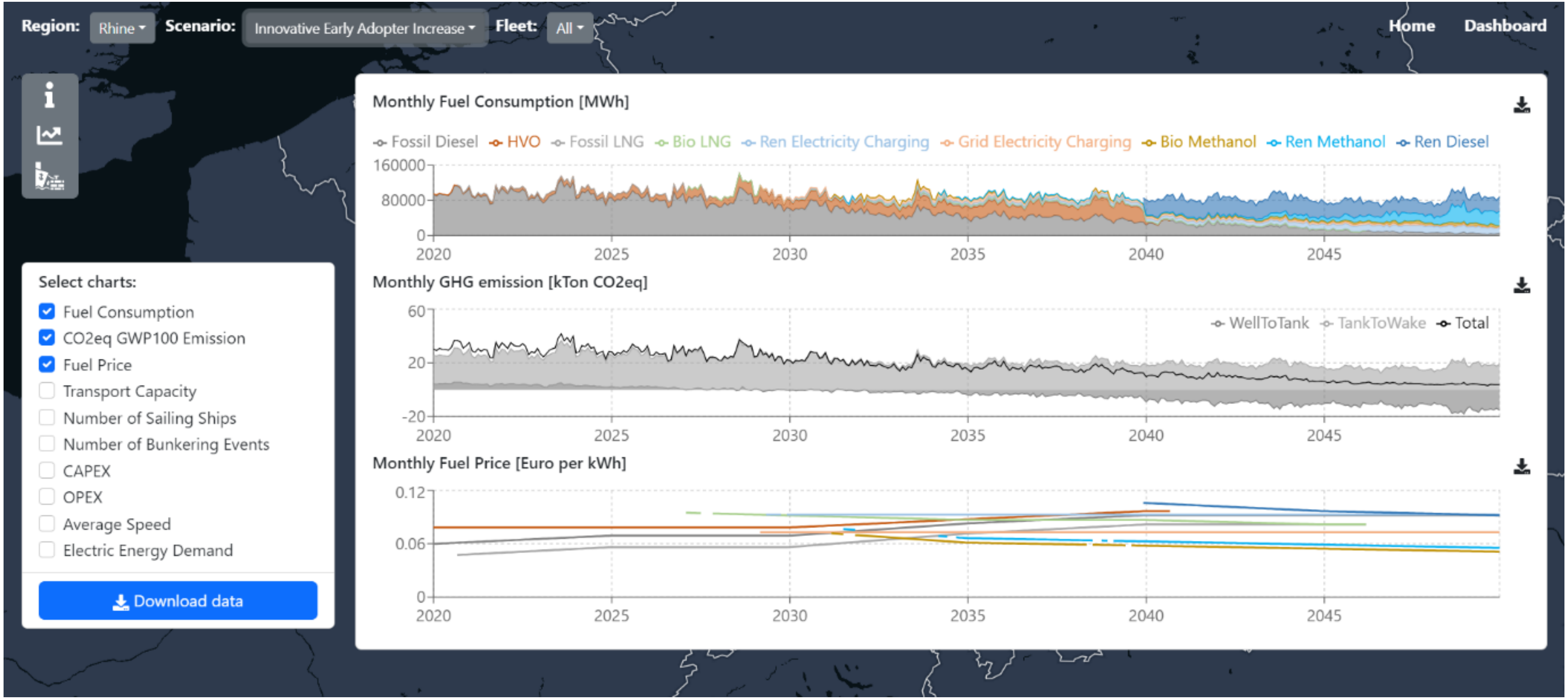


MGO
LNG
H2
NH3
CH3OH
e-
Energy carriers (production & distribution)
Harbour infrastructure
(energy storage & supply)
Transport network
(routes & fleet)
Resources
FOSSIL
BIOMASS
Crops & Waste
RENEWABLES
Wind, solar, hydraulic, thermal, waves
NUCLEAR
Harbour 1
Harbour 2
Harbour 3
Harbour 4
Harbour 5
Harbour 6
Harbour 7
Harbour 8
Harbour 9
Harbour 10

- Online dashboard example studies: https://needs.application.marin.nl



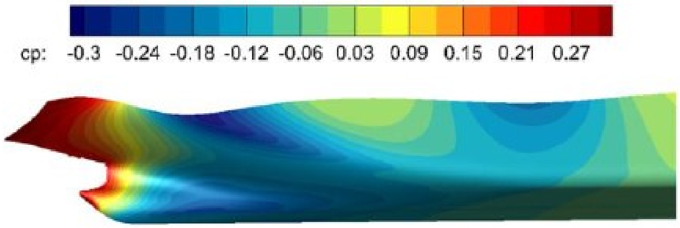
• Online dashboard example studies: https://needs.application.marin.nl



USE LESS ENERGY

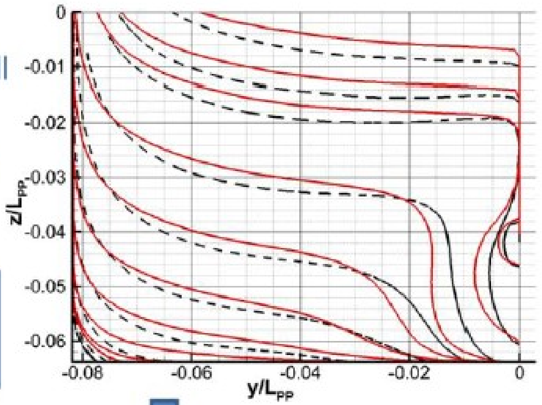
MARIN

Analyze original ship, locate problems and link to hull lines

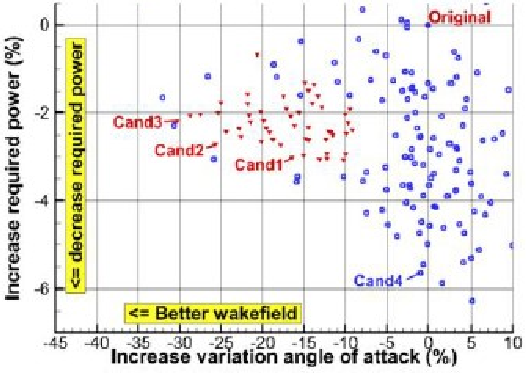


Define basic hull shapes

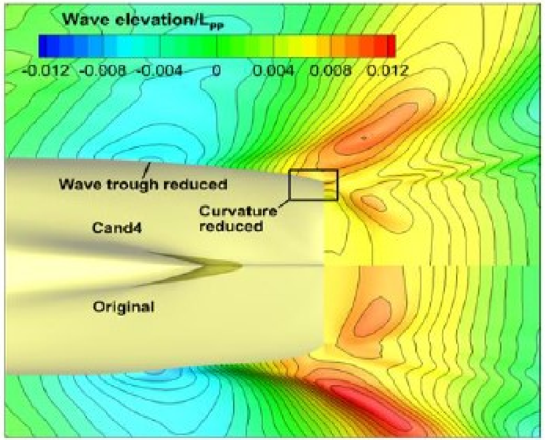
Design knowledge

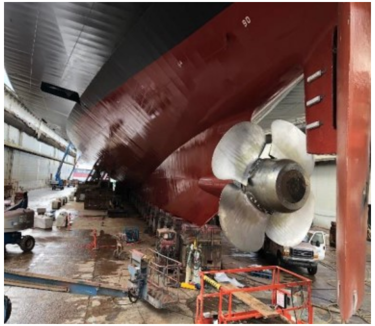


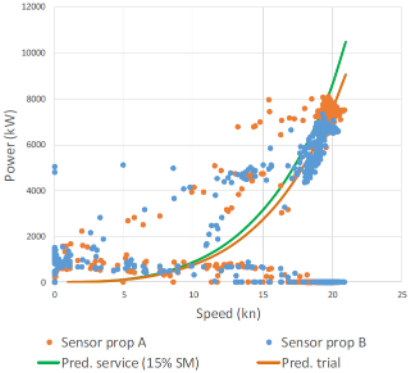
Calculate flow for >100 hull shapes



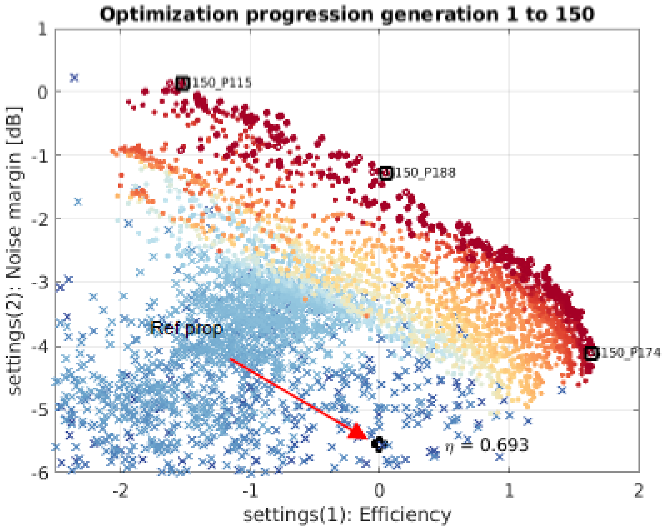
Analyze and determine optimal compromise between power and comfort



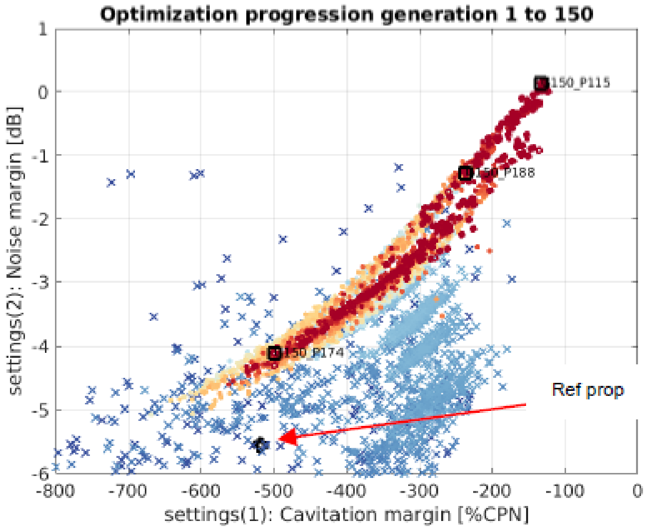




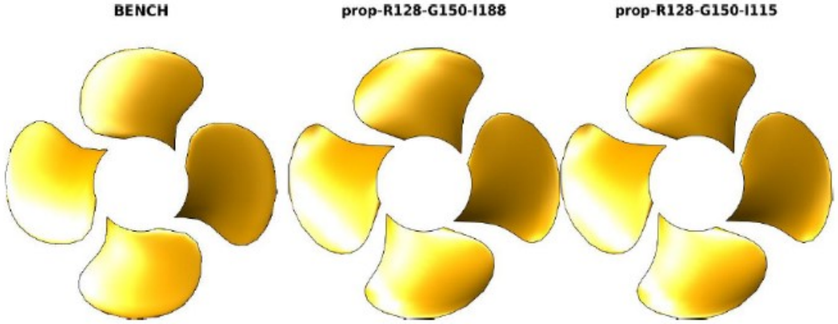
Power (kW)
Speed (kn)
Sensor prop A
Sensor prop B
Pred. service (15% SM)
Pred. trial



Optimization progression generation 1 to 150
settings(2): Noise margin [dB]
settings(1): Efficiency
150_P115
150_P188
150_P174
Ref prop
η = 0.693



Optimization progression generation 1 to 150
settings(2): Noise margin [dB]
settings(1): Cavitation margin [%CPN]
150_P115
150_P188
150_P174
Ref prop

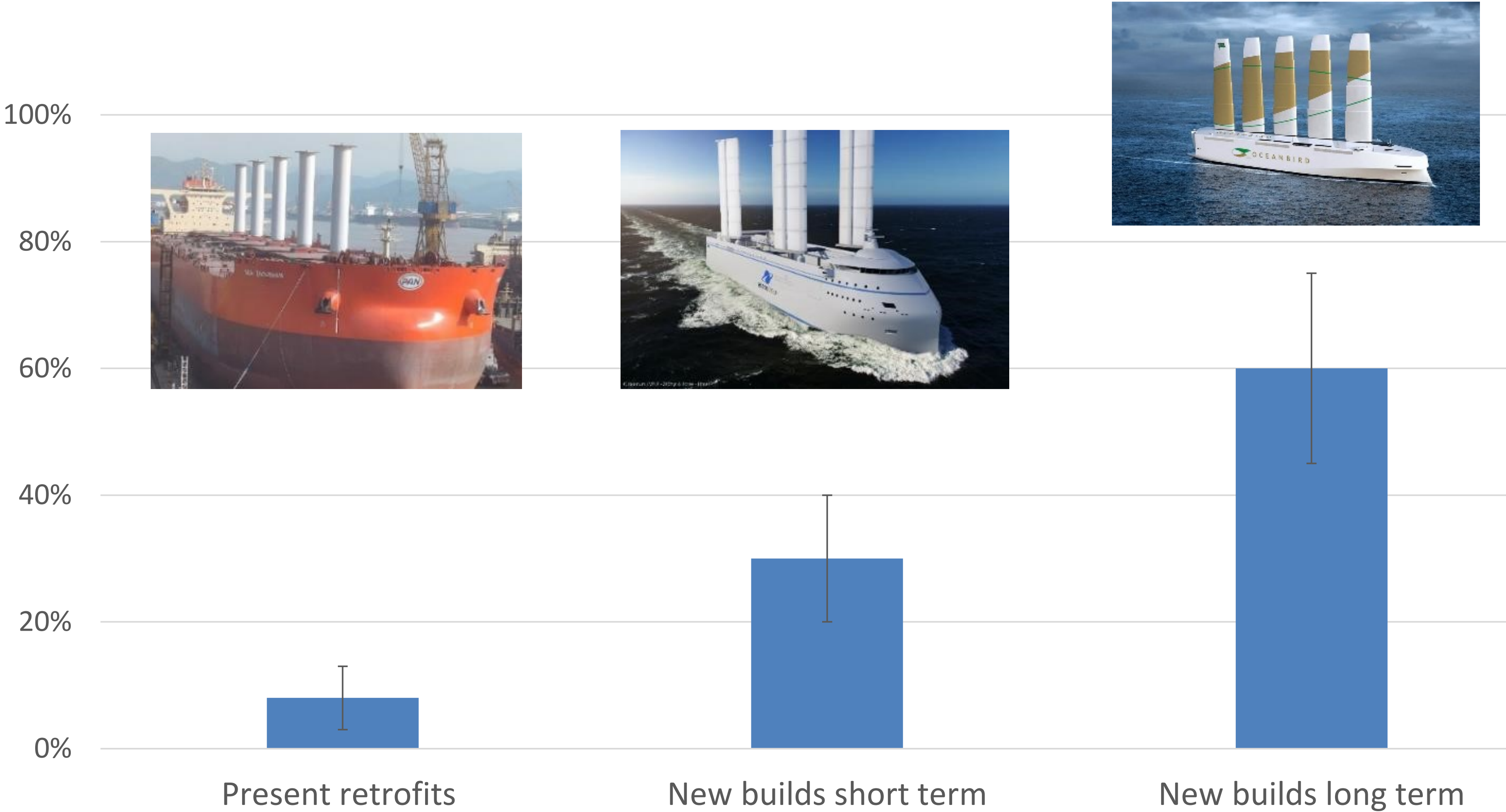


BENCH
prop-R128-G150-I188
prop-R128-G150-I115

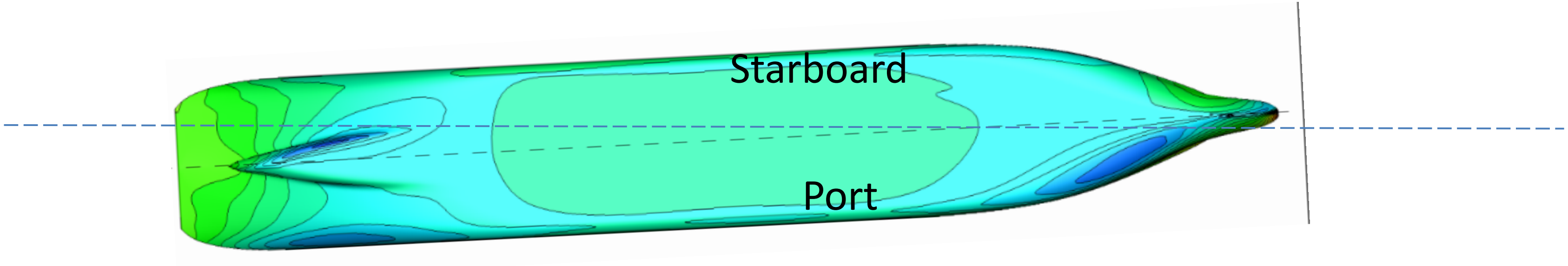
USE FREE AVAILABLE ENERGY

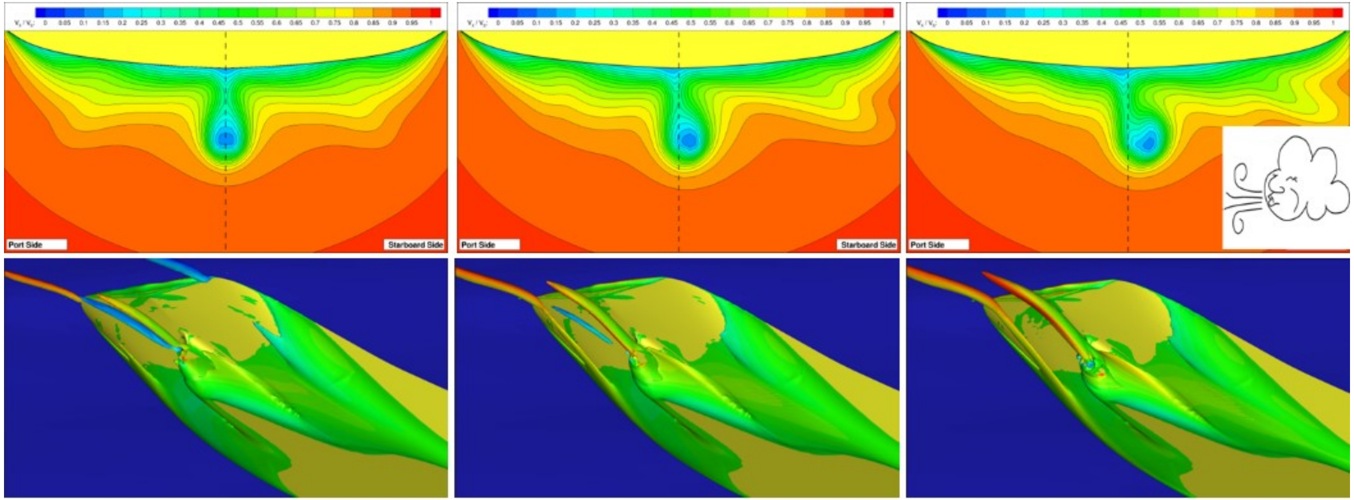
WIND

The most sustainable energy is simply the energy you don’t use…

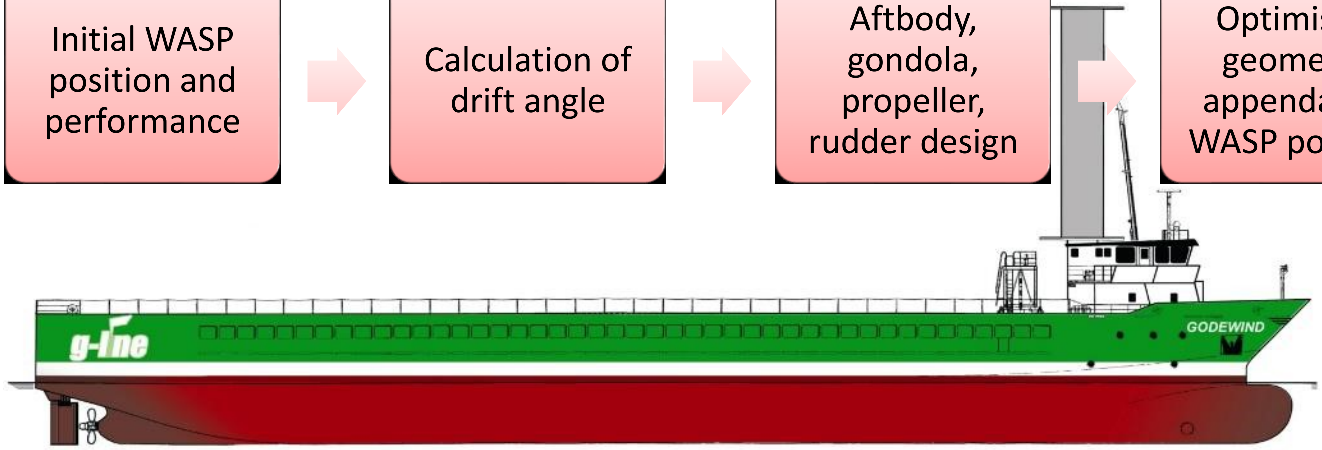

100%
80%
60%
40%
20%
0%
Present retrofits
New builds short term
New builds long term

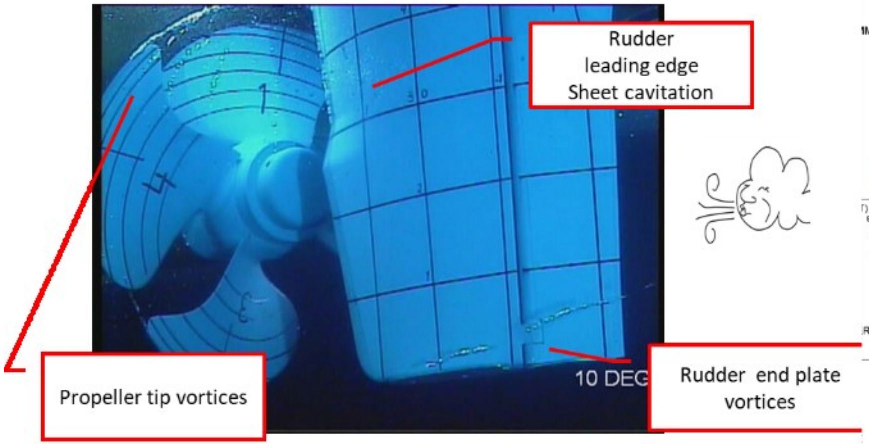
Drifting to port at angles 0, 2 and 4 degrees:
The vortices from the gondola affect the wake

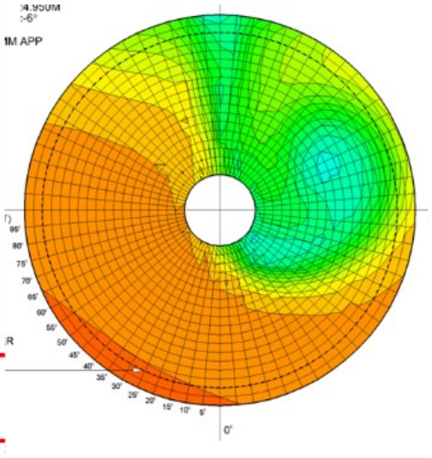




Initial hull geometry → Initial WASP position and performance → Calculation of drift angle → Aftbody, gondola, propeller, rudder design → Optimised, geometry, appendages, WASP position







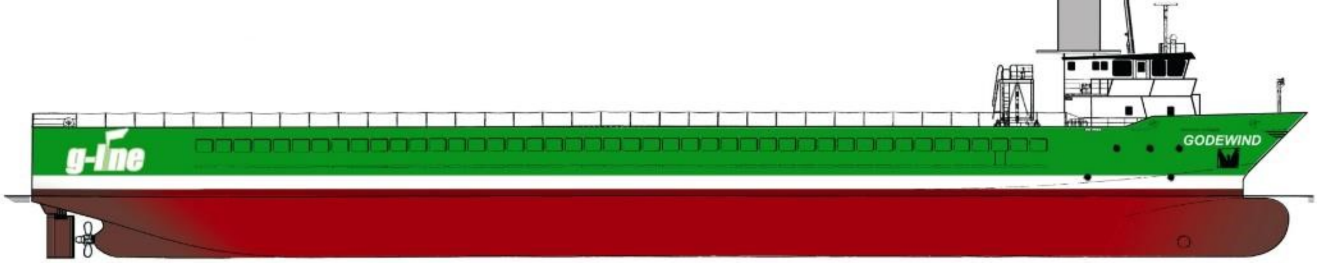
Initial hull geometry

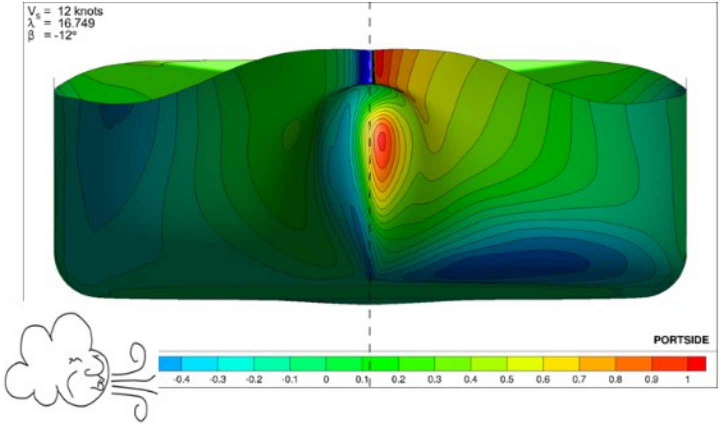
Initial WASP position and performance

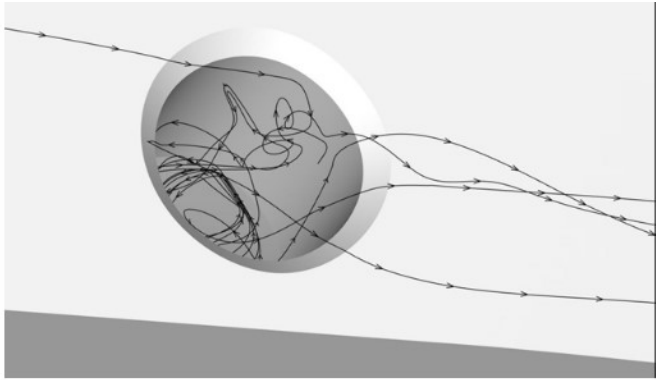
Calculation of drift angle

Aftbody, gondola, propeller, rudder design

Optimised, geometry, appendages, WASP position

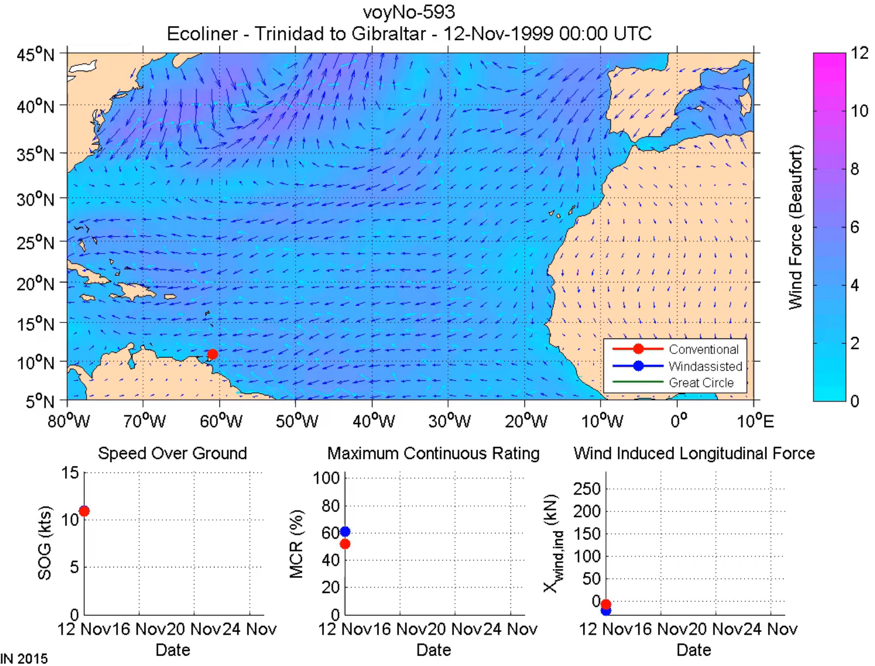




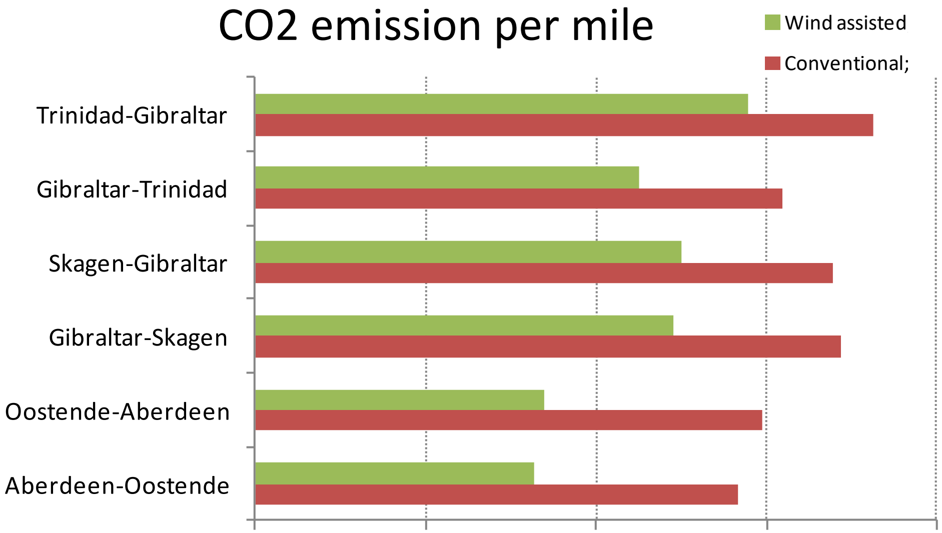


- Design changes:
  - Change hull dimensions (more draught, …)
  - Use V-shaped sections or box keels (in stern area)
  - Avoid wide flat transom
  - Enlarge skegs and bilge keels
  - Use appendages (like keels or dagger boards)
  - High-lift/multiple rudders

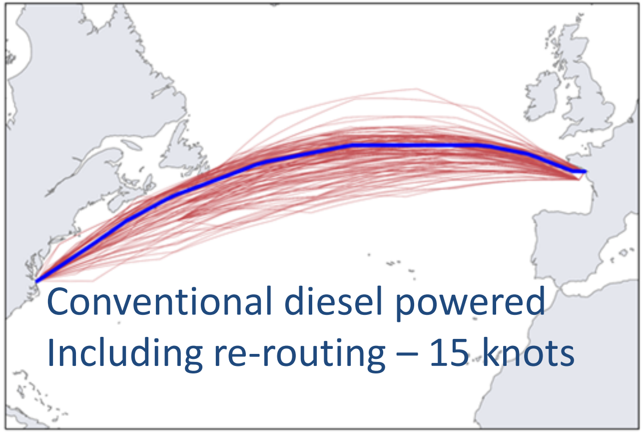
- Most of these modifications come with performance degradation when sailing straight, in low wind.
- Find best compromise considering operational profile.

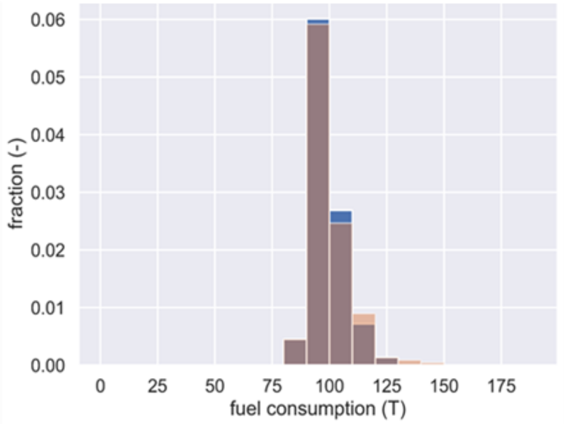


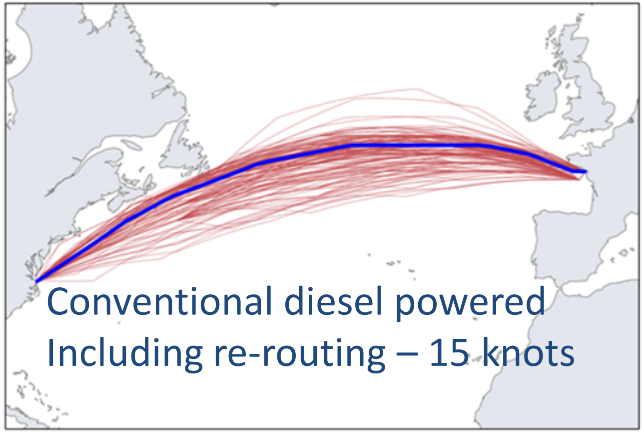
Animation made with Weather Route Ani 1.88 on 19 January 2015

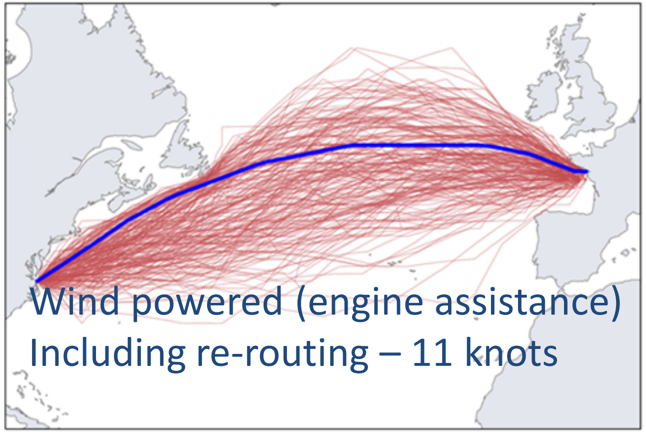


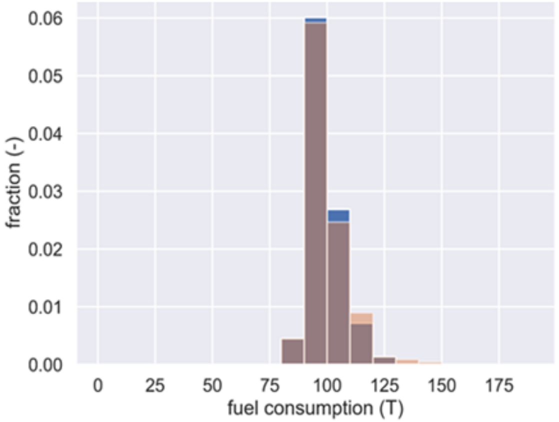
"Wind Assisted Ship Propulsion" (WASP) can save between 5% and 40% on emissions, but route should be optimized

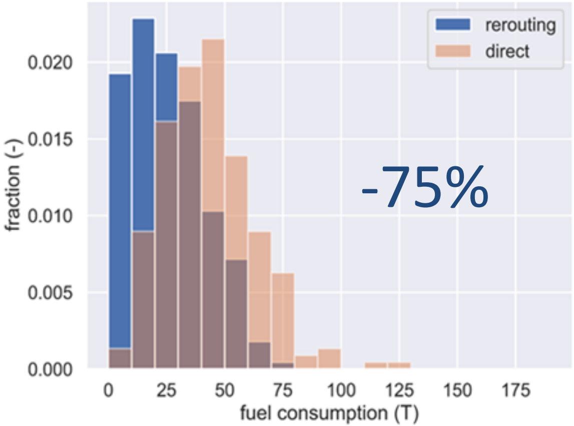

Conventional diesel powered
Including re-routing – 15 knots


0.06
0.05
0.04
0.03
0.02
0.01
0.00
fraction (-)
0
25
50
75
100
125
150
175
fuel consumption (T)


Conventional diesel powered
Including re-routing – 15 knots


Wind powered (engine assistance)
Including re-routing – 11 knots


0.06
0.05
0.04
0.03
0.02
0.01
0.00
fraction (-)
0
25
50
75
100
125
150
175
fuel consumption (T)


rerouting
direct
0.020
0.015
0.010
0.005
0.000
fraction (-)
0
25
50
75
100
125
150
175
fuel consumption (T)
-75%

Designing sustainable ships and waterborne operations is technically possible but necessitates a holistic approach, full of challenges and requires making choices and accepting changes.

- **Use sustainable energy**
- **Know and optimise energy operational profile**
- **Design only for operations**
- **Adapt infrastructure**
- **Use less energy**
- **Use Wind whenever possible (freely available energy)**


WALLENIUS
OCEANBIRD
OCEANBIRD
ALFA LAVAL


Zéphyr & Borée


FREE
VIRTUAL CONFERENCE
Canopée, the first modern sail ship Zéphyr & Borée
CANOPÉE
2021
NATURAL PROPULSION IN SHIP DESIGN CONFERENCE
16 NOVEMBER 2021
9 AM - 4:30 PM EST
REGISTRATION REQUIRED
SESSIONS WILL BE RECORDED
BROUGHT TO YOU BY:
wind support
MARIN
BETTER SHIPS, BLUE OCEANS
Webb Institute

Success is not final

Failure is not fatal

It is the courage to continue that counts

Churchill

Simplicity is the ultimate sophistication

Da Vinci

Thank you for your attention!

WINDWINGS

The journey so far...

BAR TECHNOLOGIES

BAR TECHNOLOGIES

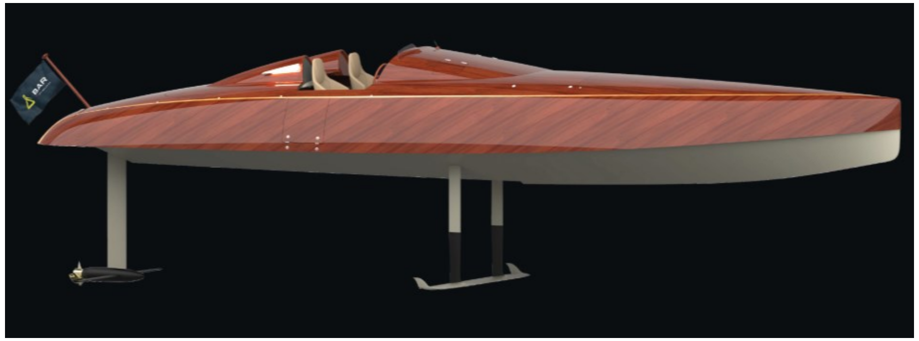
Simulation Driven Marine Innovation

AC 35

Dynamic Foils on Princess R35

BAR Tech 30 CTV + FOSS

BAR Tech WindWings



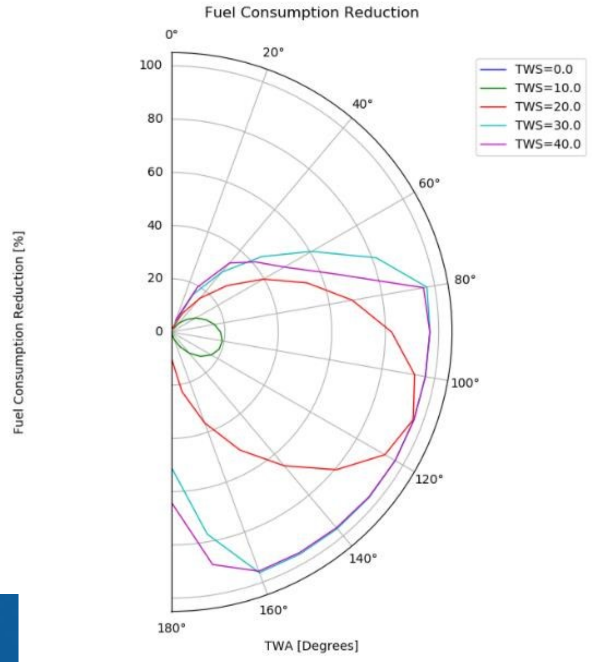
BAR Tech Foiling launch with Spirit Yachts Hull

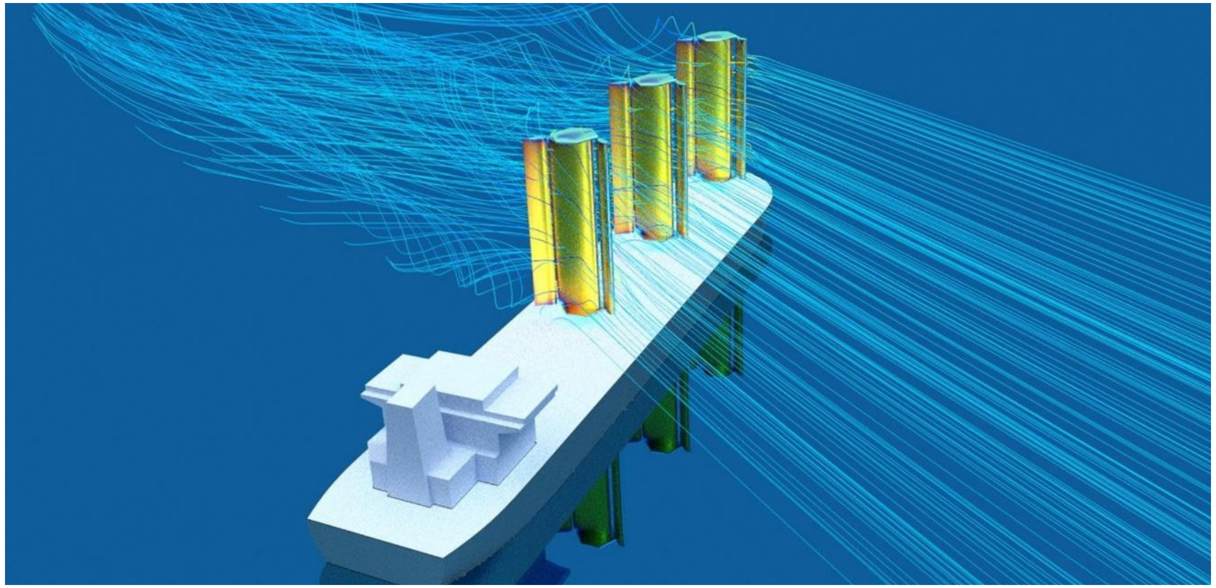
WindWings

Mitsubishi Corporation
Cargill
BAR TECHNOLOGIES
WIND WINGS
YARA
Co-funded by the European Union
PYXIS OCEAN

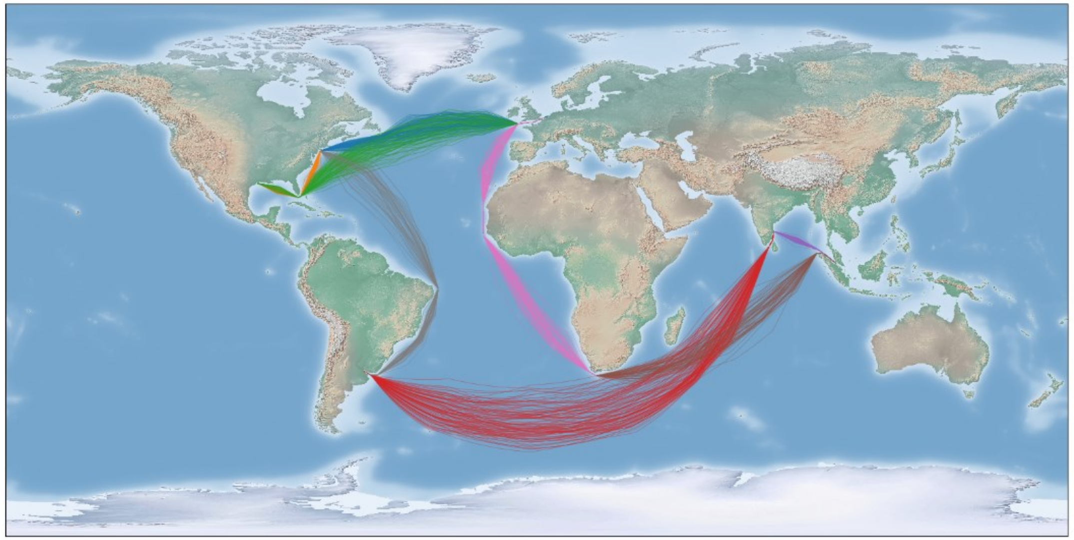
VPP

- Full force and moment models for each hydrodynamic and aerodynamic component are derived from computational simulations using ***machine learning techniques***.
- These force models are combined and then balanced while minimising the fuel consumption of the vessel subject to the ***operational limits*** of each individual component.
- The complete performance of the vessel to variable external conditions is simulated in this way, building a ***full performance profile***.
- Wing-Wing, Wing- Vessel and Wind Shear ***Interactions*** are modelled
- Depowering models included





Routing and Performance Analysis



ShipSEAT : Ship System Efficiency Analysis Tool

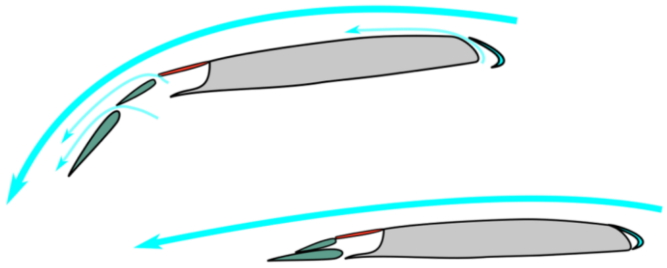
- ***Influence of Leeway*** on vessel drag and monk moment
- Full ***yaw balance***
- The propeller characteristics are input into ShipSEAT and specific ***propeller efficiency curves*** are derived including influences from loading variations and inflow angle deltas
- Engine information is input and an SFC curve is added for the particular engine size.
- ***Engine limits*** are set to ensure both the power and the RPM remain in an achievable region.
- Performance models of the vessel with a technology are used along with the ***corresponding baseline ship***.
- Both vessels are simulated over a ***large number of start dates*** and their performance is evaluated using ***historical weather data***.
- Each vessel's course, speed and control settings are optimised continuously over each leg, in the same way that the real vessel would be operated.
- Results are used to evaluate savings potential and ***inform design decisions***.

Scrutinized by industry leaders

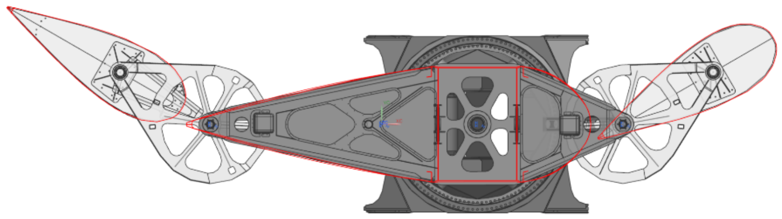
Our simulation techniques, performance predictions and claims have been ***studied and verified*** by both the acclaimed Wolfson Unit and Lloyds Register on behalf of clients of note. In both cases they have fully supported our finding and commended our thorough analysis methodologies.

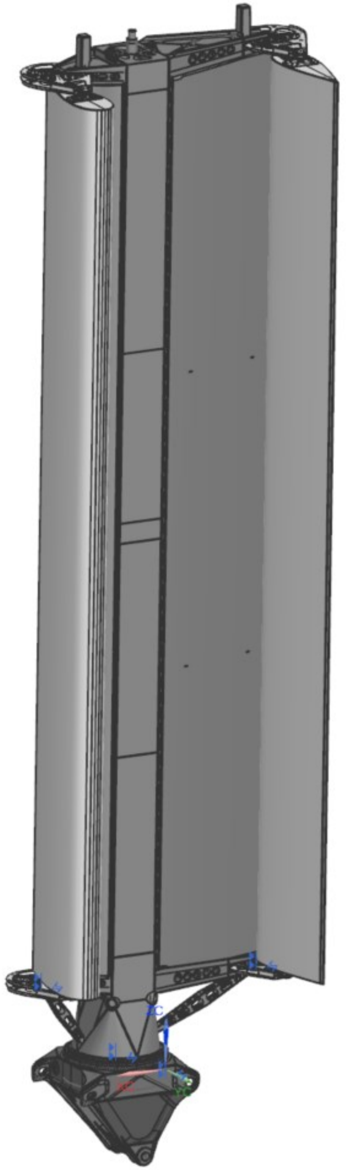
3 Element, High Lift Rigid Wing

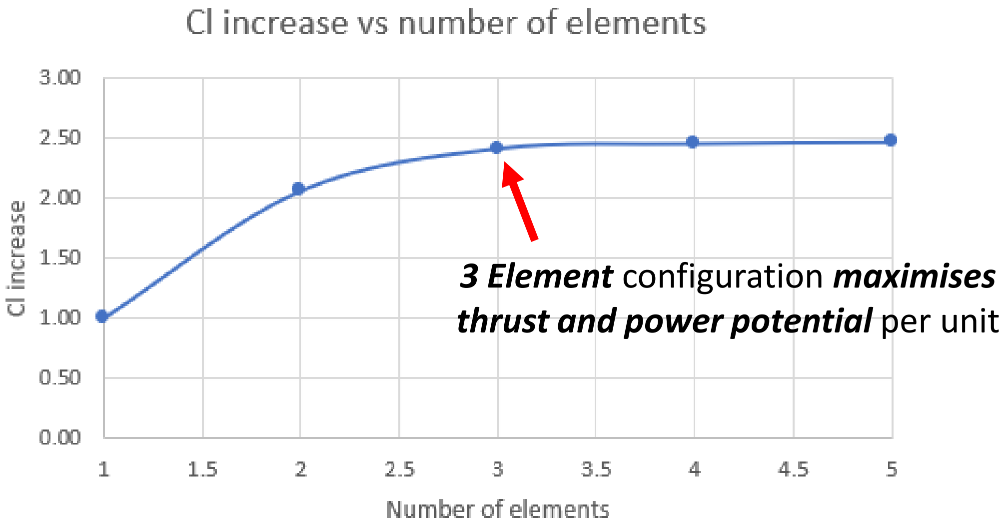
- *Increased Lift = Increased Fuel Savings*
- *Improved Forgiveness & Stall Characteristics*
- *Flexibility & Reduced Drag*



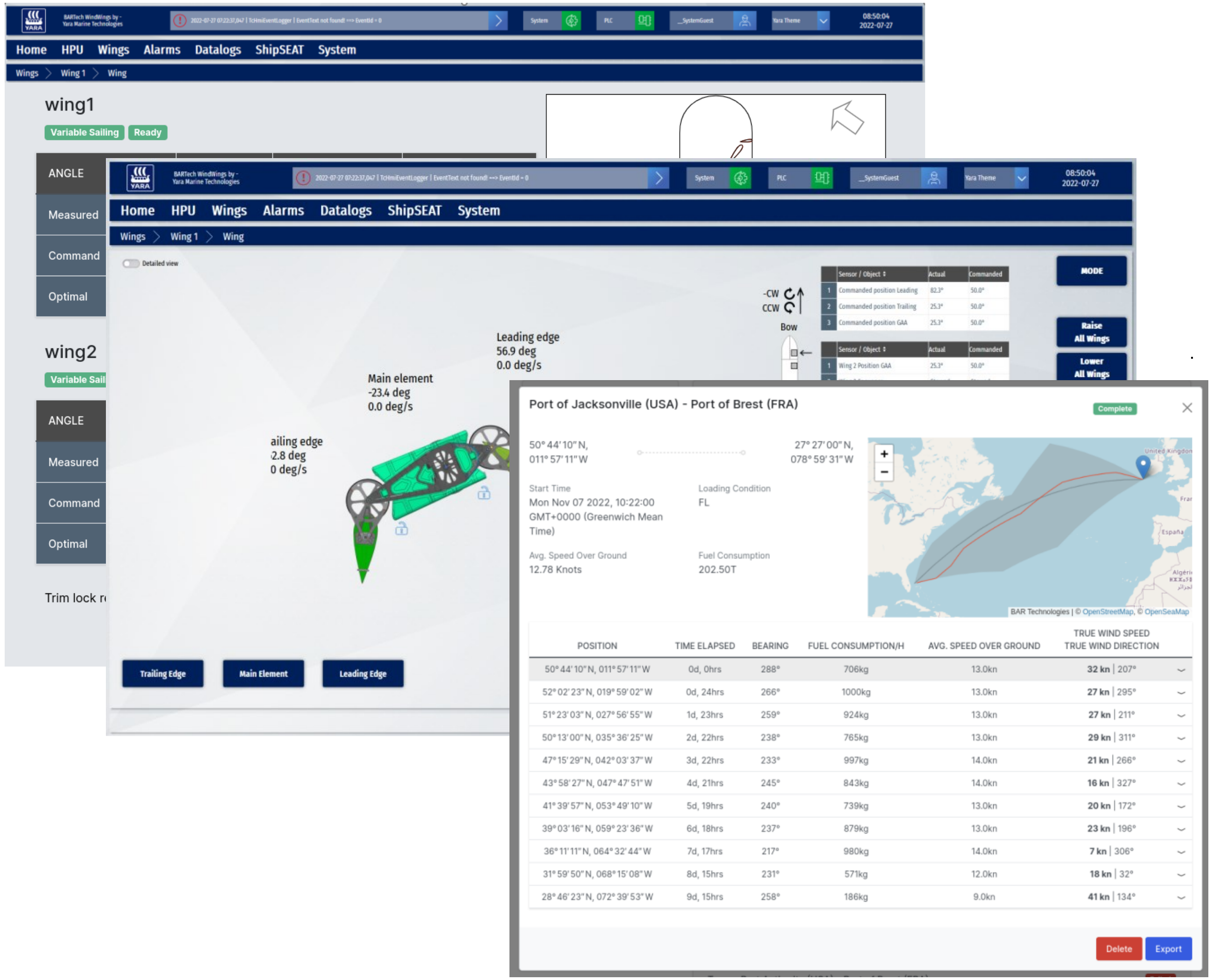
Fully Adjustable Camber & Angle of Attack







Delivered With A Suit Of Automation And Optimisation Tools



Wing Control System (WCS)

Provides complete control automation, health safety and alarm monitoring. On vessel interface for manual wing interaction, maintenance processes etc.

ShipSEAT Onboard

Undertakes the performance aspects of the control, customised on a vessel-by-vessel basis. This bespoke code determines the optimum wing orientation and camber shape ensuring maximum fuel savings at all times. Additionally reports live thrust values.

ShipSEAT Routing

A custom state of the art routing package developed specifically for Wind Assisted Vessels. Assessable via a web interface, accessible either by a shore-based ops team and/or onboard with a variety of automated workflow tools to aid efficient use.

First Launches

__Vessel 1__

Pyxis Ocean:	Kamasamax
Owner:	MC Shipping
Charterer:	Cargill
No. Wings:	2

__Vessel 2__

Berge Olympus:	Newcastlemax
Owner:	Berge Bulk
Charterer:	Vale
No. Wings:	4

Further announcements to follow including first multi- vessel run new build program

Average Saving → **Fuel- C.1.5 Tonnes/WindWing/Day**

=

CO_2- 4.65 Tonnes WindWing/Day

Saving in 25kts @ 90 AWA → **Fuel- >5.5 Tonnes/WindWing/Day**

=

CO_2-> 17.5 Tonnes WindWing/Day

Route and vessel dependent- bespoke predictions and trust guarantees available

Realistic simulations- *fully representation of performance through life. Negative effects such depowering (yaw balances limits etc), interference, unfavorable conditions etc included.*

Ratified Savings- *Performance predictions independently verified for major oil company by the Wolfson Unit & and for another by Lloyds Register*

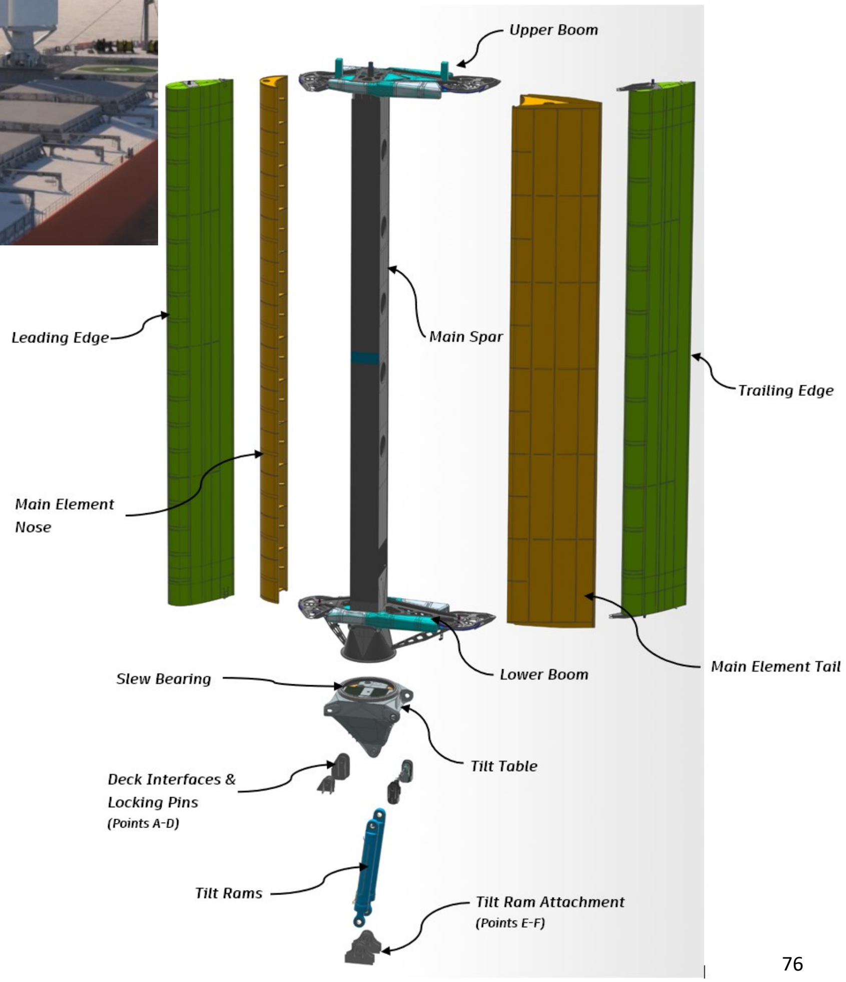
Extractable Performance- *Forgive design ensures delivery of performance in off optional conditions*

Presenting BAR Technologies WindWings by Yaramarine Technologies

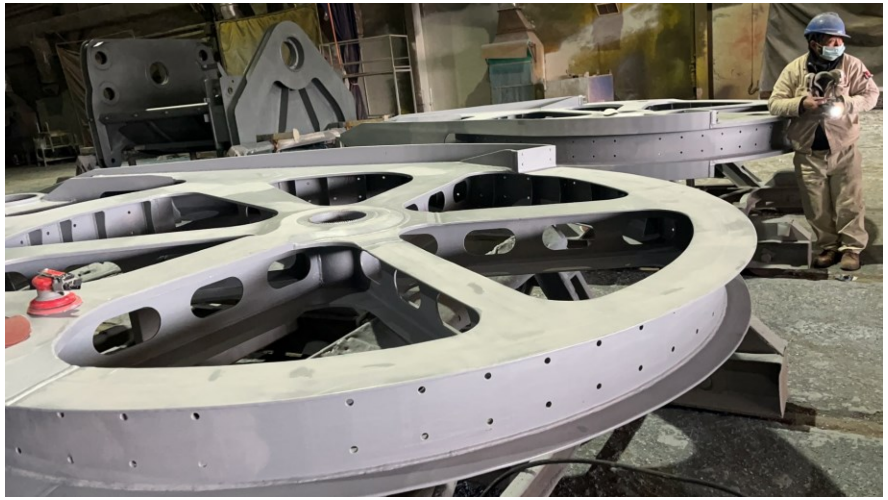
Robust Steel and Industrial Composite Construction

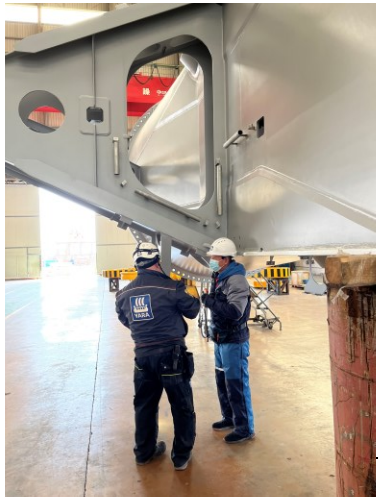
Folds To Deck for Pilotage and Port Operations

Low O&M requirements – Known Maintenance Knowledge

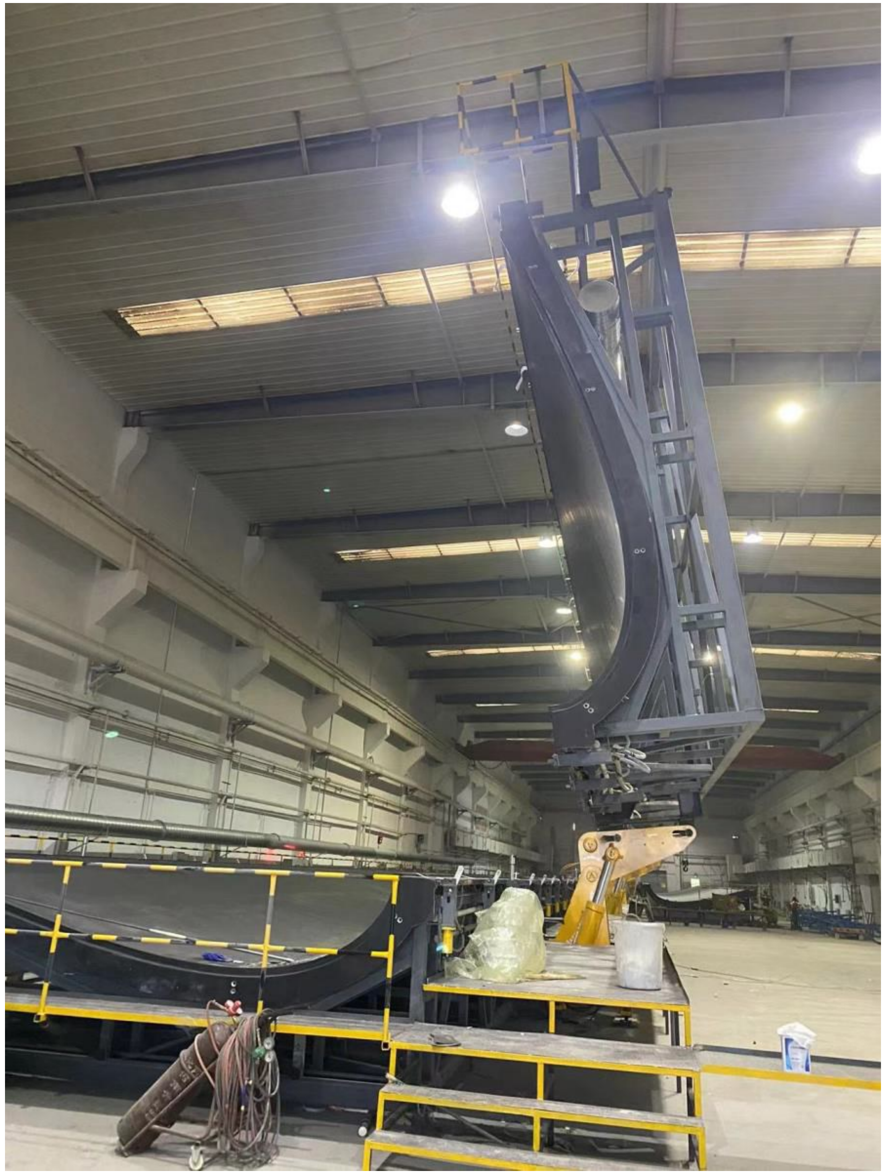


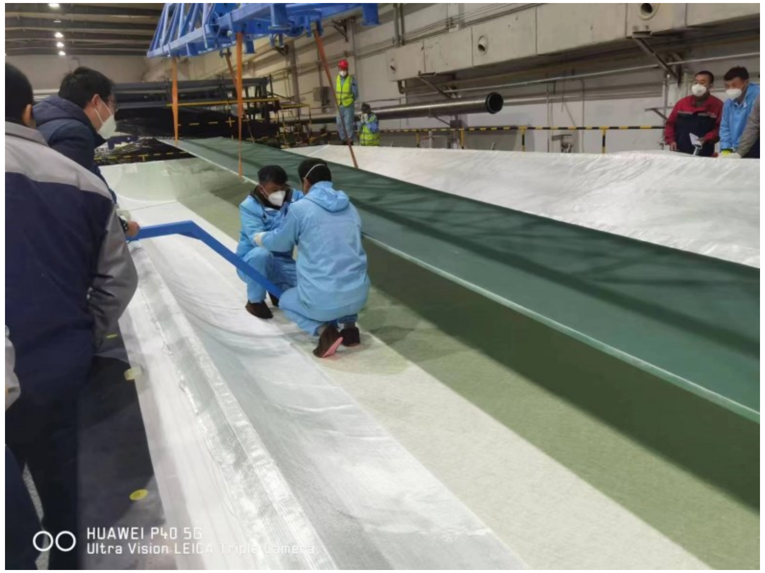
Metalwork Production Views

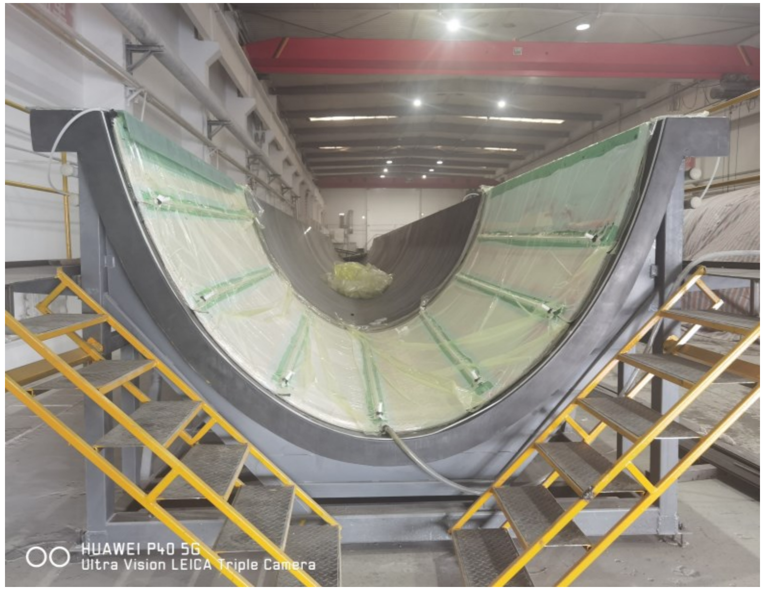




Composite Production Views

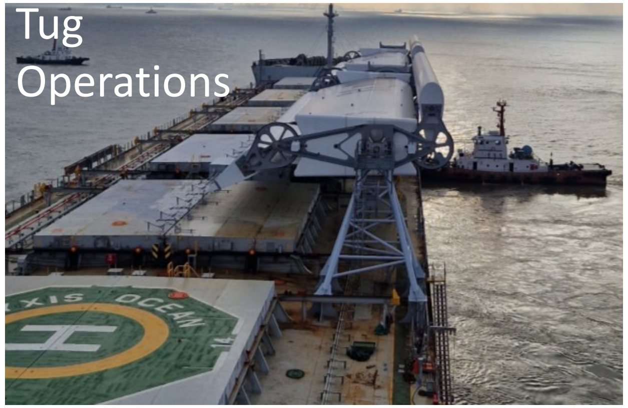


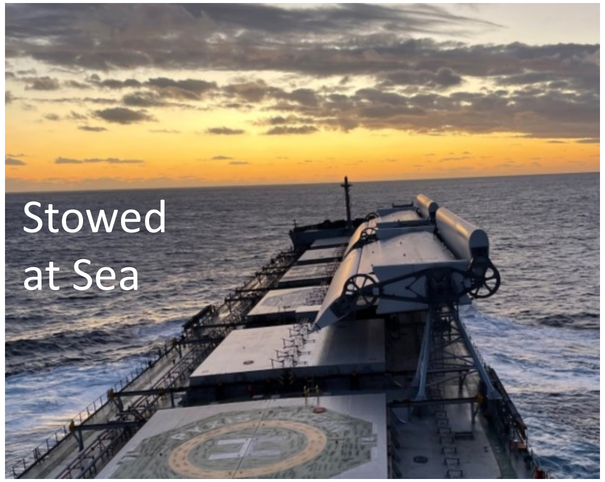


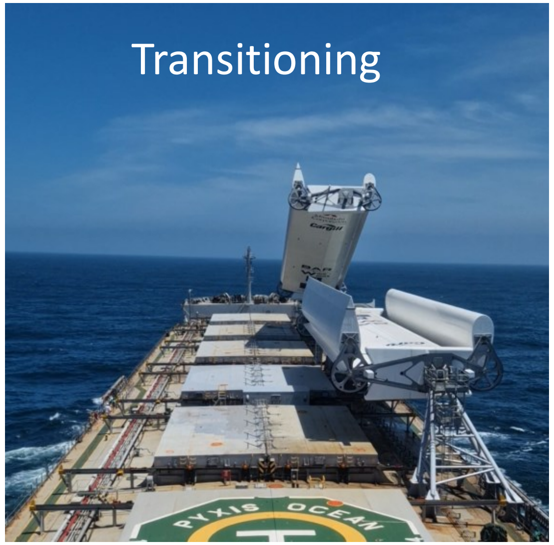


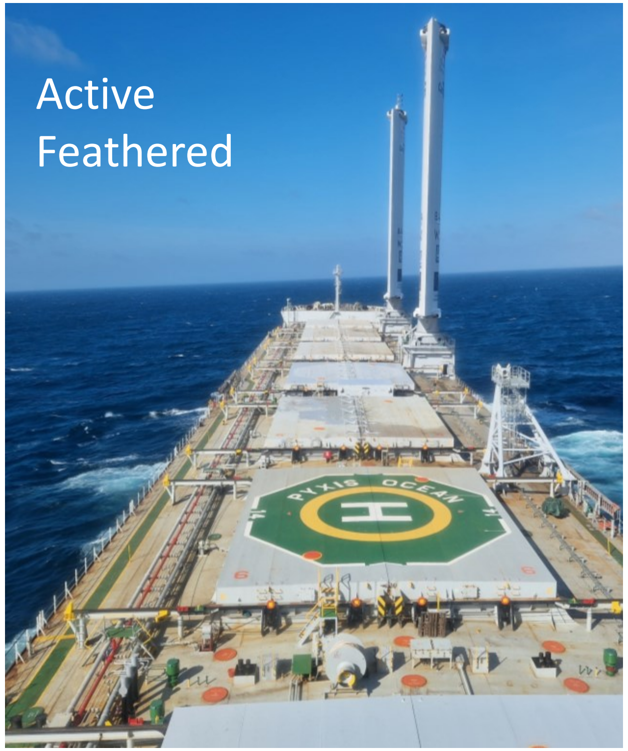
BAR TECHNOLOGIES

Sea Operations









Port Operations

Cargo Loading

Cargo Discharge

BAR TECHNOLOGIES

Why WindWings

- ✓ WingWing ***patented 3 Element configuration*** maximises thrust and power potential
- ✓ Configurability and controllability of the shape allows exploitation of potential across a ***wider range of AWS and AWA***
- ✓ The multielement configuration is ***naturally more forgiving*** to variation in external condition meaning ***low power requirements***
- ✓ ***Minimal interaction effects***; more wings means more savings
- ✓ ***Practical, reliable and robust construction-*** *know technologies*, minimising maintenance requirements and costs.
- ✓ The design allows the ***folding and stowing of the wings*** for port operations without the complexity and reliability challenges of telescopic designs
- ✓ ***Proven Technology***
- ✓ ***c.1.5T Fuel Saved Per WindWing Per Day***

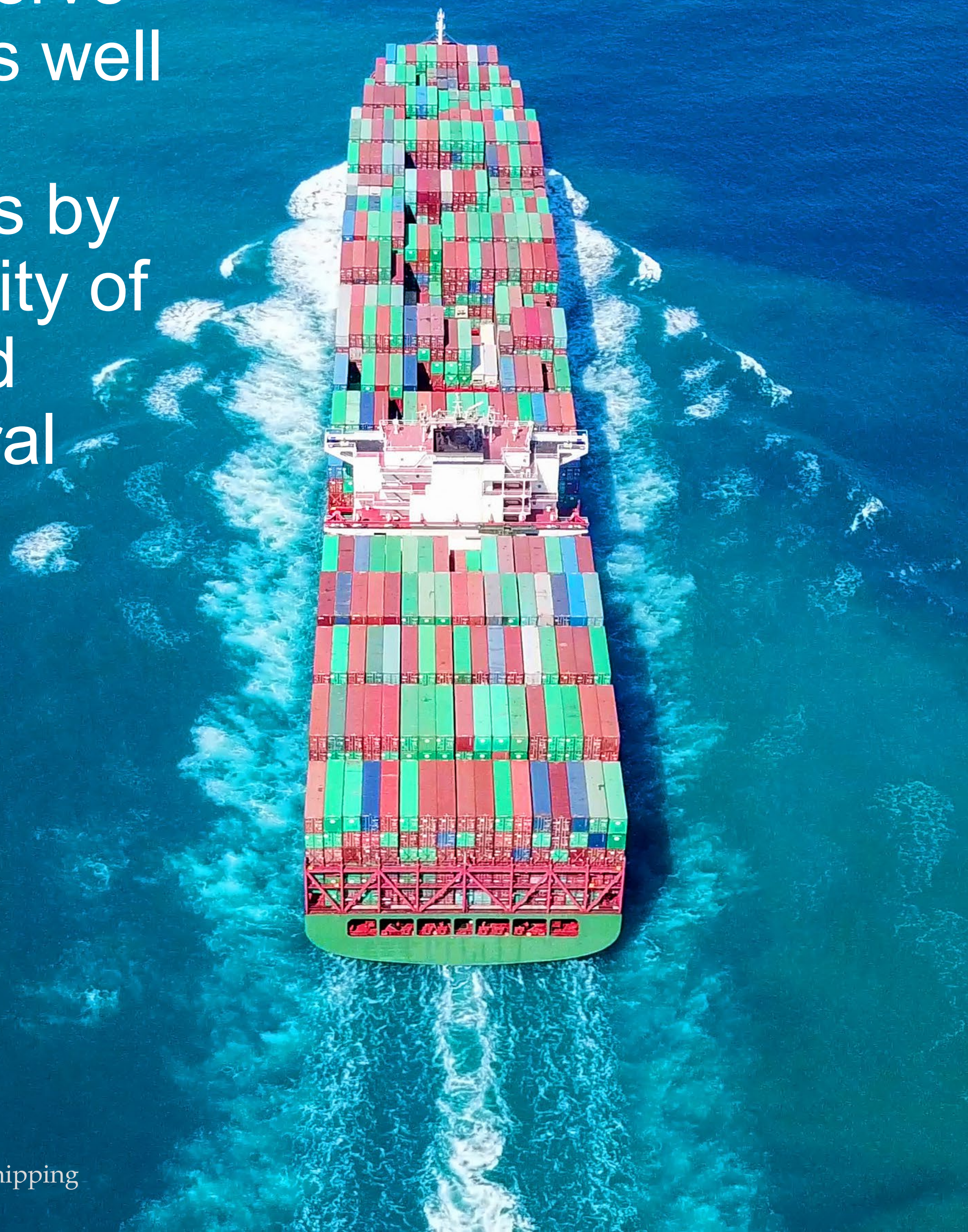
WindWings


Mitsubishi Corporation
Cargill
BAR
WIND WINGS
YARA
Co-funded by the European Union
PYXIS OCEAN

CFD-assisted Hull Form Optimization for Sustainable Shipping

Dae-Hyun Kim | November 6, 2023

ABS' mission is to serve the public interest as well as the needs of our members and clients by promoting the security of life and property and preserving the natural environment.

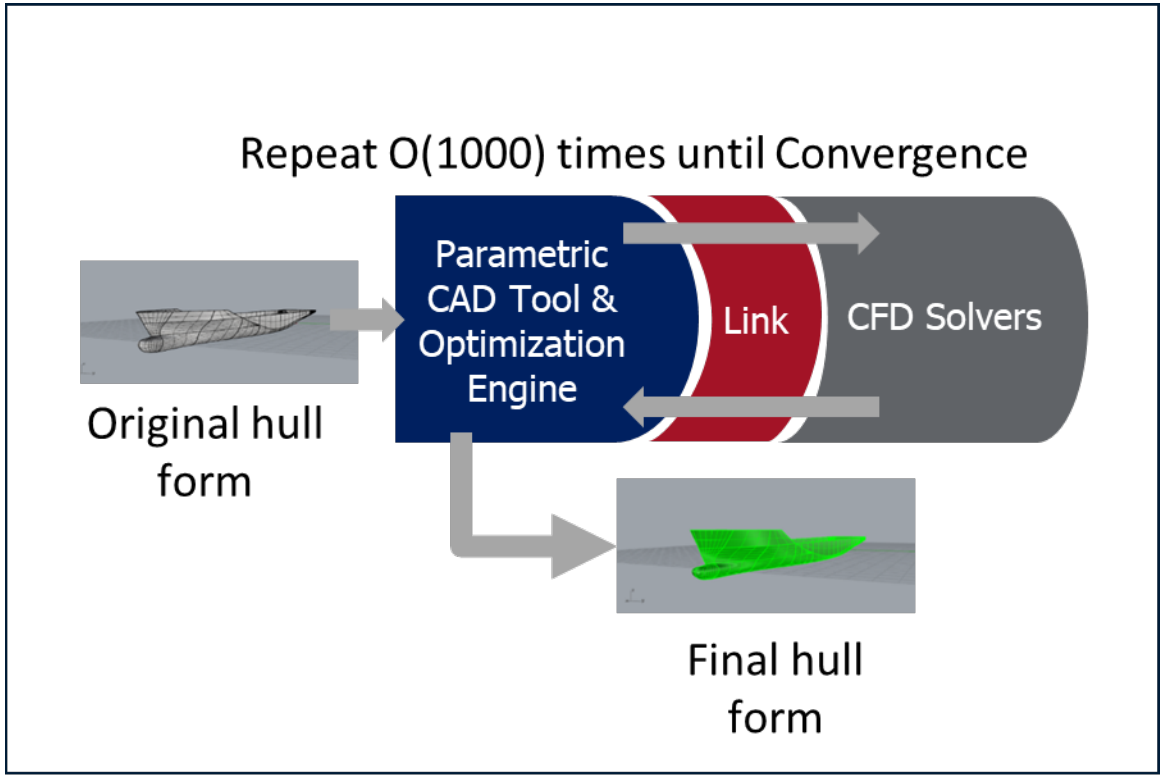


ABS

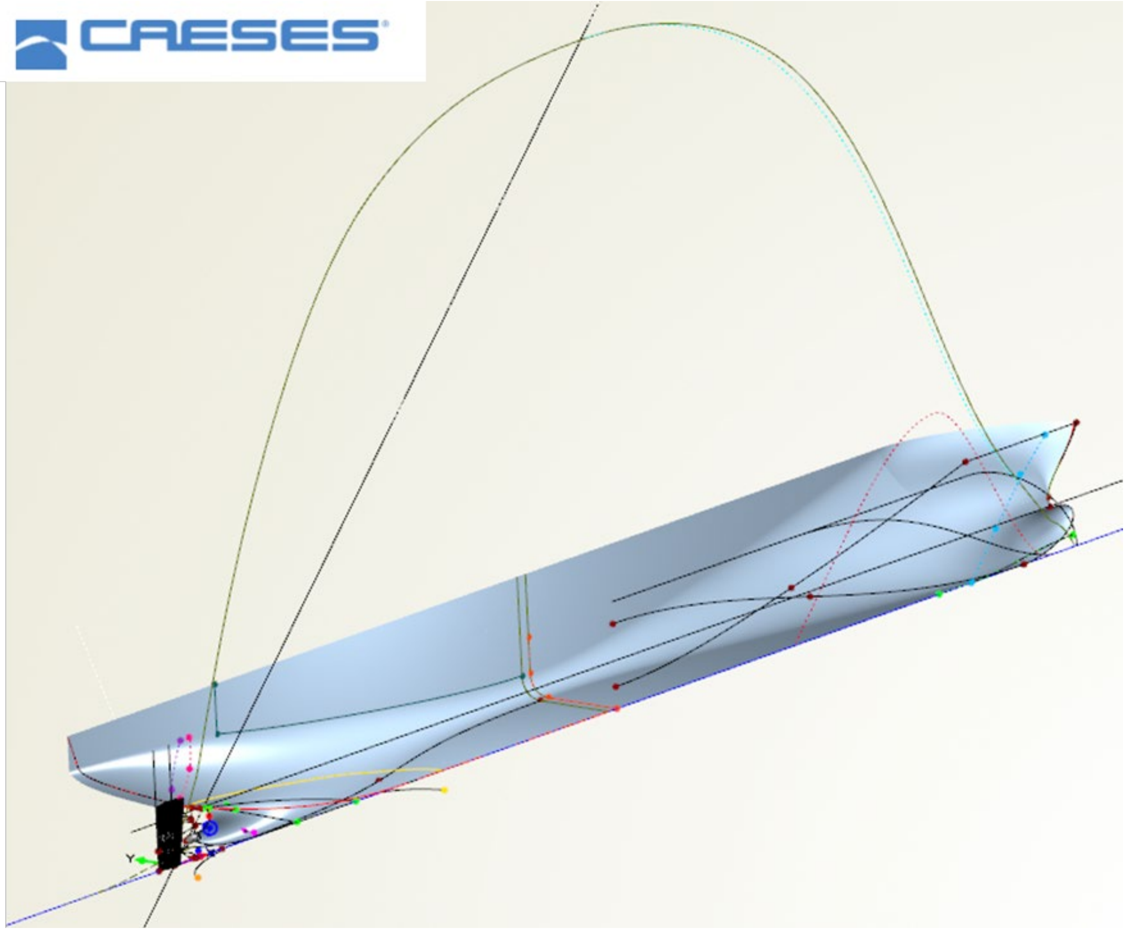
Parametric Hull Form Optimization

- New technologies for more sustainable shipping are being developed, but they must be incorporated into ship designs in an optimal way.
- Parametric hull form optimization guided by RANS CFD could help stakeholders find the optimal way.
- ABS has been assisting its clients with this parametric hull form optimization framework.

Optimization Framework

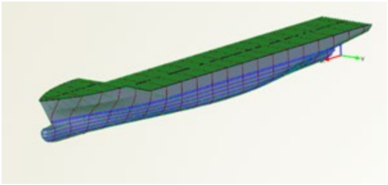


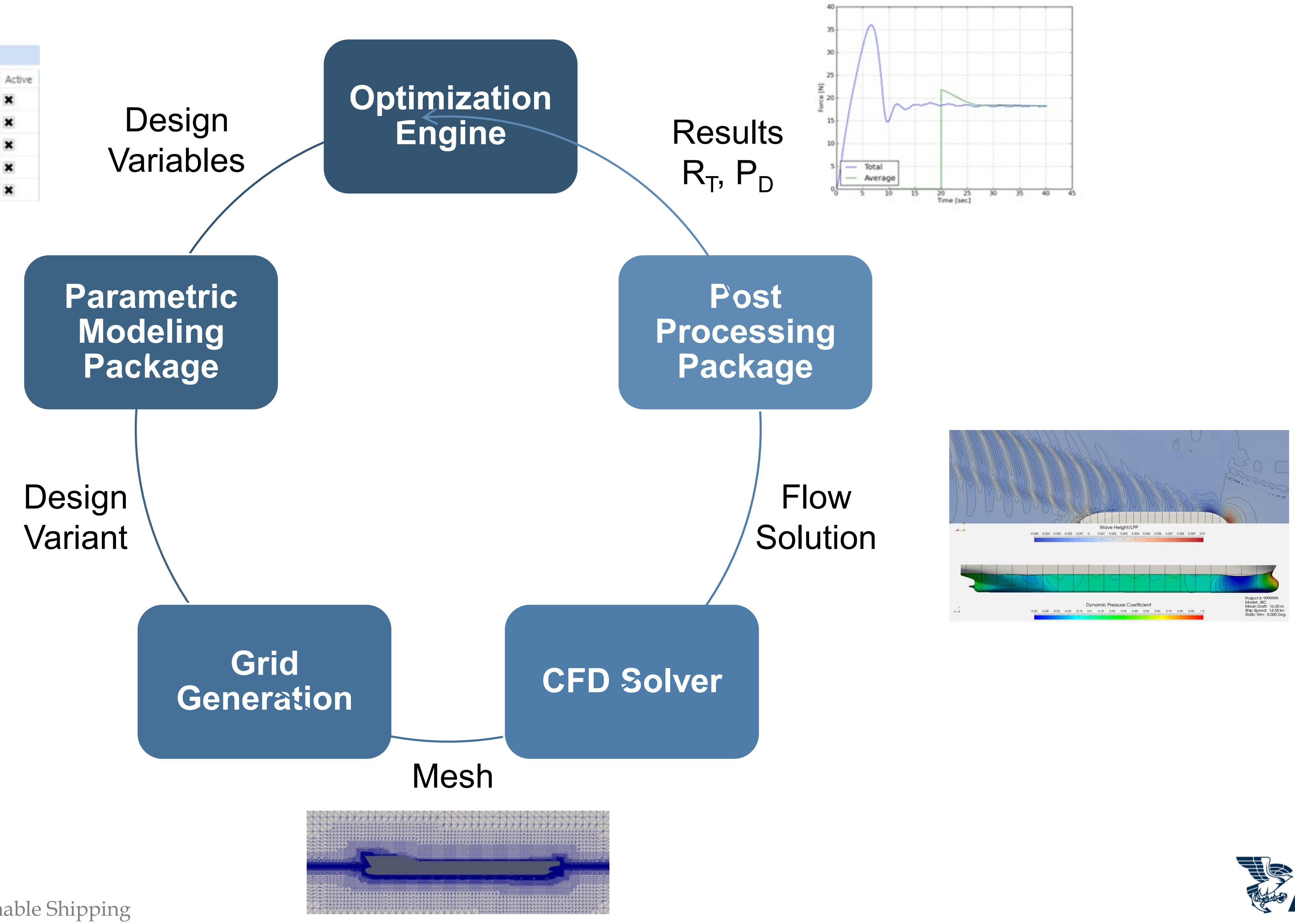
- Hull form is modeled by parameters (variables) using a parametric CAD modeling software.
- Depending on the area of interest, relevant parameters (i.e., design variables) are optimized against given objective function(s).
- Each variation of design variables produces unique design candidate.
- Objective functions (e.g., minimum power and/or maximum cargo capacity) associated with each design candidate is evaluated by CFD tool.
- It often becomes a multi-objective nonlinear optimization problem with a set of design constraints.



Design Variables

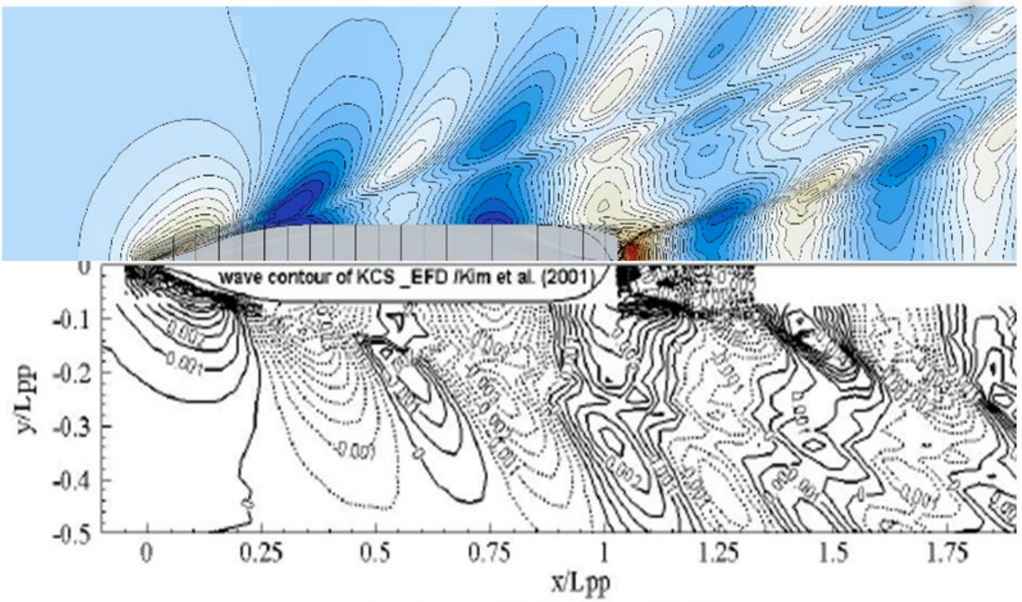
	Design Variable	Lower	Value	Upper	Active
1	maxBeam	1.5	2.4	2.6	✖
2	SectionlowFullness	0.65	0.74	0.85	✖
3	SectionuppFullness	0.67	0.78	0.85	✖
4	xBulbTip	234	237	240	✖
5	zBulbTip	4	5.90193387	6.5	✖





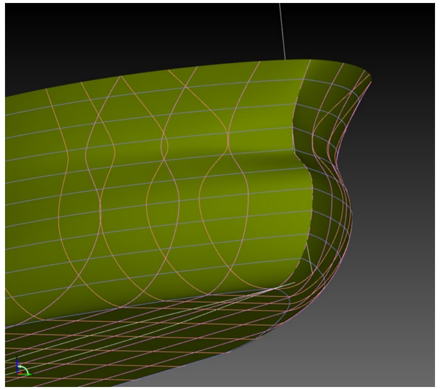
- Calm water resistance computed by CFD and compared to KCS model test results from "Gothenburg 2010: A Workshop on Numerical Ship Hydrodynamics".
- Average difference between CFD and experimental resistance values is 0.88%.
- Good comparison in free surface wakes.

KCS Benchmark							
Speed	[knots]	**10.0**	**14.0**	**18.0**	**20.0**	**24.0**	**26.0**
Froude Number		0.1083	0.1516	0.1949	0.2166	0.2599	0.2816
Dynamic Sinkage, CFD	[mm]	-1.552	3.610	-6.689	-8.656	-13.518	-16.907
Dynamic Sinkage, Exp.	[mm]	-0.900	-2.750	-5.990	-9.440	-13.040	-17.020
Dynamic Trim, CFD	[deg]	0.031	0.057	0.099	0.124	0.184	0.160
Dynamic Trim, Exp.	[deg]	0.170	0.053	0.097	0.127	0.169	0.159
C_{TM} x 10^3, CFD		3.741	3.674	3.506	3.477	3.663	4.478
C_{TM} x 10^3, Exp.		3.796	3.641	3.475	3.467	3.711	4.501
Delta CFD-Exp.	**[%]**	**1.44%**	**0.90%**	**0.90%**	**0.29%**	**-1.30%**	**-0.51%**

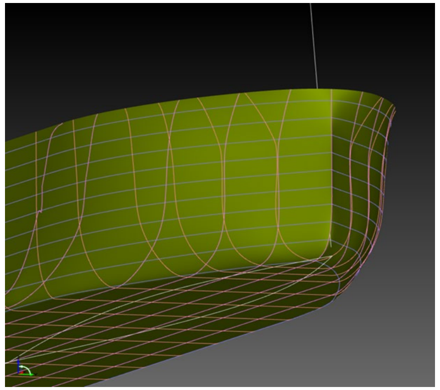


Experiment (MOERI, Kim et al. 2001)

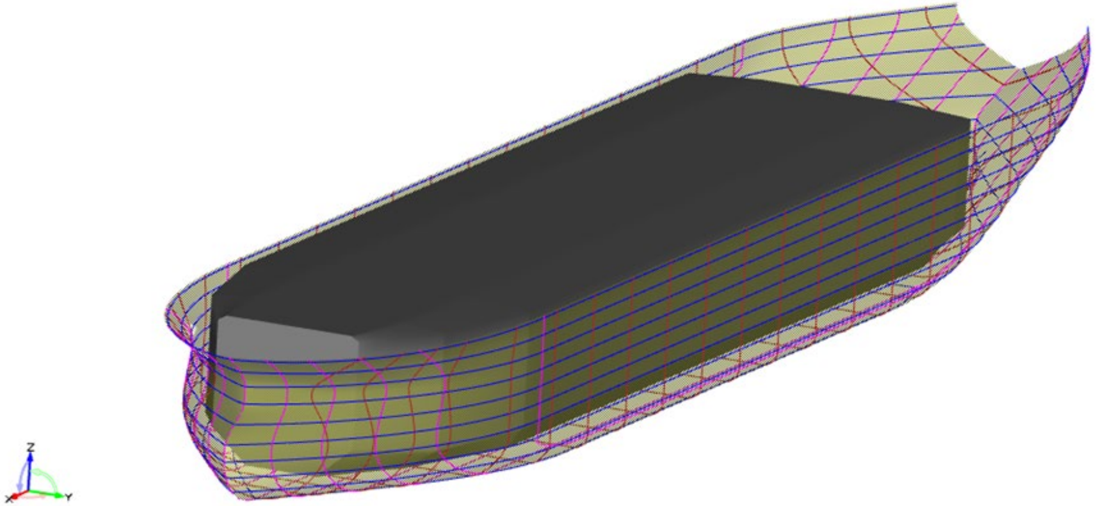
- Optimize the hull form for minimum delivered power over the operational profile (Design Draft: 60%, Ballast Draft: 40%) subject to the following constraints:
  - Cargo tank volume of 85,000 m^3
  - Hull maximum depth (15.0 m max. freeboard @ Midship and Ballast Draft)
  - Draft @ Aft-ship to ensure propeller immersion
  - Speed: 14.5 kn for both drafts



Bulbous Bow (BB)



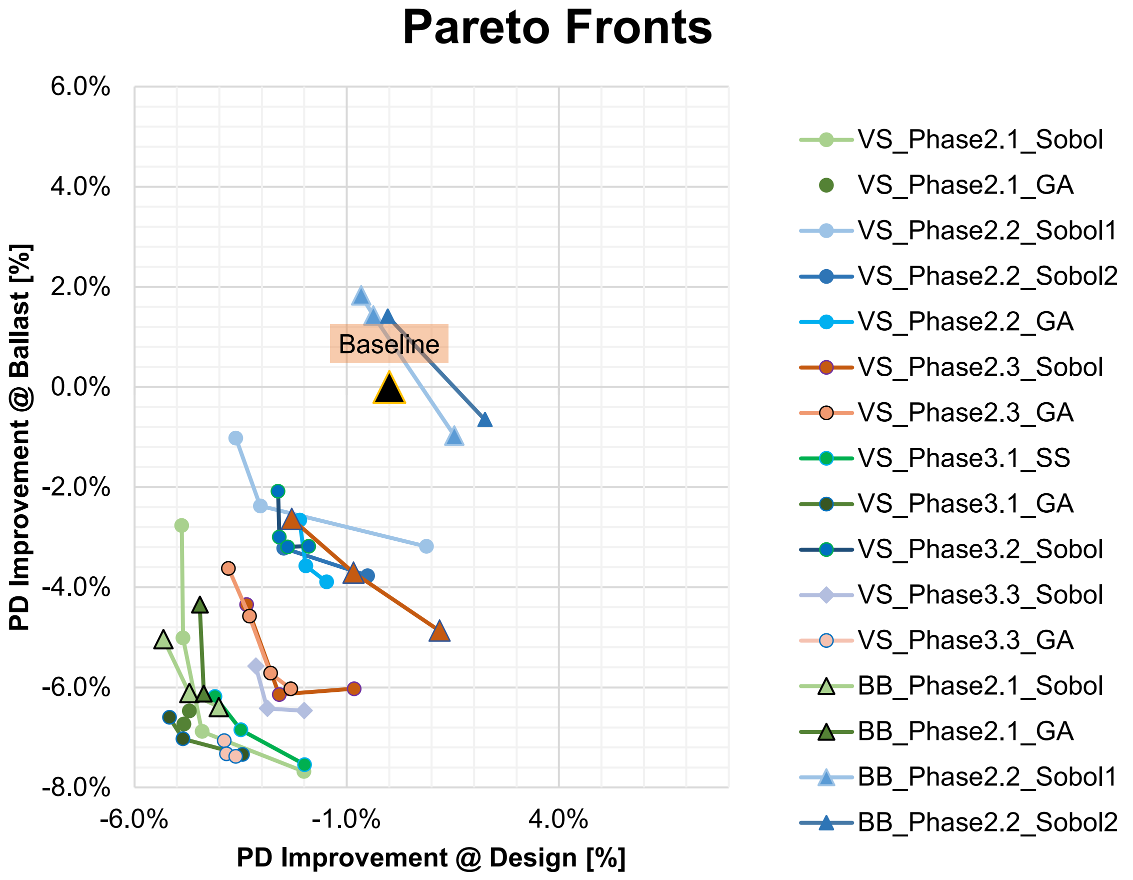
Vertical Stem (VS)



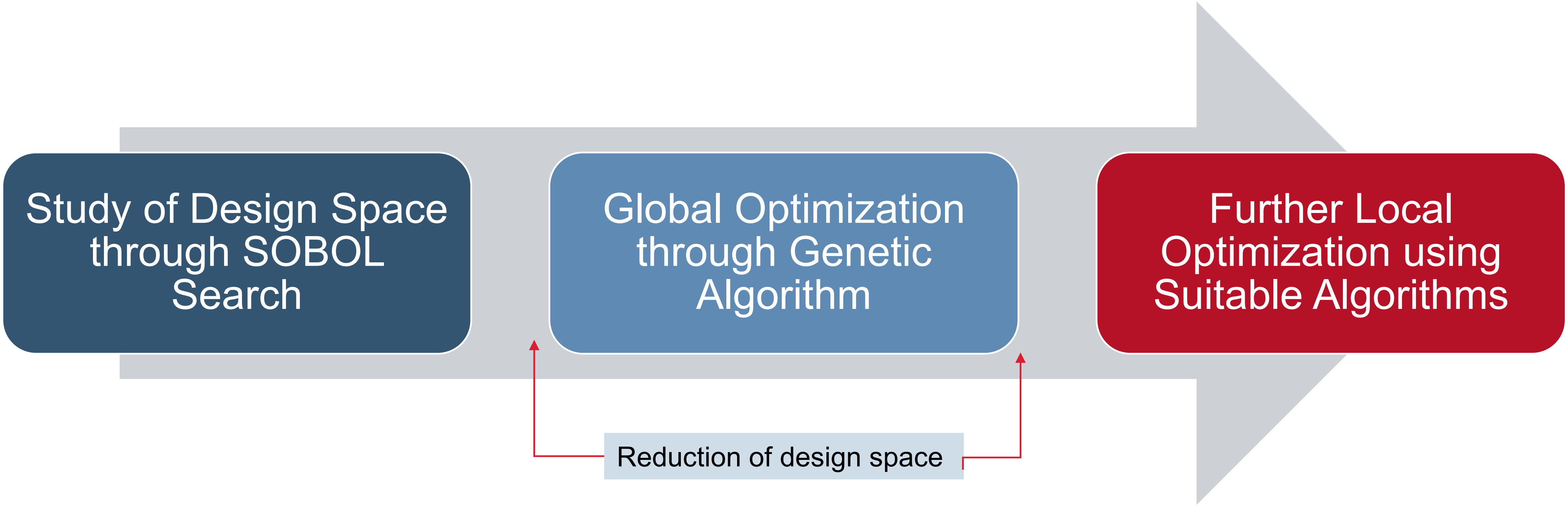
Modeling of Hull and Cargo Tank: As hull form changes, cargo tank also changes with a pre-defined clearance between Hull and Tank.

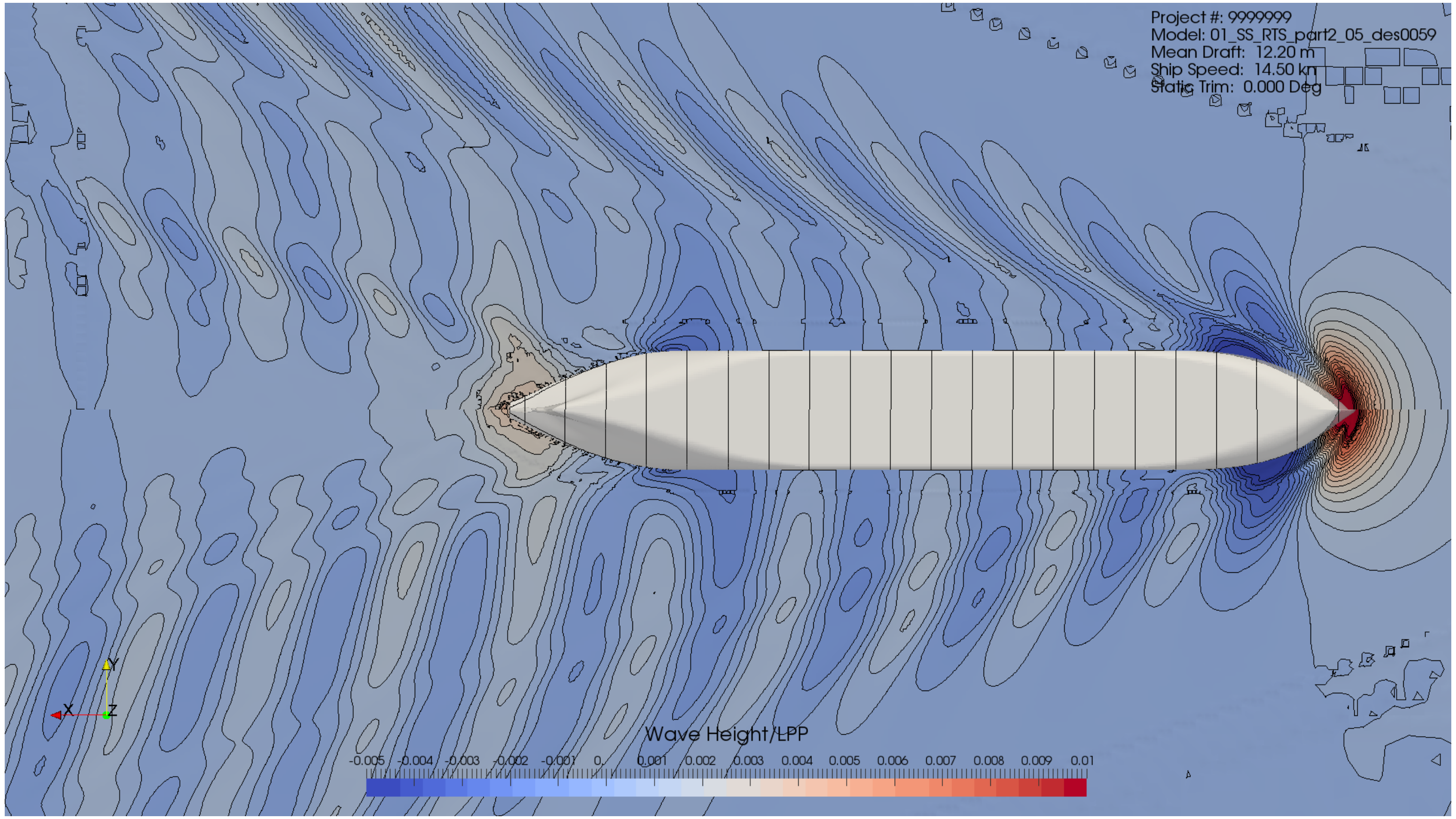
Summary:

- Optimization with Panamax beam and no limit on length have the best potential to push performance up
- Vertical stem bow type appears to have better performance compared to the bulbous bow type



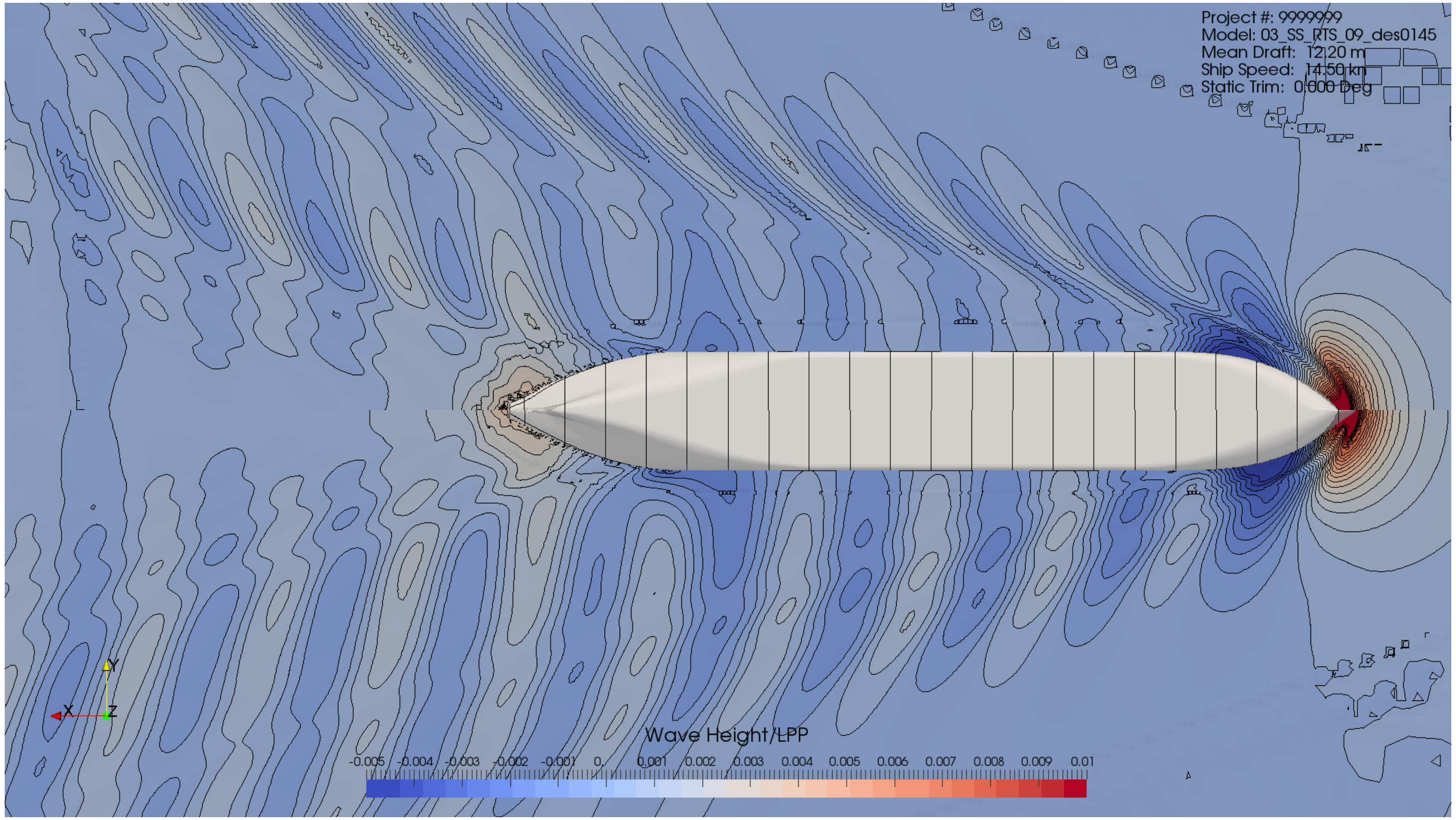
- Depending on the problem, different optimization algorithms will be used but in general, a multi-step approach is efficient.





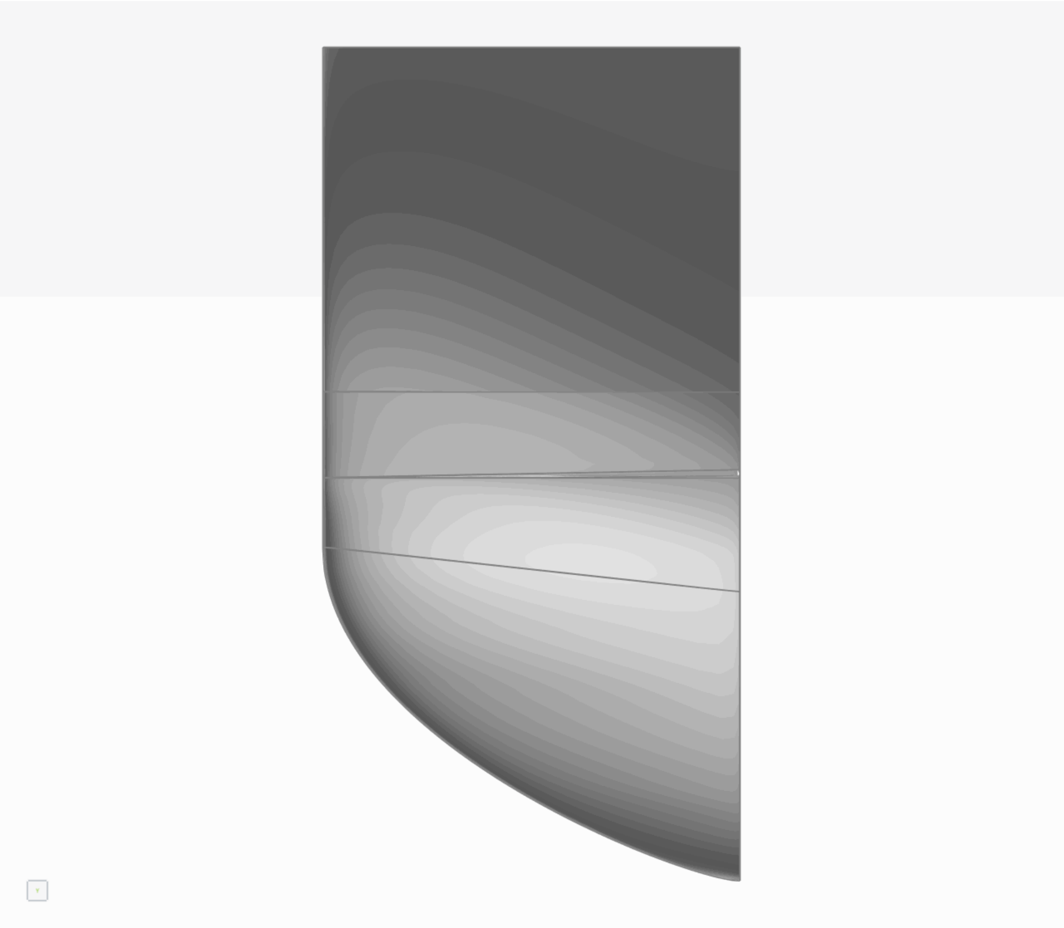
New Variant 1 (Bulbous Bow)

Baseline

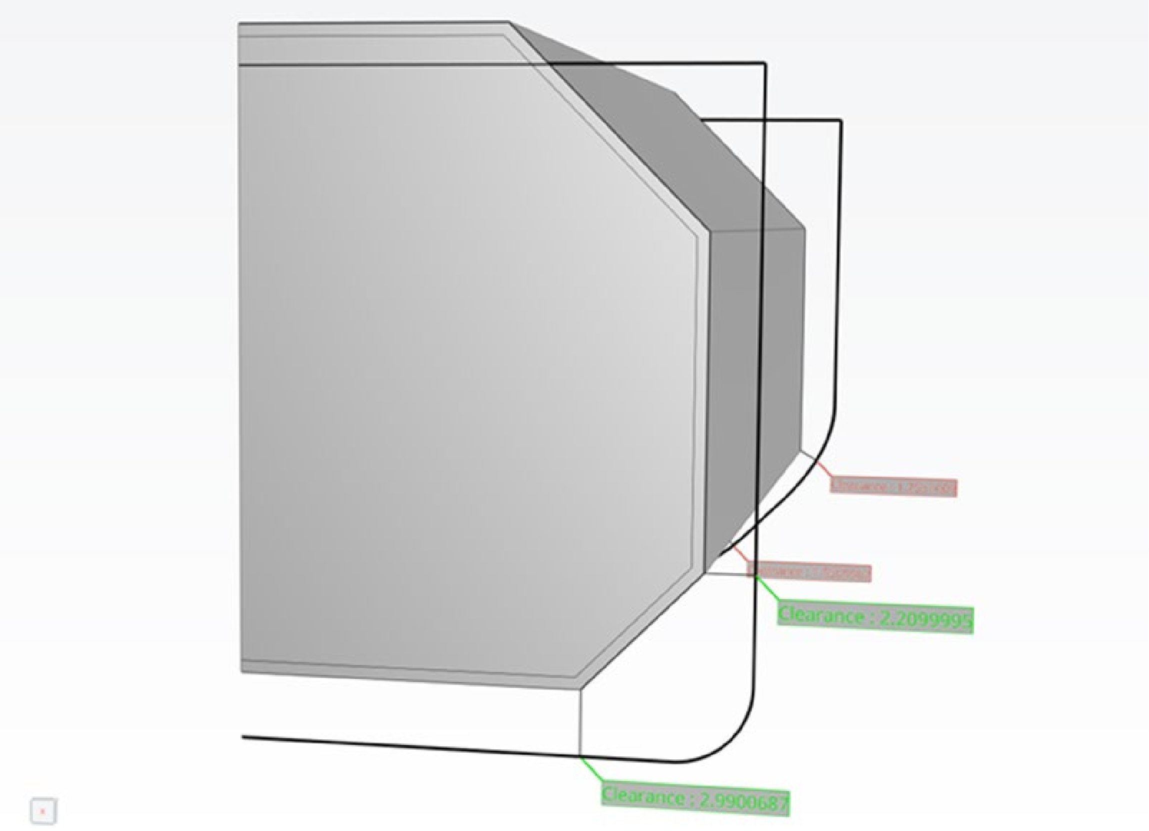


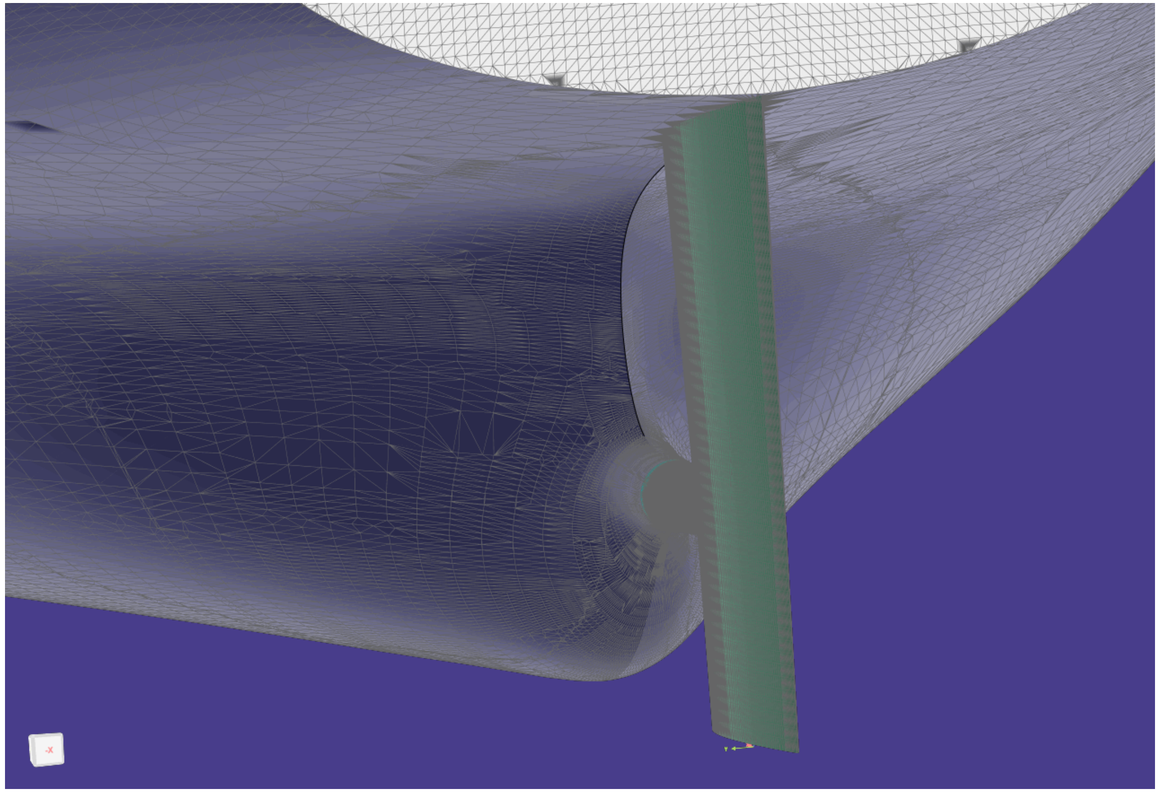
New Variant 2 (Vertical Stem)

Baseline



- It is possible to model not only vertical stem bow but also bulbous bow with a single parametric model.
- The efficiency of the design space investigation depends on how the parametric model is built (e.g., number of design variables).
- How to implement the constraints should also be considered in building parametric models.





- Automatically checking the hull tank clearance to ensure constraints are met.
- Example of partially parametric model for asymmetric stern hull.

- CFD-based parametric optimization approach became feasible for hull form design and optimization.
- Parametric optimization approach enables a more efficient investigation of design space with various constraints and multiple objective functions.
- However, it still requires various knowledge and experience from multiple subject matter experts.
  - Computational fluid dynamics (CFD)
  - Parametric CAD modeling
  - Nonlinear multi-objective optimization
  - Ship resistance, propulsion and powering (<u>or the physics of the problem</u>)
  - Ship design, construction, and operation (<u>or practical considerations of the engineering problem</u>)

Contact Us

Email or Give Us a Call

Our team of experts can help you.

Email Us at daekim@eagle.org

Thank You

www.eagle.org

MARIN

BETTER SHIPS, BLUE OCEANS

Saturn

Developing Solutions for Underwater Radiated Noise

Balancing energy efficiency and underwater radiated noise reduction of ships

Frans Hendrik Lafeber, Johan Bosschers, Thomas Lloyd, Evert-Jan Foeth, John Huisman

Greenhouse gas emissions

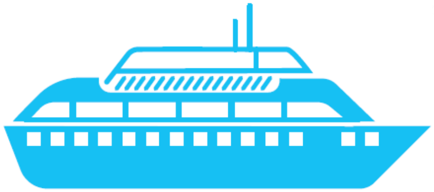
INTERNATIONAL
MARITIME
ORGANIZATION

- IMO Greenhouse Gas Strategy:
  - uptake of zero and near-zero GHG fuels by 2030 (at least 5%)
  - reduce CO_2 emissions per transport work in 2030 by 40% compared to 2008
  - net-zero GHG emissions close to 2050

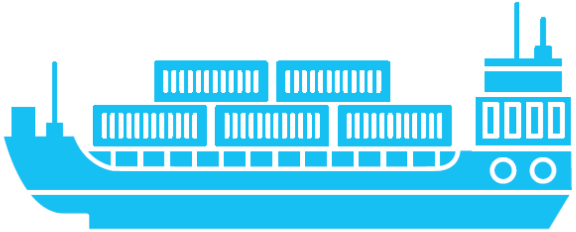
Greenhouse gas emissions

EEDI

ENERGY EFFICIENCY DESIGN INDEX
IMPROVING THE TECHNICAL
PERFORMANCE OF NEW BUILD SHIPS



EEXI



ENERGY EFFICIENCY EXISTING SHIPS INDEX IMPROVING
THE TECHNICAL PERFORMANCE OF EXISTING SHIPS

CARBON INTENSITY INDICATOR (CII RATING)

IMPROVING THE OPERATIONAL PERFORMANCE OF EXISTING SHIPS

EEXI / EEDI / CII

New ships only **EEDI**	All ships **EEXI**	All ships **CII**
IMPROVED HULL DESIGN	POWER LIMITATION	SPEED OPTIMIZATION
WASTE HEAT RECOVERY	WIND ASSISTANCE	BIOFOULING MANAGEMENT
REDUCED ELECTRIC CONSUMPTION	PROPELLER OPTIMIZATION	ALTERNATIVE FUELS
etc.	etc.	etc.

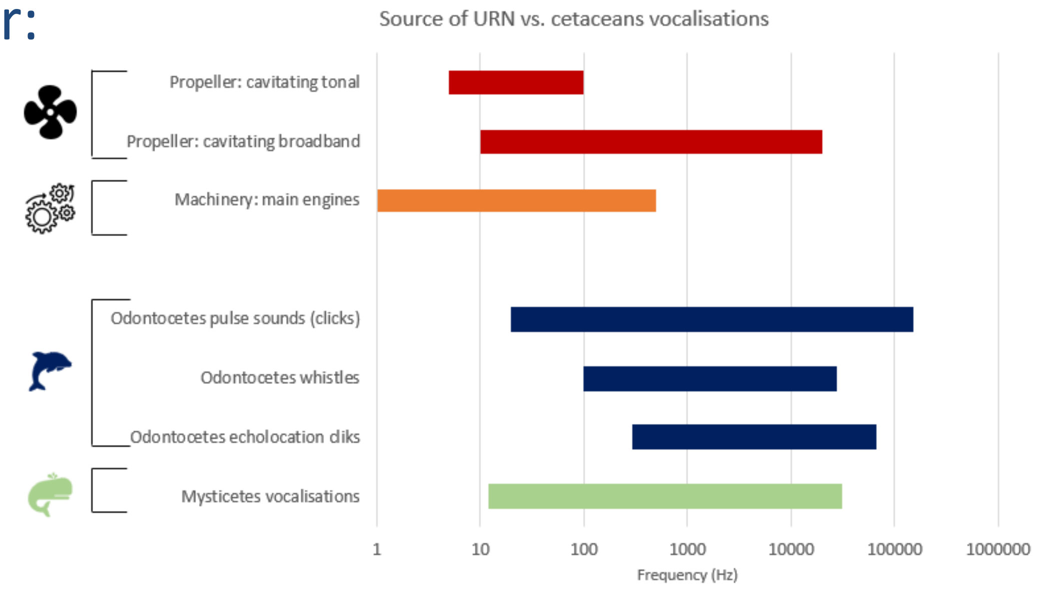
Source: https://www.imo.org/en/MediaCentre/HotTopics/Pages/EEXI-CII-FAQ.aspx

URN from ships: impact on marine life

- Growing evidence of impact of underwater radiated noise (URN) of ships on marine life

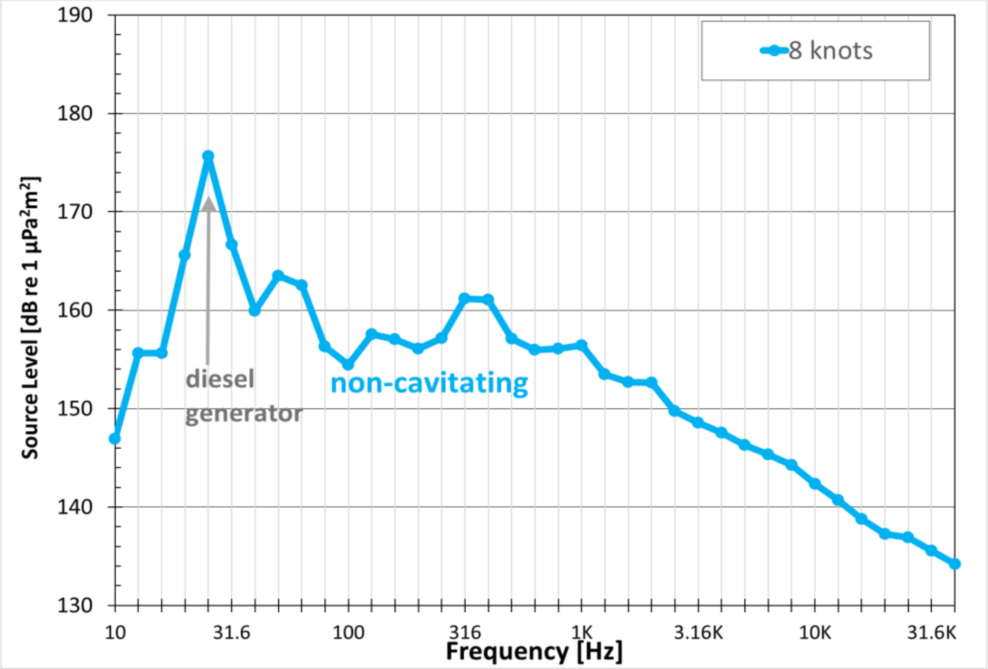
- Masking of sounds used for:
  - Communication
  - Hunting
  - Navigation

- Physical damage:
  - Hearing loss

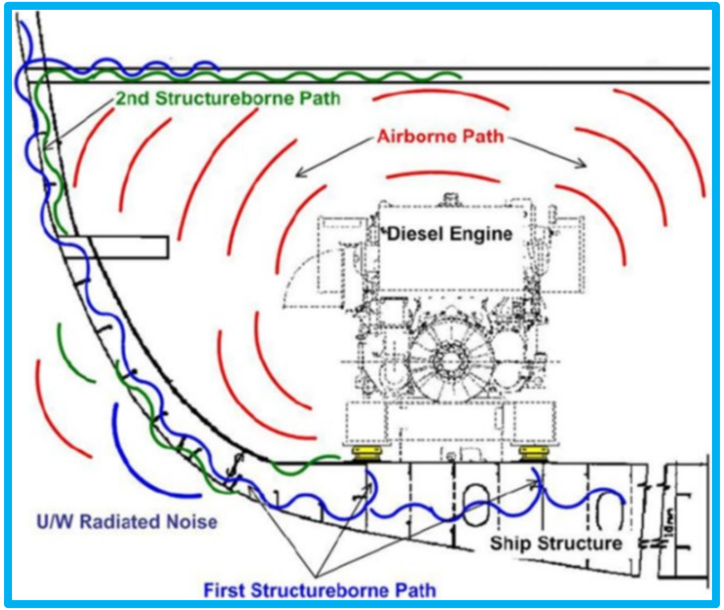


Source: Cruz, E. Lloyd, T., Bosschers, J., Lafeber, F.H., Vinagre, P. Vaz, G. (2021). Study on inventory of existing policy, research and impacts of continuous underwater noise in Europe

URN from ships: sources

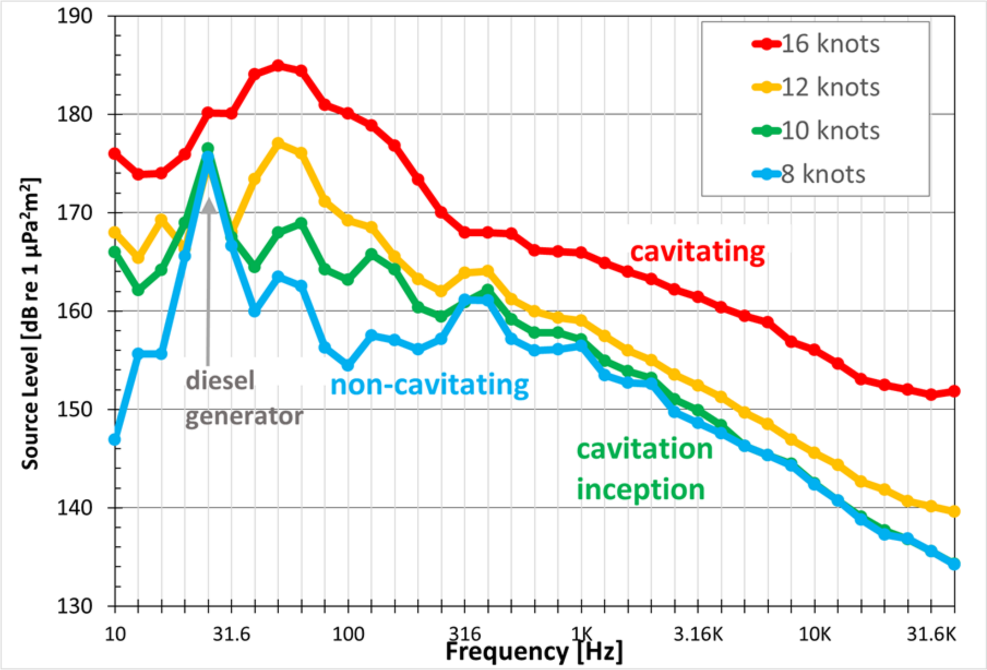


Source: Arveson & Vendittis (2000) 173 m cargo vessel



Source: Spence and Fischer, 2017

URN from ships: sources



Source: Arveson & Vendittis (2000) 173 m cargo vessel

URN from ships: regulations, incentives and class rules

MARIN

European Commission

IMO

ECHO PROGRAM

PORT of vancouver | Vancouver Fraser Port Authority

GREEN MARINE EUROPE

DNV

ABS

RINA

KR KOREAN REGISTER

Lloyd's Register

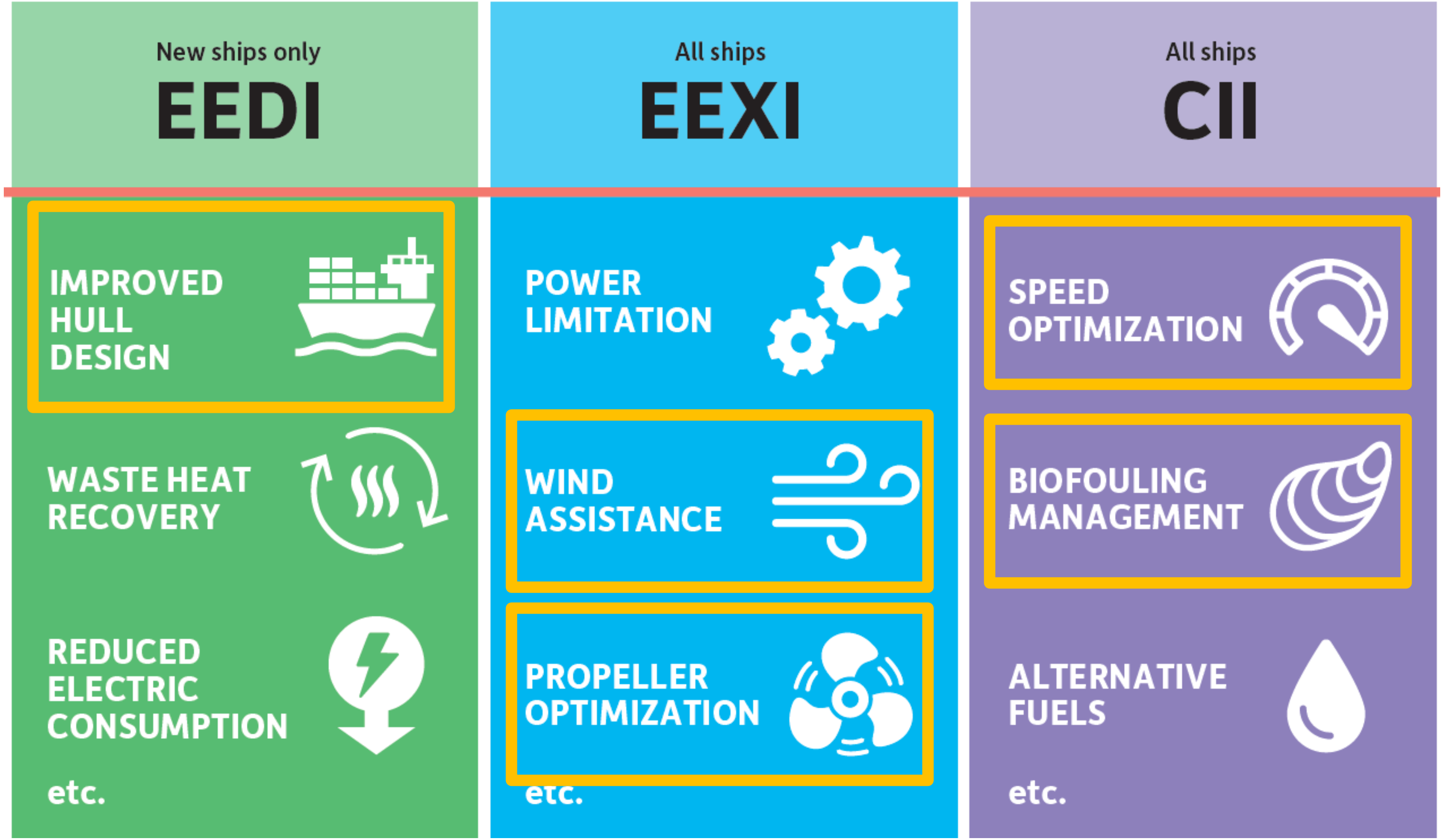
BUREAU VERITAS 1828

BUREAU VERITAS

CCS CHINA CLASSIFICATION SOCIETY 中国船级社

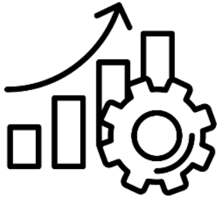
ISO

Energy efficiency and URN reduction

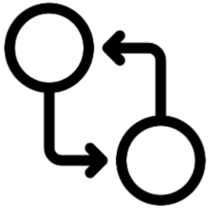


Source: https://www.imo.org/en/MediaCentre/HotTopics/Pages/EEXI-CII-FAQ.aspx

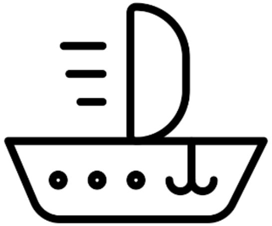
Example of mitigation measures



- Optimise the hull design
  - Minimise resistance
  - Optimise propeller inflow
- Optimise the propeller design
  - Trade-off efficiency and noise reduction

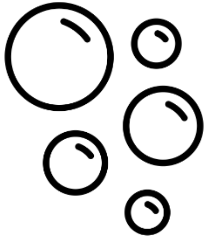


- Change the propulsor concept
  - Pumpjet, trochoidal propeller, etc.



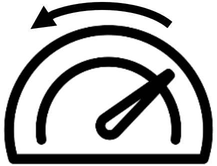
- Use wind-assistance
  - Reduce required thrust

Example of mitigation measures



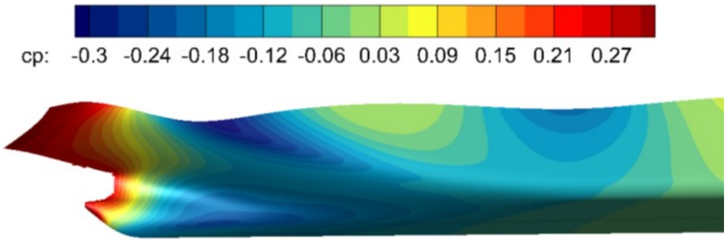
- Inject air bubbles:
  - Air lubrication to reduce resistance
  - Around hull against machinery noise (“Masker system”)
  - Into the cavitation (“Prairie-like system”)

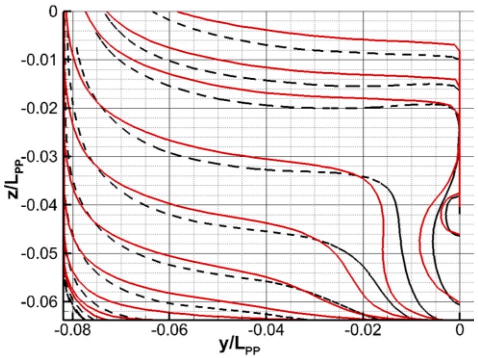
- Clean the hull and propeller
  - Minimise required thrust



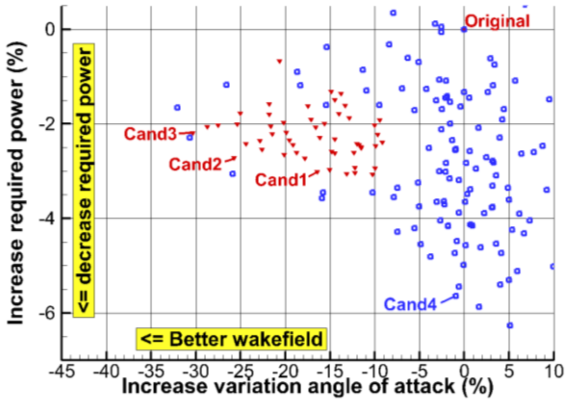
- Reduce speed
  - Minimise required thrust
  - On-board monitoring for real-time advice

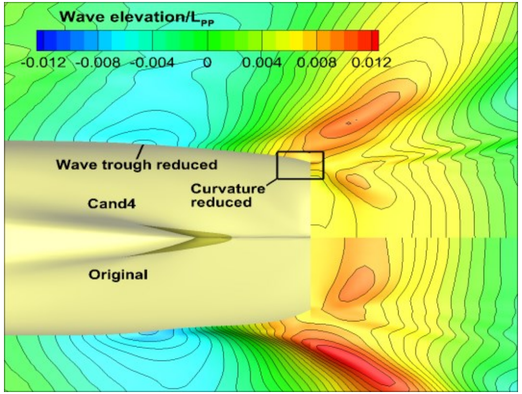
Hull form optimisation





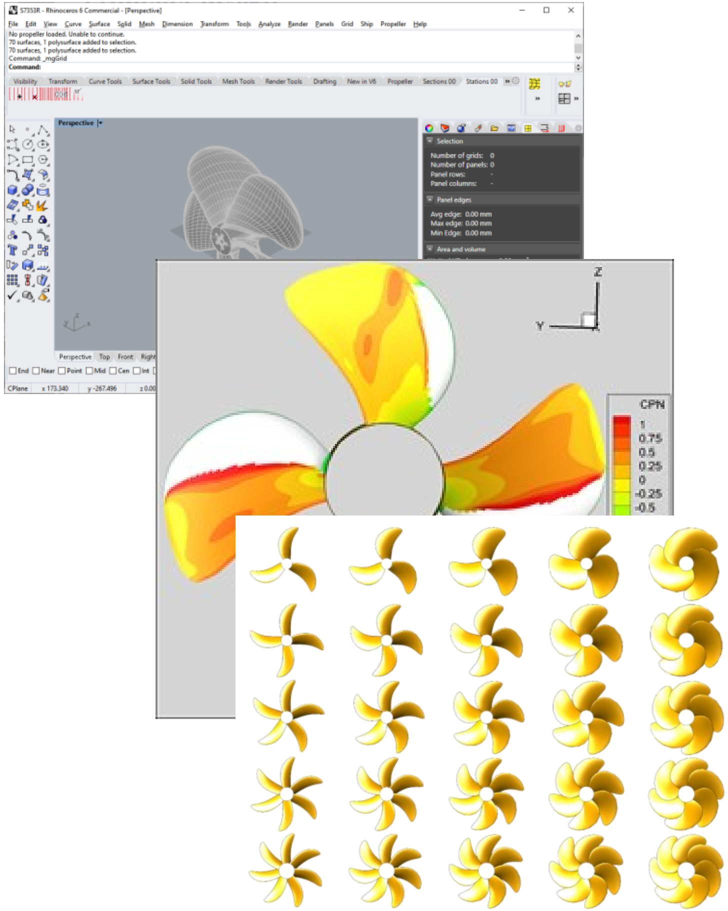
Calculate flow for >100 hull shapes

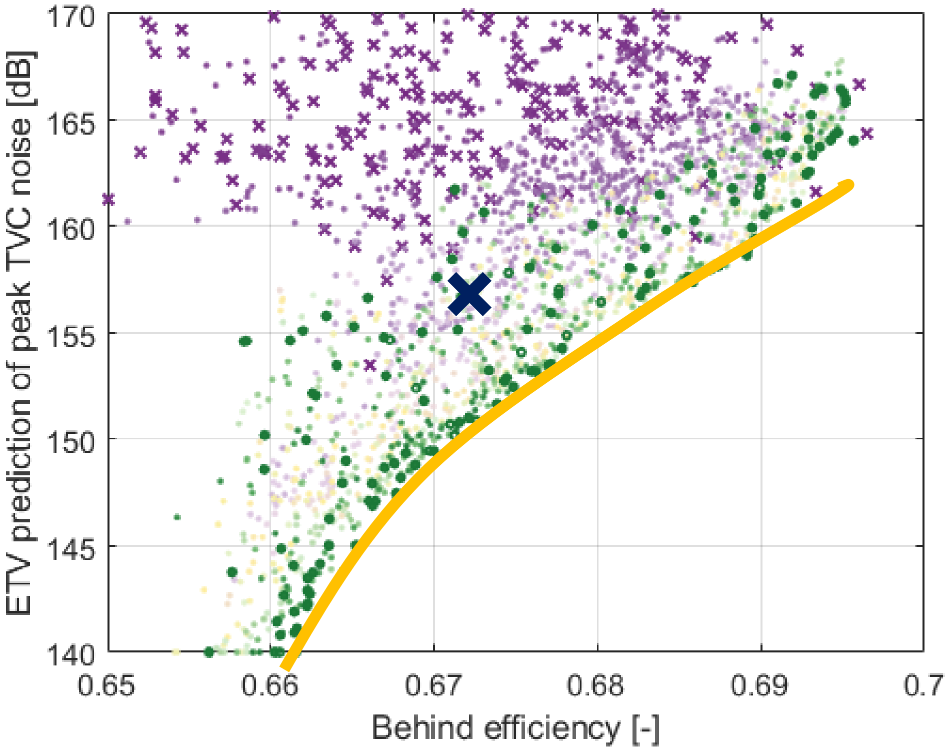




Analyse and determine optimal compromise

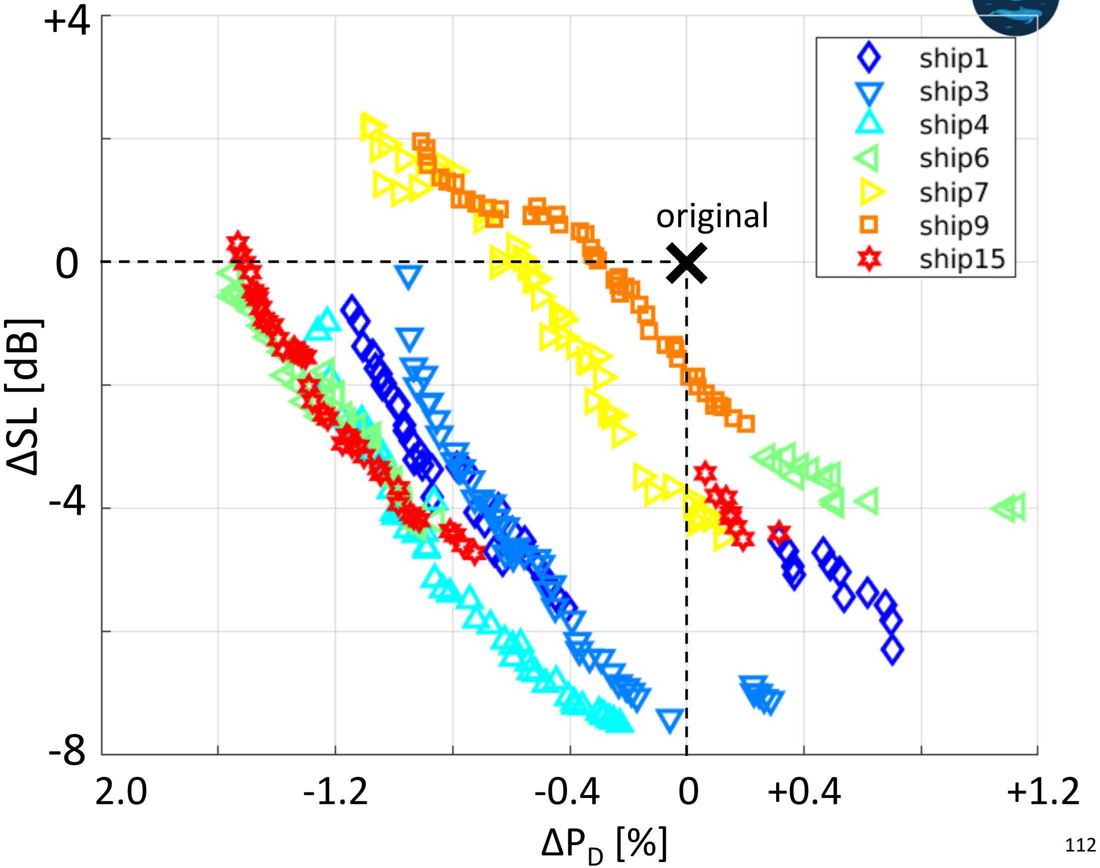
Propeller design



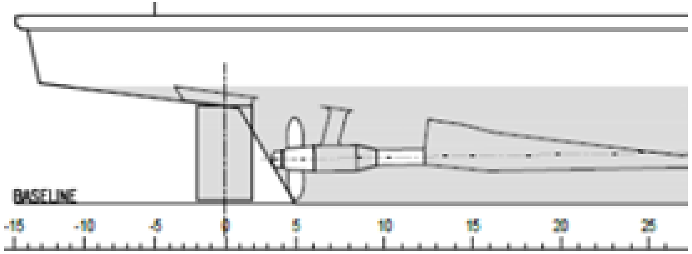


Integrated hull & propeller design

- Traditionally:
  - optimise hull form for resistance
- Integrated aproach:
  - optimise hull form and propeller *simultaneously* for efficiency and URN



Change propulsion concept (SATURN WP4)



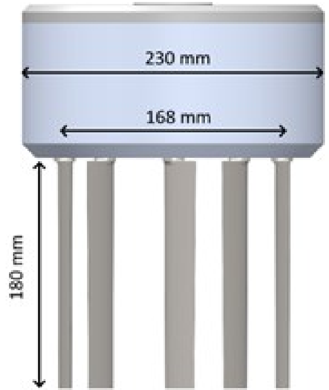
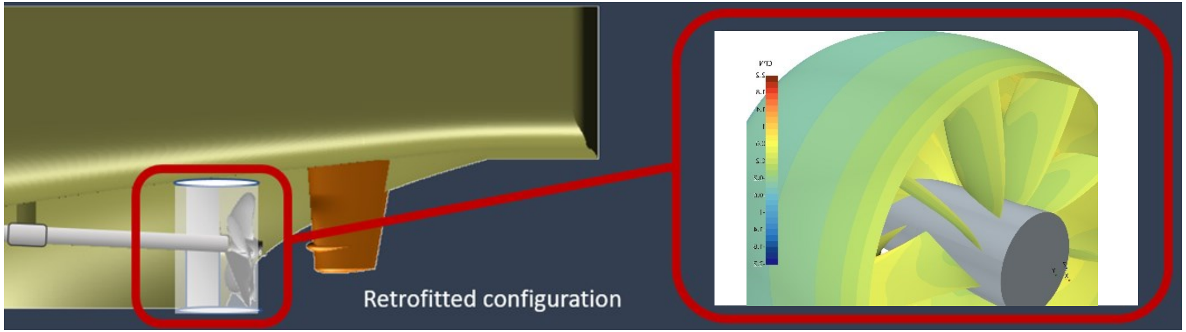
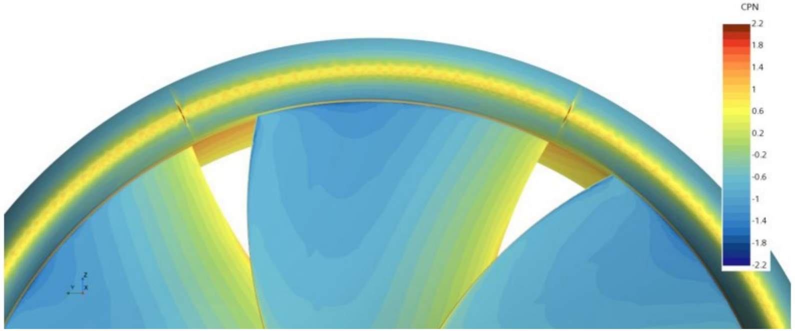


Figure 2 : Drawing of the ADV propeller, with main dimensions.

Change propulsion concept (SATURN WP4)

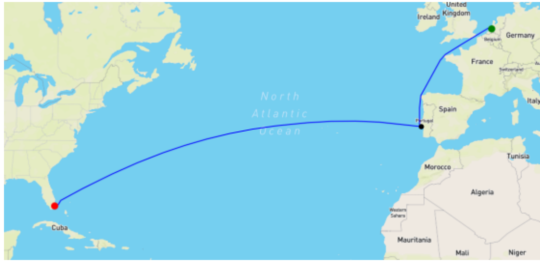


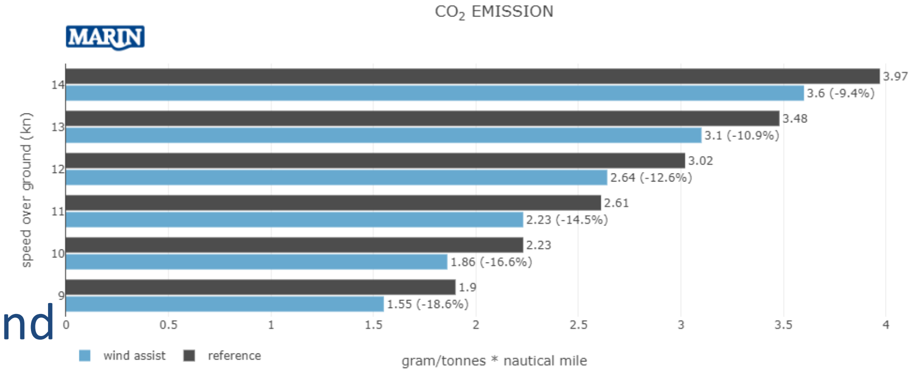


- Suppresses cavitation on rotor
- Improves efficiency +2% in comparison with existing propeller

Wind assistance

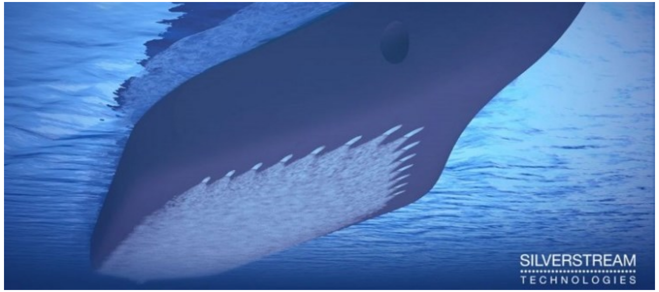
- Wind assistance reduces thrust delivered by propeller
  - Reduced cavitation (reduced noise)
  - Reduced GHG emissions
- Additional complexity in propeller design:
  - Oblique inflow into propeller due to sailing at a drift angle
  - Propeller works has multiple design conditions
  - Consequences thereof on efficiency and noise currently being researched





Air injection

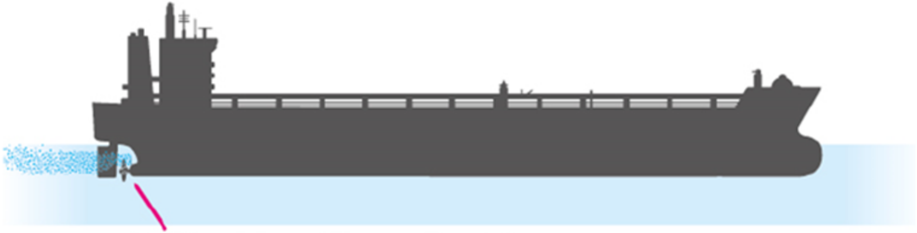
- Air lubrication
  - Various studies show around 5% reduction of fuel consumption



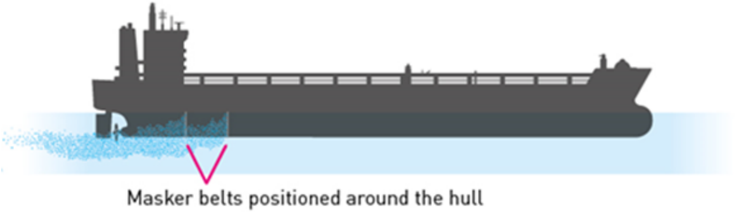
https://www.silverstream-tech.com/

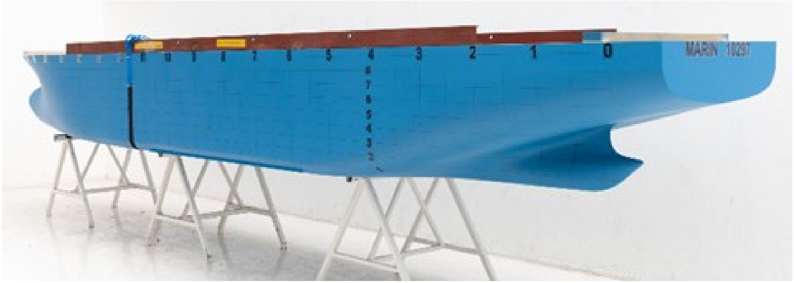
- Along the hull to reduce machinery-induced URN:
  - Masker system

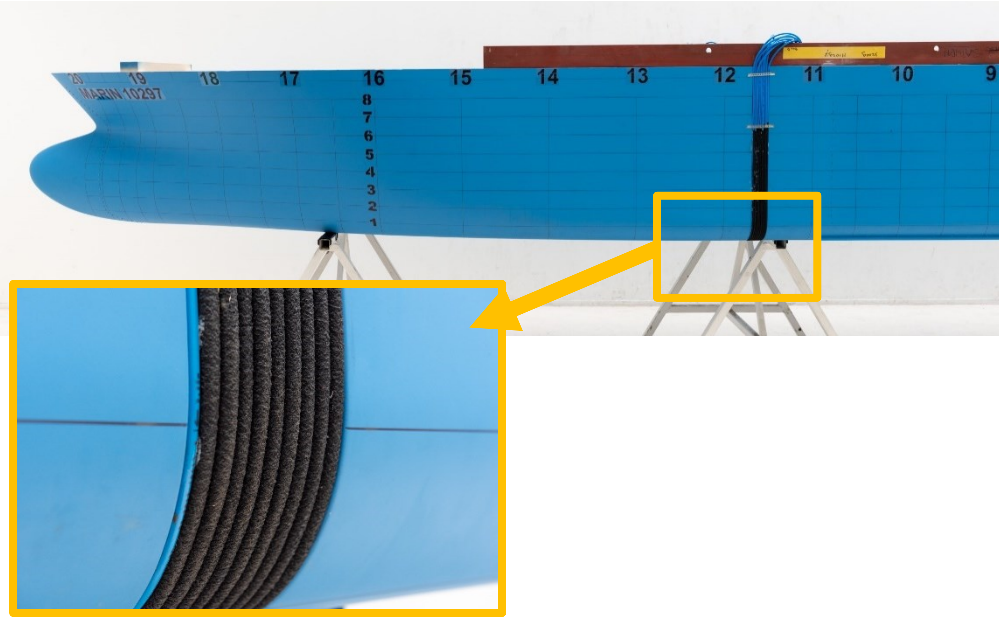
- Into the propeller disk to reduce cavitation-induced URN:
  - Prairie-like system

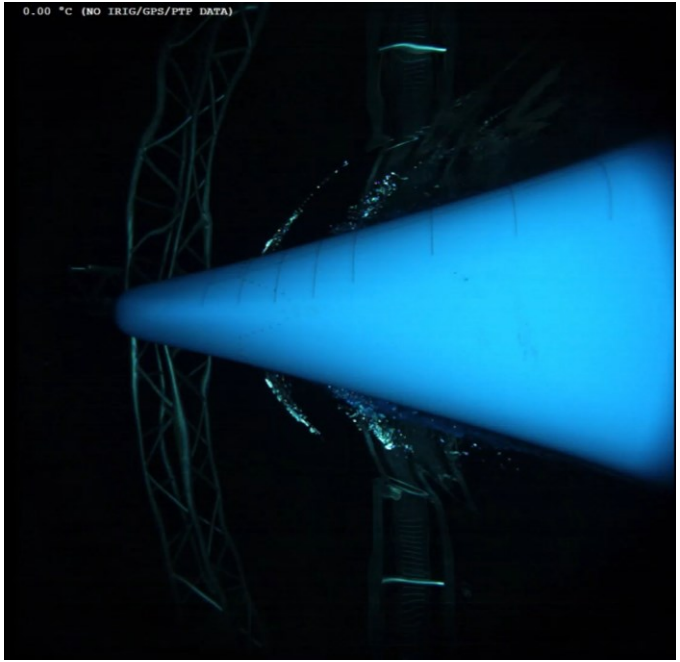


Air injection: Masker system (SATURN WP4)

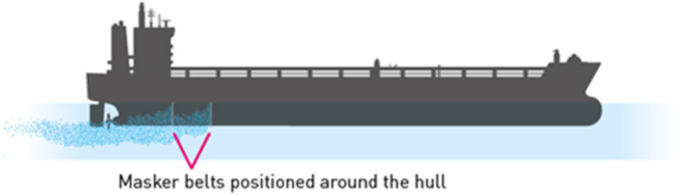


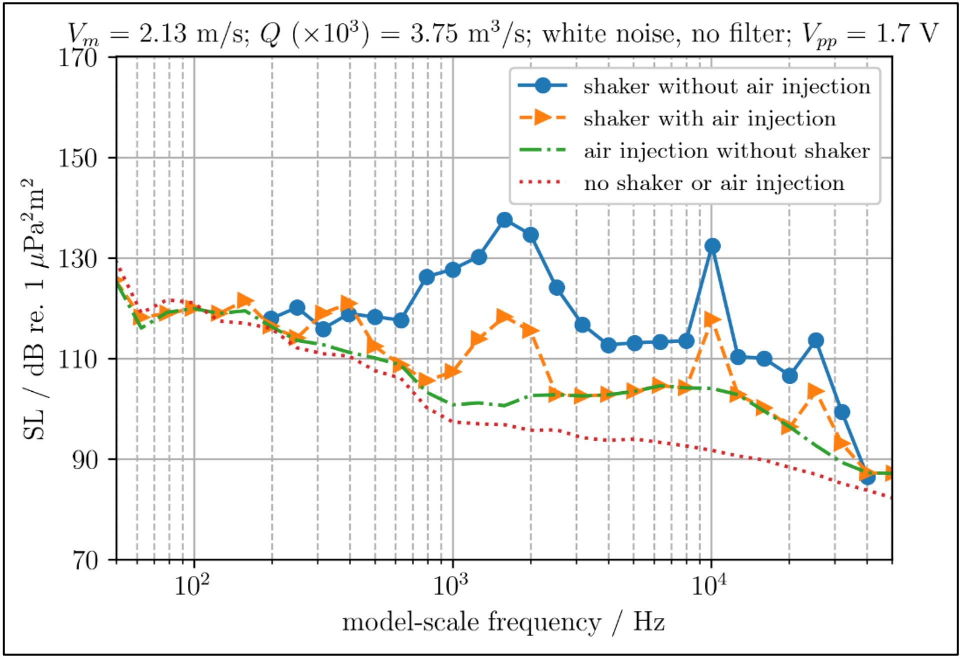


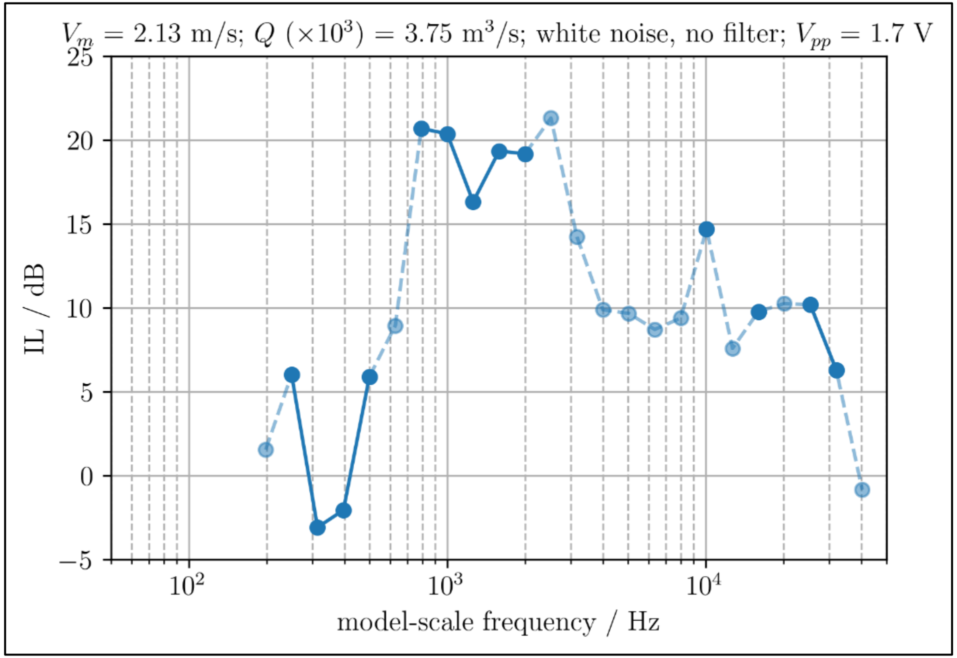




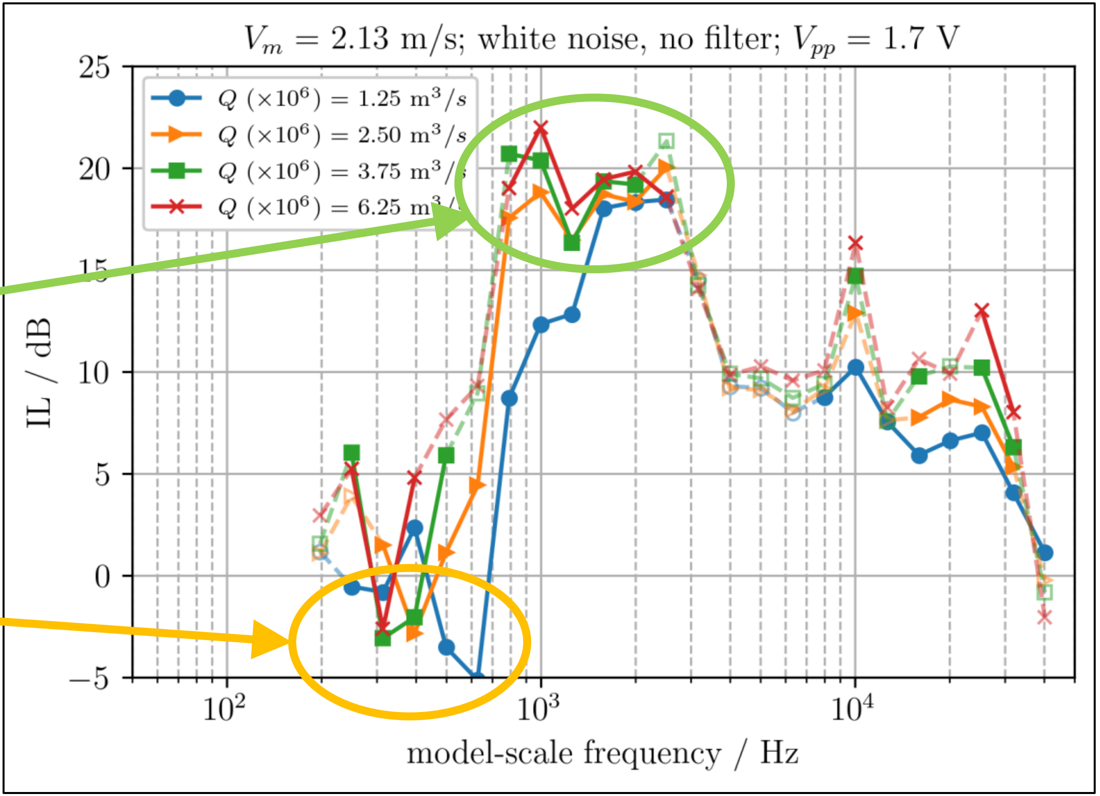
Injection: Masker system (SATURN WP4)







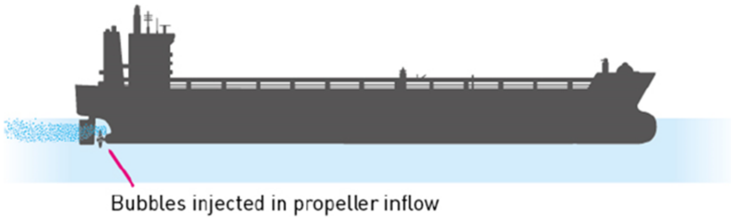
Air injection: Masker system (SATURN WP4)

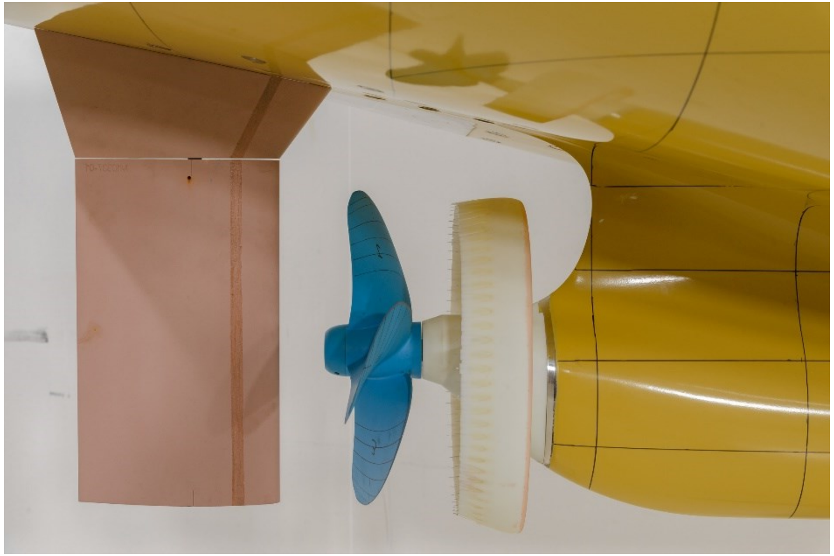


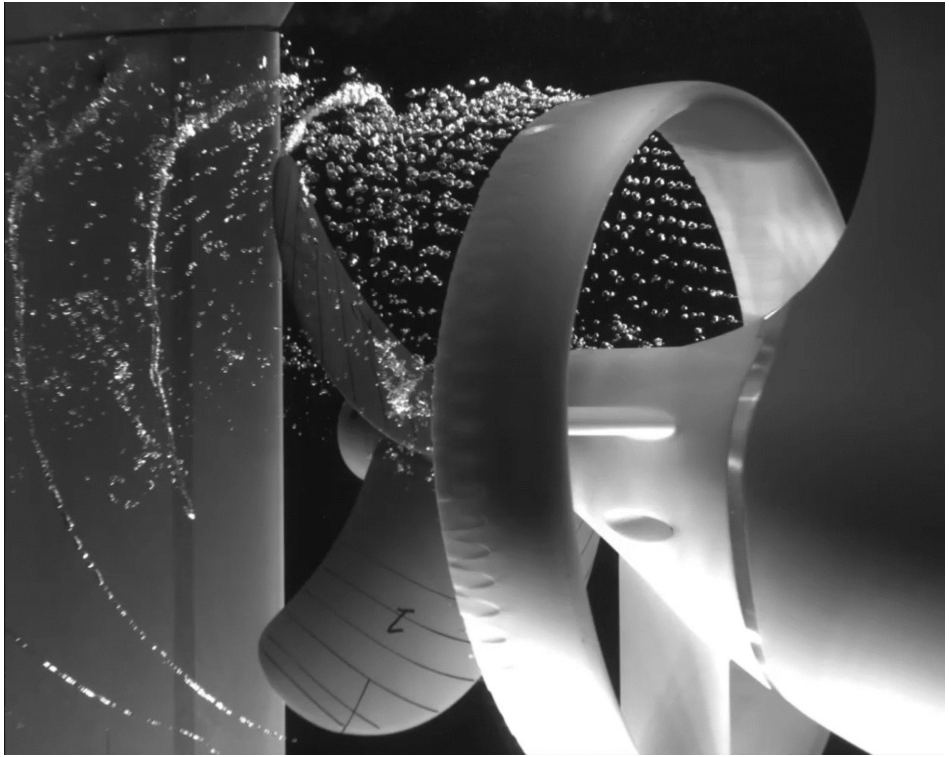
up to 20 dB reduction

sometimes small increase

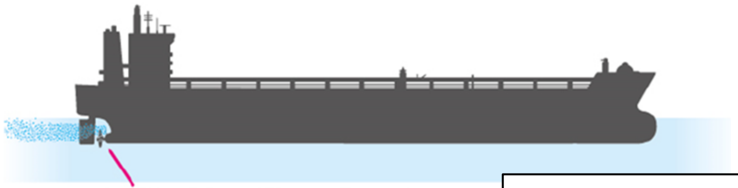
Air injection: Prairie-like system (SATURN WP4)



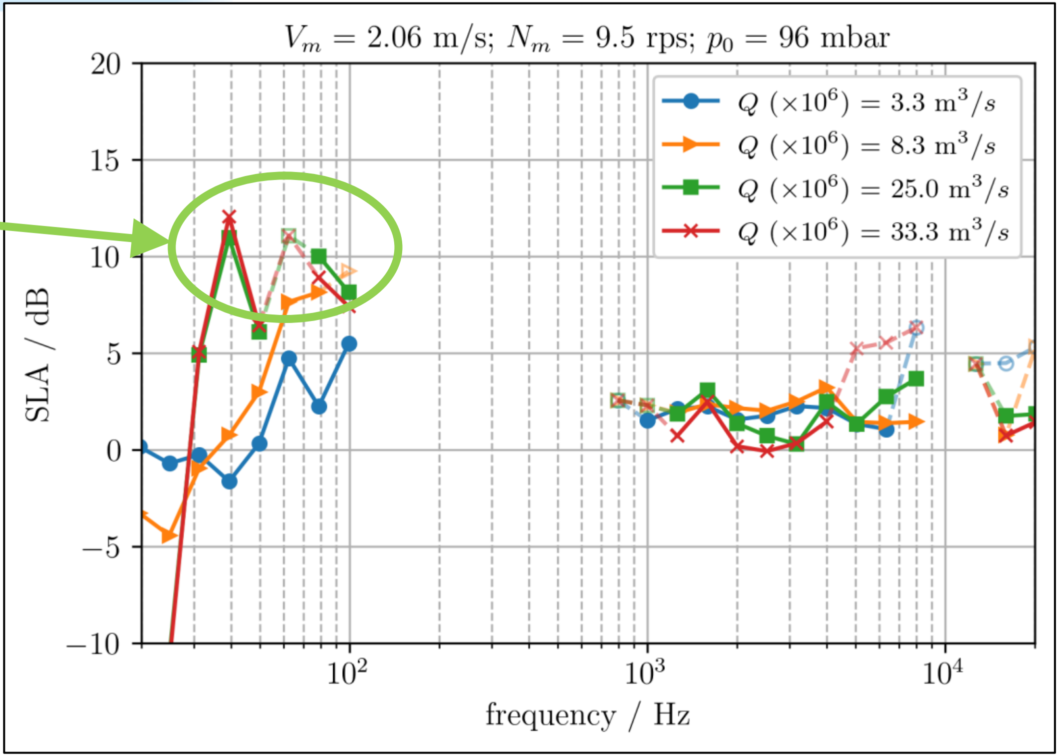




Air injection: Prairie-like system (SATURN WP4)

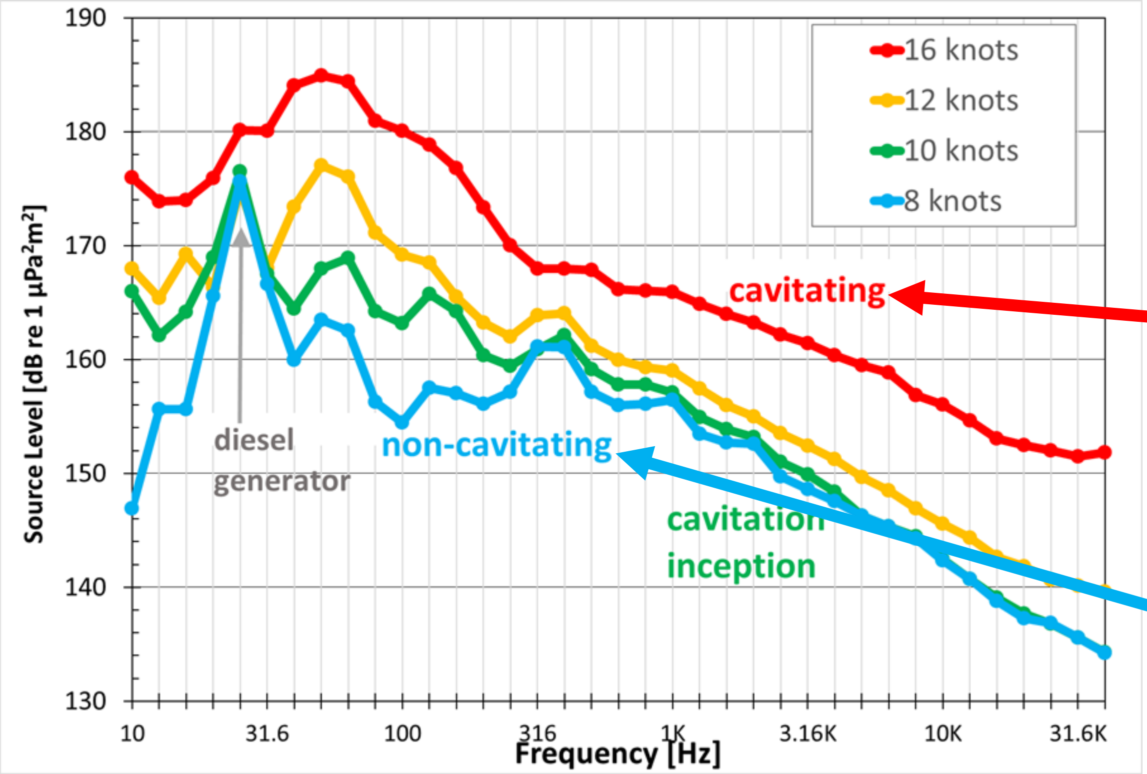


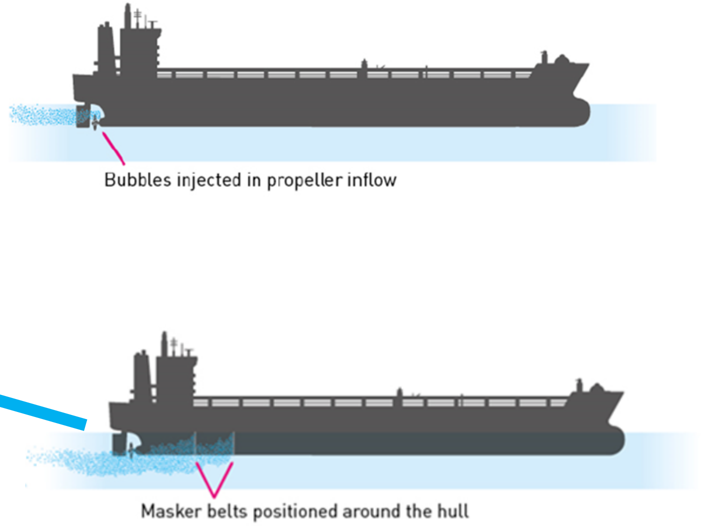
up to 10 dB reduction



- Small influence of air bubbles on propeller thrust and efficiency

Application of air injection: 173 m cargo vessel

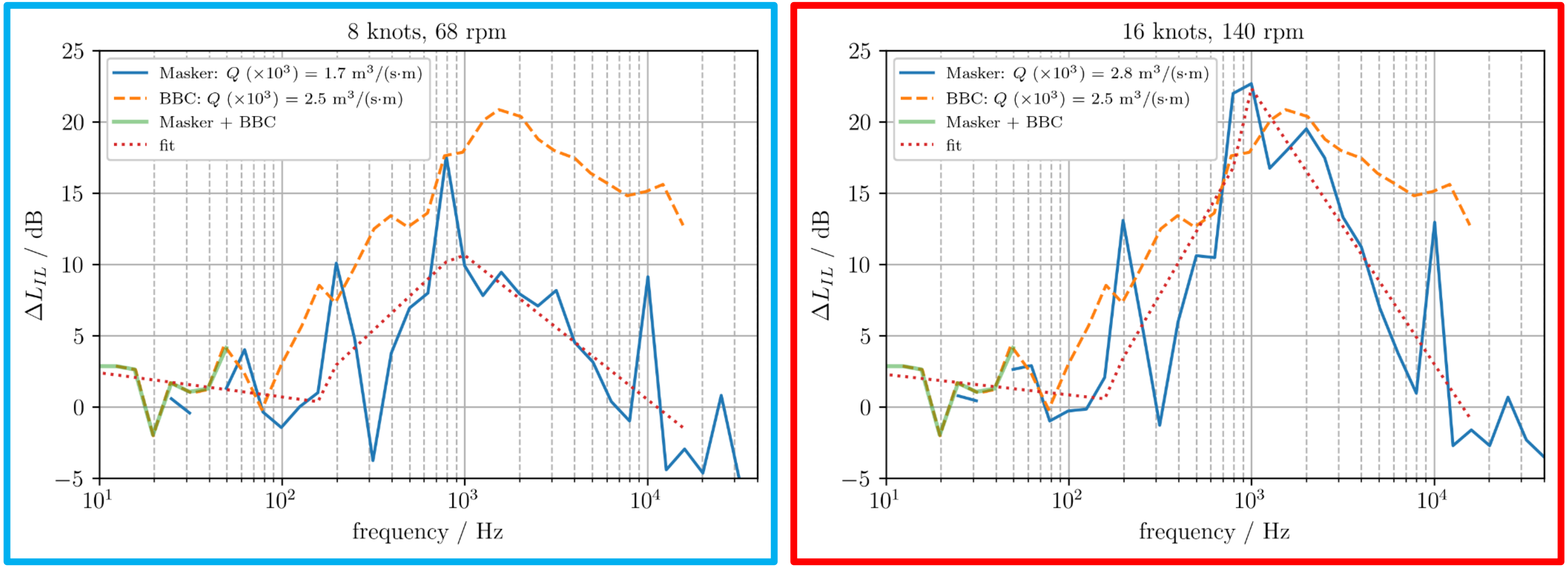




Source: Arveson & Vendittis (2000) 173 m cargo vessel

Application of air injection: 173 m cargo vessel

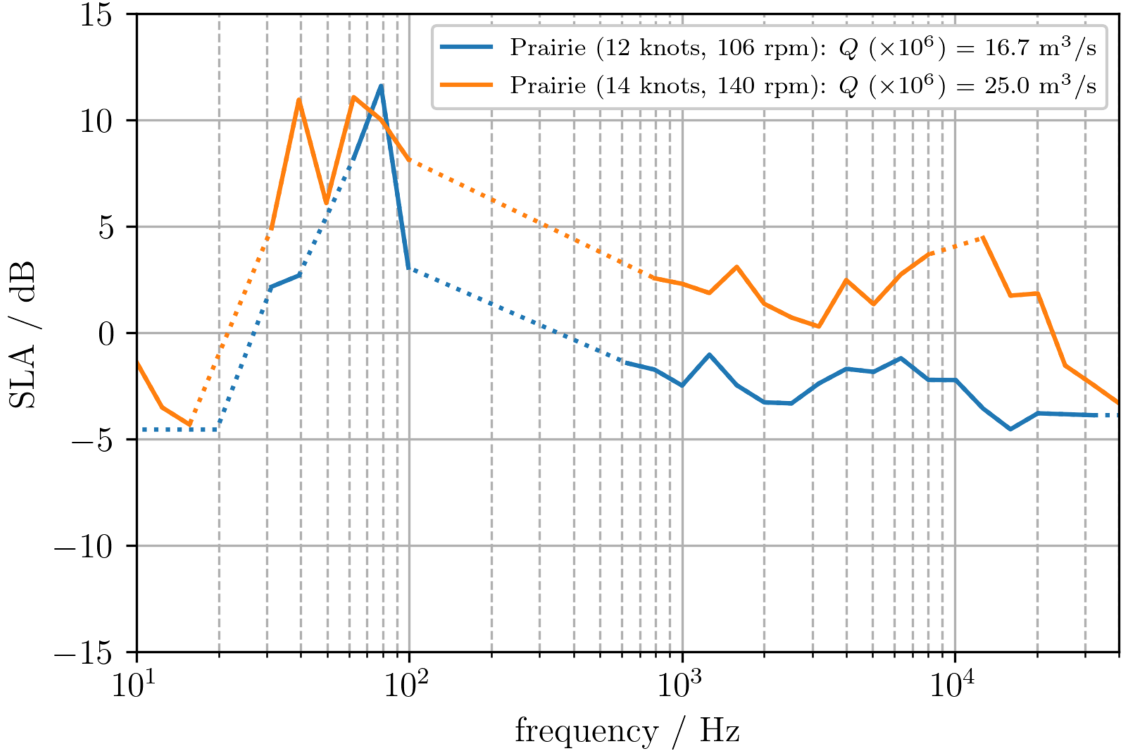
- Insertion loss due to Masker system



Big Bubble Curtain data: M.A. Bellmann (2014). Overview of existing Noise Mitigation Systems for reducing Pile-Driving Noise

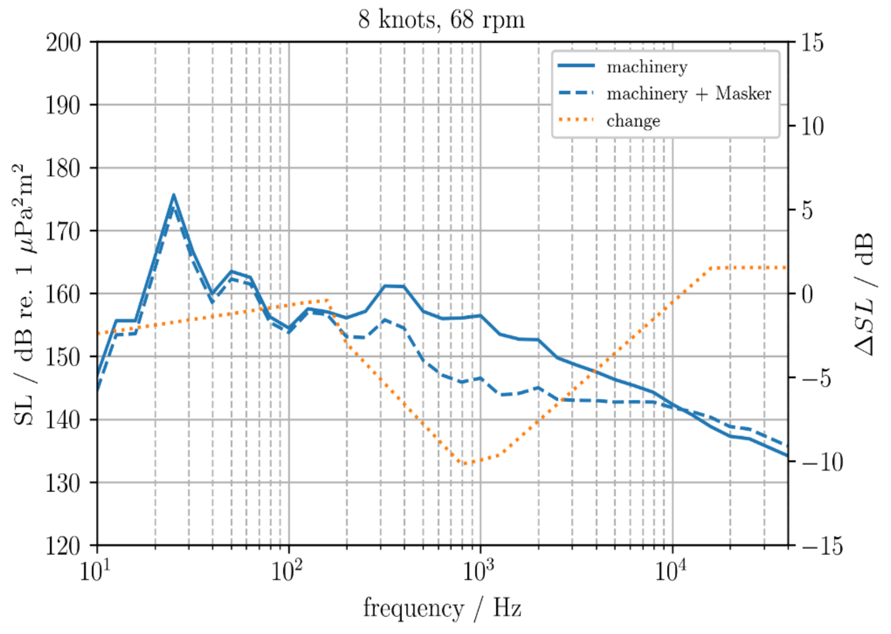
Application of air injection: 173 m cargo vessel

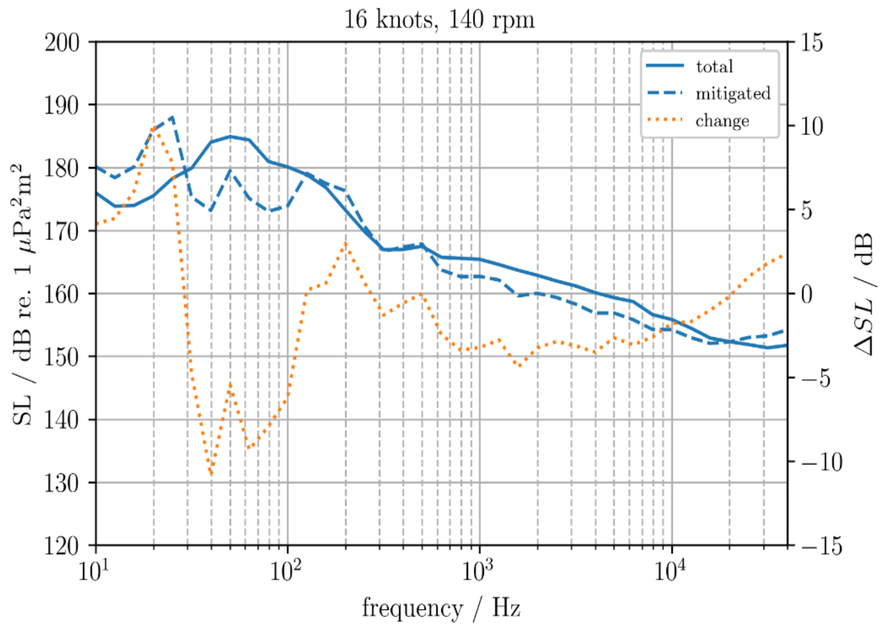
- Source level attenuation due to Prairie-like system



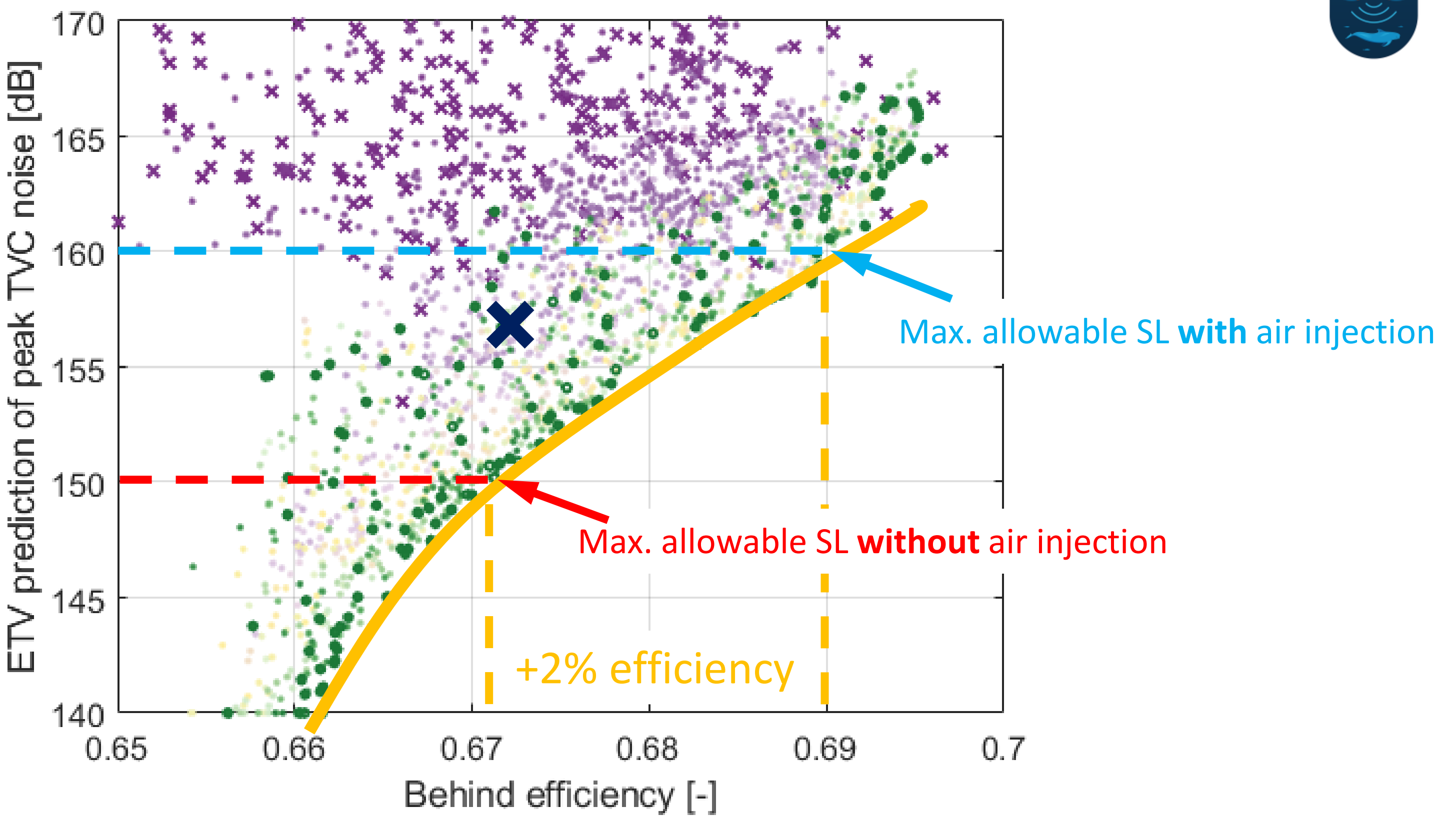
Application of air injection

- Resulting noise levels



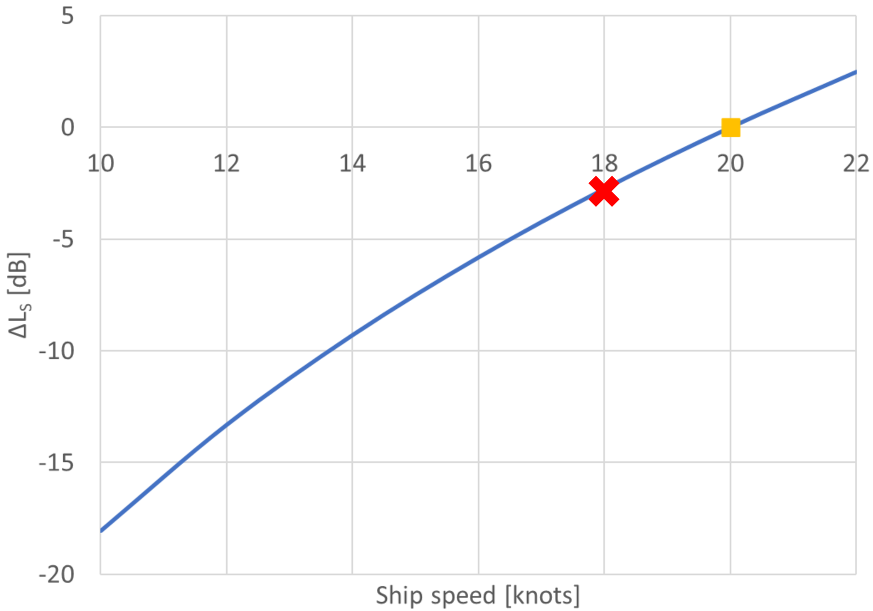


Prairie-like system: influepropeller design



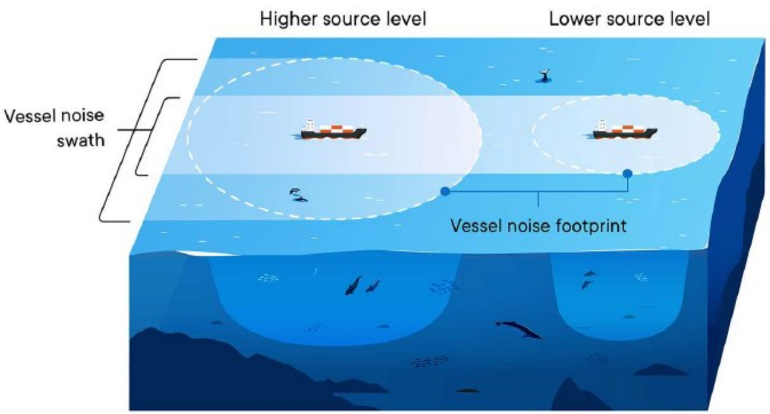
Effect of speed reduction on URN and GHG emissions

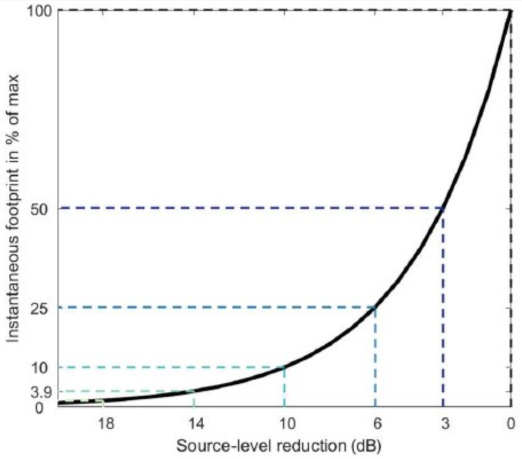
- Speed reduction very effective against URN
  - JOMOPANS-ECHO model*
- 10% speed reduction yields:
  - 3 dB noise reduction
  - 13% GHG emission reduction**
  - Some studies state 30% GHG emission reduction
- Big step in noise reduction:
  - Reduce speed to cavitation inception speed (CIS)
  - CIS not in JOMOPANS-ECHO model



* MacGillivray & De Jong (2021)
** Faber et al. (2017)

Effect of speed reduction on URN (SATURN WP3)





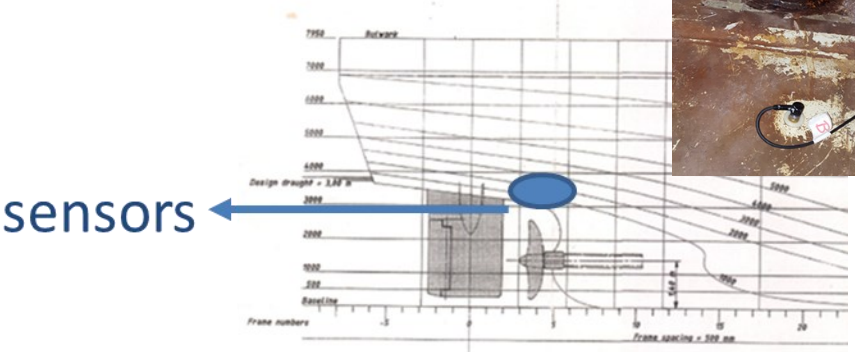
Source: Findlay et al. (2023). Small reductions in cargo vessel speed substantially reduce noise impacts to marine mammals

- 25% speed reduction:
  - Source-level reduction of 6 dB:
    - 50% reduction in the swath
    - 75% reduction in the instantaneous acoustic footprint
  - Transit time increased by 25%
- Net reduced noise impact: footprint deceases more than transit time increases

Cavitation URN estimation by onboard sensors

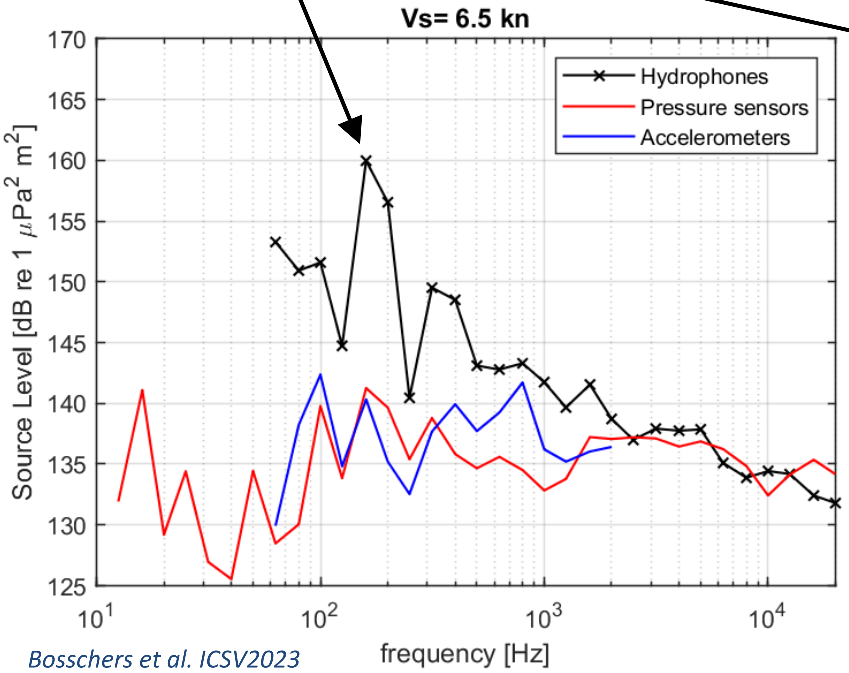
- How slow is slow enough?
- Onboard monitoring to estimate URN real-time
- Tested on RV Pelagia
- 4 pressure sensors and 4 accelerometers on hull above propeller
- Real-time advice:
  - Reduce speed to reduce noise

Bosschers et al. ICSV2023

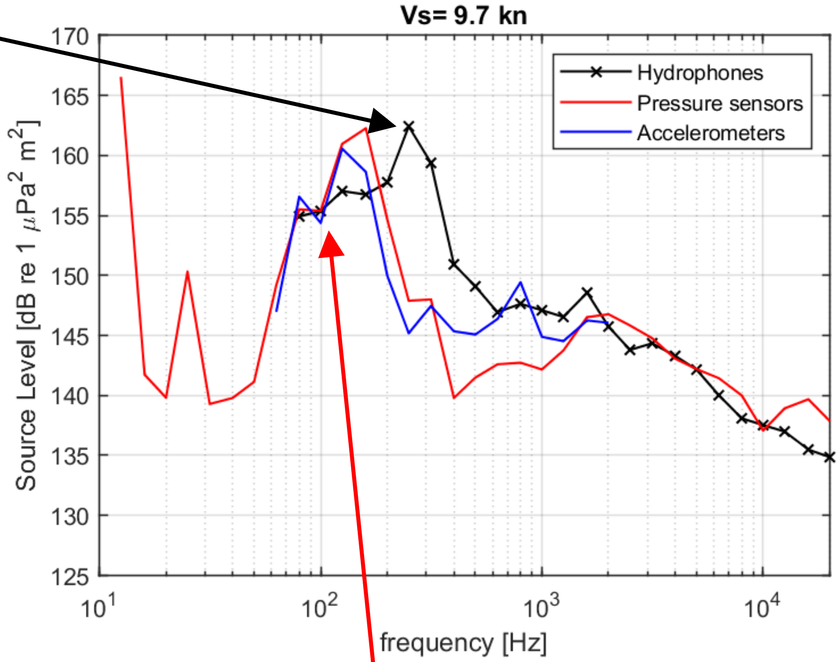


Validation of URN estimation by onboard sensors

Peak in URN caused by diesel generator



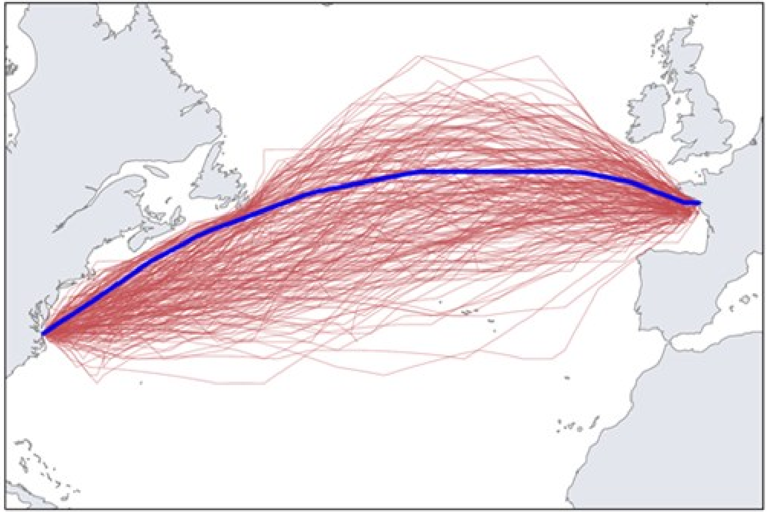
Bosschers et al. ICSV2023



Peak in pressures caused cavitation

Route optimisation

- Optimise route for minimum noise impact:
  - Minimise speed (in areas with sensitive wildlife)
  - Optimal use of wind assistance
  - Just-in-time arrival
  - Try to avoid increasing speed to compensate for slowing down

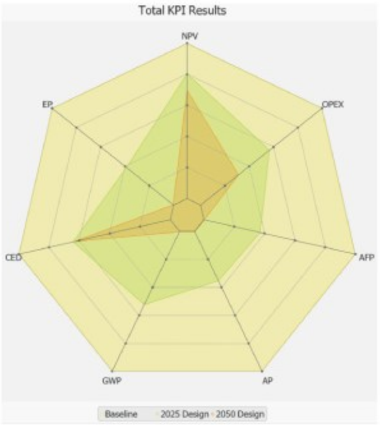


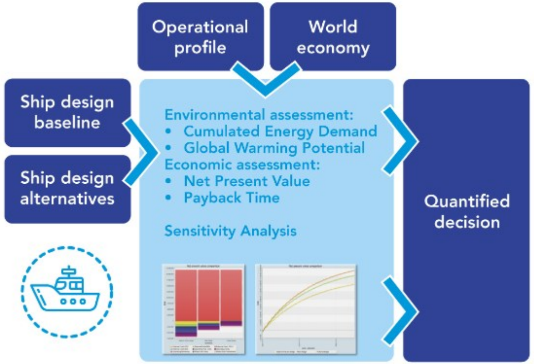
- More ships needed due to speed reduction:
  - Reduced fuel costs compensate operational costs of additional ships

Lee et al. (2015)

Cost-benefit analysis (SATURN WP4)

- SATURN: Cost-benefit analysis of mitigation solutions
- KPI: Capital costs + operational costs
  - Depends on ship type and operational profile
- KPI: Reduction of impact on marine species
  - Translate change in source levels to change in impact for single ship
- KPI: Impact on energy efficiency
  - Use will be made of LCPA software





Summary

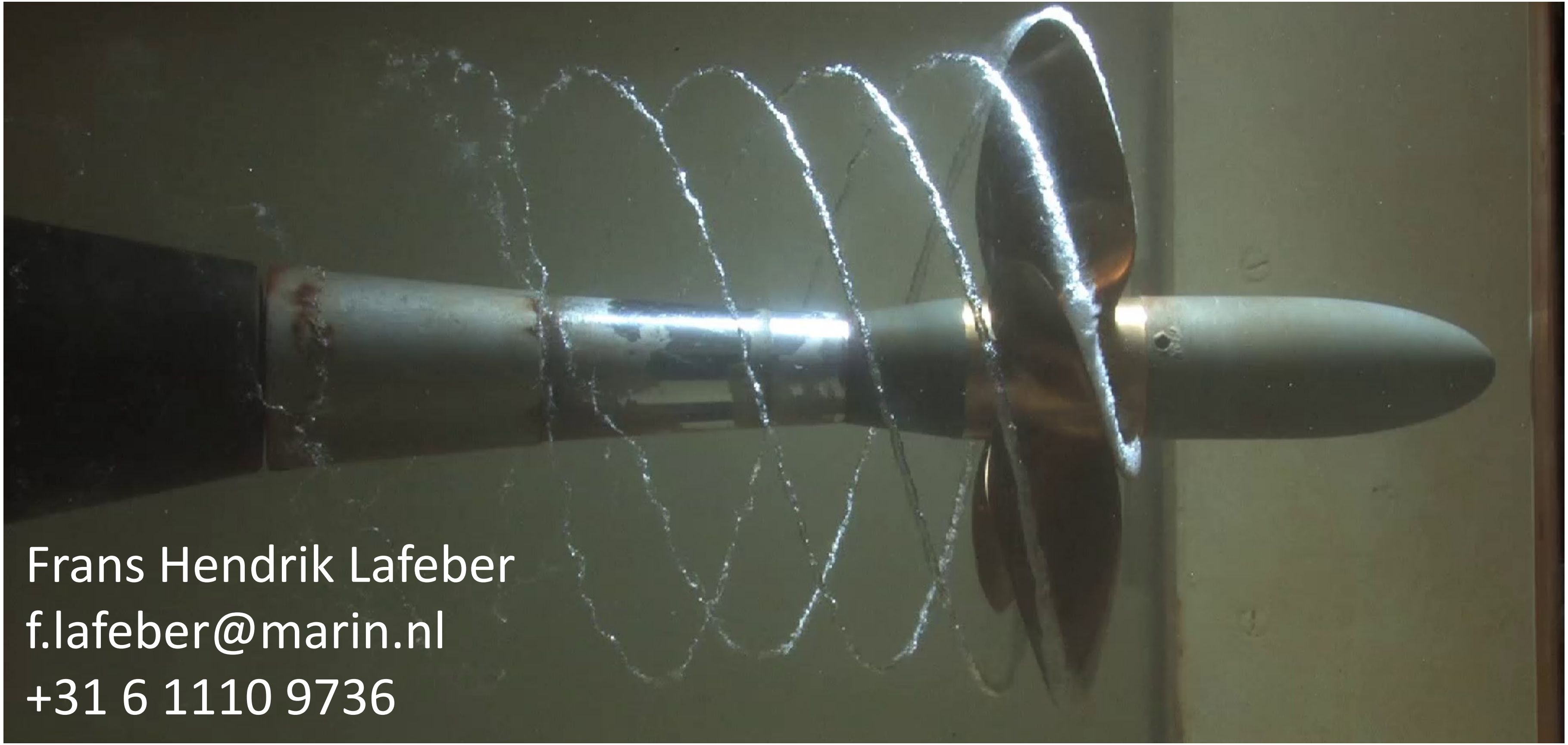
- To be done
- What are win-win solutions?
  - Speed reduction is a win-win but there is a need to deliver goods on time
  - Technological mitigation measures can help to increase flexibility in ship speed while maintaining acceptable noise and GHG emissions

Saturn

Developing Solutions for Underwater Radiated Noise

SATURN has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 101006443.

Thank you



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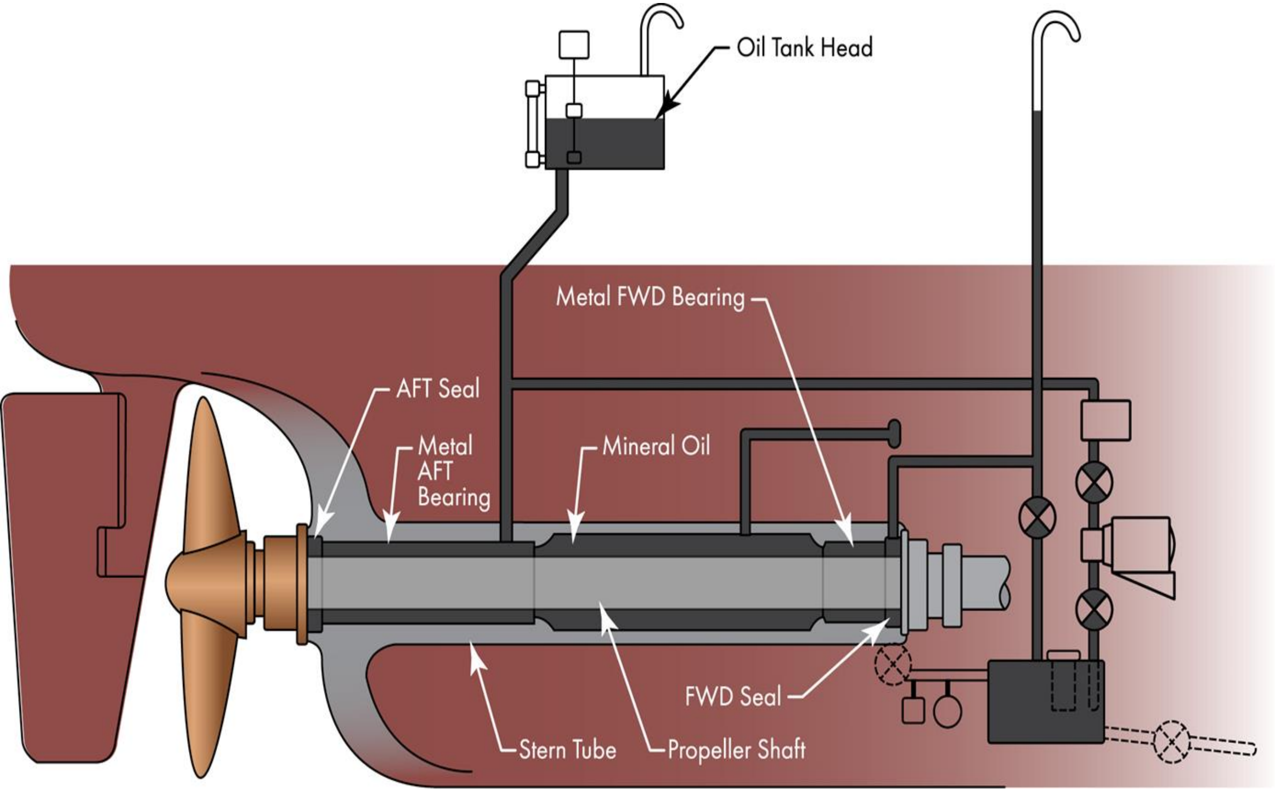
REVOLUTIONARY
T-BOSS STERNTUBE-LESS DESIGN
Saving Shipowners Thousands
While Keeping Oceans Clean

It’s all about stopping oil pollution



95% of Merchant Fleet still Use Sterntube Oil Bath System

Sterntube Oil pollution is a regular occurrence

Ship type	Discharge rate ($L\,d^{-1}$)
RoPax ship	6
Container/ro-ro cargo ship	4
Passenger cruise ship	2
Passenger ferry	2
Cargo ship	6
Refrigerated cargo ship	4
Container ship	5
Chemical tanker	4
Crude-oil tanker	4
Oil products tanker	3
LPG tanker	3
LNG tanker	1
Fishing vessel	2
Vehicle carrier	3

Source: J.-P. Jalkanen et al., 2021: Leakage rates of stern tube oil for different ship types.

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Accidental Oil discharge from sterntube

Webinar hosted by Riviera Maritime Media, 25 Feb. 2021

Q&A with Wartsila Shaft Line Solutions Team

Q: How many emergency seal repairs do you perform in a year?

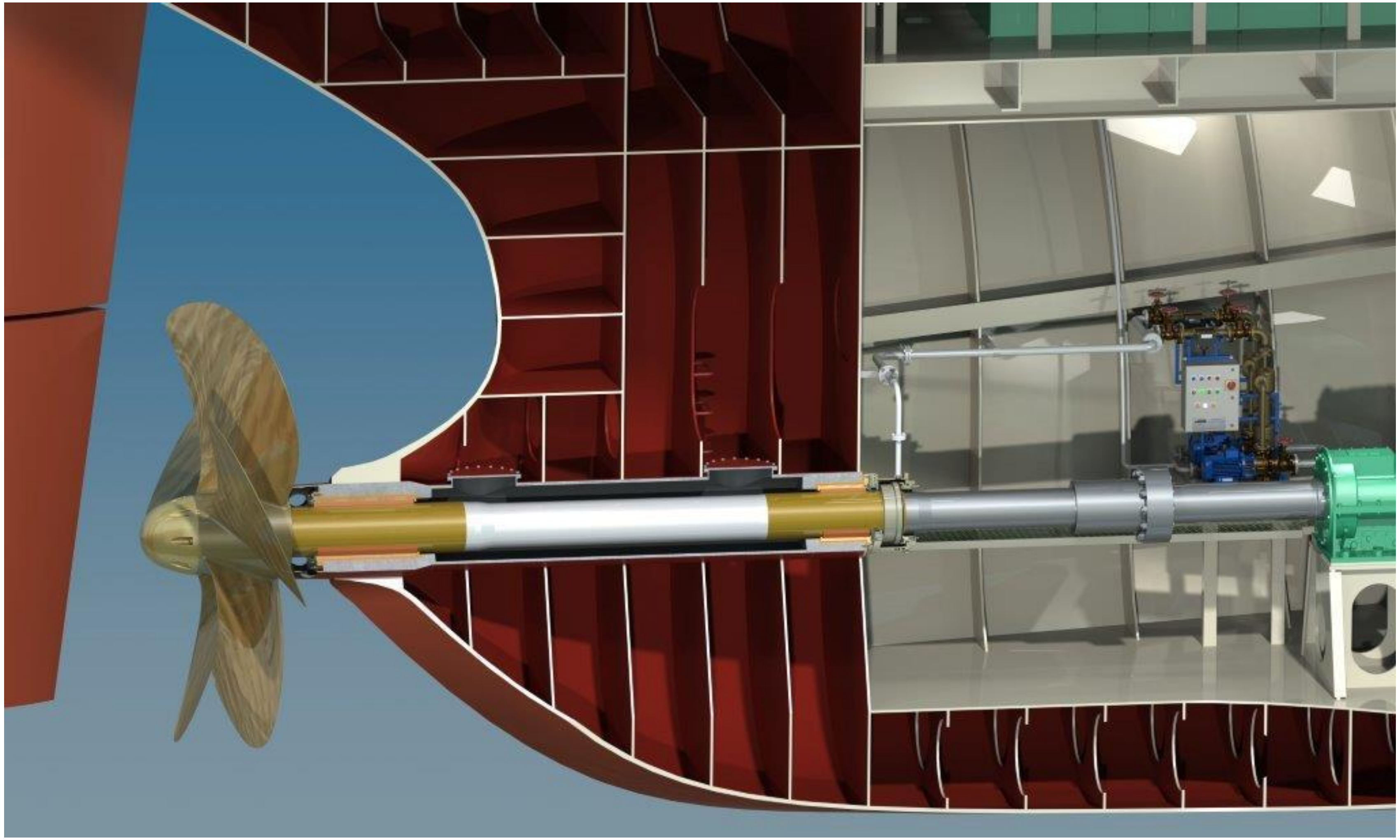
A:* Good question.. *Several hundred I would say.

(Answered by Wärtsilä Shaft Line Solutions)

A: It is a tricky question and from the top of my head I cannot give an exact figure for emergency seal repairs. There are a good number of emergency repairs coming from fishing lines, ropes and some are done dockside and some underwater.

(Answered by Wärtsilä Shaft Line Solutions)

Modern open seawater-lubricated system (sterntube)



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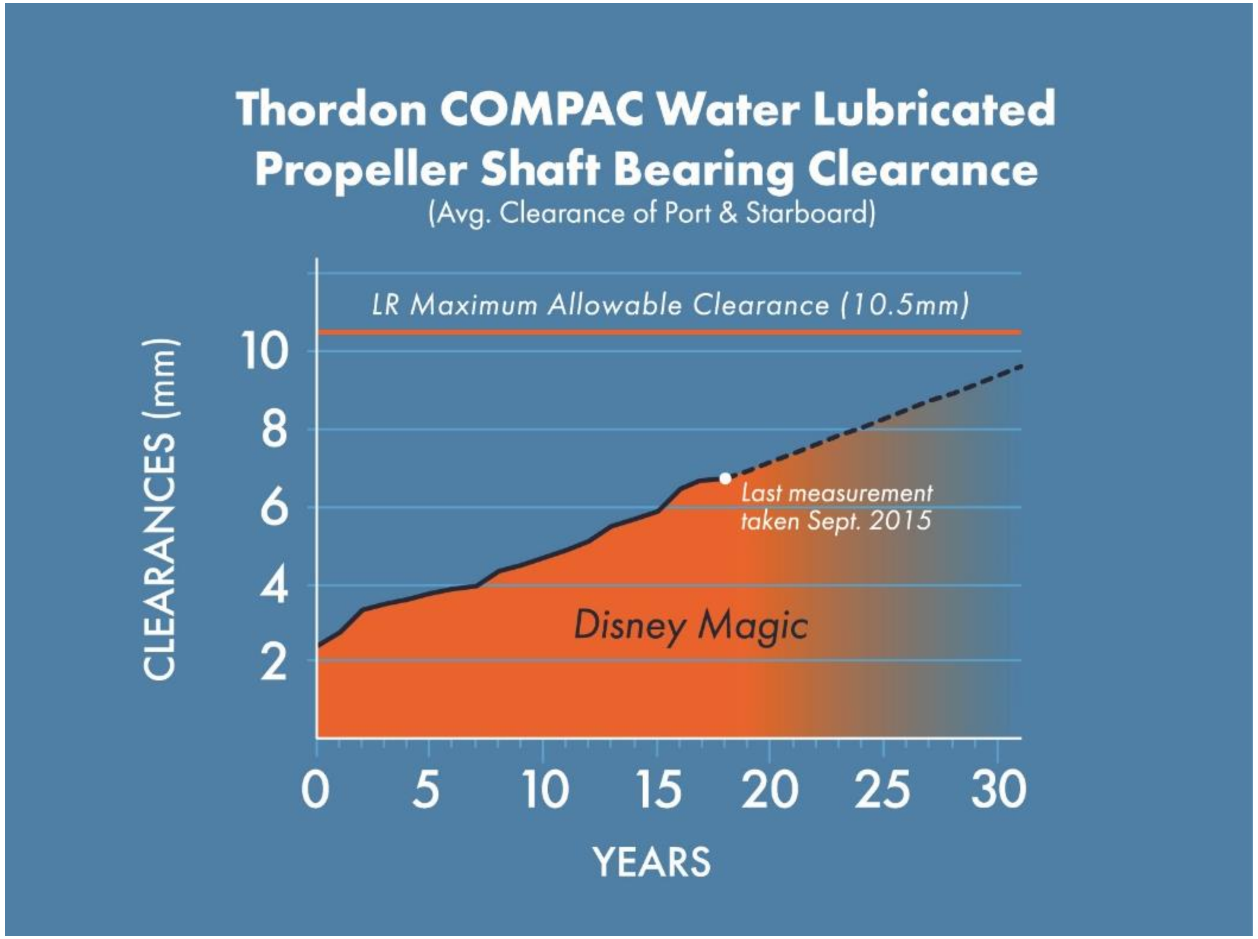
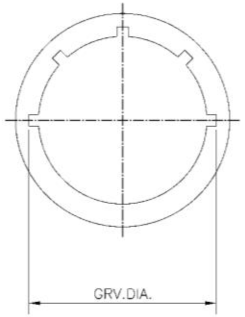
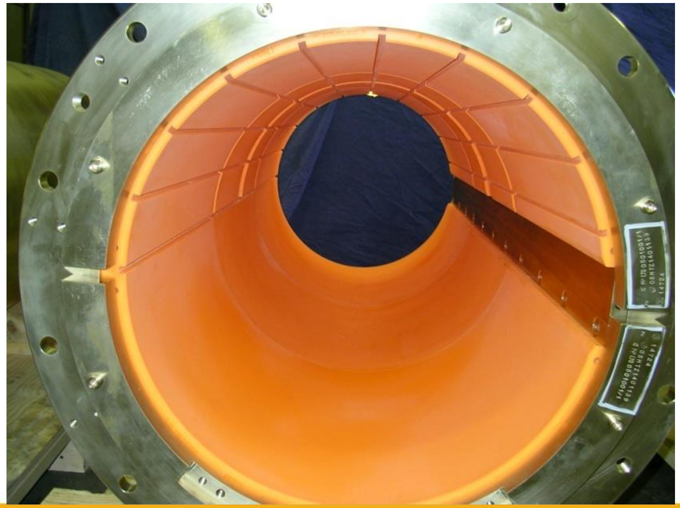
Modern Seawater-lubricated Bearings – Long Life



Elastomeric Polymer Alloy COMPAC Bearings



- Toughness, abrasion resistance, shock loading
- Typically, 2:1 L/D ratio for AFT bearing and 1:1 L/D ratio for FWD position
- Class approved design for pressures to 0.6MPa (87 psi or 6 Bar)
- Fitted in bronze carrier or installed directly into stern tube



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Thordon Bearings – Elastomers

Thordon Bearings Inc. - YouTube

https://www.youtube.com › user › ThordonBearings

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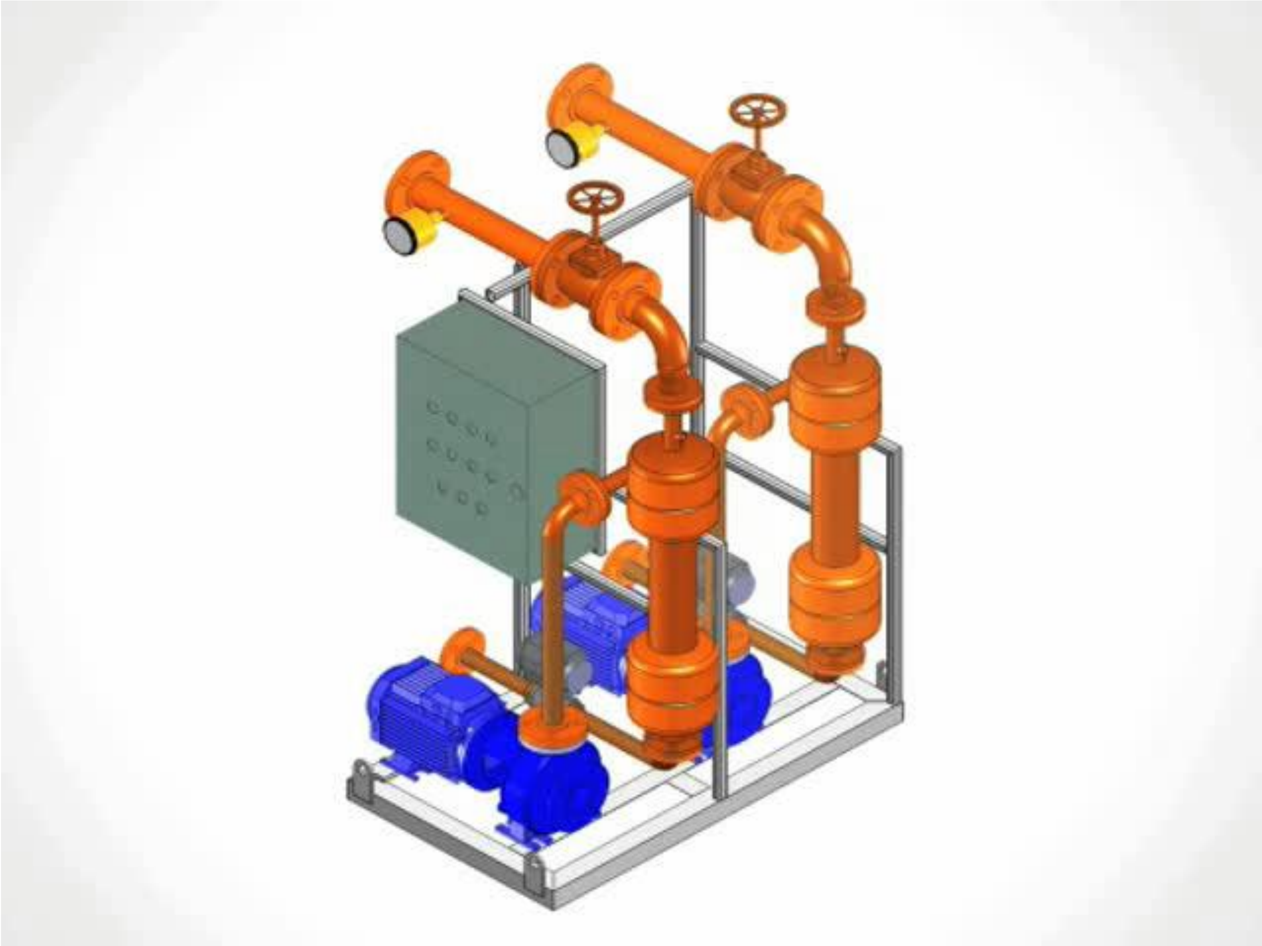
Water Quality Package

- Designed to provide a clean supply of water to the water lubricated bearings
    - Controlled environment
        - Flow is monitored and low flow alarms provided
    - Removes abrasives
    - Improves bearing wear life
    - Self contained unit
    - Several configurations available

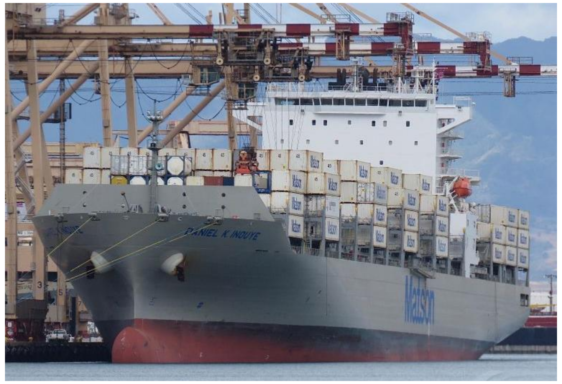
Thordon Water Quality Package



Seawater Lubricated Shaftlines…

Already in Use





Why Seawater?

LIFETIME
BEARING WEARLIFE
GUARANTEE

Proven Performance

- Fitted to over 700 commercial ships
  - Thordon (500), Wartsila, KEMEL, Duramax, Lagersmit, Maprom
- Lifetime Propeller Shaft Bearing Wearlife Guarantee

Zero Pollution Risk *(Zero Fines)*

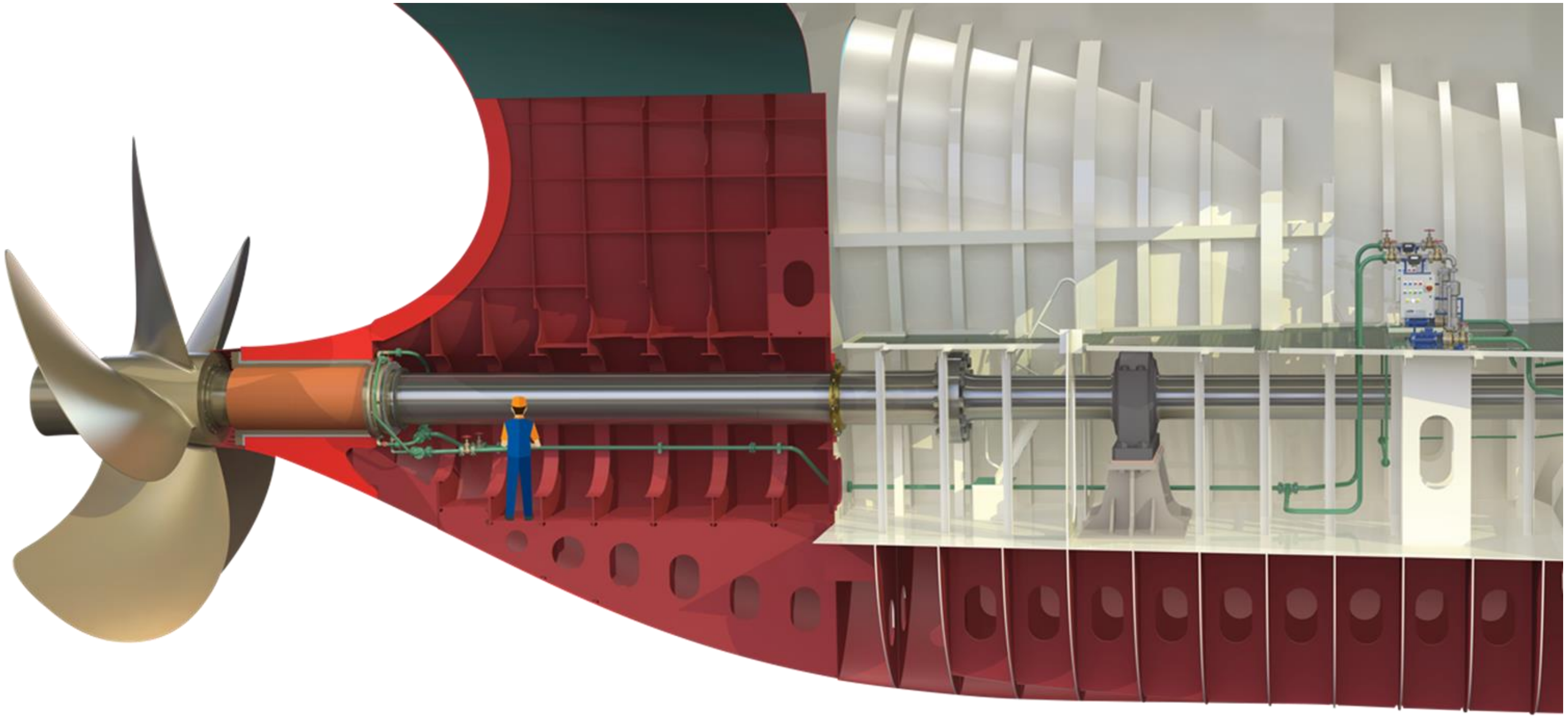
Eliminates Oil and
Grease Discharges
(Seawater Lubricated)

- Eliminate oil from below the waterline
- Meets US Vessel General Permit (VGP) and Polar Code

All major Classification Societies agree…

Extended Shaft
Withdrawal Notations for
Open Seawater-Lubricated
Propeller Shafts are
Approved by all
Major Class Societies.

THE FUTURE…
REVOLUTIONARY STERNTUBE-LESS DESIGN – T-BOSS



A Joint Development Project

Elimination of the Stern Tube

Joint Development R&D and Innovation project with:

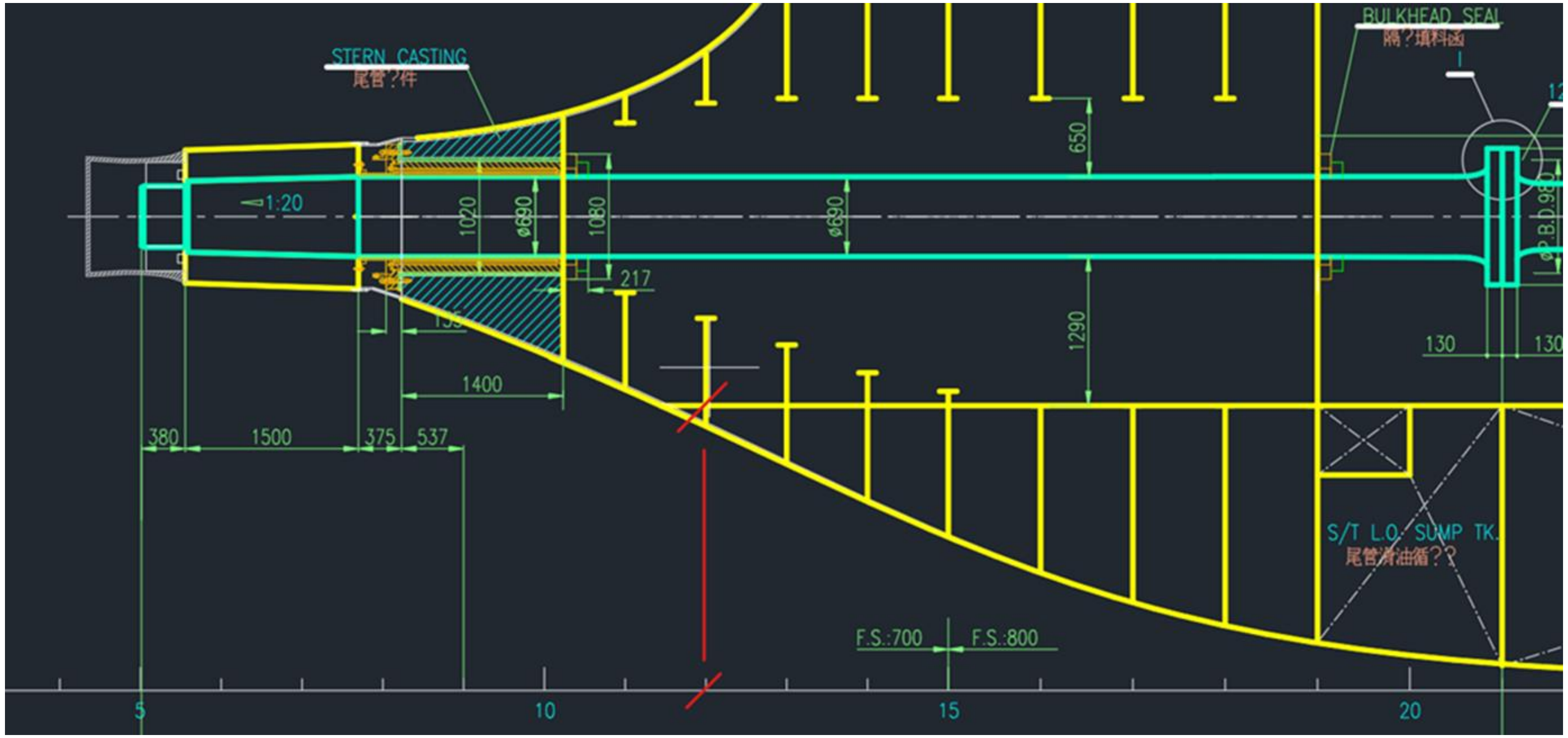
- ABS (American Bureau of Shipping), Greece office
- CSSC-SDARI, China
- Thordon Bearings, Canada
- National Technical University of Athens (NTUA), Greece

Key Focus

- Environmental impact by addressing the oil leakage from sterntube seals
- Sterntube removal and aft vessel interior re-designed
- Lower shipbuilding and maintenance costs for the ship owner
- No Shaft Withdrawal

Sterntube-less vessel Concept

- Sterntube, Aft Seal and Forward Sterntube Bearing Removed
- Aft Sterntube bearing replaced with Seawater lubricated bearing
- Irregularly Shaped Dry Aft Stern Chamber formed

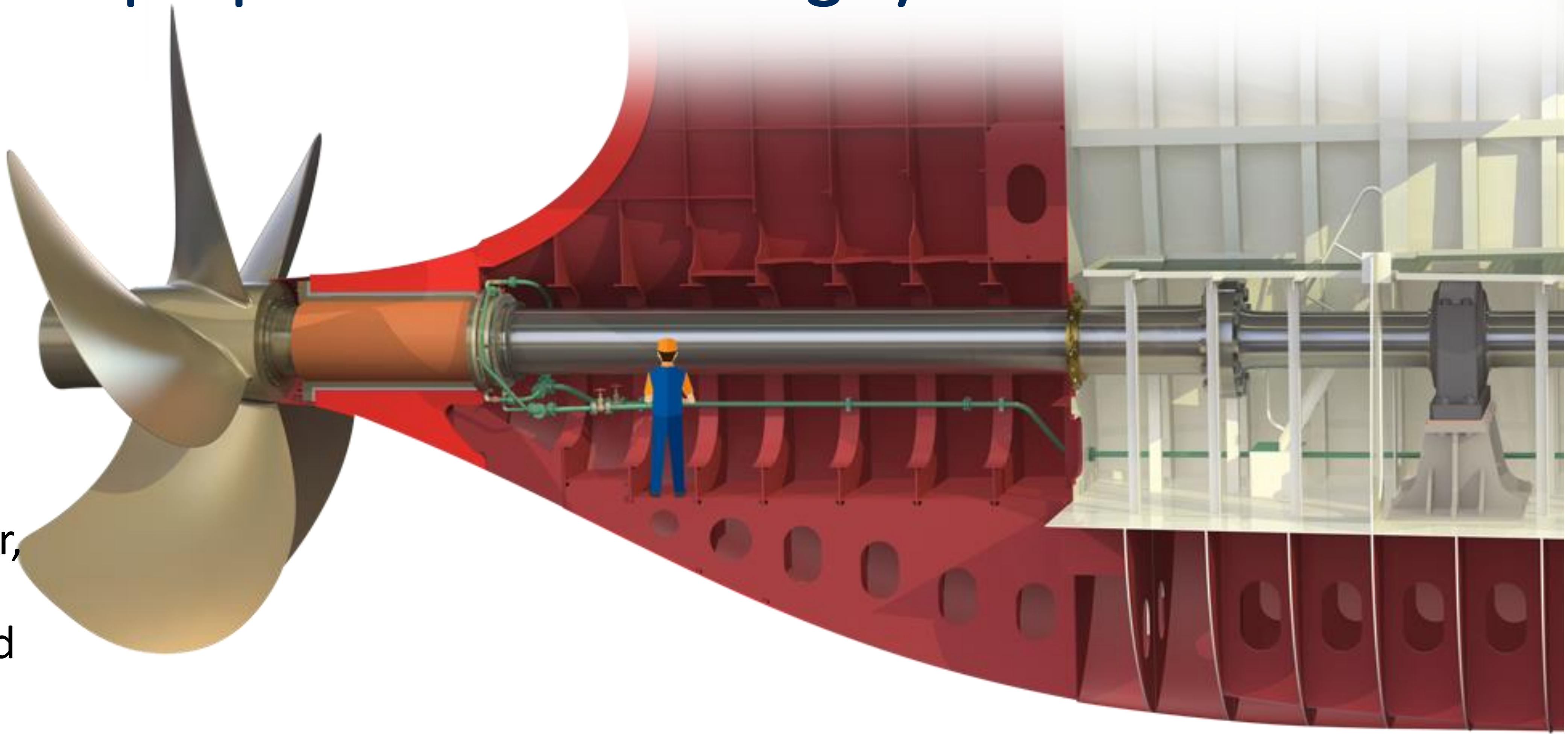


Design modifications to a sealed oil sterntube system

- Remove Sterntube
- Remove Forward Sterntube Bearing
- Replace AFT Sterntube Bearing with Water Lubricated Bearing
- No Aft Seal, Fwd Seal only
- Shorten shaftline, Optimize Engine Room Space, Increase Cargo Space

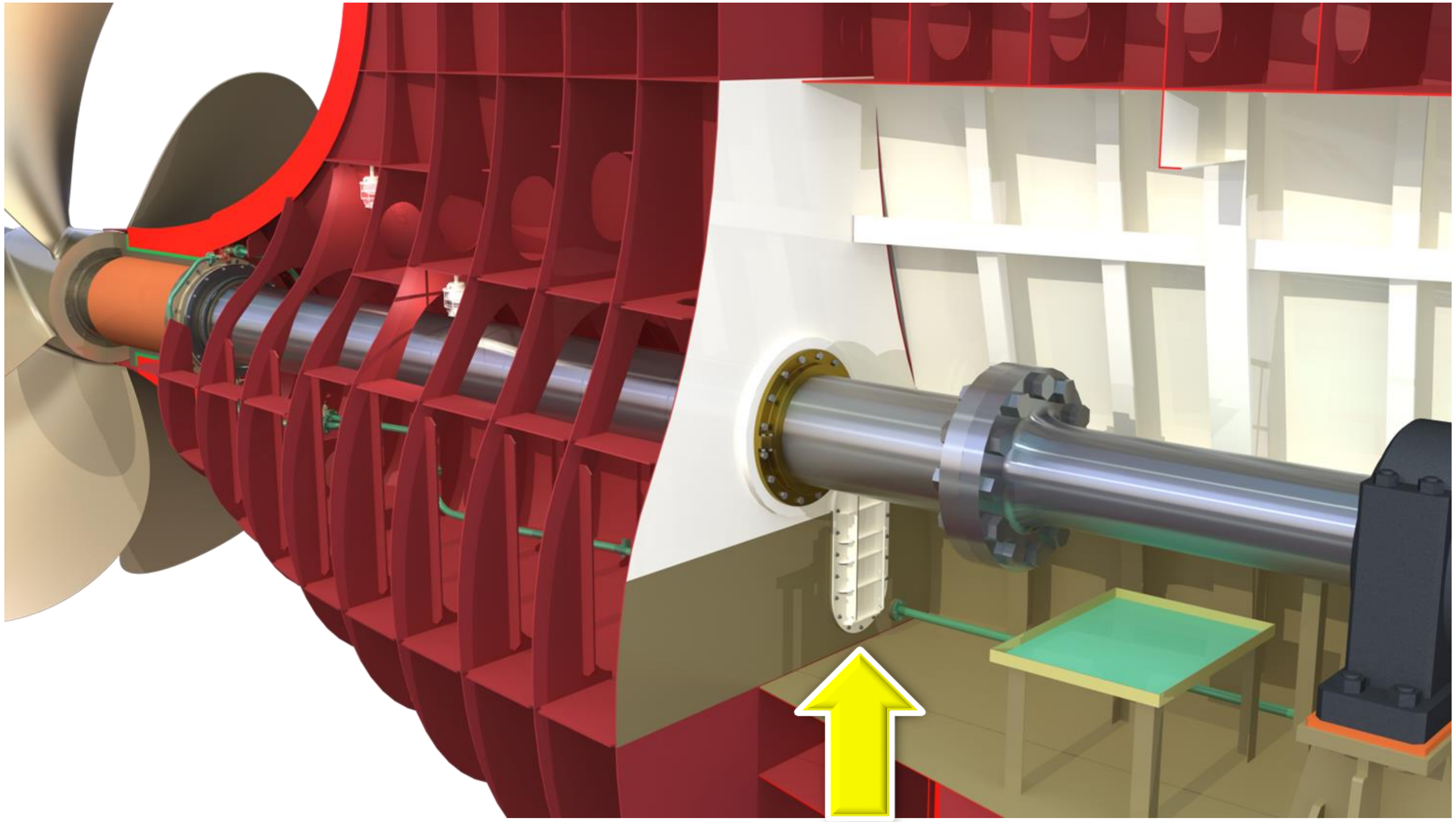
T-BOSS – Thordon Blue Ocean Stern Space

T-BOSS Sterntube-less vessel with seawater lubricated propeller shaft bearing system – 3D CAD



Formation of the Dry Aft Stern Chamber, where the sterntube used to exist.

T-BOSS Sterntube-less Ship

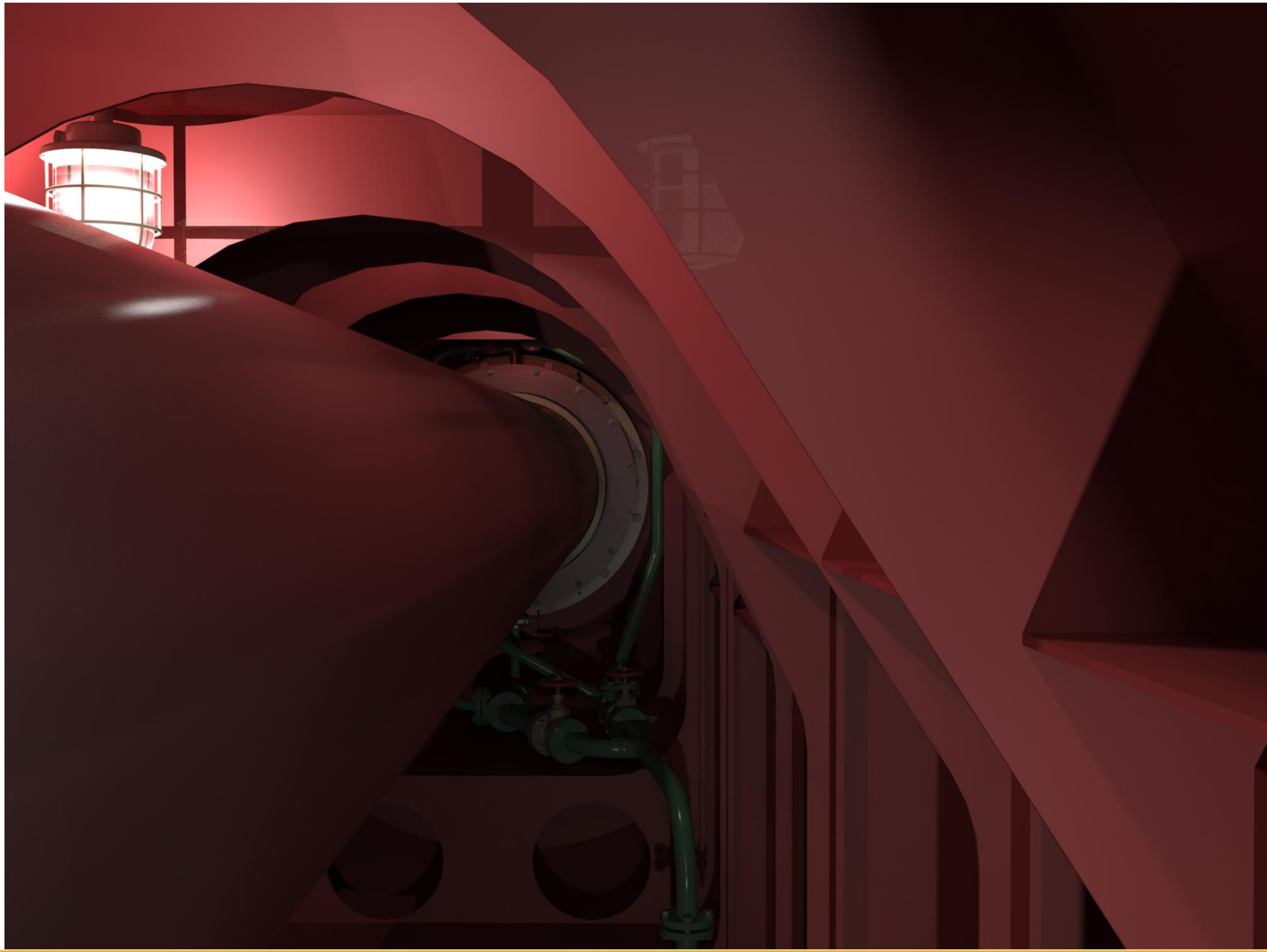


Opening to the Aft Stern Chamber ("temporary means of access")

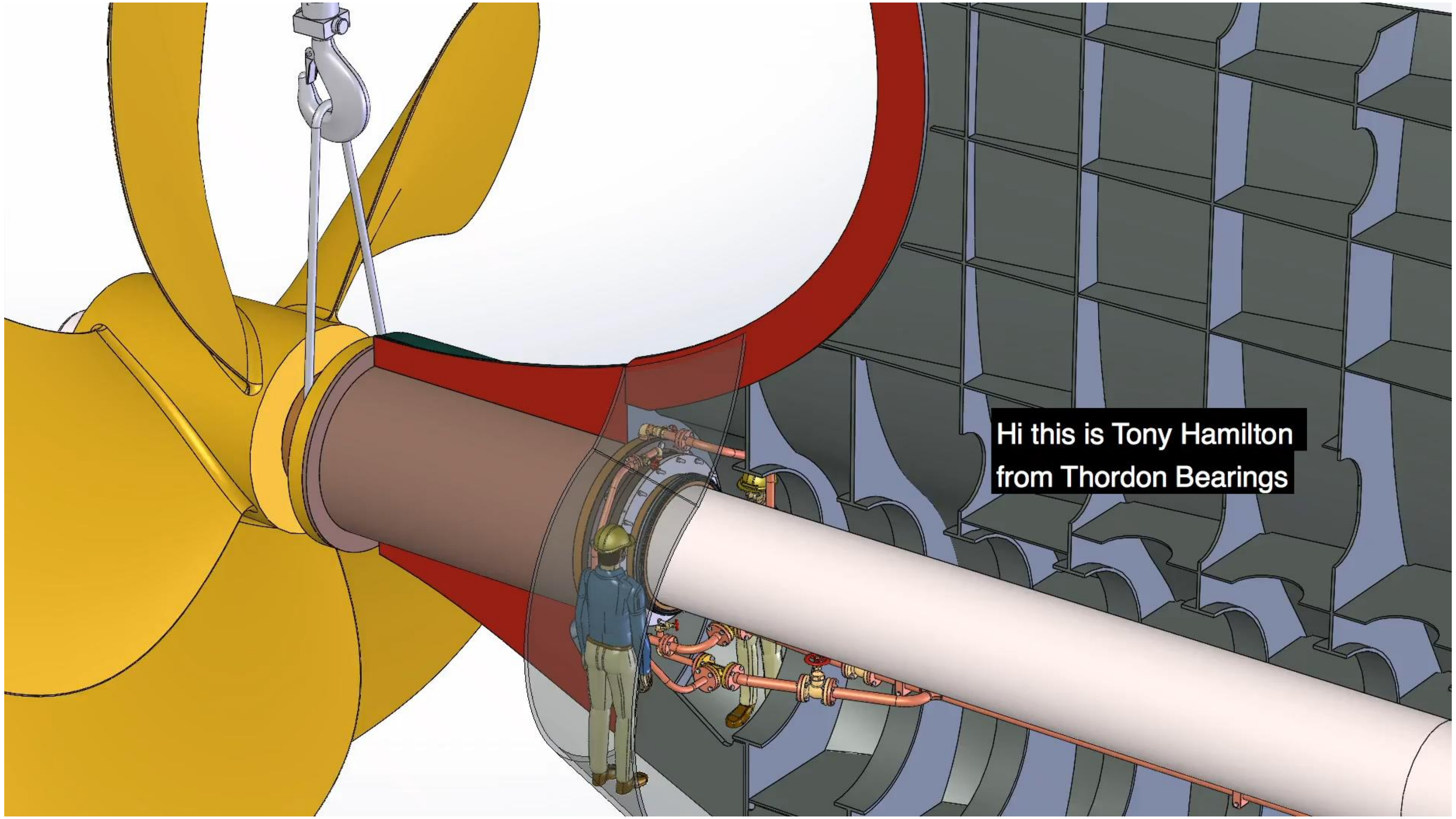
T-BOSS Sterntube-less Ship

Access to the Irregularly Shaped Chamber

View from the inside



T-BOSS Sterntube-less Ship



Access to the bearing from the inside of the vessel (animation video)

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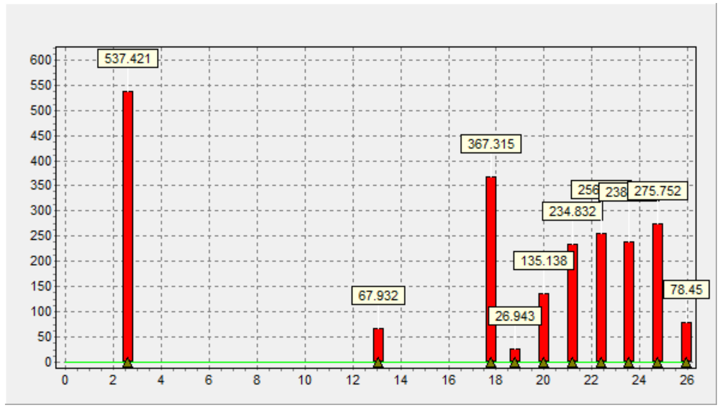
Sterntube-less Vessels – ABS Rule Compliance

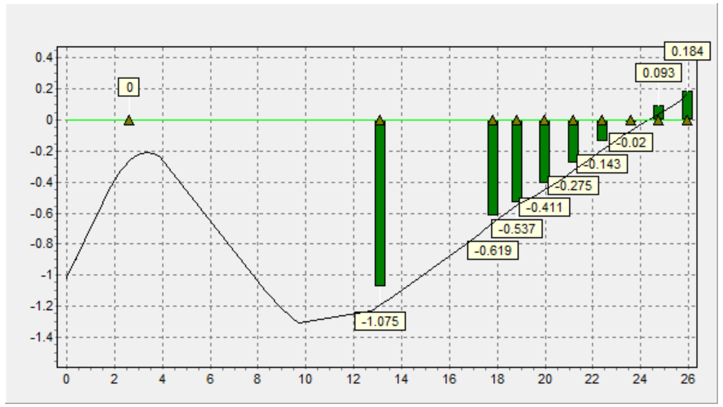
- Shaft Alignment Optimization

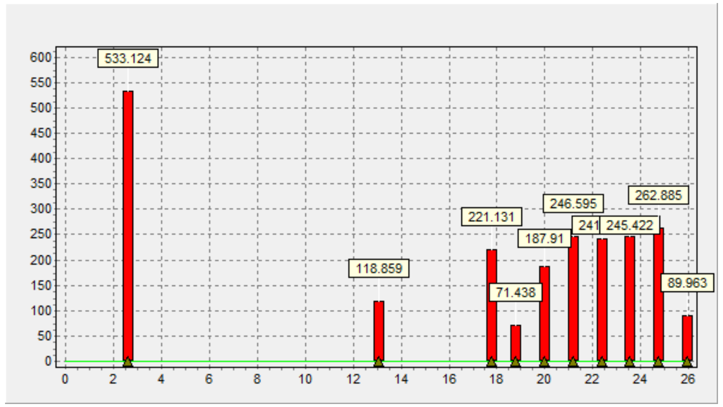
	Optimised Drydock offsets [mm]	Fully Laden Hot Static Offsets [mm]	Ballast Hot Static Offsets [mm]
ASTB	0	0	0
I/M Bearing	0	-0.394	-1.075
M/E 1	-0.146	0.792	-0.619
M/E 2	-0.146	0.828	-0.536
M/E 3	-0.146	0.846	-0.41
M/E 4	-0.146	0.816	-0.276
M/E 5	-0.146	0.75	-0.143
M/E 6	-0.146	0.615	-0.02
M/E 7	-0.146	0.433	0.092
M/E 8	-0.146	0.184	0.184

Fully Laden Offsets [mm]



Fully Laden Bearing Reactions [kN]





Ballast Offsets [mm]

Ballast Reactions [kN]

All bearings are positively loaded and within their maker's limits

THORDON BEARINGS INC.

Sterntube-less Vessels – ABS Rule Compliance

- Engine Flange Shear Force- Bending Moment Envelope

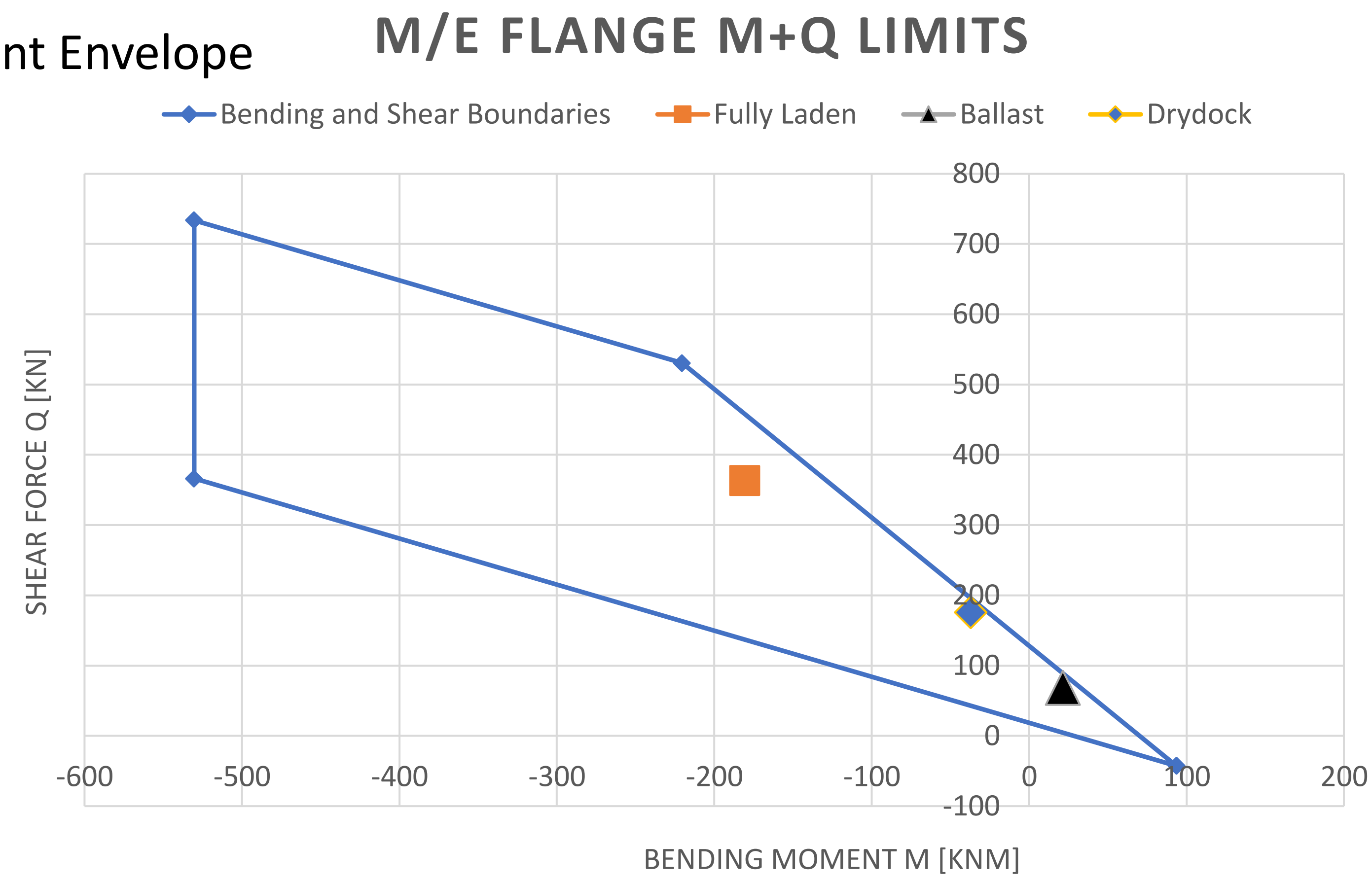
	Bending Moment M [kNm]	Shear Force Q [kN]	Flywheel Weight G [kN]
Fully Laden	-196.0	363.5	125.2
Ballast	21.4	68.4	125.2
Drydock	-37.0	175.9	125.2

All above conditions are "Hot Static"

Total Shear Force Q = F + G, where:

F: Model-calculated Shear Force [kN]

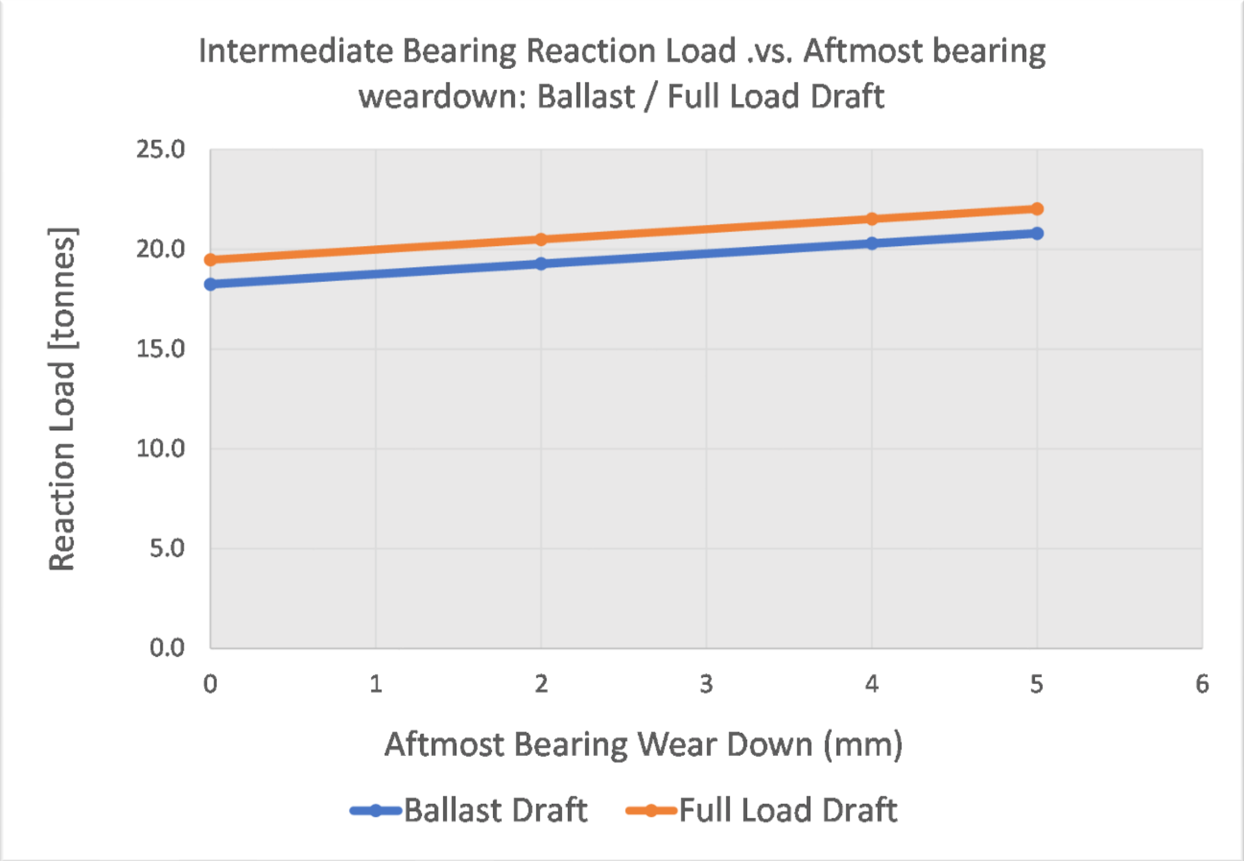
G: Flywheel Weight [kN]

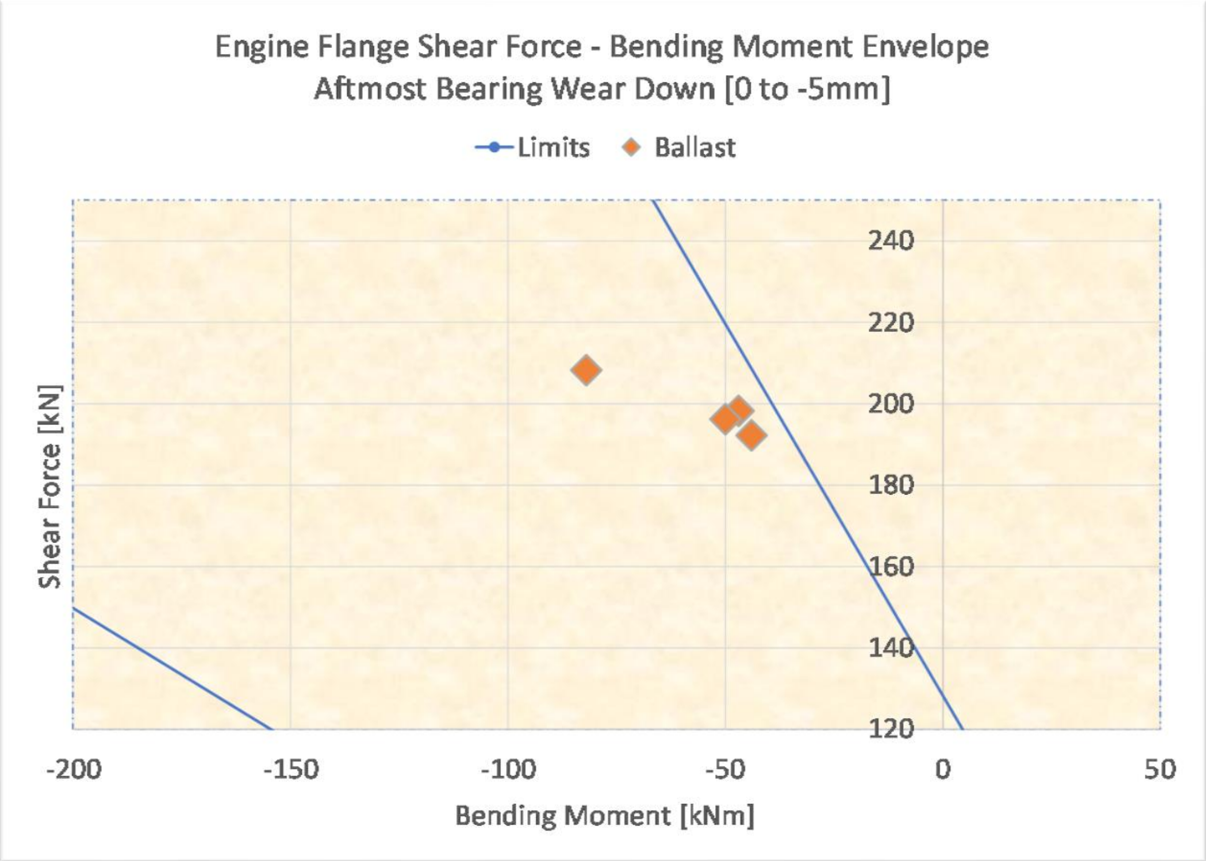


Engine Flange Bending Moment – Shear Force Envelope within maker's limits

Sterntube-less Vessels – ABS Rule Compliance

Water Lubricated Bearing Wear-Down Effects





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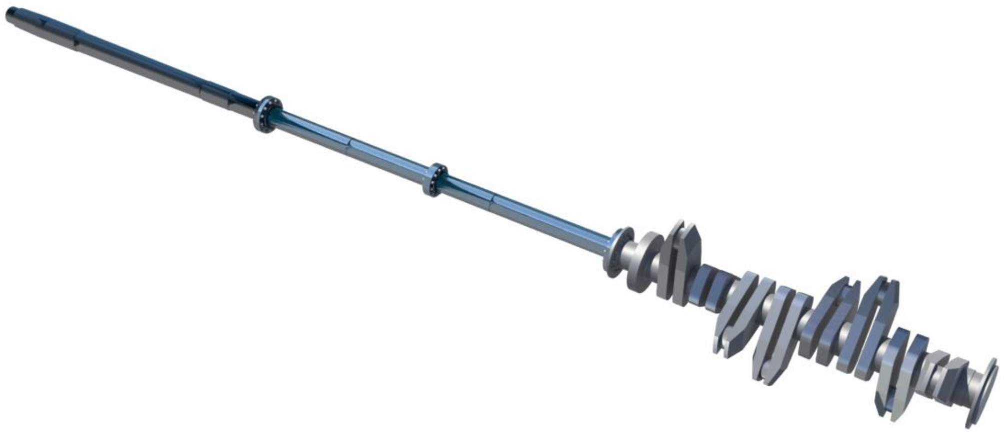
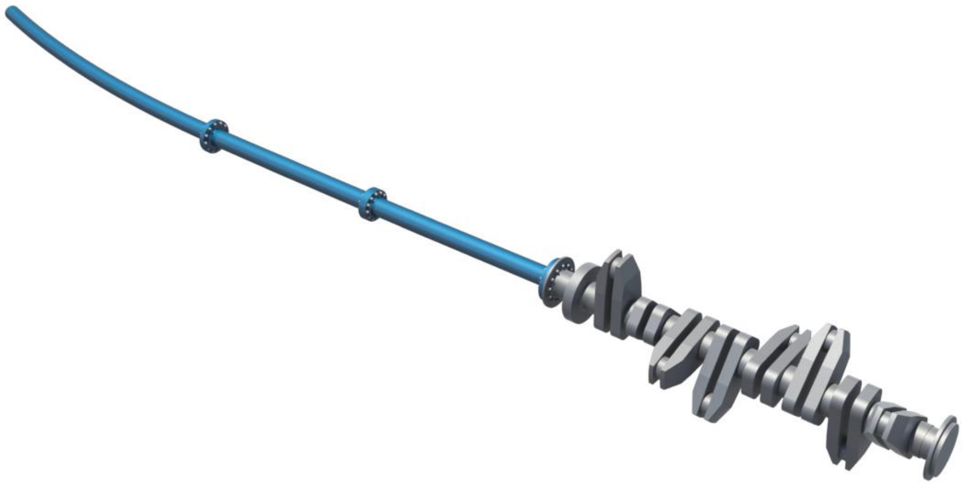
Sterntube-less Vessels – ABS Rule Compliance

Torsio-axial mode

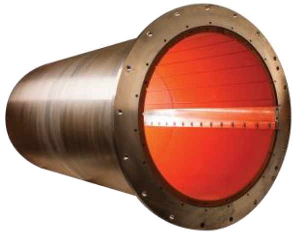


Lateral (whirling) mode



ABS Approval in Principle (AIP) for Sterntube-less Vessel

June 2022



APPROVAL IN PRINCIPLE

ABS

as requested by:

SHANGHAI MERCHANT SHIP DESIGN & RESEARCH INSTITUTE CSSC

Date of Issuance: 09 June 2022

Certificate Number: T2258617

ABS has reviewed the documentation as specified in the ABS letter dated 13 May 2022 (Task No. T2258617) in accordance with the ABS 2017 *Guidance Notes on Review and Approval of Novel Concepts*, and considers that the conceptual engineering as proposed is feasible for the intended application, and the facilities as presented are, in principle, in compliance with the applicable requirements of the ABS Rules for Building and Classing Marine Vessels 2022, International Convention for the Safety of Life at Sea (SOLAS 1974).

Facility: None Associated Facilities

Description: Sterntube-less Vessels with Thordon COMPAC Split Water Lubricated Aftmost Bearing

New Technology Maturity Level: Subsystem A – Feasibility Stage

To achieve final class approval of the subject design, the conditions and requirements as specified in the Approval Road Map [ABS letter dated 13 May 2022, Task No. T2258617] must be satisfied.

Bin-Hong Wang
Director of Engineering, ABS

By:

Ya-Lin Li
Manager – Global Engineering Shanghai ESD, ABS

Note: This certificate evidences compliance with one or more of the Rules, Guides, standards or other criteria of American Bureau of Shipping or a statutory, industrial or manufacturer's standards and is issued solely for the use of the Bureau, its committees, its clients or other authorized entities. Any significant changes to the aforementioned product without ABS approval will result in this certificate becoming void. This certificate is governed by the terms and conditions in the ABS Rules.

T-BOSS Sterntube-less vessel benefits – for the Shipowner

- **Lower operating expenses**
  - No oil, no risky aft oil seal to maintain
  - lower friction with elastomer polymer bearing in water = **fuel savings** compared to sealed oil/metal bearing shaftline

- **No shaft withdrawal**
  - maintain and inspect bearings, liners and seals without drydocking the vessel
  - A 2-week re-alignment job (100k USD) in the dry-dock can be done in 1 day afloat, dispensing with the need for a drydock !
- **Zero pollution**
  - open seawater lubricated propeller shaft bearing system = **regulatory compliance** world-wide
- **Improved EEDI**
  - reduced fuel consumption and ME Emissions

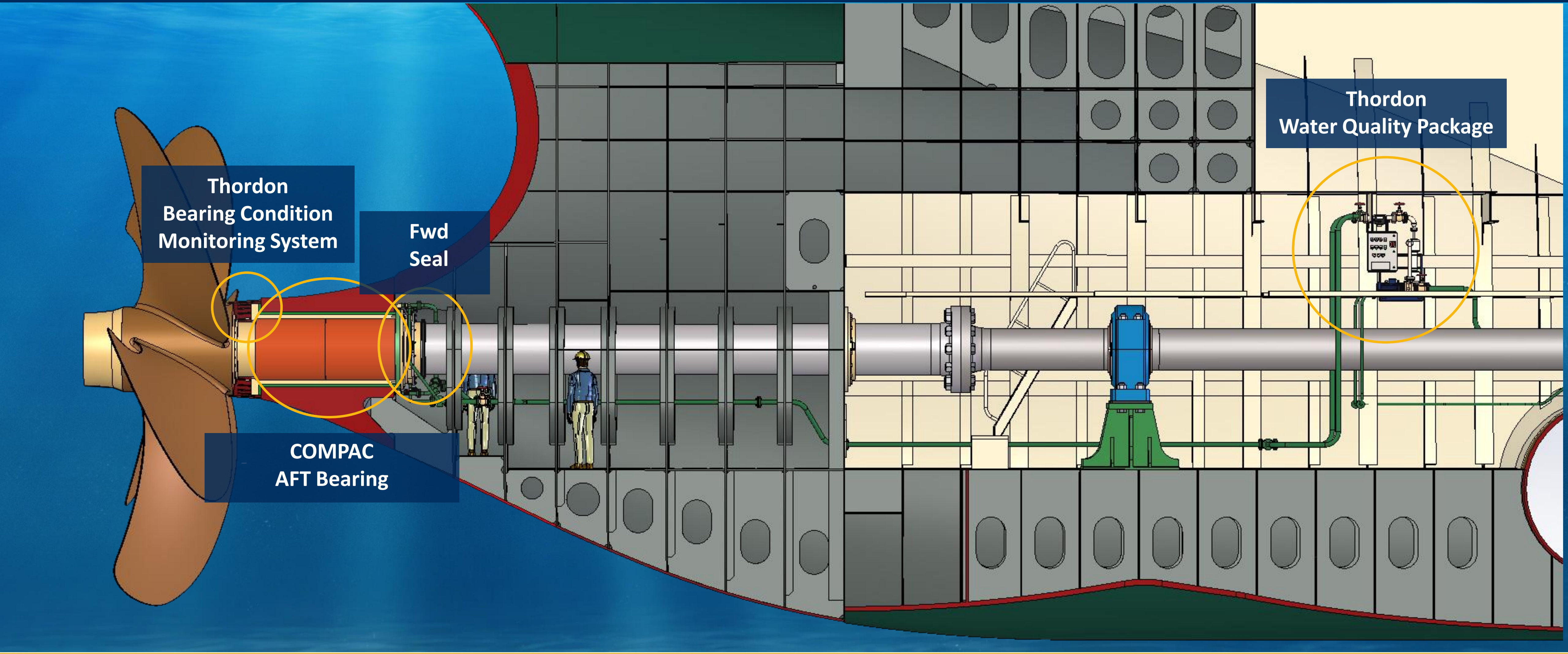
T-BOSS Sterntube-less vessel benefits – for the Shipyard

- **Reduced cost with simplified scope of supply**
  - No Sterntube
  - Single propeller shaft Bearing
  - No Oil and Oil piping systems
  - No Shaft Coating
  - No Aft Seal
  - Less Steel

- **Simplified Installation Procedures**
  - Fewer Components
  - Easier Alignment

14 LIFE BELOW WATER

T-BOSS Propeller Shaft Bearing System



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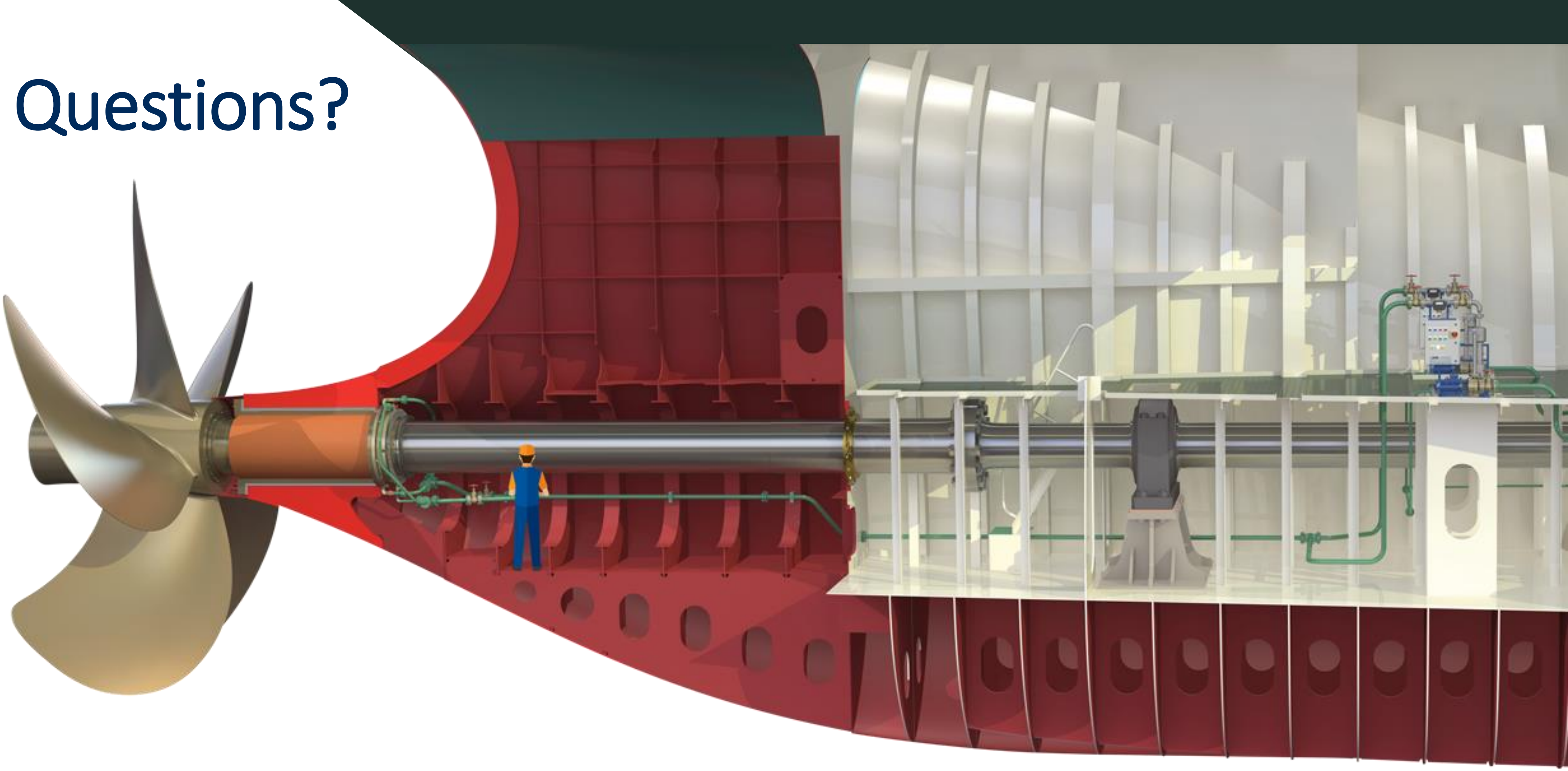
Questions?



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THORDON
THORDON BEARINGS INC.

Questions?

Thank You!

Thordon Bearings Inc.

3225 Mainway, Burlington, ON L7M 1A6 Canada

www.ThordonBearings.com

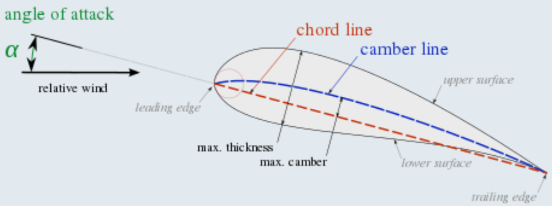
Enter in the Green Era

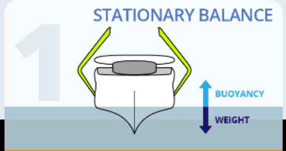
SEAir
FLYING BOAT

Non contractual renderings

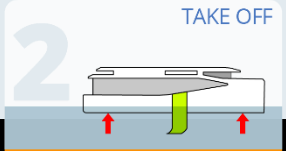
Non contractual renderings

HOW DOES HYDROFOIL WORK?



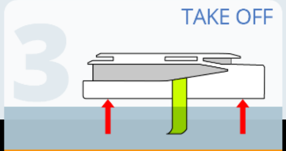


The boat is in equilibrium when its weight (gravity) matches its buoyancy (Archimedes' Principle).



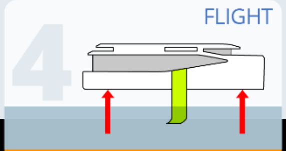
The skipper increases the angle of attack of the foil.

The boat speed rises gradually.



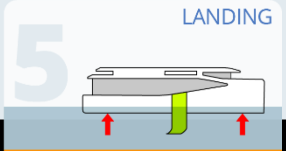
The hull's resistance reduces as the boat rises out of the water.

Flight height is controlled by the angle of attack of the foil.



The hull is no longer in the water and there is no hull drag.

The weight and the lift balance out. The boat flies above the water with foils like an aeroplane flies with wings.



The skipper slows the boat down and the lift reduces.

The boat gradually descends and the hull becomes immersed.

Principles

Leaving the harbour: 100% electric, 0% fuel

Transit: full flying + solar panels, 40% fuel

Arrival in port: 100% electric, 0 % fuel

Non contractual renderings

THE HYDROFOIL TECHNOLOGY
For reducing carbon emissions in the naval sector

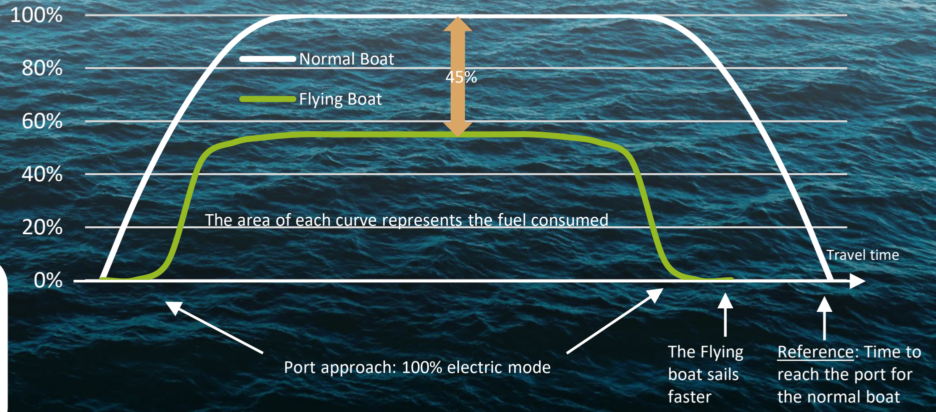
- **FLYING TO CONSIDERABLY REDUCE DRAG & IMPROVE HYDRODYNAMICS**
  - Drastic reduction of the energy required to sail
  - Up to 40% lower fuel consumption resulting in reduced carbon emissions

- **ELECTRIC PROPULSION SYSTEMS POWERED BY**
  - Hybrid engines today (fossil + electric)
  - Renewable energy sources when mature (e.g., H2)
  - Whatever the solution, emission-free energy use, with electric power:
    - When approaching the coasts
    - When sailing in protected areas
    - For short trips

- **OTHER MAIN BENEFITS**
  - Higher speeds resulting in shorter journey times and lower energy consumption
  - Impressive shock mitigation

In the water, weight is our enemy

CO_2 emission & fuel saving



Targeting **Zero Emission ships**, combining **Excellence of technology**

- **Less CO2 Emission thanks to**
  - Hydrofoil technology
  - Electronic ship management
  - Solar panels
  - Recycled materials,
  - Environment-friendly hull paint
  - …

- **Key benefits for operators and passengers**
  - **Carbon footprint reduction**
  - **Speed**
  - **Comfort**
  - **Innovative, positive and leadership image**

Non contractual renderings

SKIM IN **PERFECT COMFORT**

OVER THE SEA **LIKE A BIRD**

WITH **SUSTAINABLE SHIPS**

2024

Thank you for your attention

Richard FOREST, CEO
richard@seair.fr

Non contractual renderings

Nuclear Power for Commercial Maritime and Offshore

Peter Wallace

Principal Engineer—Risk and Regulatory Advisory

Introduction

Nuclear is becoming fashionable

Nuclear is becoming fashionable

Nuclear is Timely for Maritime and Offshore

Nuclear system applications

Size Range	Applications	Arrangements
<10 MW	Small ships and small rigs	Islanded
10-50 MW	Medium size ships and medium size rigs	Islanded and Shore Power
50-100 MW	Larger ships, medium sized floaters	Islanded, Shore Power, and Microgrid
100 MW -1+ GW	Offshore Systems	Islanded, Macrogrid, and Microgrid

Application	Power	Trade	Replacement or Revolution	Notes
3,000 TEU Container Ship	20 MW	Regional	Replacement	Potential for worldwide trade
18,000 TEU Container Ship	100 MW	Worldwide	Replacement	
170,000 m3 LNG Carrier	30-50 MW	Worldwide	Replacement	Currently in a challenged position regarding emissions
FSRU	50 MW	Stationary	Replacement	Powers can be higher if used for local power generation
FPSO 250,000 bpd crude oil with gas compression and reinjection	100+ MW	Stationary	Replacement	Potentially lead to light duty refining
150,000 DWT (~1 M bbl) chemical/product carrier	50+ MW	Worldwide	Revolution	Additive Manufacturing
Desalination	100 MW	Stationary	Quasi-Revolution	Desalination is energy intensive
E-Fuel Production	100 MW	Stationary	Revolution	Alternative fuels such as H2, NH3, Methanol, Ethanol, etc.
Multiple FPSOs in field	1+ GW	Stationary	Revolution	
Municipal/Industrial Power	1+ GW	Stationary	Quasi-Revolution	

Changes

Design and Operational Changes

Industry Structural Changes (Nature of Shipping) for Nuclear

Classification and Regulatory

Regulatory

IMO

IAEA
International Atomic Energy Agency

IACS
International Association of Classification Societies

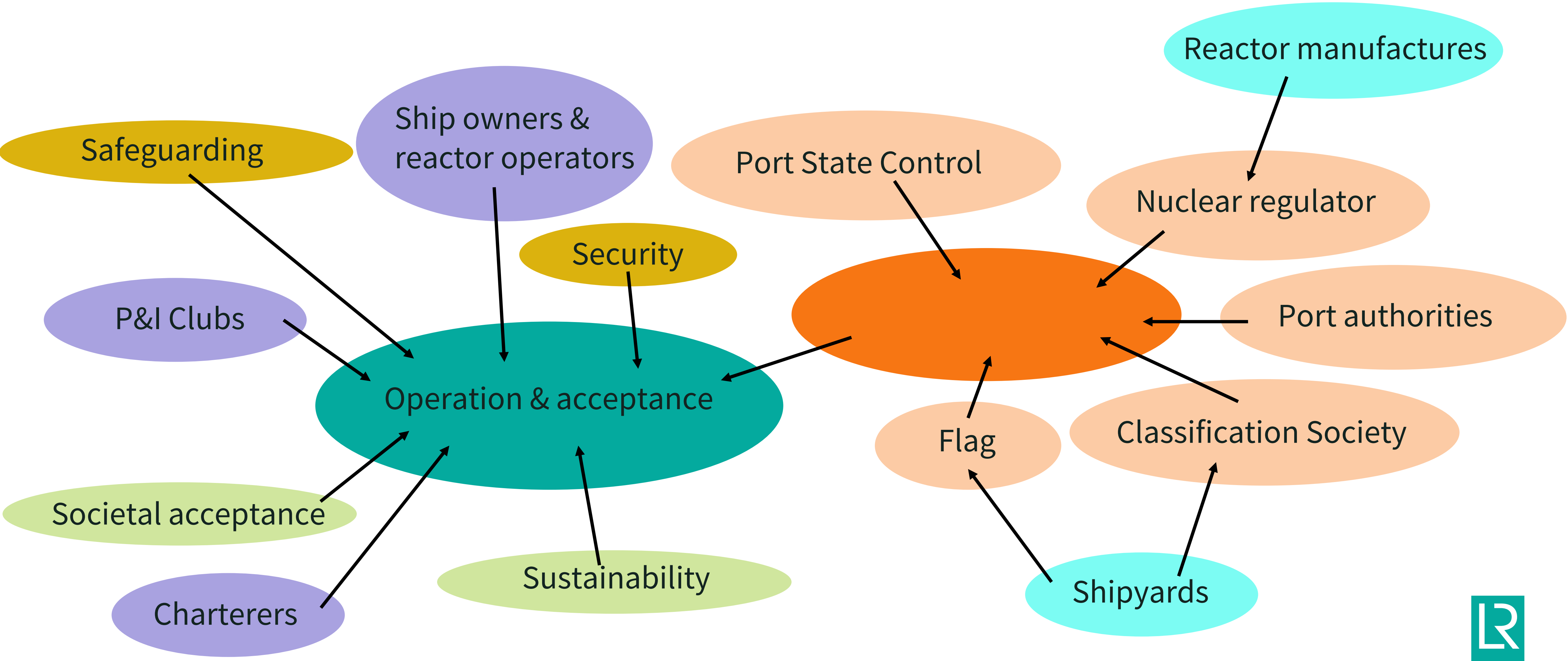
Regulatory--International

Regulatory--Local

Classification Societies

Pathways

The nuclear stakeholders eco system



Pathways to adoption for early projects

Building confidence of successful outcomes

1

Technology review

Review of the technologies and those suitable for the specific application

2

Regulatory pathway

Identify the countries and regulators needed to agree a project specific pathway

3

Demonstrate Assurance Framework

Based on the agreed pathway develop an assurance and Classification framework specific to the project

4

Design, Construction, Classification and Certification

Certify design and construction of facility system in accordance with agreed codes and standards and assurance framework.

Project Classification & Certification

Industry Readiness and Adoption Risk

What Needs to Be Done…

A 21st Century Shipping and Trade Revolution


SAVANNAH

Thank you

Contact details:

Peter Wallace

Peter.Wallace@lr.org

Decision Making Made Easy: Port Sustainability

Gabrielle Gordon

Advisor: Associate Professor Michelle Portman

TECHNION Israel Institute of Technology

CAMERI Coastal & Marine Engineering Research Institute Ltd

Ports drive globalization

- ⚓ 99% of trade in Israel occurs via the sea (About section, IPC website)
- ⚓ Around 3% of global CO_2 emissions are related to the maritime sector (IMO)

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of Technology

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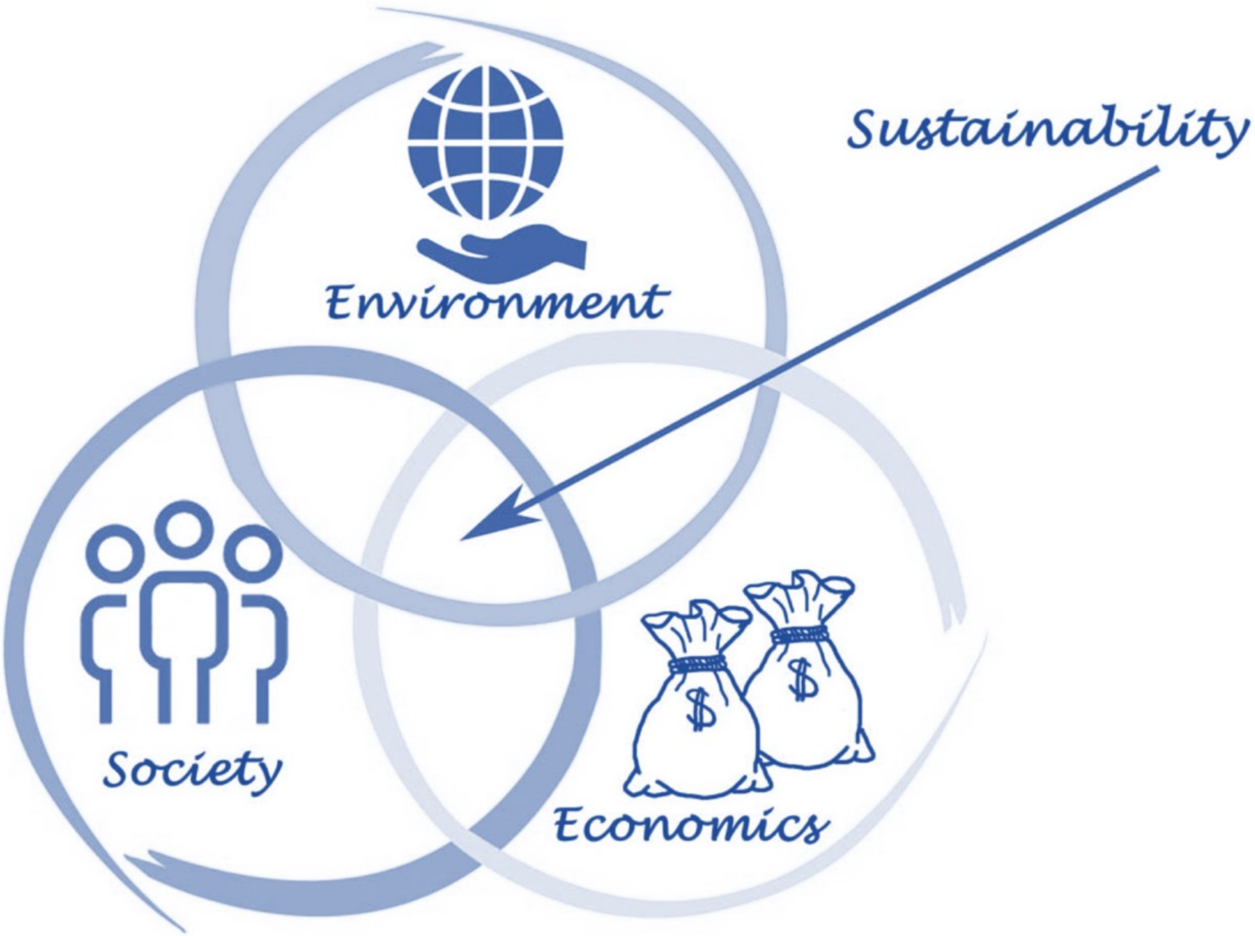
Background

Question 1: What is sustainability exactly?

Question 2: How can ports be more sustainable?

Sustainability – the ability to persist over time



What has already been done?

Problem: How can ports be more sustainable?

Literature review in three areas:

- ❑ Port sustainability
- ❑ Existing regulations and legislations
- ❑ Multi-criteria decision analysis

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Port Sustainability

- Improve sustainability in ports
- Evaluation criteria
- Comparison between ports

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Port Sustainability

- “Port Sustainability and performance: A systematic literature review” (Lim et al., 2019)
- No articles focused on all three elements of sustainability

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International Shipping and Port Regulations

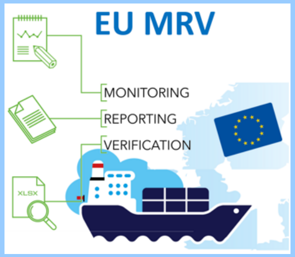
Legislative Bodies

IMO
INTERNATIONAL
MARITIME
ORGANIZATION

THE LAW
OF THE SEA

MARPOL
International Convention for the Prevention of Pollution from Ships

Data Collection and Management



Standardization and certification

CERTIFIED
ISO 14001
CERTIFIED

EMAS
VERIFIED
ENVIRONMENTAL
MANAGEMENT

ECOPORTS
PERS CERTIFIED

Israeli Shipping and Port Regulations

Ministry of Transport and Road Safety

Administration of Shipping and Ports

- Ports State Control Inspection System
- Fuel quality regulations for ships in port or anchorage areas as of Feb 2023
- Agreements with Cyprus and Lebanon

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Literature Review
Multi-Criteria Decision Analysis (MCDA)

- Port performance
- Selection

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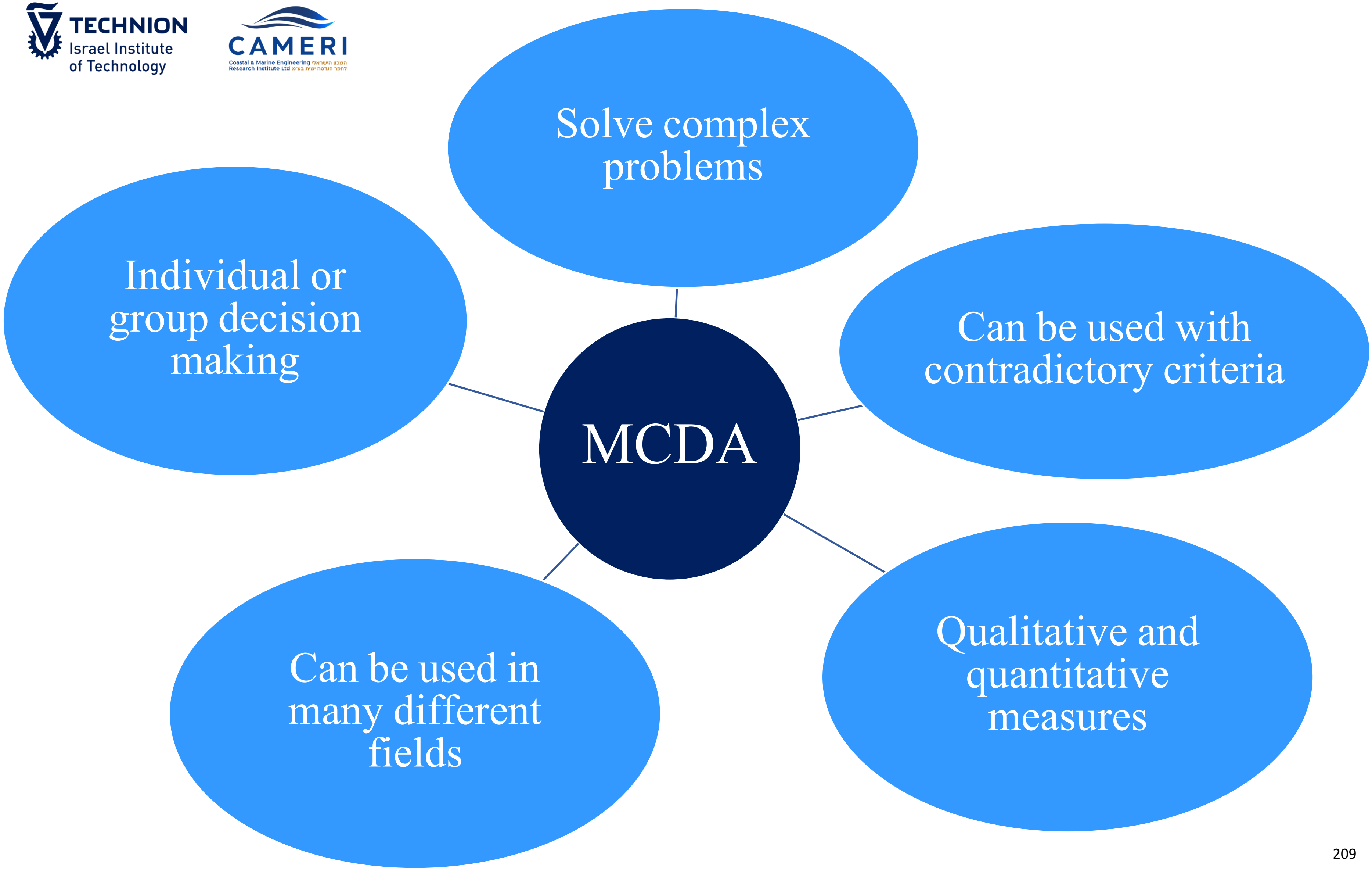
Multi-Criteria Decision Analysis (MCDA)



Literature Review Conclusions

- Very little research done which take all three elements of sustainability for ports into consideration
- No research on how best to make decisions
- MCDA, and the Analytical Hierarchy Process specifically fit the needs of my goal
- Being sustainable needs to be incentivized

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My aim

Problem: How can ports be more sustainable?

Solution: Create a tool that helps port decision-makers understand what alternative is the most sustainable

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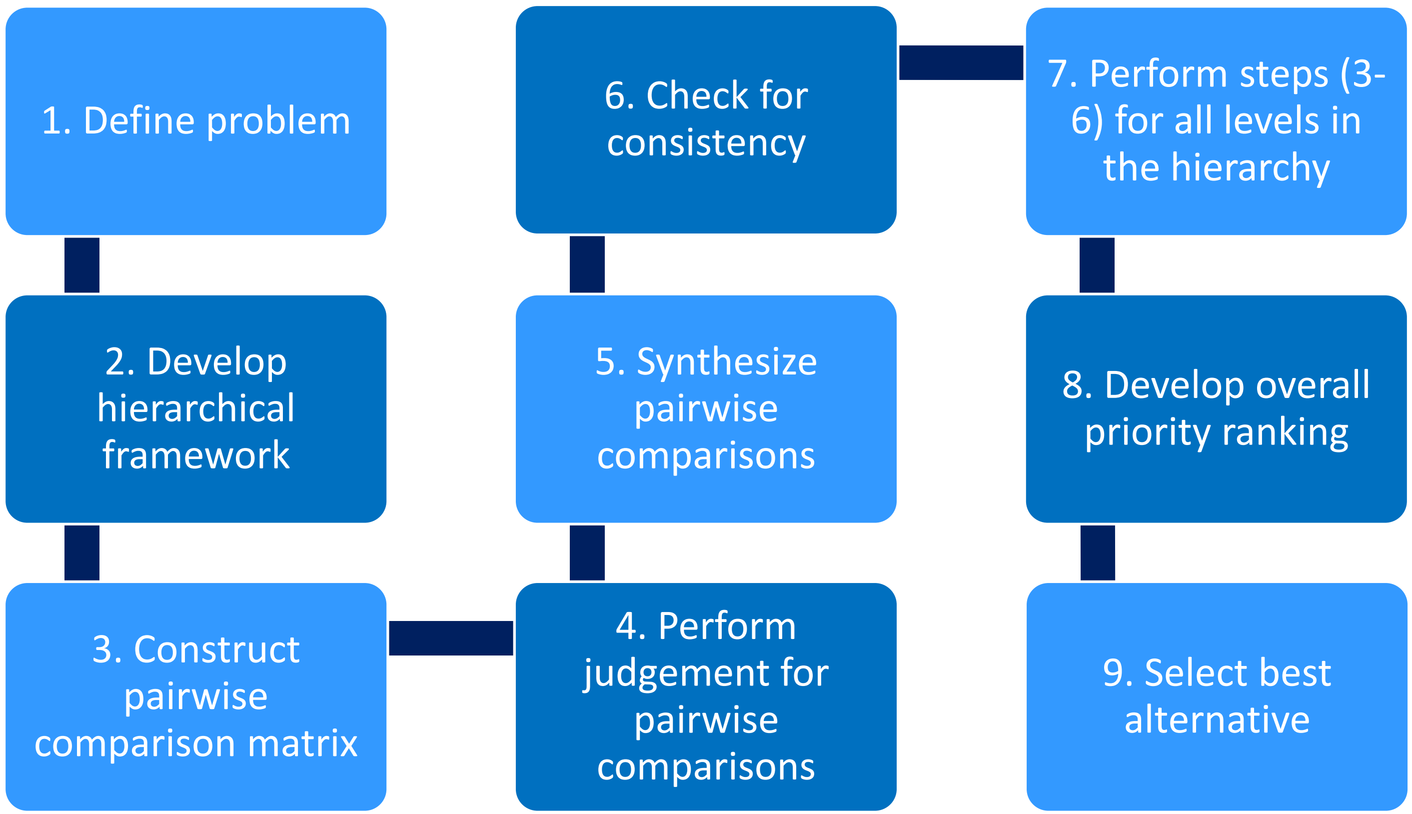
Methodology



The steps to perform an AHP for comparing alternatives (Velmurugan et al., 2011).

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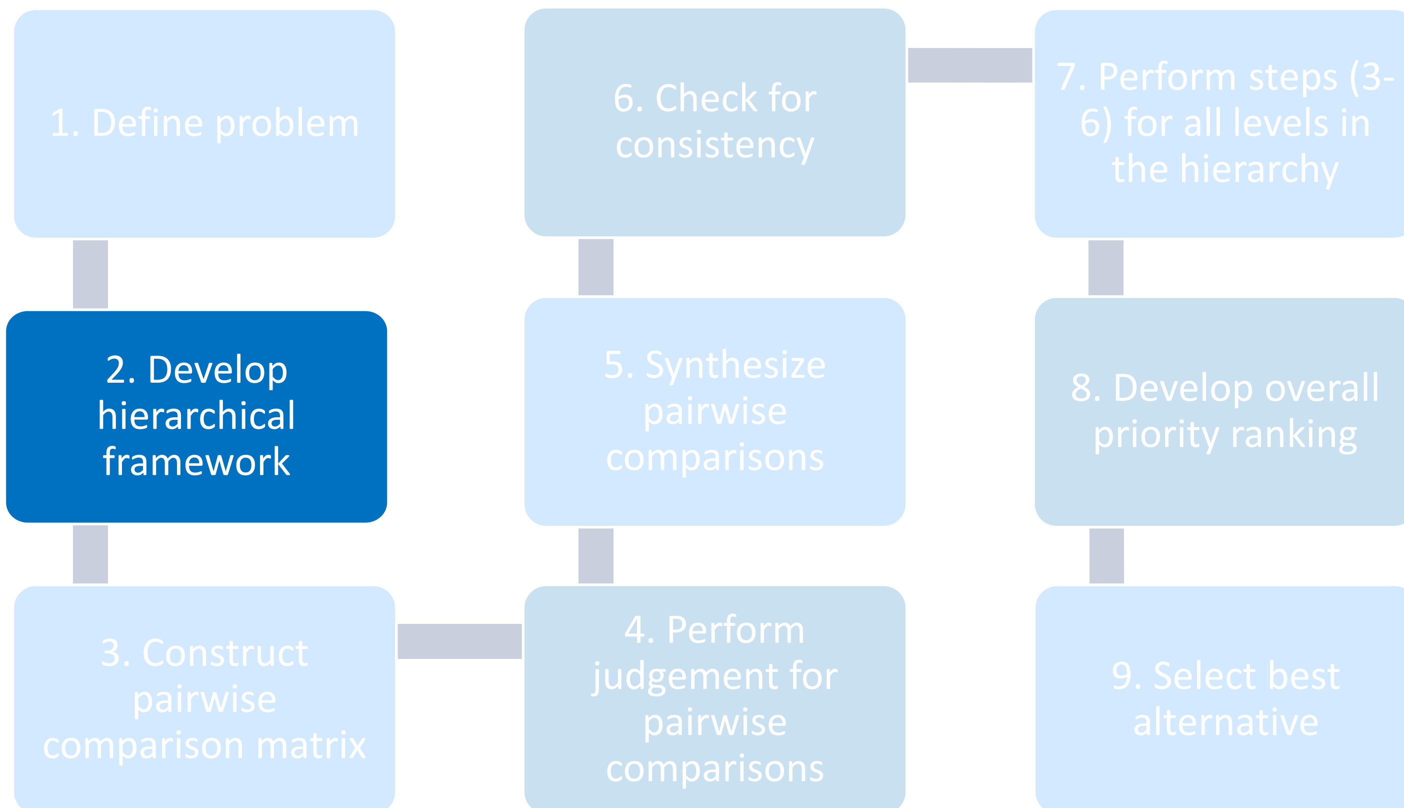
Methodology



The steps to perform an AHP for comparing alternatives (Velmurugan et al., 2011).

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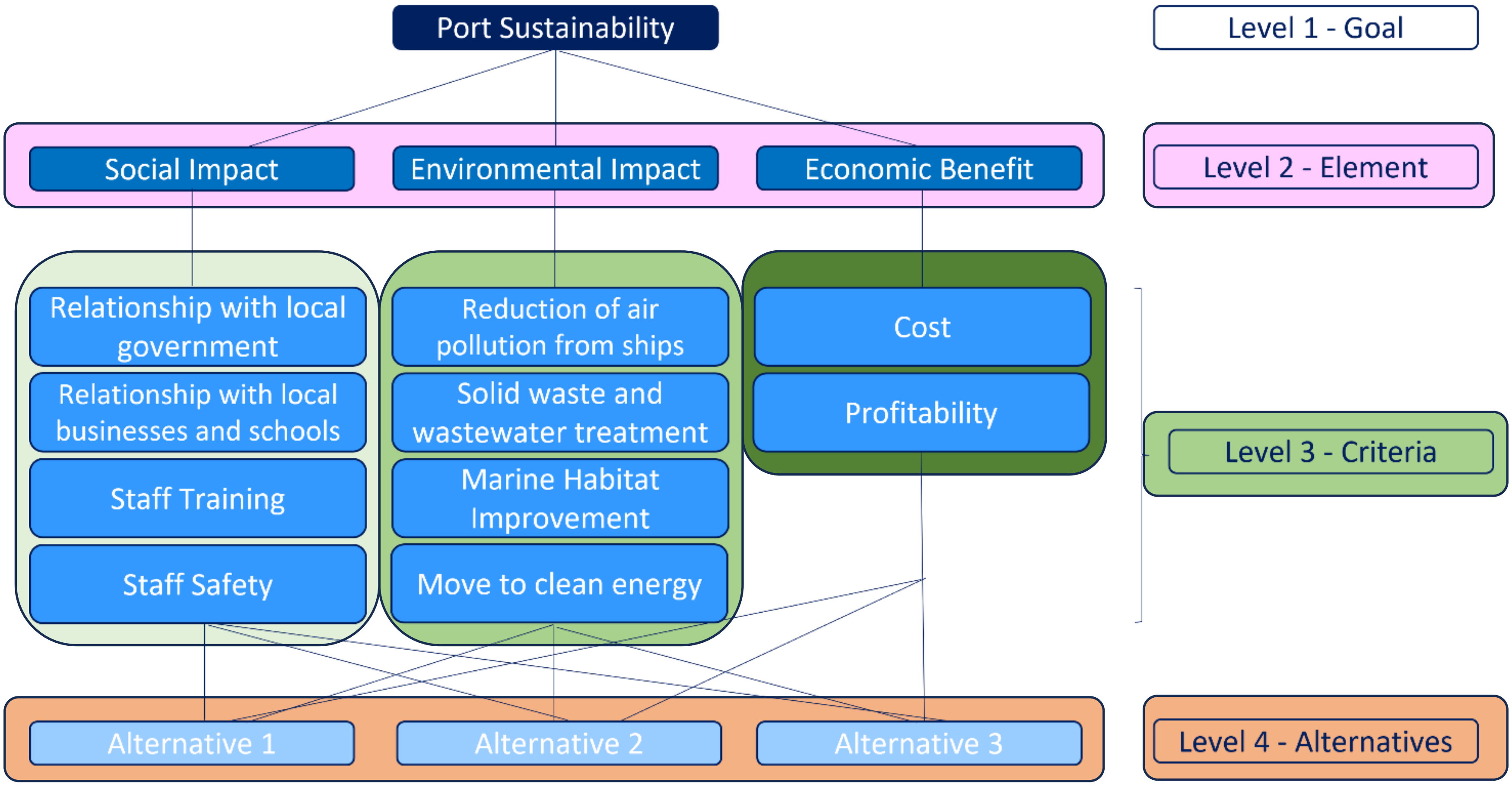
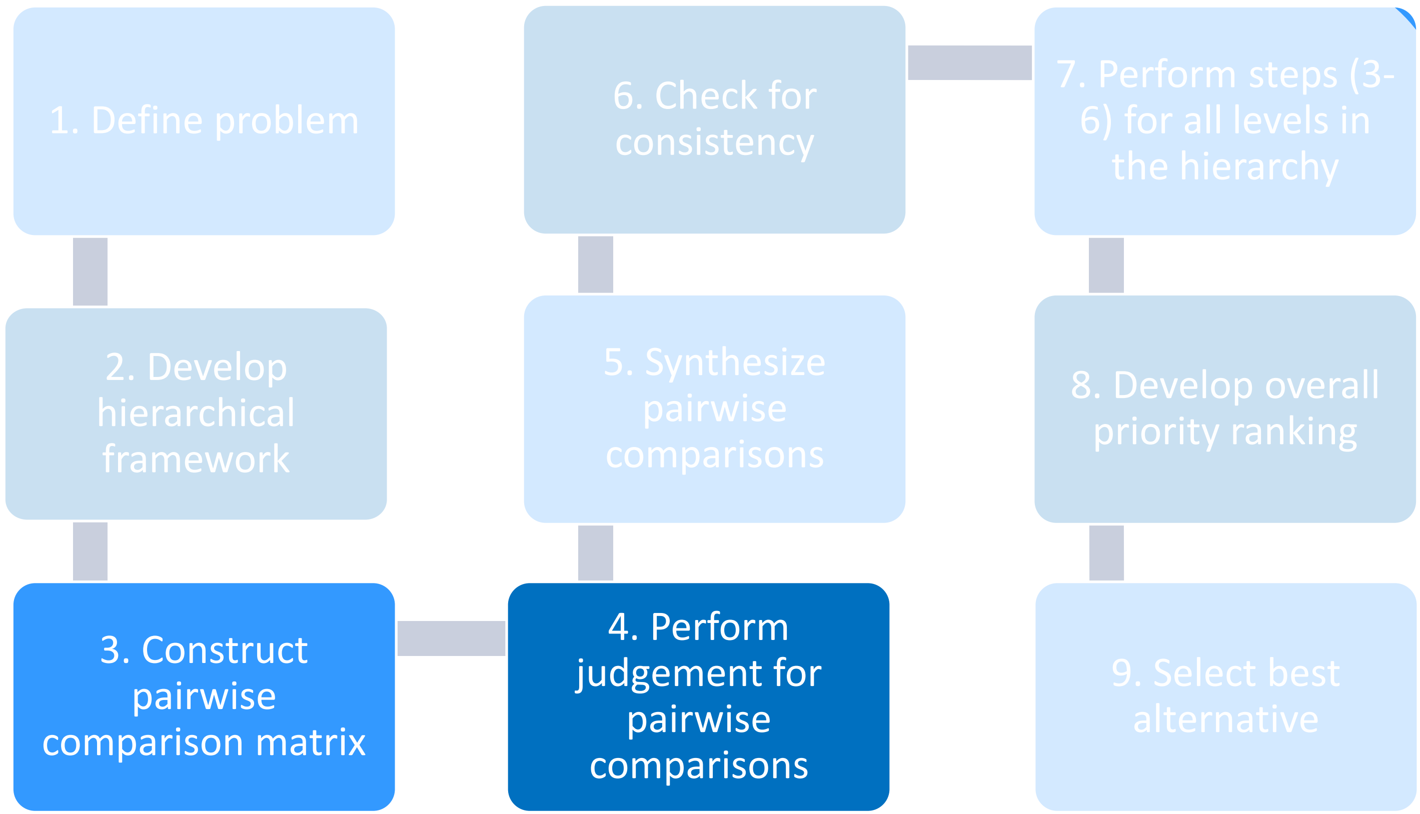
Analytical Hierarchy Process (AHP) Framework



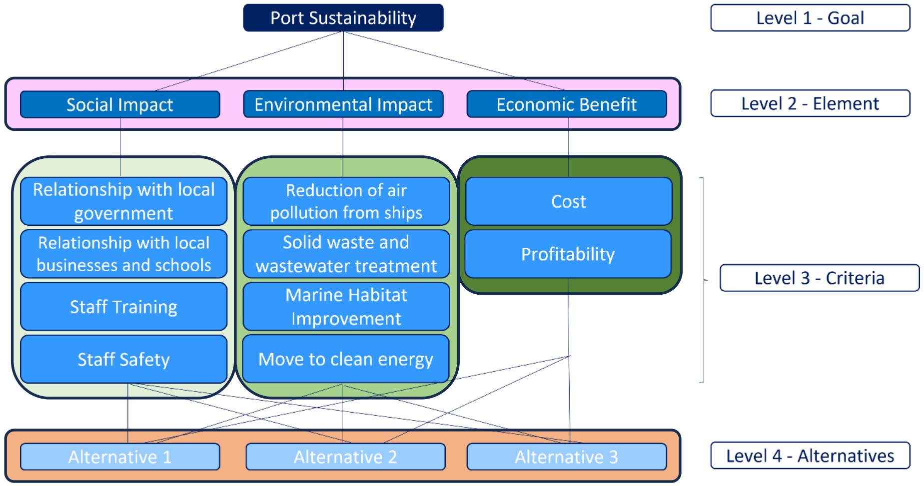
Methodology



The steps to perform an AHP for comparing alternatives (Velmurugan et al., 2011).

Building of the Survey

- Purpose: Rank between the elements and criteria
- 4 total questions
  - Same phrasing for: Elements, Social Impact Criteria, Environmental Impact Criteria
  - Economic criteria scale
  - Demographics of participants



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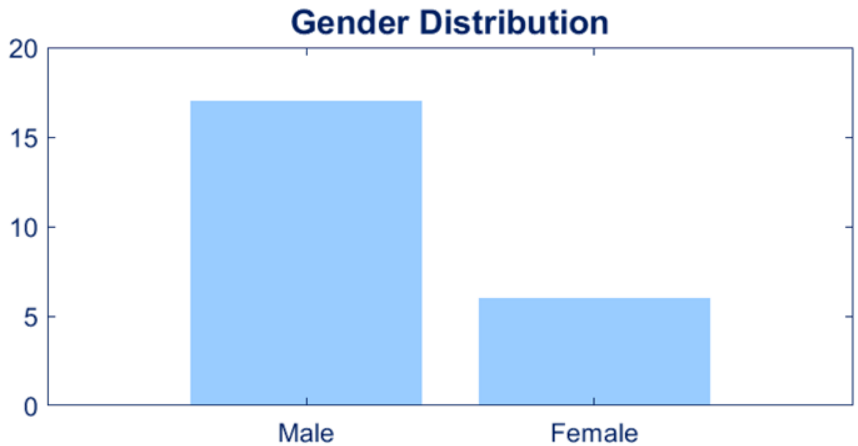
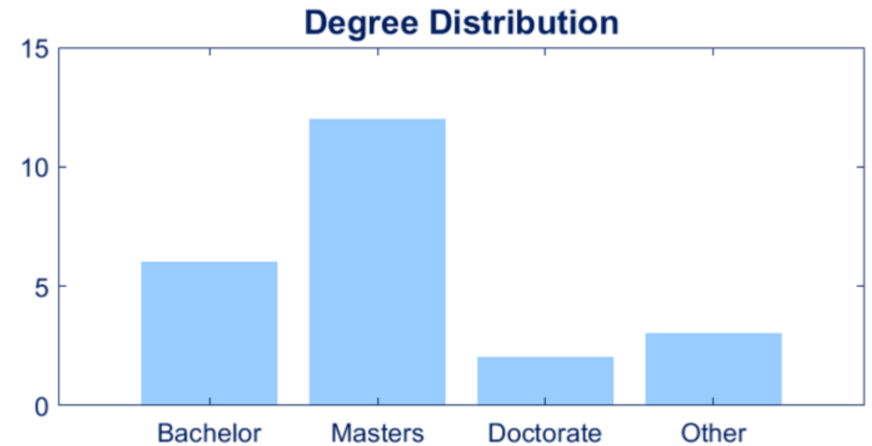
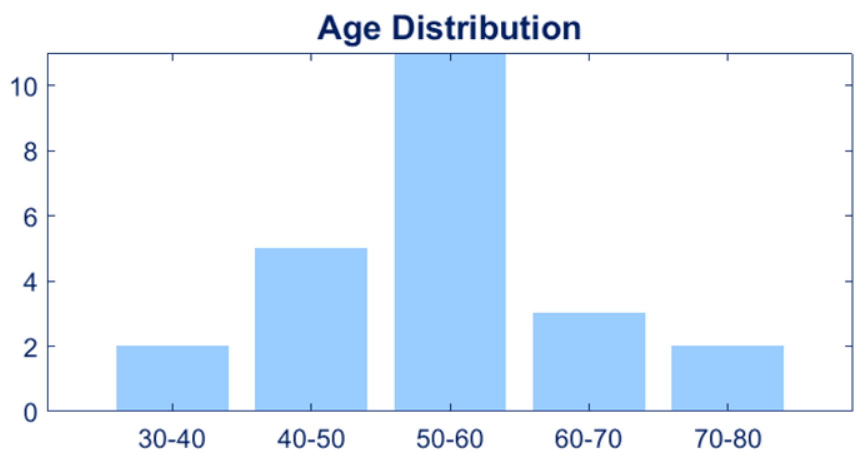
Demographic Distribution of Survey Participants







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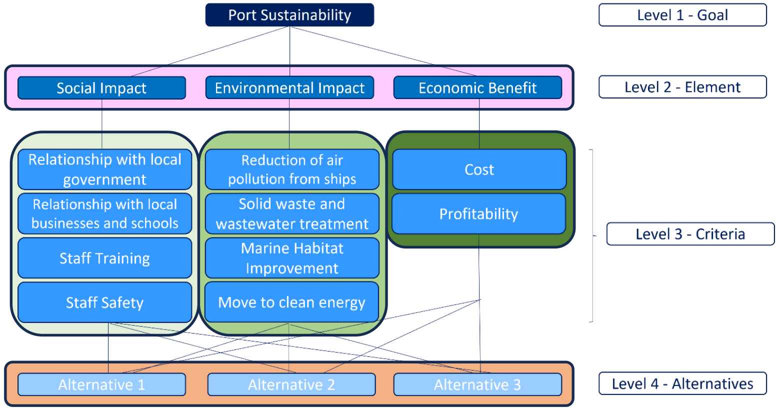
Example Response

If you had $100 to invest in new technologies and developments, how would you split the $100 between the three aspects?

Social Impact Element $10

Environmental Impact Element $40

Economic Impact Element $50



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Analysis of survey responses

Rank	Meaning
1	Equal Importance
3	Moderate Importance
5	Essential or Strong Importance
7	Demonstrated Importance
9	Extreme Importance
2,4,6,8	Intermediate Values

Scale for ranking between criteria and elements (Saaty, 1987)

x (difference in $)	Rank
$0 \leq x < 10$	1
$10 \leq x < 20$	2
$20 \leq x < 30$	3
$30 \leq x < 40$	4
$40 \leq x < 60$	5
$60 \leq x < 70$	6
$70 \leq x < 80$	7
$80 \leq x < 90$	8
$90 \leq x < 100$	9

Example survey result analysis

Response:
Environmental: $40
Social: $10
Economic: $50

	Environmental Element	Social Element	Economic Element
Environmental Element	1	4	1/2
Social Element	1/4	1	1/5
Economic Element	2	5	1

x (difference in $)	Rank
$0 \leq x < 10$	1
$10 \leq x < 20$	2
$20 \leq x < 30$	3
$30 \leq x < 40$	4
$40 \leq x < 60$	5
$60 \leq x < 70$	6
$70 \leq x < 80$	7
$80 \leq x < 90$	8
$90 \leq x < 100$	9

Methodology

1. Define problem
2. Develop hierarchical framework
3. Construct pairwise comparison matrix
4. Perform judgement for pairwise comparisons
5. Synthesize pairwise comparisons
6. Check for consistency
7. Perform steps (3-6) for all levels in the hierarchy
8. Develop overall priority ranking
9. Select best alternative

The steps to perform an AHP for comparing alternatives (Velmurugan et al., 2011).

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Example survey result analysis

Response:
Environmental: $40
Social: $10
Economic: $50

	Environmental Element	Social Element	Economic Element
Environmental Element	1	4	1/2
Social Element	1/4	1	1/5
Economic Element	2	5	1

MATLAB

	Weight
Environmental Element	0.334
Social Element	0.098
Economic Element	0.568
Total	1

MATLAB

Consistency ratio (CR)<0.1 therefore the matrix is acceptable (Saaty, 2008)

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Methodology

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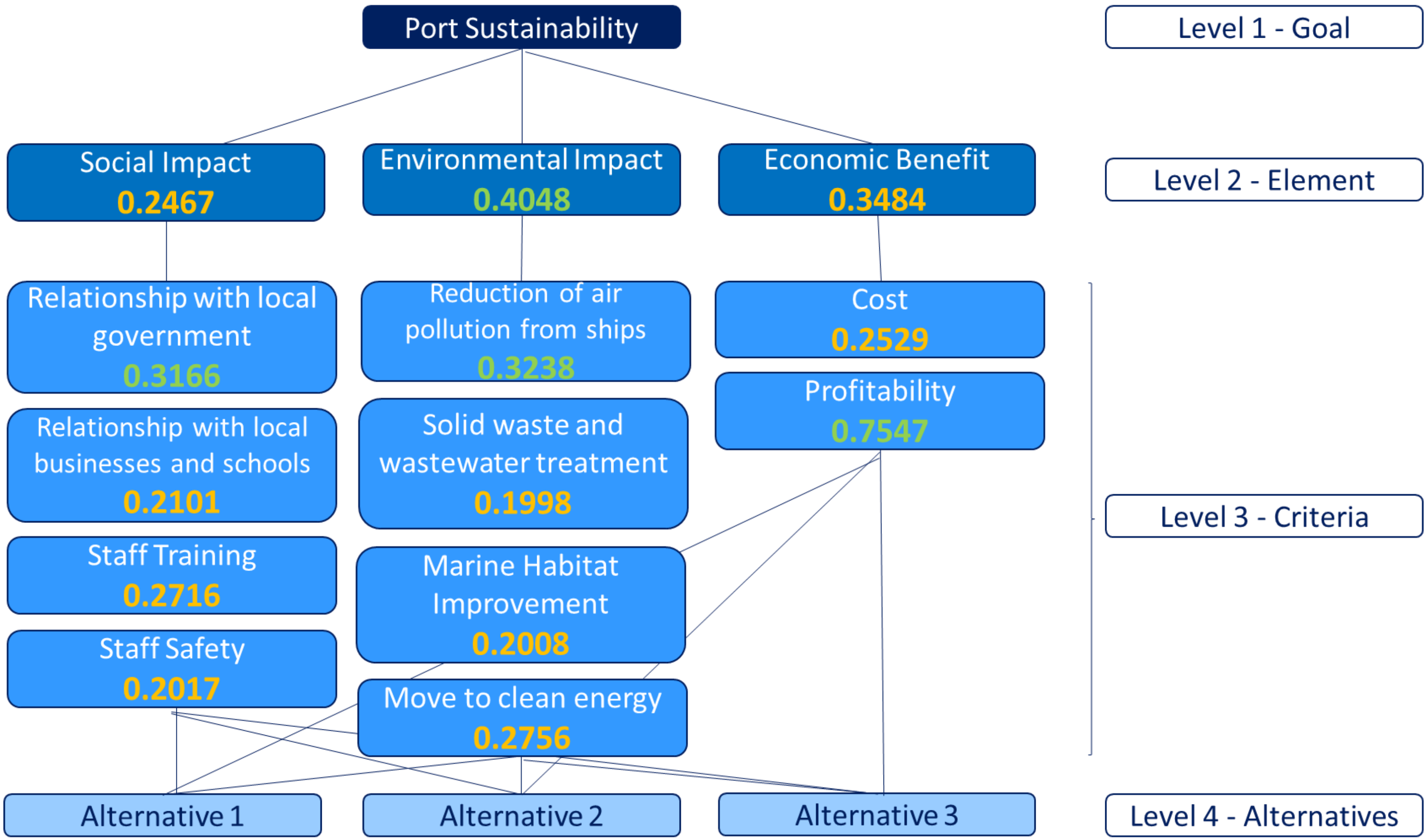
Survey Results



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Results

Criteria	Global Weight
Air pollution reduction from ships	0.1311
Solid and wastewater treatment	0.0809
Move to Clean Energy	0.1116
Marine Habitat Improvement	0.0813
Relations with Local Government	0.0781
Relations with Local Schools and Businesses	0.0518
Staff Training	0.0670
Staff Safety	0.0498
Cost	0.0855
Profitability	**0.2630**
Total	1.00

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Application

How do I use this framework?

Case Study!

Example Solutions

Drones, used at Port of Rotterdam

Electric Port Machinery, used at Port of Long Beach

Co-working space, used at Boston SeaPort

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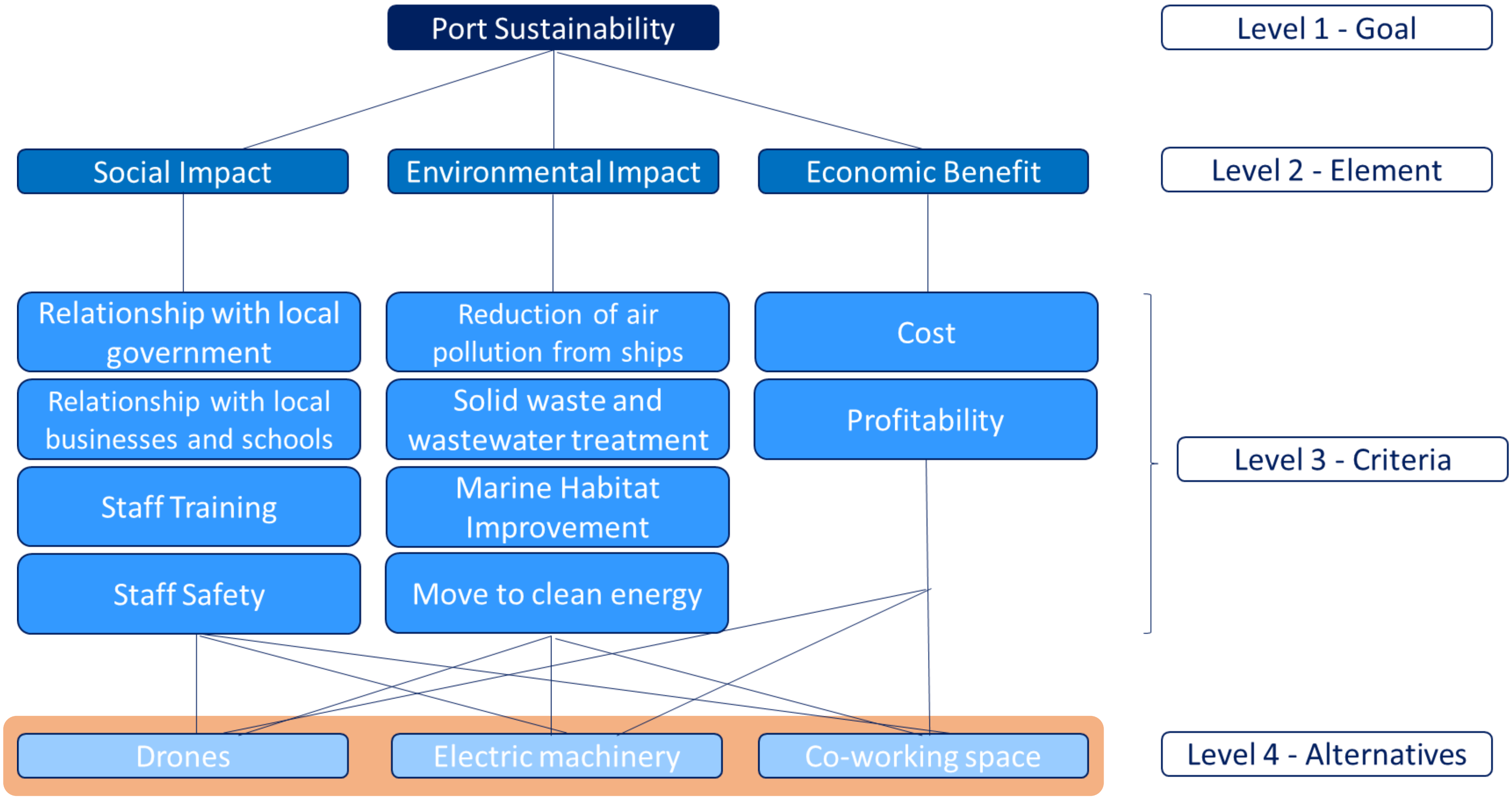
AHP Framework with alternatives



Methodology

1. Define problem
2. Develop hierarchical framework
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4. Perform judgement for pairwise comparisons
5. Synthesize pairwise comparisons
6. Check for consistency
7. Perform steps (3-6) for all levels in the hierarchy
8. Develop overall priority ranking
9. Select best alternative

The steps to perform an AHP for comparing alternatives (Velmurugan et al., 2011).

Comparison of alternatives

Example: Air pollution reduction from ships

	5		1
	7		1
	2		1

*rankings are based on my own personal perspective

Rank	Meaning
1	Equal Importance
3	Moderate Importance
5	Essential or Strong Importance
7	Demonstrated Importance
9	Extreme Importance
2,4,6,8	Intermediate Values

Scale for ranking between criteria and elements (Saaty, 1987)

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Methodology

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The steps to perform an AHP for comparing alternatives (Velmurugan et al., 2011).

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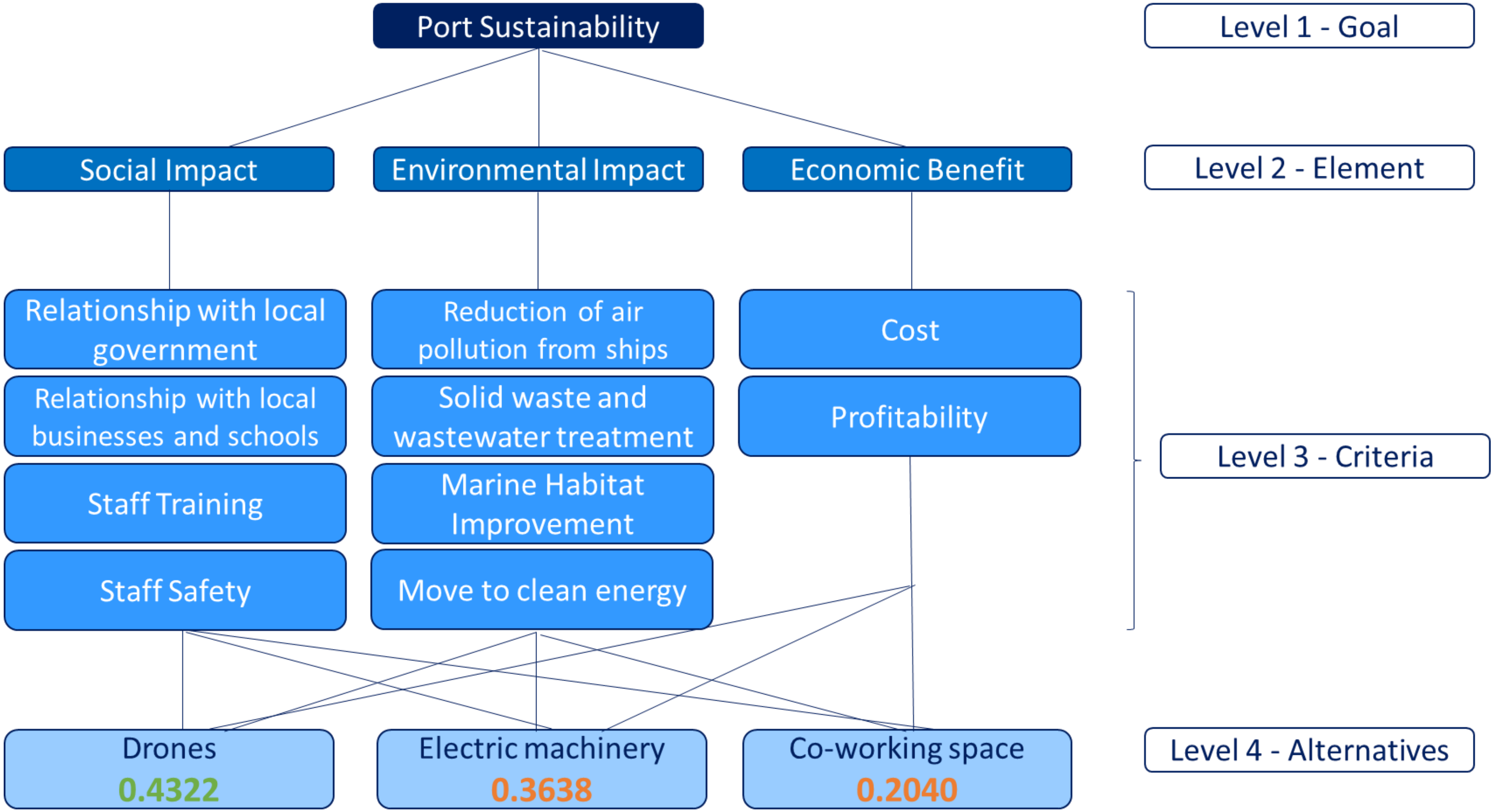
Analysis of alternatives



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Alternative rankings

Alternative	Weight (total)	Weight (environment)	Weight (social)	Weight (economic)
Drones	0.4322	0.5499	0.3990	0.3615
Machines	0.3638	0.3210	0.2223	0.5137
We-Work	0.2040	0.1291	0.4387	0.1248

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Conclusions

- Importance of ports
- Complexity of ports
- Differences in ports

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Thank you!

Questions?

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ANALYZING OPERATIONAL ENERGY EFFİCİENCY TECHNIQUES for REDUCING CO_2 EMISSIONS on TANKER VESSELS

Dr. Ali Atıl TALAY,
Capt. Anthony NIGRO

Webb Institute

wind support

Sustainability in Ship Design and Operations Conference

MARIN BETTER SHIPS, BLUE OCEANS

- Maritime transportation is responsible for the carriage of about 90 % of world trade

- Although ship trade is the most energy efficient type of transportation, enlargement of world fleet increases amount of the pollutants such as; sulphur oxides **(SOx),** nitrogen oxides **(NOx),** particulate matter **(PM),** and carbon dioxide **(CO_2).**

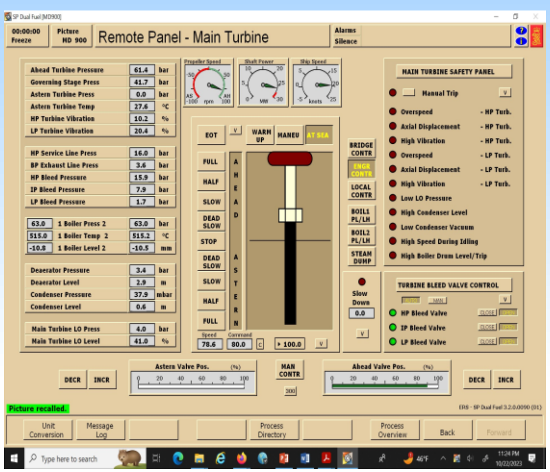
- The International Maritime Organization (IMO) has taken some measures to reduce SOx, NOx and CO_2 emissions.

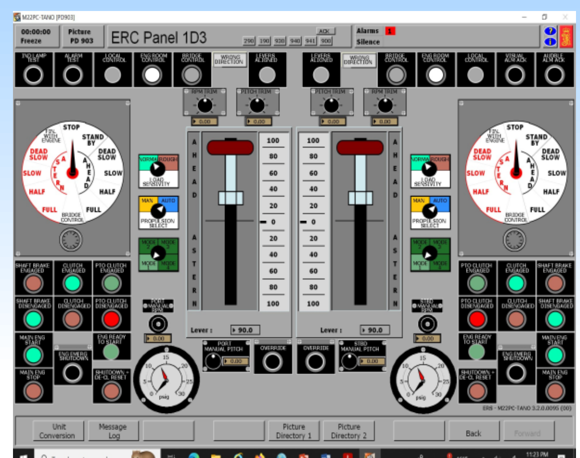
- Shipping, while essential for trade, contributes significantly to the emissions that cause climate change. Global shipping is responsible for **3%** of worldwide greenhouse gases (GHG).

- The International Maritime Organization (IMO) has been applying targets for reducing CO_2 emissions for future transportation since 2011.

- The IMO's initial strategy is to set carbon intensity goals of at least a 40% reduction in CO_2 emissions per transport work by 2030, and a 70% reduction by 2050 must be met.

- To reduce CO_2 emissions, an Energy Efficiency Design Index (EEDI) was created for new ships to increase their energy efficiency and Ship Energy Efficiency Management Plan (SEEMP) was developed for all new and existing ships to reduce fuel consumption.
- This study investigates operational energy efficiency techniques applied for tanker vessels based on Energy Efficiency Design Index (EEDI).
- A suitable data table is created for tanker vessels, which includes the CO_2 reduction methods and reduction rates based on available public data.
- As an operational technique, the impact of speed reduction for fuel consumption and CO_2 reduction for tanker vessels was analyzed.
- In the evaluation of ship speed affects on fuel consumption and reduction of CO_2 emissions, the Full Mission Engine Room Simulators (ERS) at United States Merchant Marine Academy was used.





Overview of Operational Energy Efficiency Techniques to Reduce CO_2 Emissions for Tanker Vessels

The Operational Energy Efficiency techniques for tanker vessels are evaluated as weather routing, trim optimization, voyage speed reduction, autopilot adjustments, turnaround time in port, energy saving operation awareness and power management.

- ***WEATHER ROUTING and VOYAGE PLANNING:***

- The target on weather routing is to achieve optimum speed in order to provide the voyage plan efficiency and to reduce consumption of fuel by providing the safety of ship, crew and cargo.

- On-time arrivals and effective cargo planning at the ports constitute a part of the weather routing.

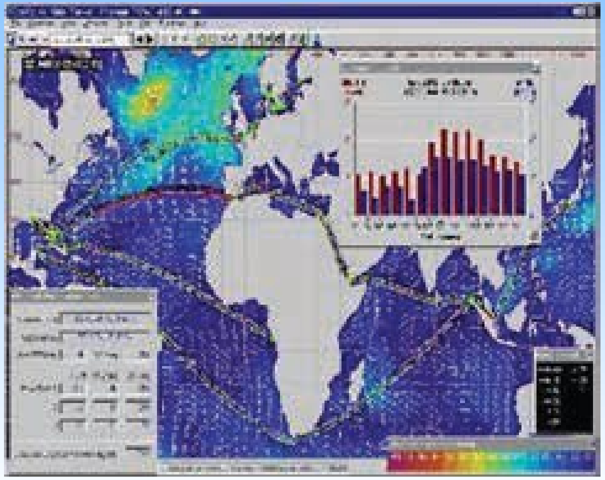


Figure 1. A sample software for weather routing

Overview of Operational Energy Efficiency Techniques to Reduce CO_2 Emissions for Tanker Vessels

- ***TRIM, DRAFT and BALLAST OPTIMIZATION***

- Trim optimization is a significant indicator to improve fuel economy and reduce emissions.
- The optimum trim is specific to the ship and depends on the ship's speed and draft.
- Optimizing the ship trim improves fuel efficiency for the specified draft and speed. Trim changes are performed with load stacking, fuel distribution and the ballast changes

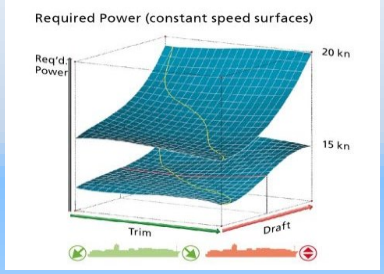


Figure 2. Output of sophisticated trim software

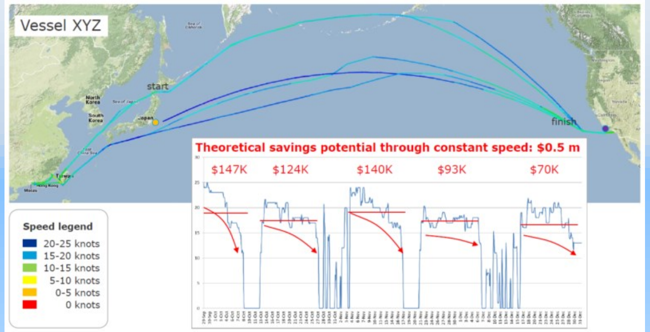


Figure 3. Speed optimization

- ***VOYAGE SPEED OPTIMIZATION:***

- Ship speed optimization can be a potentially cost-effective, CO_2 mitigation option for vessels.
- An optimal speed reduction can decrease required propulsion power and hull resistance.
- Less required propulsion power means lower fuel consumption and reduced CO_2 emissions to the atmosphere.

Overview of Operational Energy Efficiency Techniques to Reduce CO_2 Emissions for Tanker Vessels

- ***AUTOPILOT ADJUSTMENTS:***

- Autopilot optimization is quick to implement, assuming that autopilot is already installed on all vessels.
- For optimal adjustment and use of autopilot, best practice in shipboard procedures must be implemented (including recommendation on optimal number of rudder movements and angles for different sea conditions).

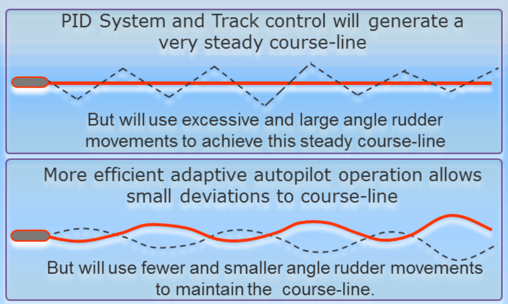


Figure 4. Adaptive autopilot operation allows small deviations to course-line

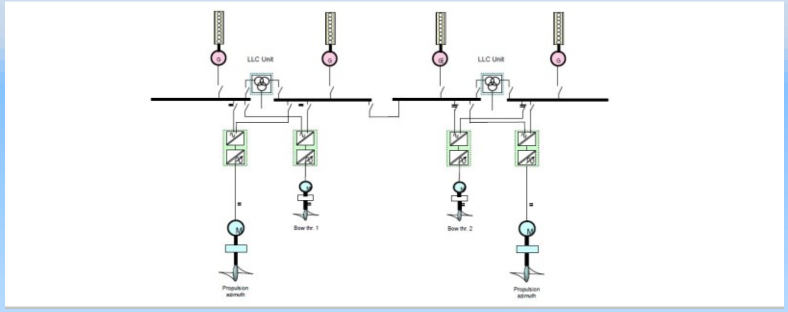


Figure 5. Power Management

- ***POWER MANAGEMENT:***

- The correct timing and changing of the number of generating sets is critical for the fuel consumption in Diesel Electric and auxiliary power installations. An efficient Power Management system is the best way to improve the system performance.

Overview of Operational Energy Efficiency Techniques to Reduce CO_2 Emissions for Tanker Vessels

- ***TURNAROUND TIME in PORT:***

- The faster port turnaround time gives possibility to decrease the vessel speed at sea.
- Turnaround time can be reduced by improving maneuvering performance or enhancing cargo flows.

- ***ENERGY SAVING OPERATION AWARENESS:***

- Energy awareness makes individuals and parties to draw on their knowledge and skills for ship energy efficiency.
- The departments and the individuals in the organization should reveal the necessary expertise in energy efficiency in order to overcome difficulties in implementing of measures.

Figure 6. Energy saving applications with parties

Overview of Operational Energy Efficiency Techniques to Reduce CO_2 Emissions for Tanker Vessels

Table 1. Operational CO_2 reduction techniques and CO_2 reduction percentages

Operational CO_2 Reduction Techniques	CO_2 Reduction (%)
Weather Routing and Voyage Planning	< 5
Trim, Draft and Ballast Optimization	<5
Voyage Speed Optimization	<23
Autopilot Adjustments	<1.5
Turnaround Time in Port	<10
Energy Saving Operation Awareness	<10
Power Management	<5

Vessel Speed Reduction as an Operational Technique

- Ship speed reduction can be a potentially cost-effective, CO_2 mitigation option for ships.
- The main principle that makes speed reduction important is that hull resistance increases exponentially with increasing the ship speed.
- Thus, even a minimal speed reduction can decrease required propulsion power. Less required propulsion power means lower fuel consumption and reduced CO_2 emissions to the environment.
- Reducing ship speed, longer voyage times and more ships being needed. Sometimes speed reductions might be expensive since they directly affect the freight capacity carried and also the profitability of a ship.

Figure 7. Speed optimization as an operational technique

- There is a trade-off between freight rates and cost. If the freight rates are low and fuel prices are high, it might be profitable to reduce ship speed.

Vessel Speed Reduction as an Operational Technique

- Our study assumes two different tanker vessels that departs from Port A and arrives at Port B.
- It is assumed that the vessels have no any other ports to stop between Port A and Port B.
- The vessels has covered a total distance of 4000 nm between two ports.

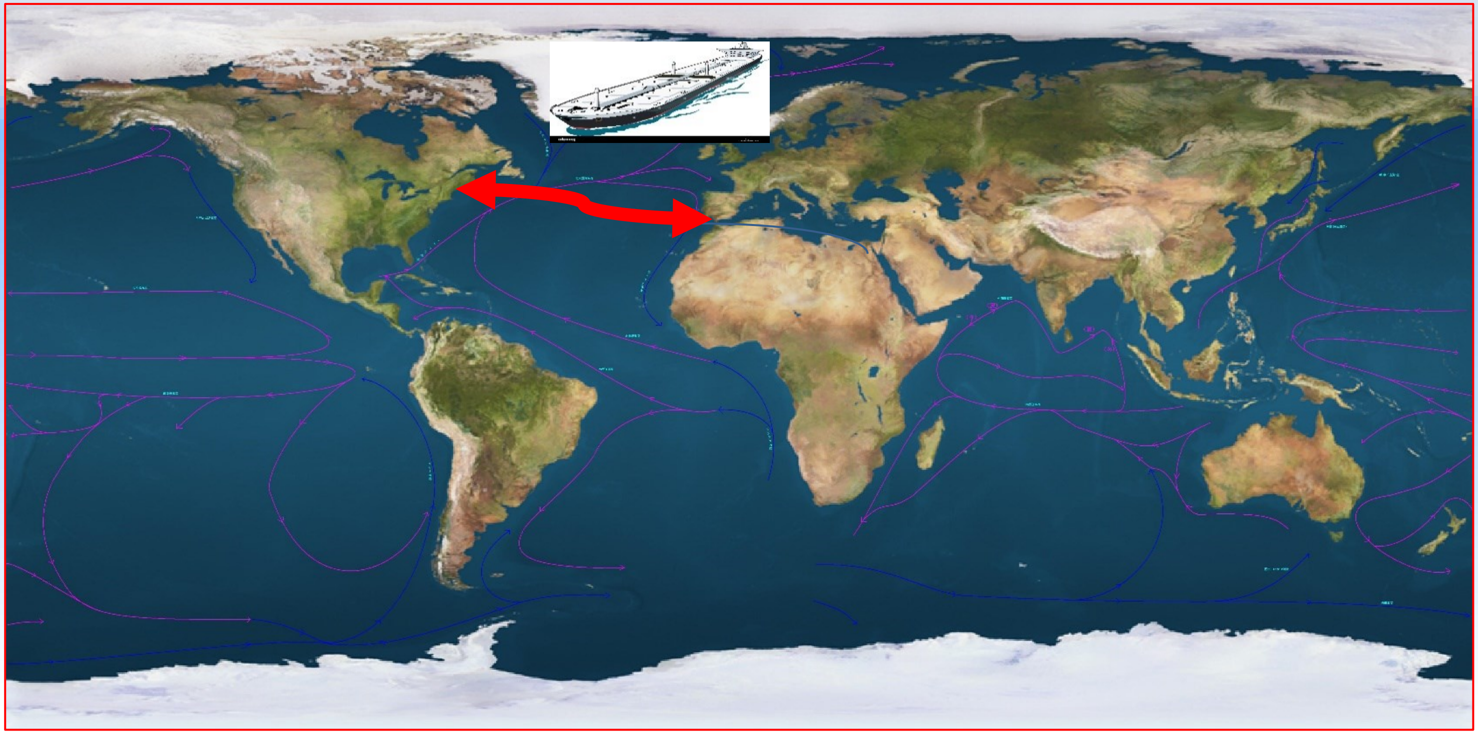


Figure 8. Navigating zone between port A and port B

Vessel Speed Reduction as an Operational Technique

- In this research, Kongsberg Full Mission Engine Room Simulator (ERS) at United States Merchant Marine Academy is used for the application of speed reduction of tanker vessels.
- We operated ERS with two different ship types which are designed as tanker vessels.

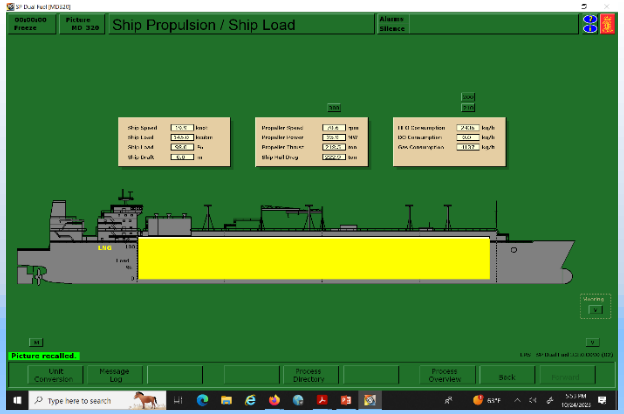


Figure 10. Vessel 1

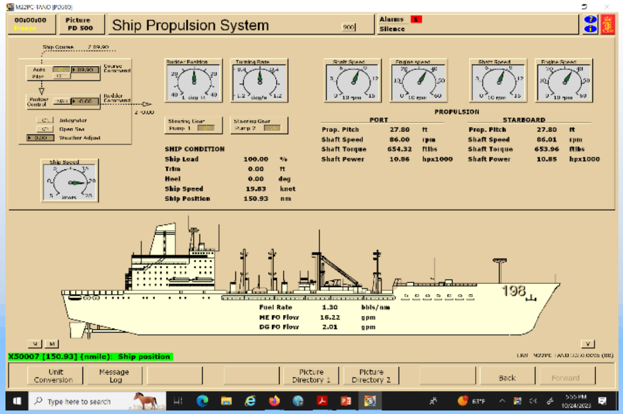


Figure 11. Vessel 2

Tanker Vessel 1 Specifications

Model :SP Dual Fuel (HFO and LNG)
Engine: Steam Power Plant with dual boiler
Electric Power Plant: two diesel , two turbo generators
Main Turbine Max. Power: 27000 kW
Service Speed: 19.5 knots

Tanker Vessel 2 Specifications

Model: M22 PC T-AO-198
Engine: Two Medium Speed Diesel
Electric Power Plant: two diesel, two power take off generators
MCR: 11760 kW
Service Speed: 20 knots

Vessel Speed Reduction as an Operational Technique

Collection and Evaluation of the Data

- The fuel consumption data at different speeds and loads were recorded by operating the ERS.
- Each vessel can be operated with different fuels and in different power generation modes.
- *For vessel 1 (steam power plant), there are two options for operation. These are;*

Option 1: HFO as fuel and Diesel Generator/ Turbo Generator as power generation

Option 2: HFO/LNG as fuel and Diesel Generator/ Turbo Generator as power generation

- *For vessel 2 (diesel power plant), there are two options for operation. These are;*

Option 1: HFO/MDO as fuel and Diesel Generator as power generation mode.

Option 2: HFO as fuel and Power Take-off as power generation mode.

Option 3: MDO as fuel and Diesel Generator as power generation mode.

Option 4: MDO as fuel and Power Take-off as power generation mode.

- It is assumed that port times take 5 days per trip.
- According to the data collected, it is evaluated that the effects of speed reduction to the total fuel consumption per trip and total number of trips in a year.

DATA COLLECTION

- Option 2 for both power plants were selected for operation and collecting data.
- Option 2 for steam power plant: HFO/LNG as fuel and Diesel Generator/ Turbo Generator as power generation
- Option 2: HFO as fuel and Power Take-off as power generation mode.

Table 2. Fuel consumption of vessel 1 in different loads and service speeds.

LOAD %	SHIP SPEED	FUEL OIL CONSUMPTION	
	knots	HFO (t/hr)	LNG (t/hr)
50	14.7	0.65	2.37
55	15.4	0.93	2.41
60	16.1	0.93	2.67
65	16.8	0.93	2.95
70	17.5	0.93	3.21
75	18.1	0.93	3.52
80	18.5	0	4.49
85	20.8	0	5.42
90	21.6	0	5.85
95	21.8	0	6.00
100	22	0	6.10

Table 3. Fuel consumption of vessel 2 in different loads and service speeds.

LOAD %	SHIP SPEED	FUEL OIL CONSUMPTION
	knots	HFO (t/hr)
50	13.05	1.93
55	13.76	2.18
60	14.53	2.42
65	15.34	2.59
70	16.09	2.80
75	17.11	3.21
80	18.15	3.60
85	19.24	4.15
90	20.23	4.86
95	21.07	5.51
100	21.5	6.08

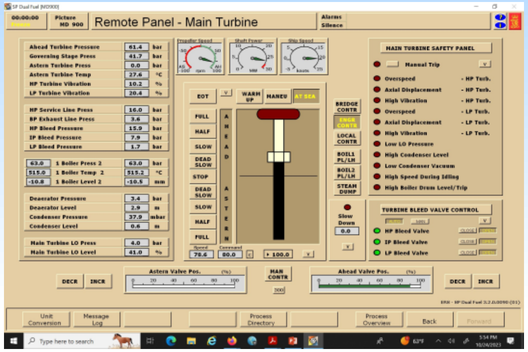


Figure 12. Engine room panel for vessel 1

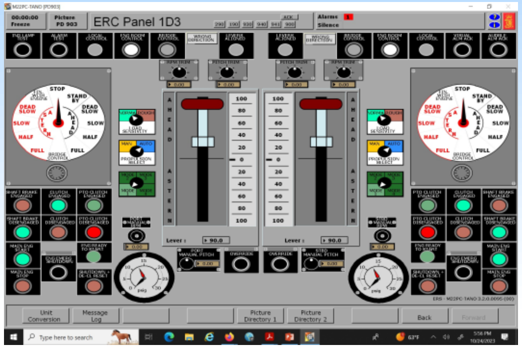


Figure 13. Engine room panel for vessel 2

DATA ANALYSIS and METHODOLOGY

Calculation of the Impact of Speed Reduction on Fuel Consumption and Total Trip Time

The times that the ship spends at sea and in port are expressed as follows:

At sea: Total time at sea (T_0)= L / 24*V_0 (days)

L = Total distance between two ports (nm)

V_0 = Certain speed of the tanker vessel (knot)

In port: Total time in port t_0 is assumed 5 days for each trip.

- The time that the tanker vessel spends at sea depends only on speed, while the time at port depends on many factors, such as amount of cargo to be handled, loading and unloading speed, etc. For our analysis, we assume that the time in port is days

DATA ANALYSIS and METHODOLOGY

Total fuel consumptions at a certain speed of the tanker vessel are expressed as follows:

At sea: Total fuel consumption per trip at sea $(F) = T_0$ (h) * f (t/h)

T_0 = Total time at sea

f = Hourly fuel consumption

At port: It is assumed that there is no fuel consumption at port.

DATA ANALYSIS and METHODOLOGY

Table 4. Total voyage times and total fuel consumptions of vessel 1 in different service speeds.

Ship Speed (knots)	Voyage Time (days)	Total Fuel Consumption HFO (t/hr)	Total Fuel Consumption LNG (t/hr)	Difference of Voyage Time (days)	Difference of Fuel Consumption HFO (t/hr)	Difference of Fuel Consumption LNG (t/hr)
14.7	11.34	177.52	644.90	0	0	0
15.4	10.82	240.88	625.97	0.52	63.36	-18.92
16.1	10.35	230.41	662.11	0.47	-10.47	36.14
16.8	9.92	220.81	702.380	0.43	-9.60	40.27
17.5	9.52	211.95	732.57	0.40	-8.86	30.19
18.1	9.21	204.93	777.90	0.32	-7.03	45.33
18.5	9.01	0	970.81	0.20	-204.93	192.91
20.8	8.01	0	1042.30	1.00	0	71.50
21.6	7.72	0	1083.33	0.30	0	41.03
21.8	7.65	0	1100.92	0.07	0	17.58
22	7.58	0	1109.63	0.07	0	87.18.

Table 5. Total voyage times and total fuel consumptions of vessel 2 in different service speeds.

Ship Speed (knots)	Voyage Time (days)	Total Fuel Consumption HFO (t/hr)	Difference of Voyage Time (days)	Difference of Fuel Consumption HFO (kg/hr)
13.05	12.77	592.44	0	0
13.76	12.11	633.18	0.66	40.74
14.53	11.47	665.27	0.64	32.10
15.34	10.86	675.75	0.61	10.47
16.09	10.36	696.20	0.51	20.45
17.11	9.74	751.33	0.62	55.13
18.15	9.18	793.37	0.56	42.04
19.24	8.66	862.70	0.52	69.32
20.23	8.24	961.04	0.42	98.35
21.07	7.91	104.65	0.33	85.44
21.5	7.75	113.03	0.16	83.86

DATA ANALYSIS and METHODOLOGY

Calculation of the impact on speed reduction to number of trips of a tanker vessel in a year

Annual total number of trips are expressed as follows :

Annual total number of trips (T)= 365 (days) / T_0 + t_0 (days)

T_0 = Total time at sea

t_0 = Total time at port (it is assumed 5 days)

DATA ANALYSIS and METHODOLOGY

Table 6. Number of trips at different speeds for vessel 1.

Ship Speed (knots)	Voyage Time (days)	Time at Port (days)	Time per Trip (days)	Number of Trips (Anually)
14.7	11.34	5	16.34	22.34
15.4	10.82	5	15.82	23.07
16.1	10.35	5	15.35	23.78
16.8	9.92	5	14.92	24.46
17.5	9.52	5	14.52	25.13
18.1	9.21	5	14.21	25.69
18.5	9.01	5	14.01	26.05
20.8	8.01	5	13.01	28.05
21.6	7.72	5	12.72	28.70
21.8	7.65	5	12.65	28.86
22	7.58	5	12.58	29.02

Table 7. Number of trips at different speeds for vessel 2.

Ship Speed (knots)	Voyage Time (days)	Time at Port (days)	Time per Trip (days)	Number of Trips (Anually)
13.05	12.77	5	17.77	20.54
13.76	12.11	5	17.11	21.33
14.53	11.47	5	16.47	22.16
15.34	10.86	5	15.86	23.01
16.09	10.36	5	15.36	23.77
17.11	9.74	5	14.74	24.76
18.15	9.18	5	14.18	25.74
19.24	8.66	5	13.66	26.72
20.23	8.24	5	13.24	27.57
21.07	7.91	5	12.91	28.27
21.5	7.75	5	12.75	28.62

CONCLUSION of the RESEARCH

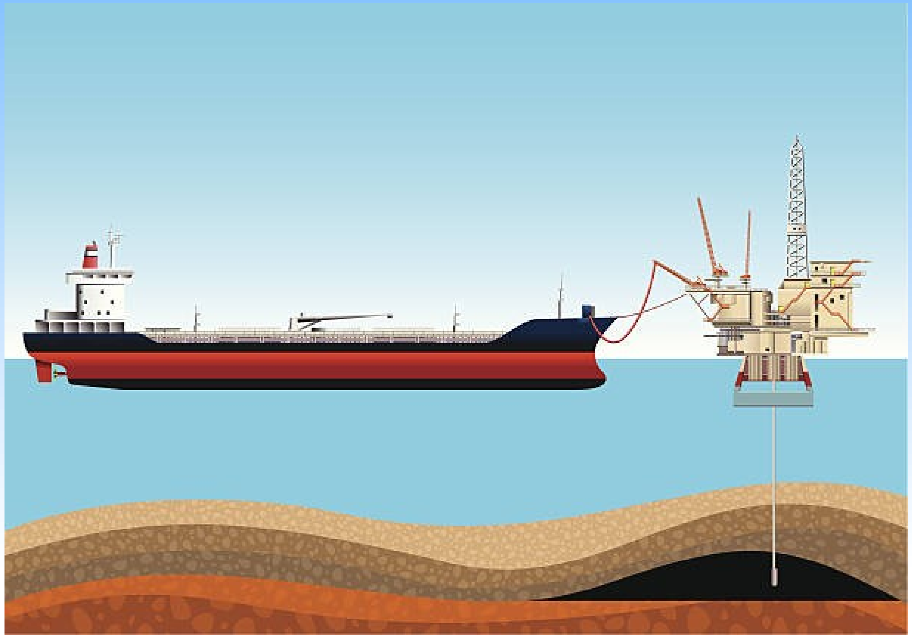
- This study has first investigated the applicable operational energy efficient techniques for tanker vessels based on EEDI measurements and SEEMP template.
- There were 7 operational techniques found with the applicability to measure CO_2 reduction potentials.
- The biggest reduction for operational applications is found as speed reduction/optimization, with 23 % CO_2 reduction potential.
- Turnaround time in port and energy saving awareness operations present another high CO_2 reduction potential of 10 % in this category.
- Also investigated, was an operational scenario, focusing on speed reduction for two different tanker vessels equipped with different power plants.
- Voyage times and fuel consumptions in different service speeds between Port A and Port B was determined by operating ERS.

CONCLUSION

- The relationship between engine load and specific fuel consumption was assessed using ERS to identify a more sophisticated measure of the relationship between fuel consumption, vessel load, and vessel speed of tanker vessels.
- The results suggest that speed reduction under certain conditions is beneficial in terms of reducing emissions, but the real effectiveness of such a scheme depends on the port time, freight market rates and fuel prices.
- Further studies are being conducted to investigate the variation in specific fuel consumption as a result of changes in engine load with operating ERS in all modes.
- The ERS will be used for a future study of cost/benefit analysis depending on speed, fuel consumption, fuel prices and freight rates between two specific ports under different speeds and emission limitations.

THANKS A LOT FOR YOUR ATTENTION …

QUESTIONS!!!



Magnetically Recoverable & Reusable NanoComposites

for Treating Vessel Discharges

Dr. Ping Y. Furlan
Math & Science Department
United States Merchant Marine Academy
November 7, 2023

United States Merchant Marine Academy
Maritime Administration of the United States of America
Department of Transportation

Research Goal

To use magnetic separation based technology for treating vessel discharges via the development of **low-cost**, **eco-friendly**, **easily recoverable**, **reusable**, and **highly functional** nanocomposites

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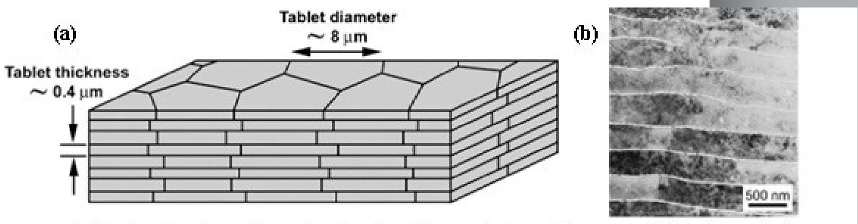
NanoComposites

- Multiphase solid with at least one phase being nano-scaled (<100 nm)
- **Nano = Size dependent new properties**
- Synergistic/hybrid properties of the components
- **Natural nanocomposites: bones, teeth & sea shells**

https://en.wikipedia.org/wiki/Mollusc_shell



(a) An illustration of the microstructural organization of nacre and (b) a transmission electron micrograph depicting the "brick-and-mortar" arrangement of the aragonite tablets and the organic interfacial layers in nacre. Both images adapted from Barthelat et al. (2007)

http://umich.edu/~acemrl/NewFiles/Bio-inspiredECC.html

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Shipping, Vessel Discharges & MARPOL Regulations

Shipping & World Economy

- 90% of world's food, products, and energy
- **Safer, greener & more efficient**
- > $649 billion to U.S. GDP
- **Increased demand for waterway transportation**

Large Amounts of Vessel Discharges

- **Bilge water (lowest space)**
- Ballast water (stability)
- **Deck runoff**
- Grey & Black water (shower, sinks, laundry facilities)

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Shipping, Vessel Discharges & MARPOL Regulations

Pollutants	MARPOL (IMO)	Sources
Oily water	<15 ppm oil (73/78, 83)	• Bilges • Accidental spills • Grey water
Invasive microbes, pathogens	**Indicator Microbes** **< 0.01-2.5 cfu/mL** (2004, 2017-Ballast, 73/78)	• Ballast water • Black & grey water • Oily water
Harmful chemicals, suspended solids, **>10 mm organisms**	No visible solids No detectable organisms (2004, 2017-Ballast, 73/78)	• Antifouling paints • Cathodic protection • All other wastes/wastewaters
SO_x, NO_x **CO_2**	% S in fuel < 0.50 % (1997, 2020) 50% reduction by 2050 rel. 2008	• Combustion Exhaust

Current Water Treatment Technology

- Filtration
- Coagulation
- Flocculation
- Ion Exchange
- AC
- pH

Harmful chemicals, suspended solids, >10 μm organism

- Oily water separator

<15 ppm oil

Disinfection

- Chlorination
  - Corrosive
  - Carcinogenic by-products
- UV Radiation
  - Costly
  - No suspended particles

<0.01-2.5 CFU/mL indicator microbes

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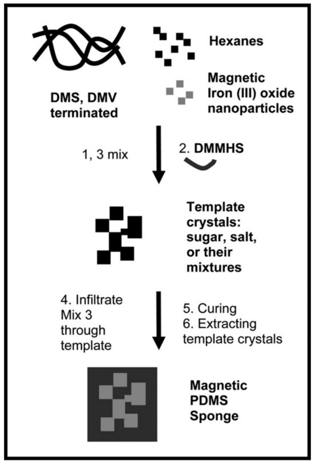
Magnetic Separation Based on Nanocomposites

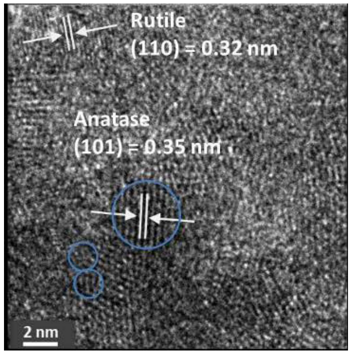
– A Promising Technology

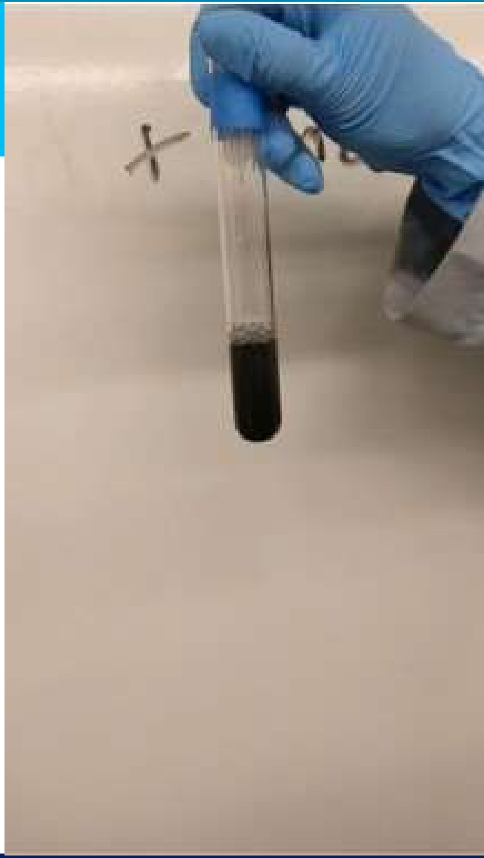
- Rapid recovery
  - reusability
  - 2nd pollution elimination
- No contact action
- Not affected by ship's motion
- Synergistic
  - highly magnetic
  - additional functionalities

Magnetic PDMS sponge



TiO_2 based magnetic nanocomposite





P.Y. Furlan, B.M. Ackerman, M. E. Melcer, S. E. Perez *J Ship Prod Des* **2017**, 33 (03): 227–236

M. Keeley, K. Kisslinger, C. Adamson, **P.Y. Furlan** *J. Mar. Sci. Eng.* **2021**, *9*(9), 943

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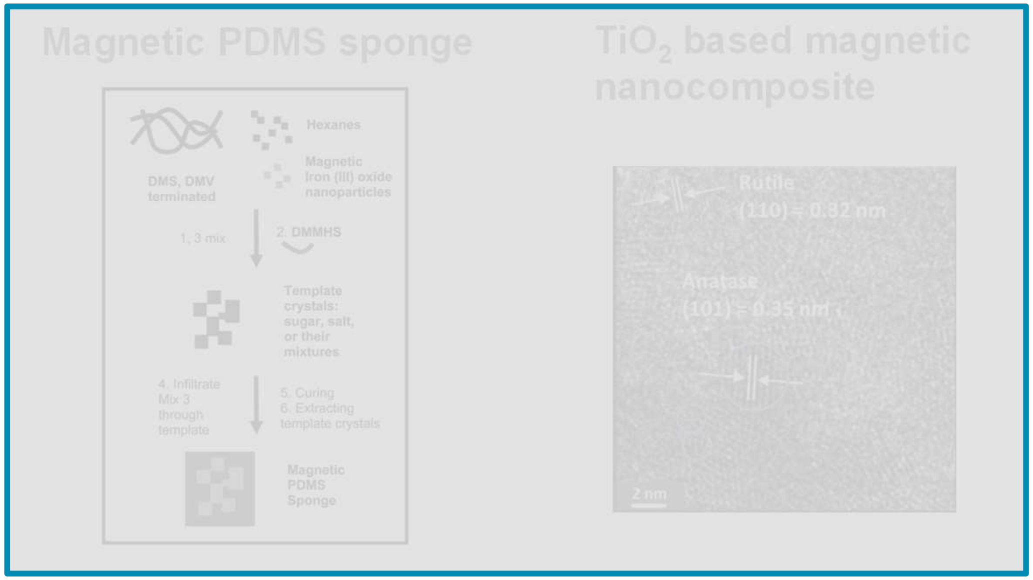

P.Y. Furlan, B.M. Ackerman, M. E. Melcer, S. E. Perez*J Ship Prod Des* **2017**, 33 (03): 227–236
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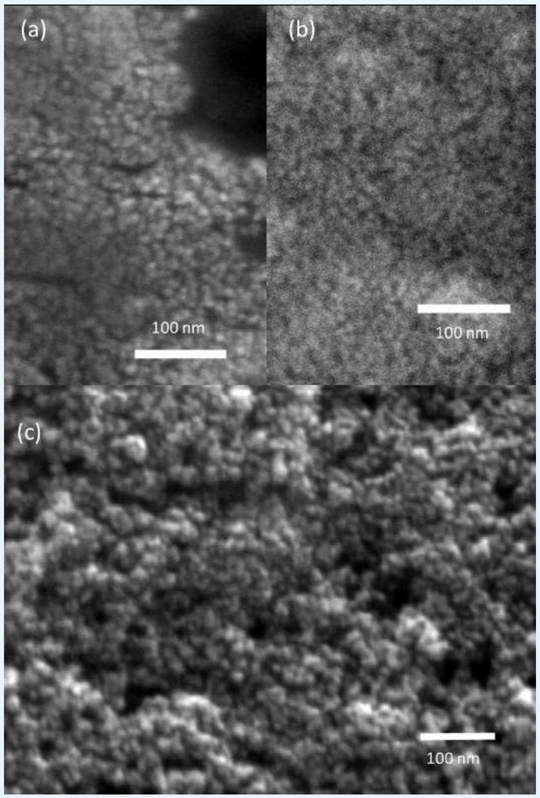
Reusable Magnetic AgNPs-Based Nanocomposites for Water Disinfection



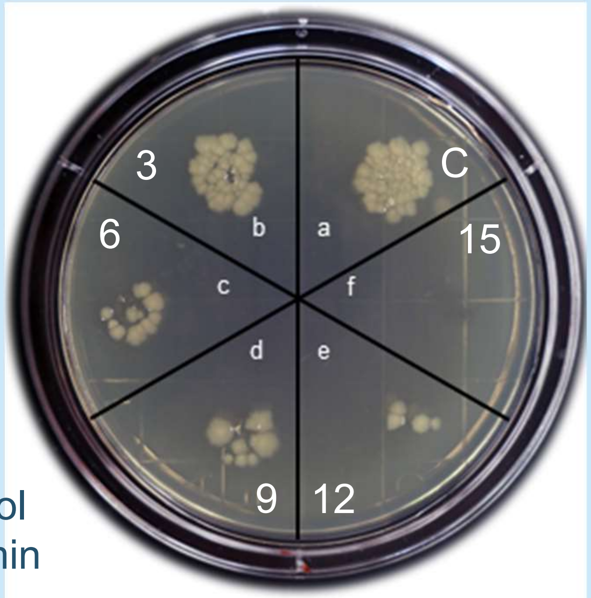
Component	Functionality
Fe_3O_4 MNPs (10-16 nm)	• Highly magnetic • Large surface area for intimate binding to AC
Activated Carbon (AC, 20 μm)	• Superior absorption ability • Host and spacer for MNPs & AgNPs
Ag NPs (10-12 nm) (Ag source - 560,000 metric tons)	• Strong antimicrobial activity to bacteria, fungi, algae, viruses • Low toxicity toward humans • EPA recommends <0.1 ppm Ag in drinking water

P.Y. Furlan, A.J. Fisher, A.Y. Furlan, M.E. Melcer, D.W. Shinn, and J.B. Warren *Inventions*, **2017**, 2, 10.
P.Y. Furlan, A.J. Fisher, M.E. Melcer, A.Y. Furlan, and J.B. Warren *J. Chem. Educ*, **2017**, 94(4), 488-493.

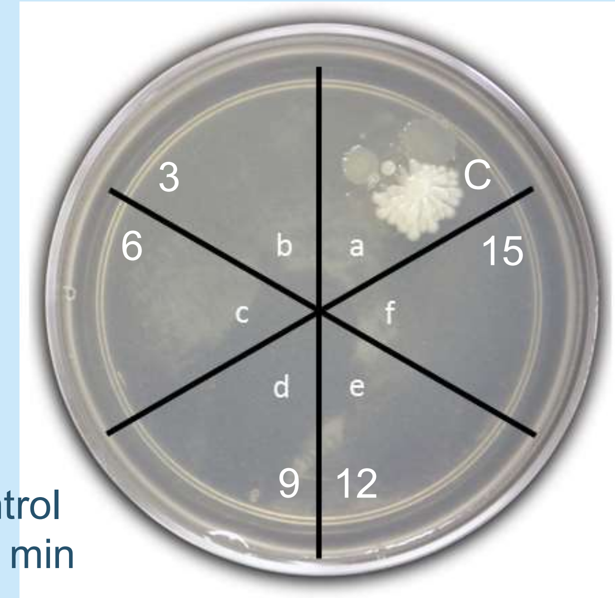
Reusable Magnetic AgNPs-Based Nanocomposites for Water Disinfection

- 0.5 g MACAg (0.15%Ag)
- Killed $2x10^6$ cfu in 15 min
- 0.01 ppm Ag release by AA

- 0.5 g MACAg (0.22%Ag)
- Removed all 10^5 viable microbes from Long Island Sound Surface Water in 3 min



cfu = colony-forming unit



C= Control
Time in min

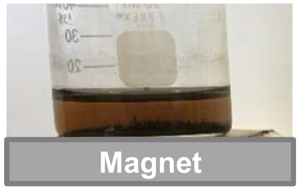
C= Control
Time in min

Reusable Magnetic AgNPs-Based Nanocomposites for Water Disinfection

Major Concerns

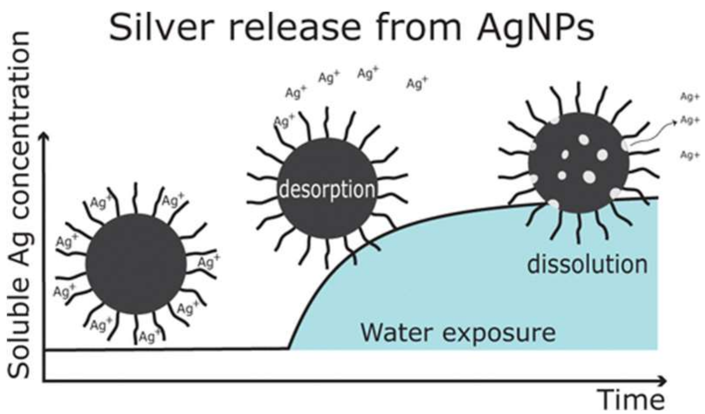
Oxidation of Magnetite

$$2\,Fe_3O_4 + \tfrac{1}{2}\,O_2 \rightarrow 3\,Fe_2O_3$$



After 1 min Sonication

Ag Release > 0.1 ppm



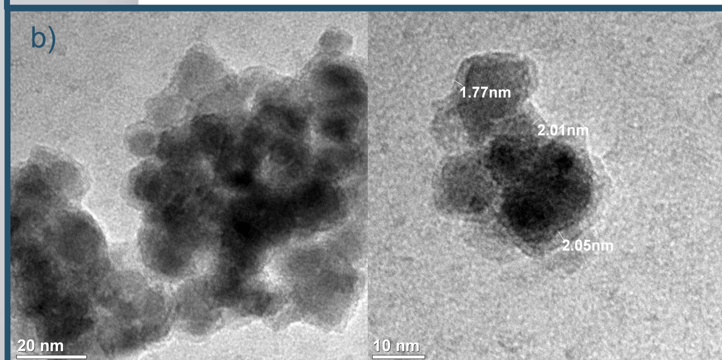
J. Dobias, R. Bernier-Latmani, *Environ. Sci. Technol.* 2013, 47, 9, 4140−4146

Reusable Magnetic AgNPs-Based Nanocomposites for Water Disinfection

Simple and Green Procedure for Forming Silica Shells

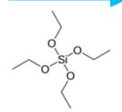
a)

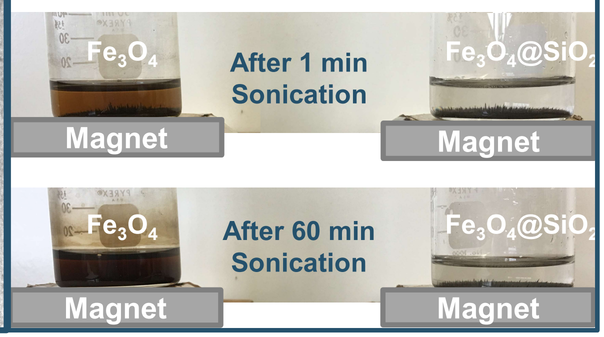
b)

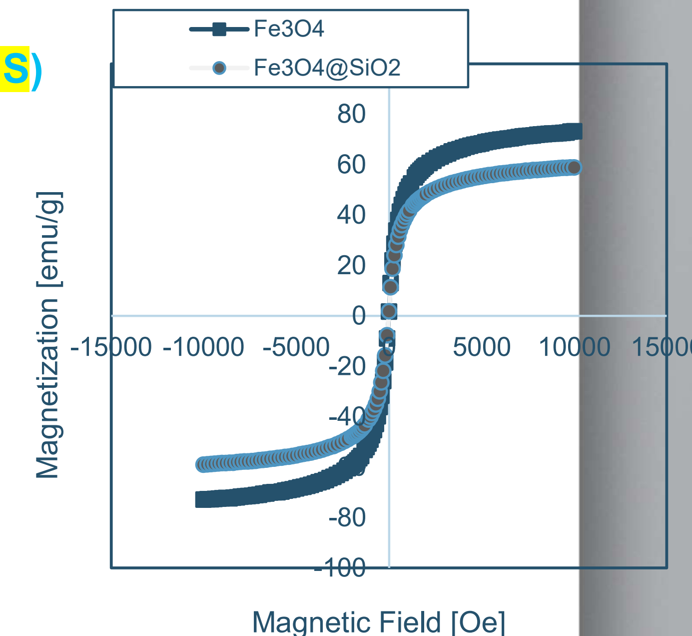


TEOS (tetraethoxysilane)

Fe_3O_4 ⟶ $Fe_3O_4@SiO_2$ (MS)





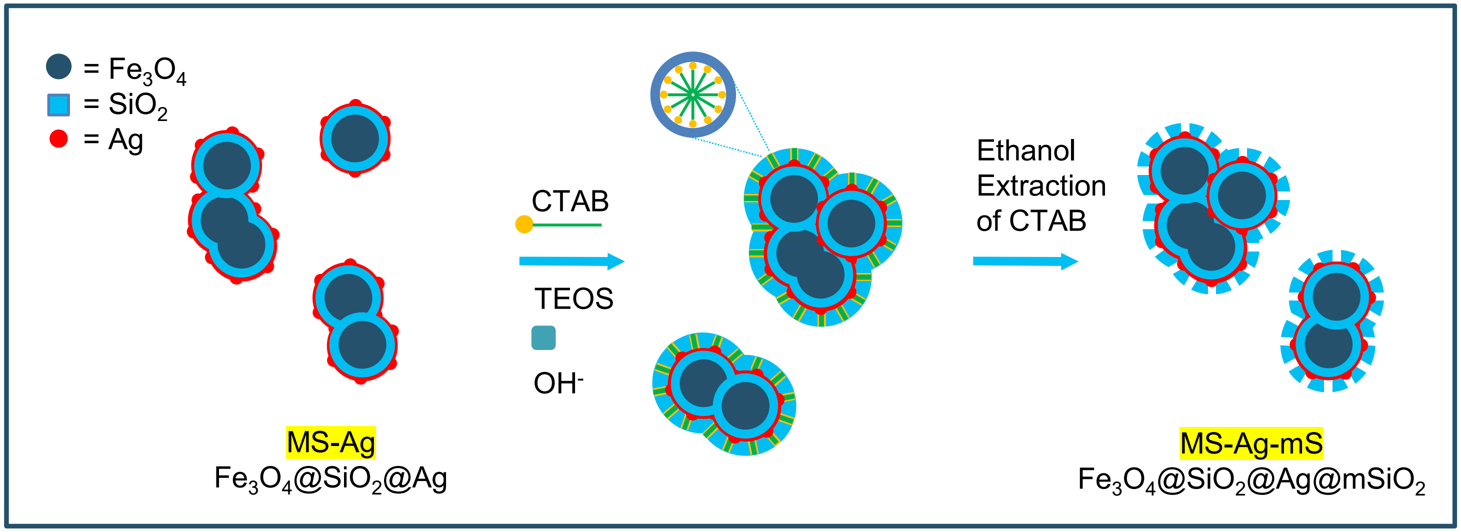


P.Y. Furlan, A.Y. Furlan, K. Kisslinger, M. Melcer, D. Shinn, J. Warren, *ACS Sustainable Chem. Eng.* **2019**, 7, 18, 15578–15584

Reusable Magnetic AgNPs-Based Nanocomposites for Water Disinfection

Novel Core-Multishell Approach

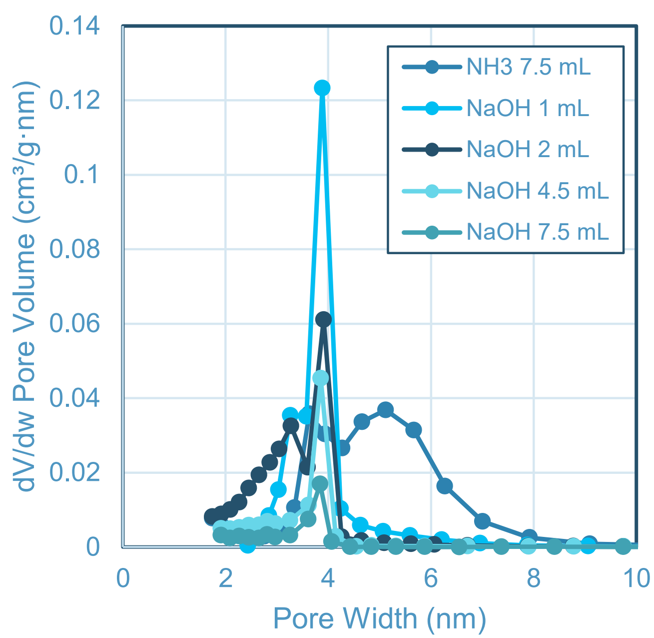
Cetyltrimethylammonium bromide (CTAB, ~2nm long)

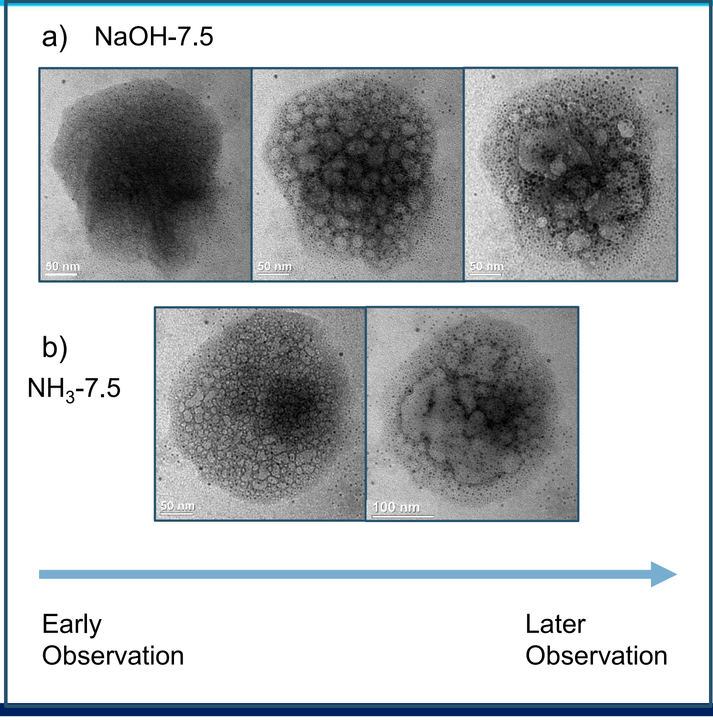


P.Y. Furlan, A.Y. Furlan, K. Kisslinger, M. Melcer *ACS Appl. Mater. Interfaces* **2021**, 13, 40, 47972–47986

Reusable Magnetic AgNPs-Based Nanocomposites for Water Disinfection

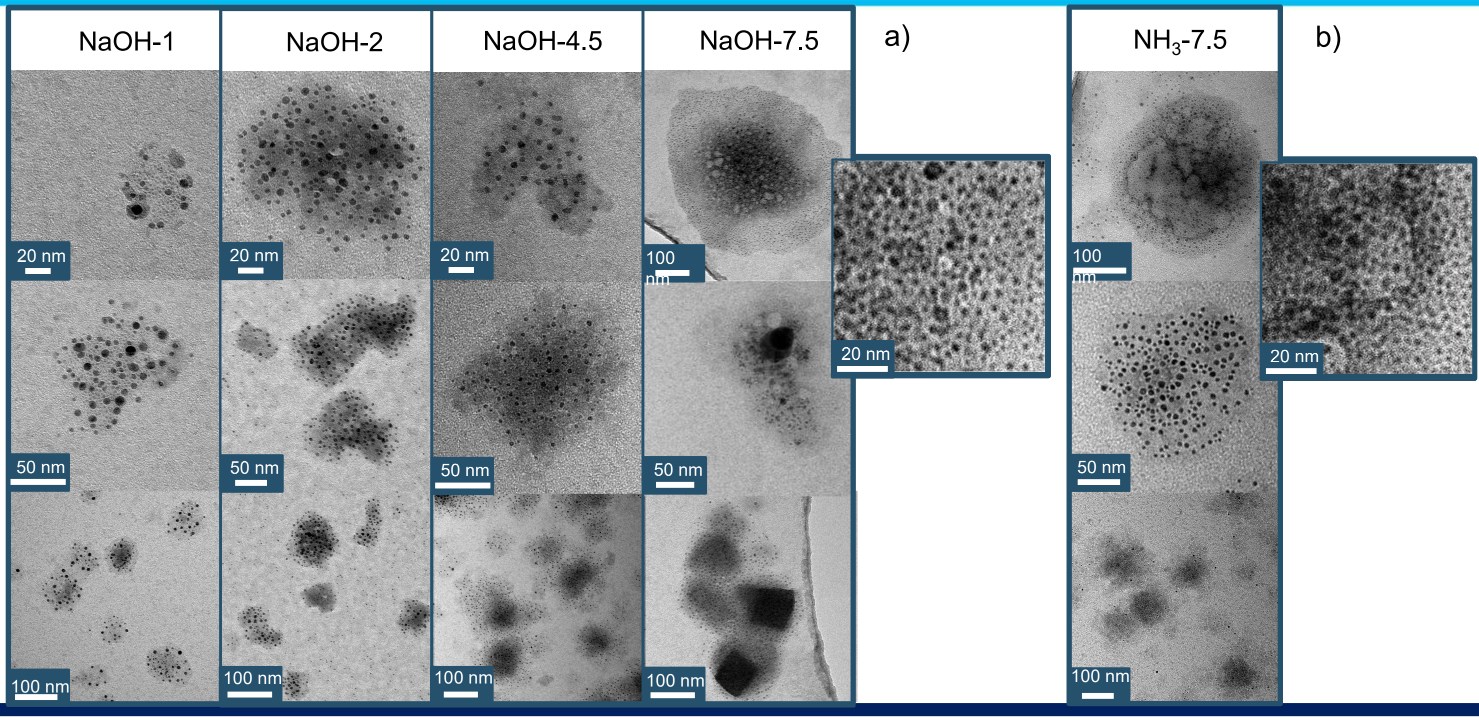
BET Results & TEM Images using an 80 kev e-Beam





Reusable Magnetic AgNPs-Based Nanocomposites for Water Disinfection

Transmission Electron Microscope (TEM) Images using an 80 kev e-Beam



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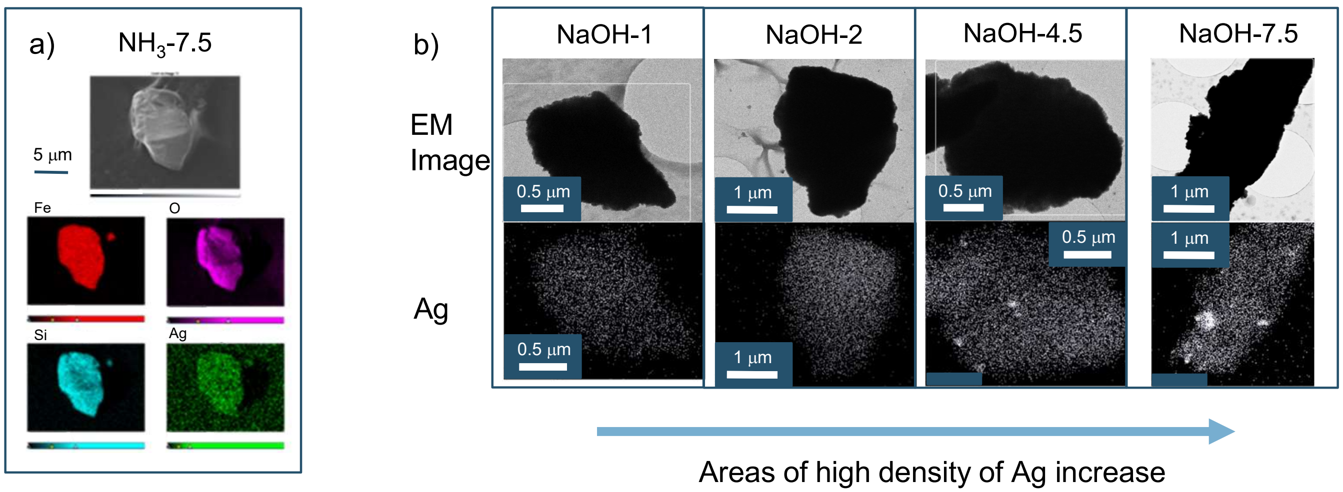
Reusable Magnetic AgNPs-Based Nanocomposites for Water Disinfection

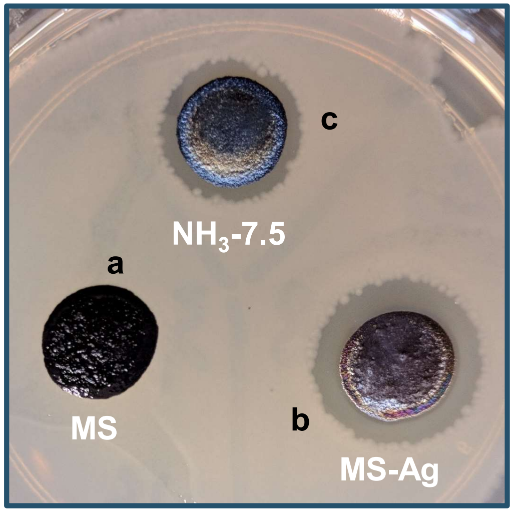
Energy Dispersive Spectroscopy (EDS) Elemental Maps

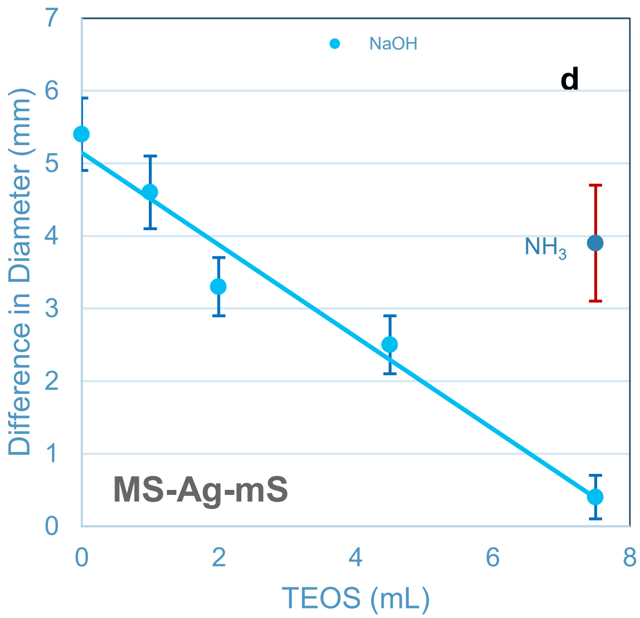


Reusable Magnetic AgNPs-Based Nanocomposites for Water Disinfection

Results of the Diameter of Inhibition Zone

100 µL 5x10^7 cfu/mL *E. coli* culture
25 mg/25 µL sample
(cfu = colony-forming unit)



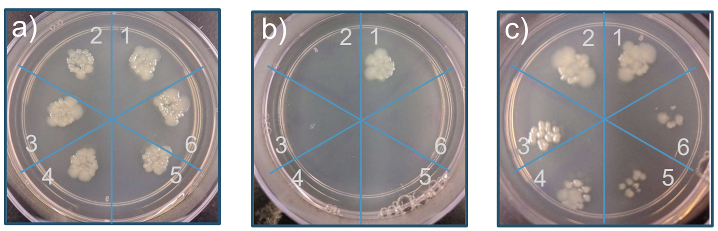


Reusable Magnetic AgNPs-Based Nanocomposites for Water Disinfection

Antimicrobial Activities against *E. coli*

Shaking Test: 5 mg in 1 mL culture. Sampling every 3 min. Plate results of 10^4 cfu/mL *E. coli* culture.

MS	MS-Ag	NH_3-7.5



Reusability Test: 3 repeated cycles, each 15 min shaking. Plate results of 10^4 cfu/mL *E.coli* culture.

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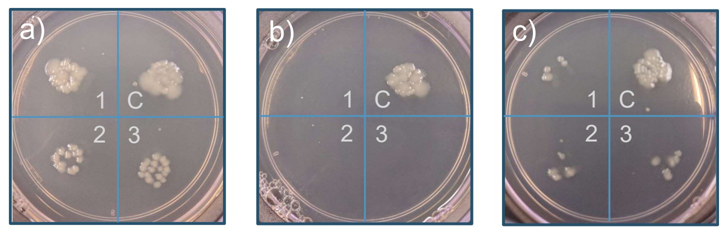

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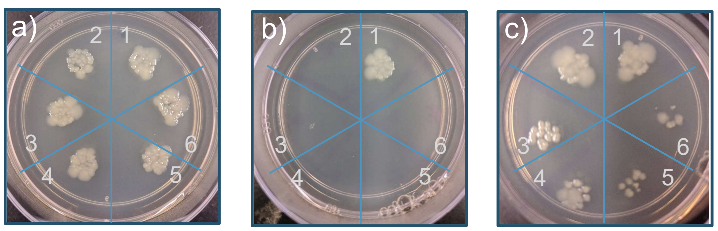

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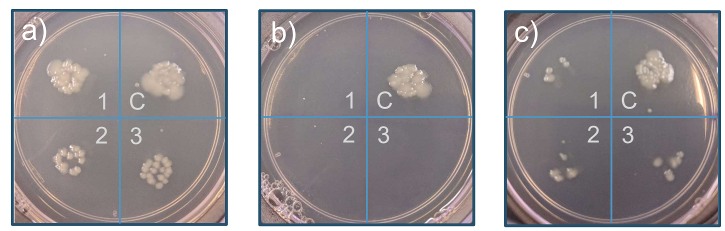

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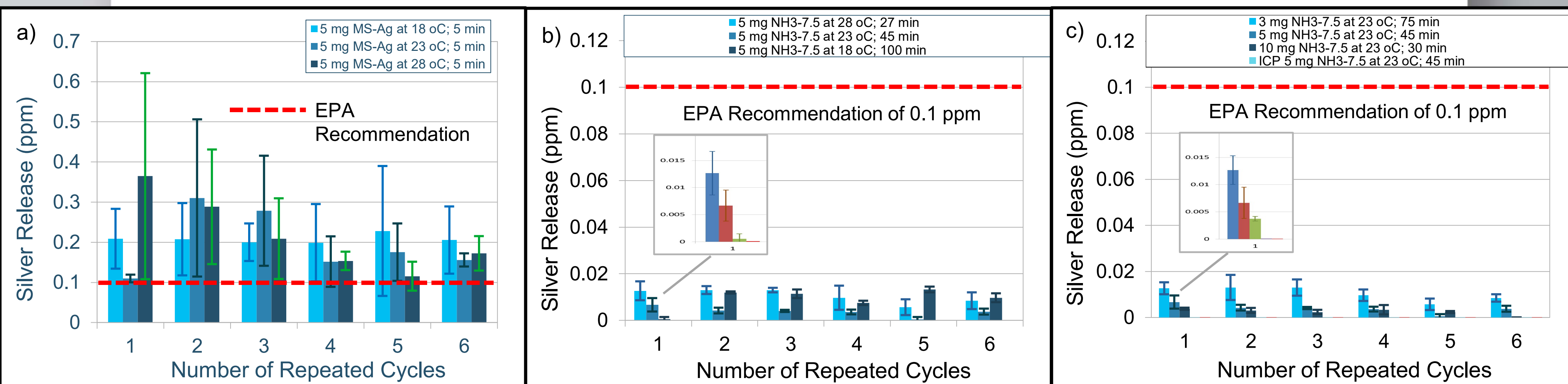
Reusable Magnetic AgNPs-Based Nanocomposites for Water Disinfection

Silver Release Profile by AA Spectroscopy & ICP-MS

4-Log Reduction in Viable E. coli Counts



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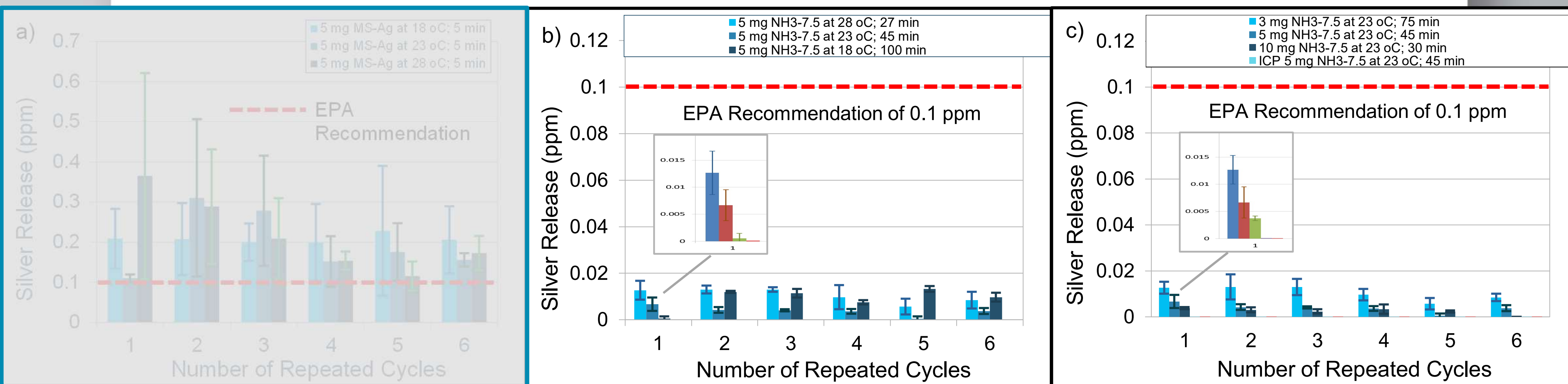

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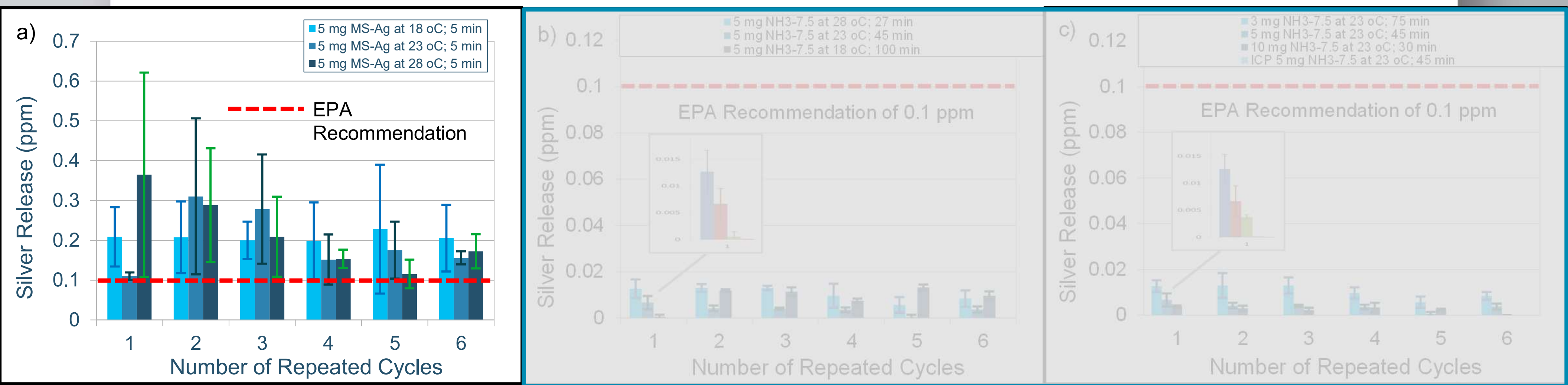

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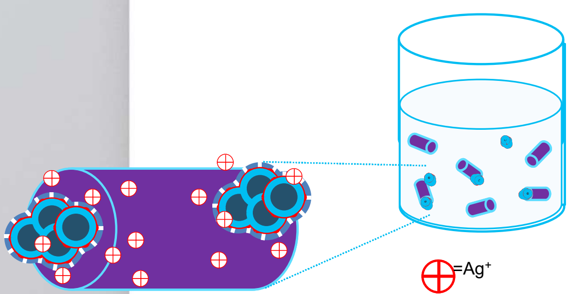

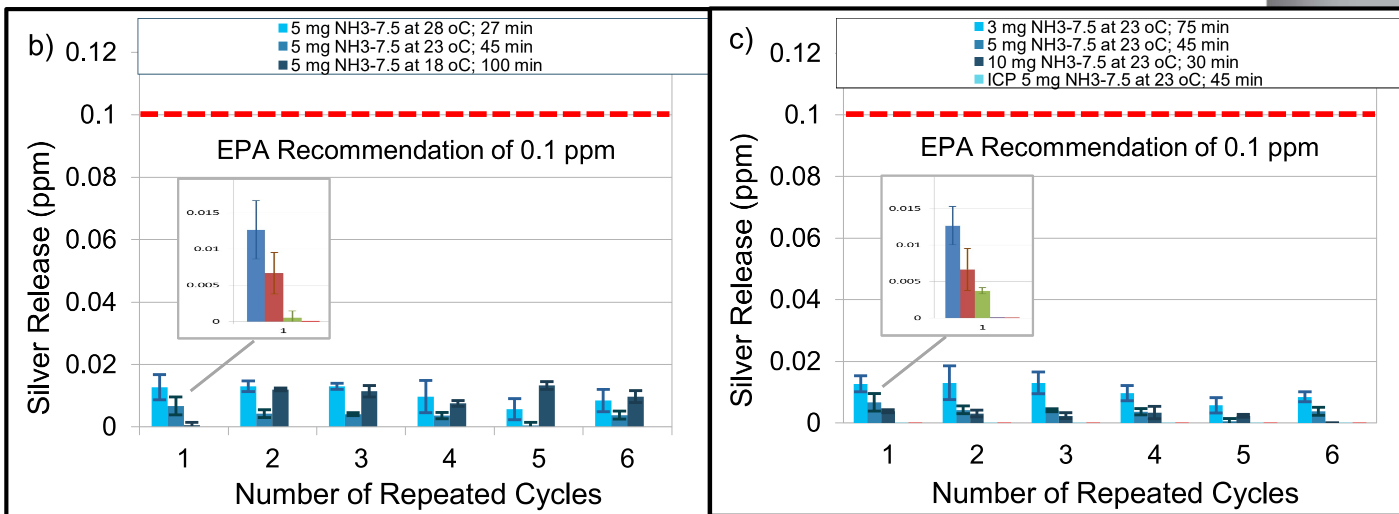

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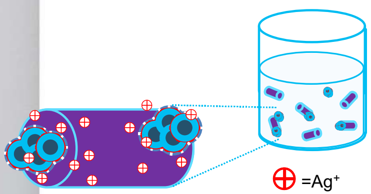
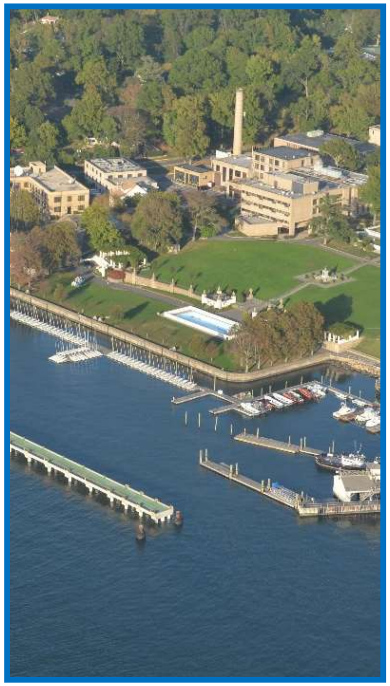
Reusable Magnetic AgNPs-Based Nanocomposites for Water Disinfection

Disinfection of Long Island Sound Surface Water



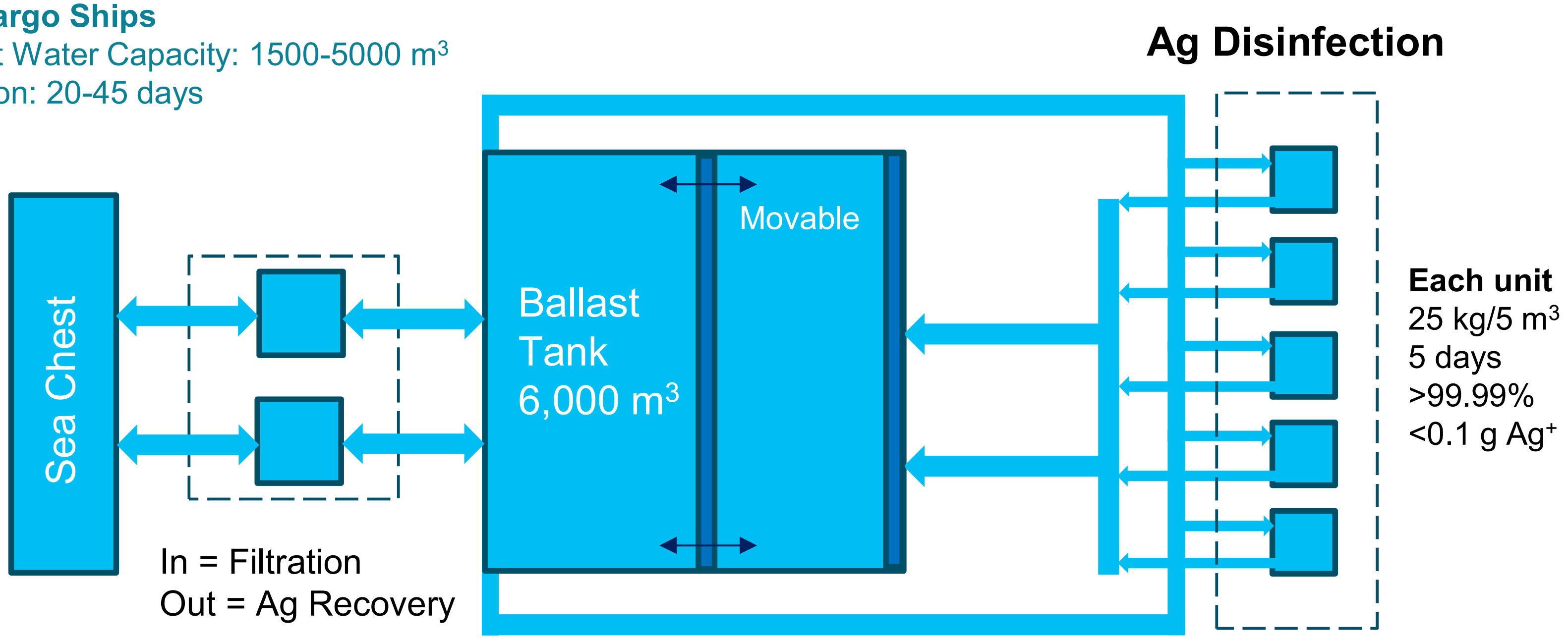
Treating LISS water collected in Sept. at 23-24°C by 1 mg/mL of a) NH_3-7.5 b) NaOH-2



Reusable Magnetic AgNPs-Based Nanocomposites for Water Disinfection

Ballast Water Treatment System – Ag Nanocomposite Units

For Cargo Ships
Ballast Water Capacity: 1500-5000 m^3
Duration: 20-45 days



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Conclusion

Via nanotechnology, magnetic functional nanocomposites

Simple

Common Chemicals/Facilities

Recoverable

Highly magnetic for easy & rapid recovery

Stable

Highly oxidation resistant

Synergistic

Highly Functional (e.g. antimicrobial)

Tailorable

Highly tunable structures

Green

Highly eco-friendly w/ minimum chemical release

Promising green & low cost technology for treating vessel discharges such as disinfecting ballast water

Acknowlegement

Funds

- USMMA Academic Dean's Office
- Brookhaven National Laboratory

  Contract No. DE-SC0012704

Individuals

- Alexander Furlan
- Adam Fisher
- Monica Keeley
- Kim Kisslinger
- Mike Melcer
- Dmytro Nykypanchuk
- Brian Ackerman, Sergio Perez, David Shinn

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THANKS!

Any questions?

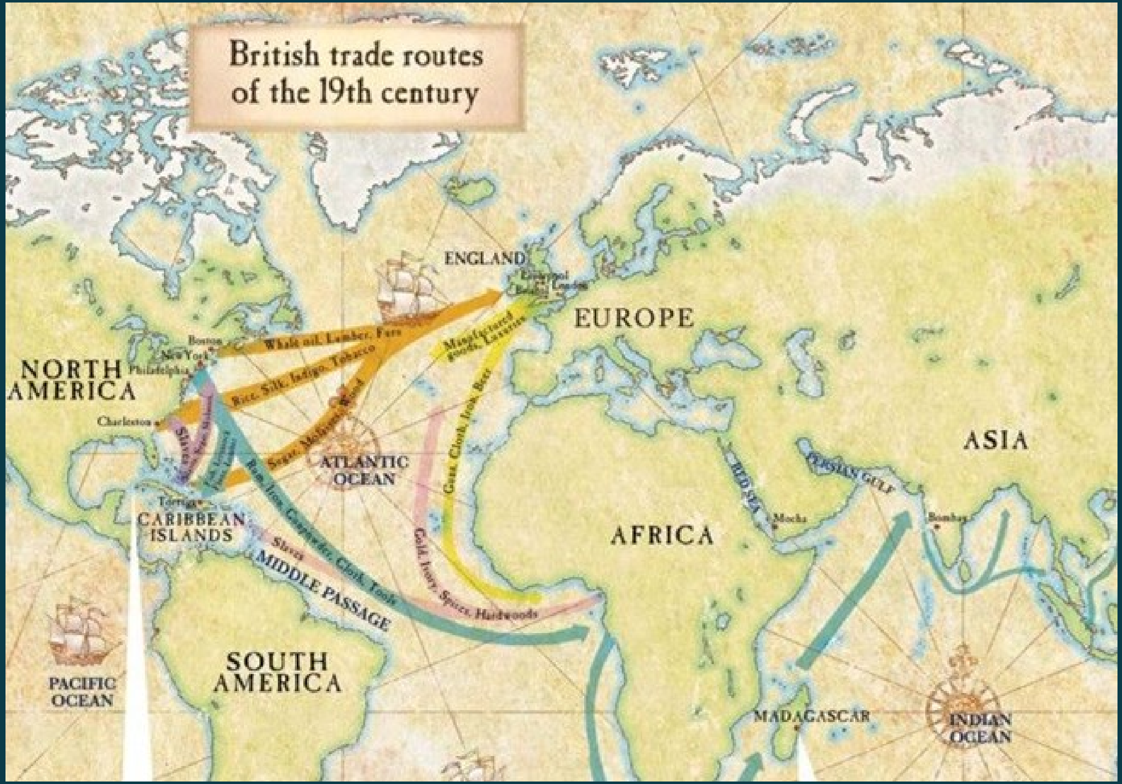
I can be reached at:

FurlanP@usmma.edu

SAILCARGO INC.

Modernizing the past: Powering wooden sailing cargo vessels with electric & hydrogen technology

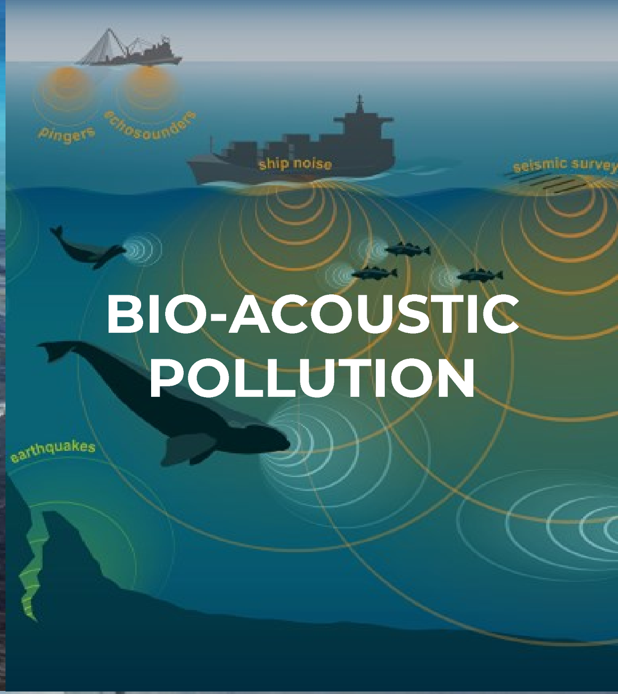
Sailing cargo vessels were the workhorses of global commerce




90%
OF GOODS ARE SHIPPED
BY CONTAINER SHIPS

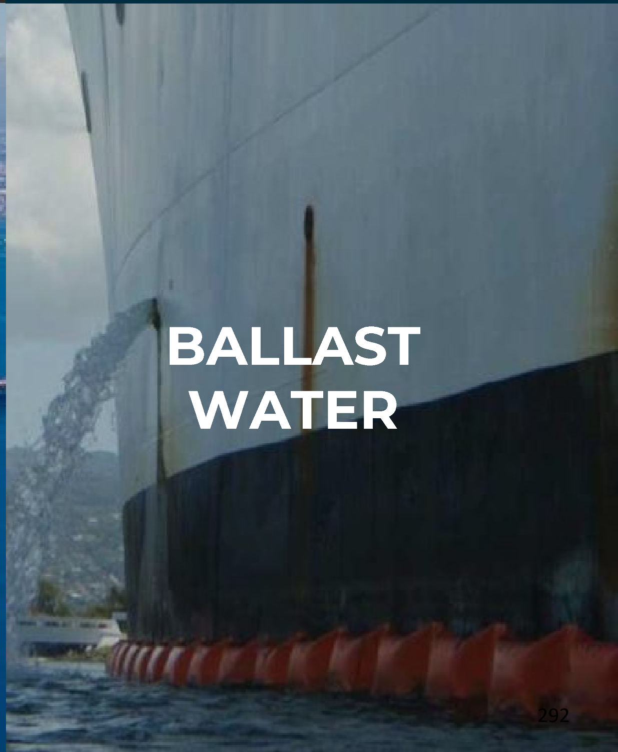

IRON ORE MINING

SHIPBREAKING

OIL SPILLS

pingers
echosounders
ship noise
seismic survey
BIO-ACOUSTIC POLLUTION
earthquakes

ACCIDENTS AT SEA
MAERSK

AIR POLLUTION

DELAYS

BALLAST WATER


SUSTAINABLY HARVESTED WOOD
LOW IMPACT SHIPYARD
ZERO EMISSION TRANSPORTATION
REFORESTATION INITIATIVES

SUSTAINABLY HARVESTED WOOD
LOW IMPACT SHIPYARD
ZERO EMISSION TRANSPORTATION
REFORESTATION INITIATIVES

FASE I

THE FLAGSHIP

CEIBA

46M / 150FT

250 TONS OF CARGO

14 SAILS & ELECTRIC PROPULSION SYSTEM

FASE II

FLEET EXPANSION

THREE MORE SHIPS

OVER 5,000 TONS OF CARGO ANNUALLY

CLEAN HYDROGEN PROPULSION

FASE III

CONTAINER SHIPS & BEYOND

GREEN STEEL
CONTAINER SHIPS

EXTREME SCALABILITY

CLEAN HYDROGEN
TAKEOVER

CEIBA DESIGN

Inspired by ‘Ingrid’ (1907), a three-masted schooner sailed cargo in Scandinavia long after sooty steamships and diesel engines came to dominate the seas.

VESSEL SPECIFICATIONS

Length Overall (LOA): 46m / 150ft
Length on Deck (LOD): 38m / 124ft
Length Water Line (LWL): 32m / 106ft
Height of Rig: 33.5m / 110ft
Beam: 8m / 26ft
Draught: 4.3m / 14ft

Cargo Capacity: 250 metric tonnes / 350 cubic meters (9 TEU)
Tonnage 281 GT

Crew 12 crew + 12 guest crew

Mechanical Auxiliary Propulsion System
100% Electric Engine, Lithium-ion (NCM) Batteries

Wood Species Used for construction:
- Hymenaea courbaril (Guapinol)
- Dialium guianense (Tamarindo)
- Cedrela odorata (Spanish Cedar)
- Picea sitchensis (Sitka Spruce)

Naval Architect *Pepijn van Schaik* of Manta Marine Design is the lead architect behind Ceiba.

PRIMARY

For 90% of the voyage, our ships will be propelled by the power of wind.

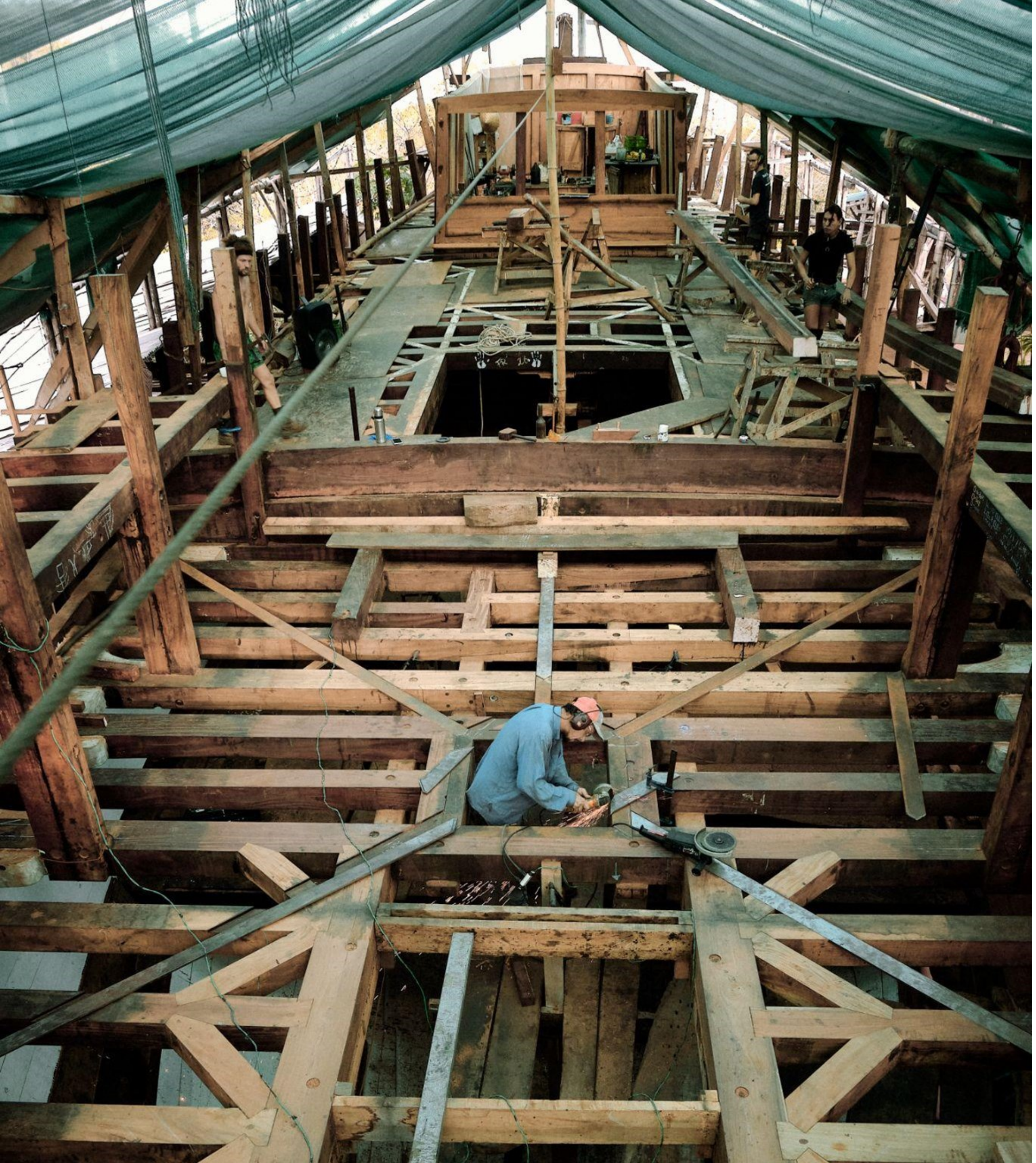
AUXILIARY

The remaining 10% of the time, the ships will be propelled by electric engines powered by variable pitch propellers, solar panels, and green hydrogen.

SUSTAINABLY HARVESTED

WOOD

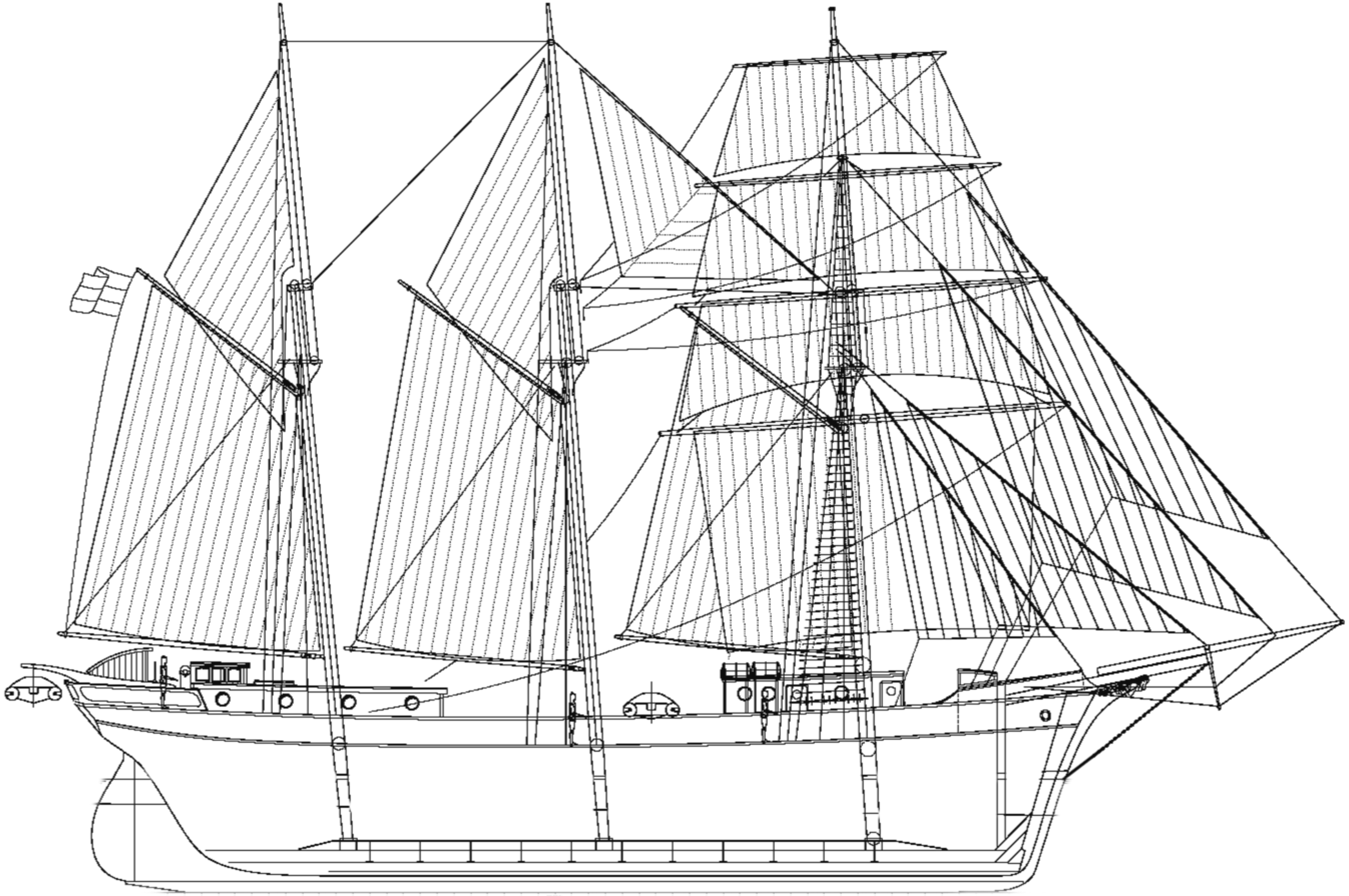
- ➔ THE ONLY TRULY RENEWABLE REGENERATIVE RESOURCE
- ➔ WHERE POSSIBLE, WE UTILIZE NATURALLY FALLEN TREES
- ➔ COSTA RICA HAS SOME OF THE MOST PROTECTED FORESTS IN THE WORLD
- ➔ NO NEED TO MINE IRON FOR STEEL
- ➔ DURABILITY



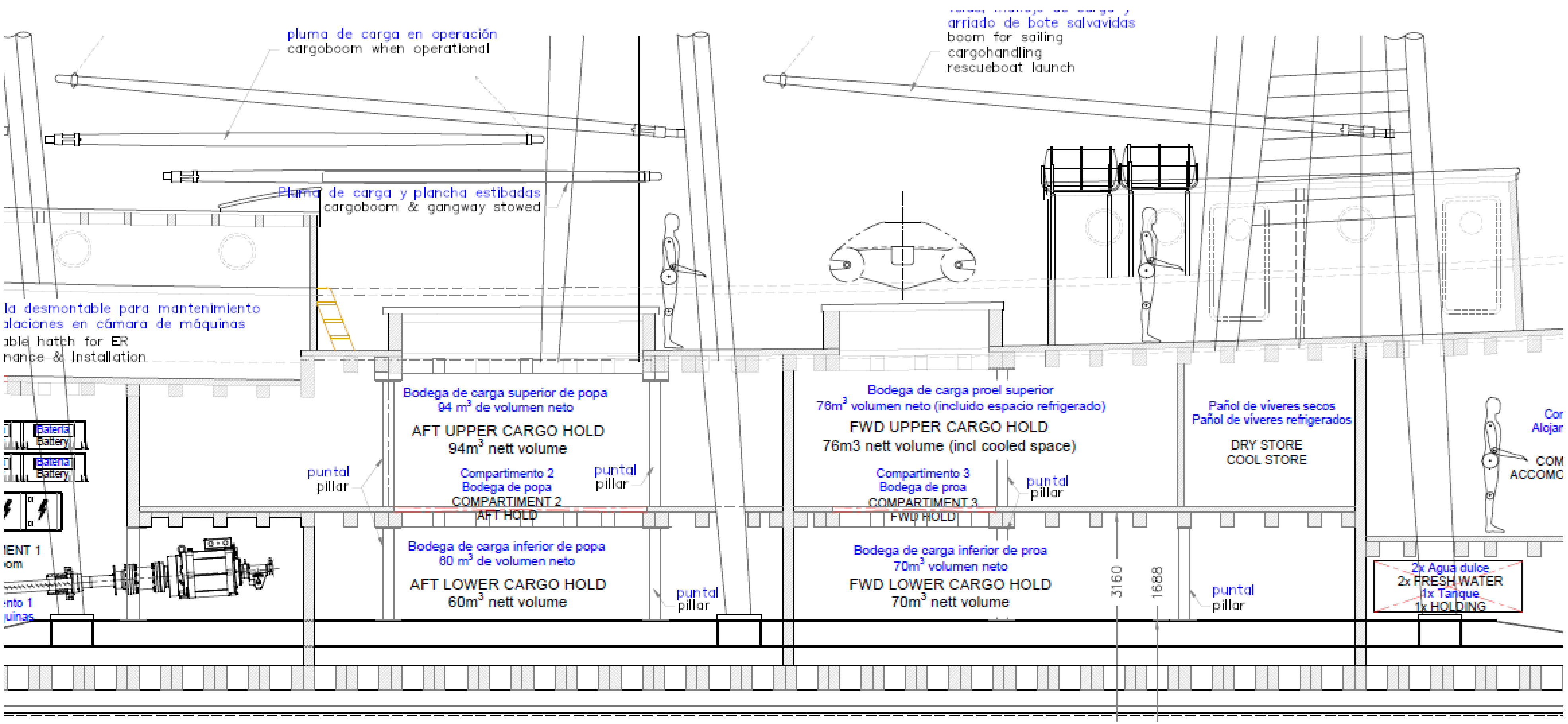
ONLY 3 PARTS

STEEL

- ➔ STRAPPING: In order to secure Ceiba against the extreme forces of sailing heavy cargo, steel strapping was inlaid to the top deck of the ship. This lattice work of half inch steel was welded in place and will prevent the ship from twisting and turning as the ship sails through the open ocean.
- ➔ GALVANIZED NAILS
- ➔ KEEL



3 MASTS
14 SQUARE-RIGGED SAILS

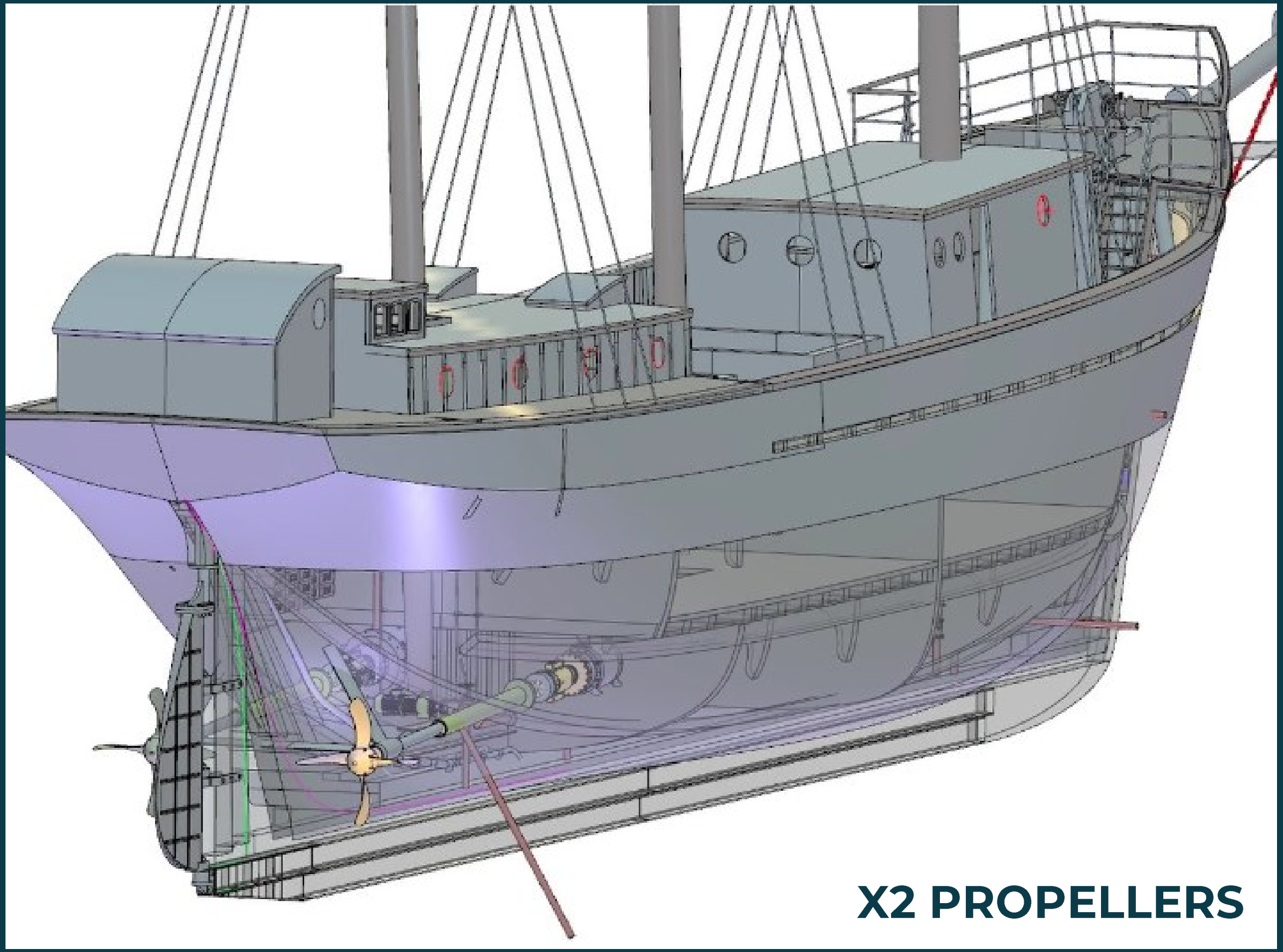


2 CARGO HATCHES

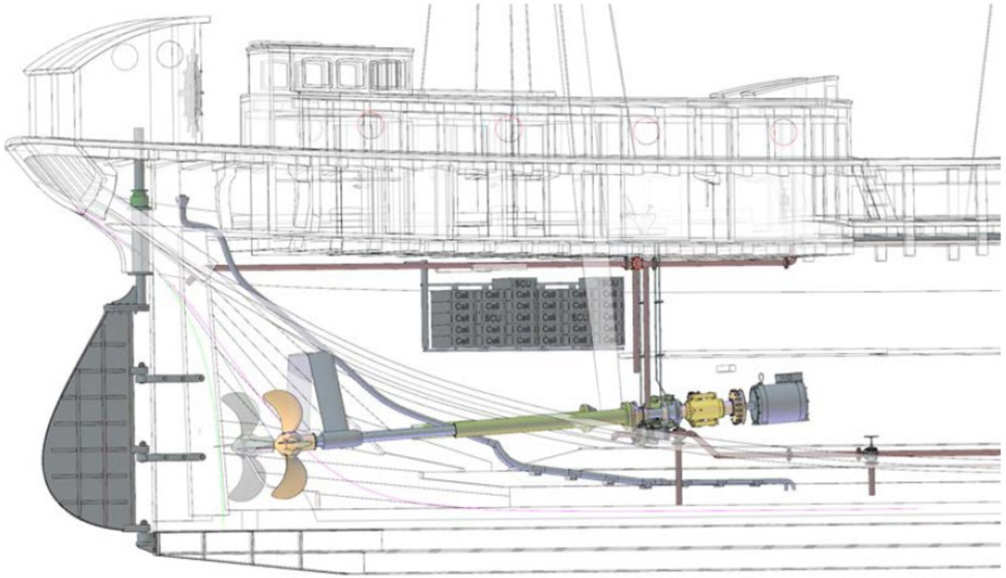
TRADITIONAL TALL SHIPS

VS

CEIBA ZERO EMISSION DESIGN



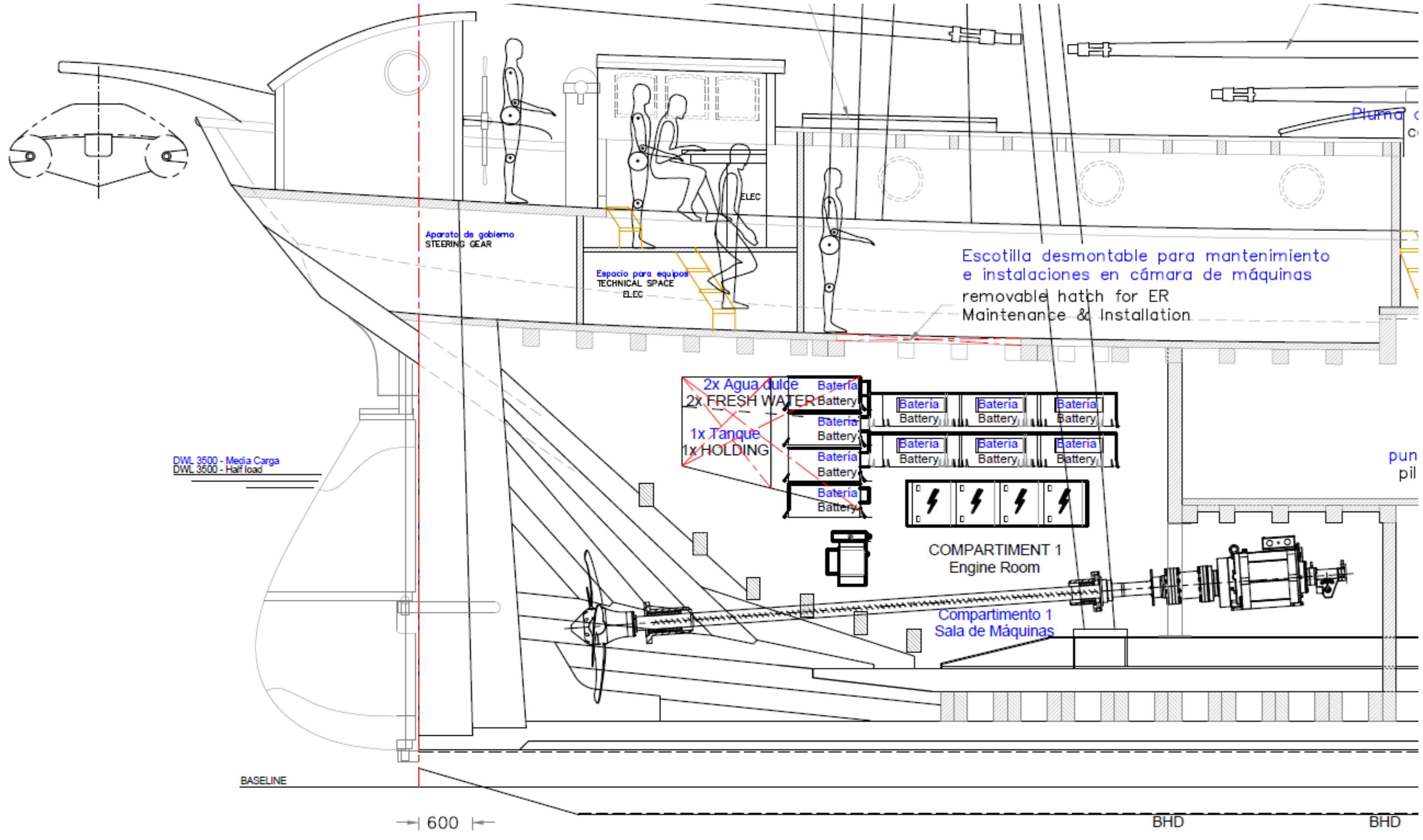
AUXILIARY PROPULSION SYSTEM



Two 150 kW electric motors with twin variable pitch propellers will be installed on board as a secondary propulsion system. Once in the water, the Ceiba will adapt in three different ways to changing sailing conditions to maximize efficiency.

1) In ideal winds, she will be propelled solely under sail, with the variable pitch propellers turned so that the batteries can be recharged.
2) In moderate winds, Ceiba will continue to be propelled by her sails, but with the propeller blades set parallel to the current to reduce drag.
3) In harbors or in poor sailing conditions, Ceiba can use the electric motors on board to maneuver.

AUXILIARY PROPULSION SYSTEM

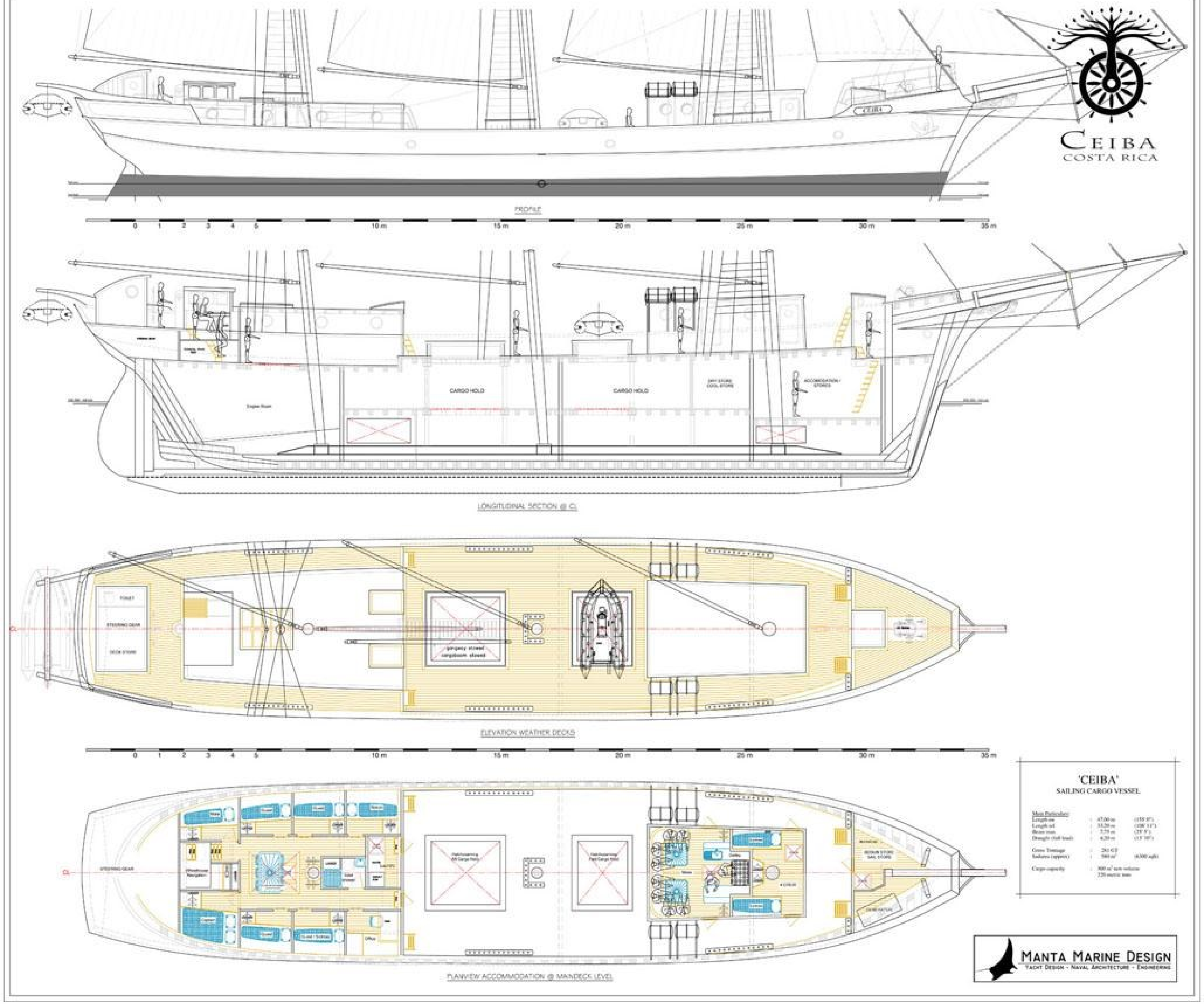


Variable Pitch Propellers

Batteries with maximum discharge power of 350 kW & energy embedded 317 kWh.

Electric Motors


CEIBA
MANTA MARINE DESIGN
YACHT DESIGN - NAVAL ARCHITECTURE - ENGINEERING

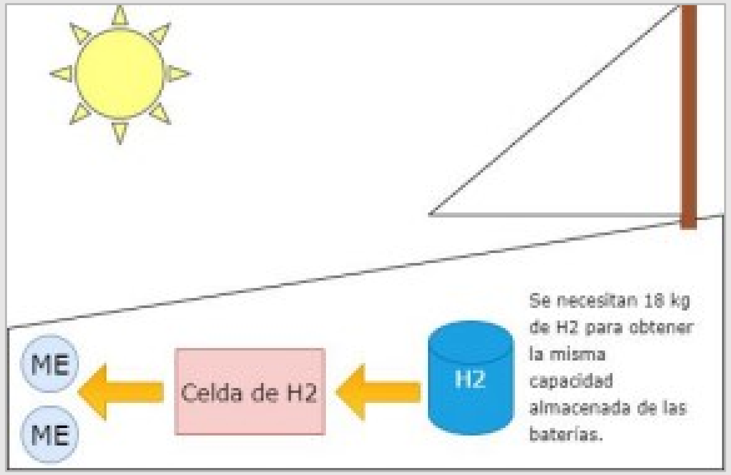

CEIBA
COSTA RICA
PROFILE
0
1
2
3
4
5
10 m
15 m
20 m
25 m
30 m
35 m
CARGO HOLD
CARGO HOLD
LONGITUDINAL SECTION @ CL
STEERING GEAR
ELEVATION WEATHER DECKS
STEERING GEAR
PLANVIEW ACCOMMODATION @ MAINDECK LEVEL
'CEIBA'
SAILING CARGO VESSEL
Main Particulars
Length oa
Length wl
Beam max
Draught (full load)
Gross Tonnage
Cargo capacity
MANTA MARINE DESIGN
YACHT DESIGN - NAVAL ARCHITECTURE - ENGINEERING

HYDROGEN FOR SEAS

EXPLORING CLEAN ENERGY

Hydrogen for Seas was born as a strategic alliance between Ad Astra Rocket and Sailcargo. Its main objective is to promote the research, development and implementation of **hydrogen technologies as a propellant in the maritime industry.**

Architecture with H_2 storage



- Hydrogen storage space volume size: 15 m3
- Max speed: 8kts
- Motor power: 300 kW
- Autonomy: 7.25 days

Route: Santa Marca CO - New Jersey USA

THE WORLD IS CHANGING

HOW IS UP TO US

SAILCARGO INC.

VELA

SAIL FOR GOODS

CARRYING TOMORROW'S WORLD

Webb Institute & US Merchant Marine Academy | Sustainability in Ship Design and Operations Conference 2023 | November 7, 2023

Leveraging ocean racing technologies for clean maritime transportation

Future ocean transportation sails on 3 hulls

What we offer

A premium transportation service for committed shippers

99% CO_2 emission reduction on propulsion

CO_2eq/T.km

0.00002 | 0.01 | 1.74

8 to 13 days transit time “at sea” from 2025

Days (lead time)

Westbound FR>US 3-7 | 12-15 | 15-21

Eastbound US>FR 3-7 | 10-12 | 29-40

Competitive and **stable** prices vs conventional freight

€/US pallet

200-500 | 1600-2500

IMO CO_2 tax schemes
Oil cost increase

Sustainable fuels

DECARBONIZE MASSIVELY

–99%

GHG EMISSIONS
ON PROPULSION

RELIABLE LEAD TIMES AT HIGH FREQUENCY

🇫🇷 ⇔ 🇺🇸 10 TO 15 DAYS
1 DEPARTURE/WEEK


VELA1

Provide large capacity at fair and stable prices

Vessel capacity

580 EU pallets

= 490 US pallets

~ equivalent to 25 trucks

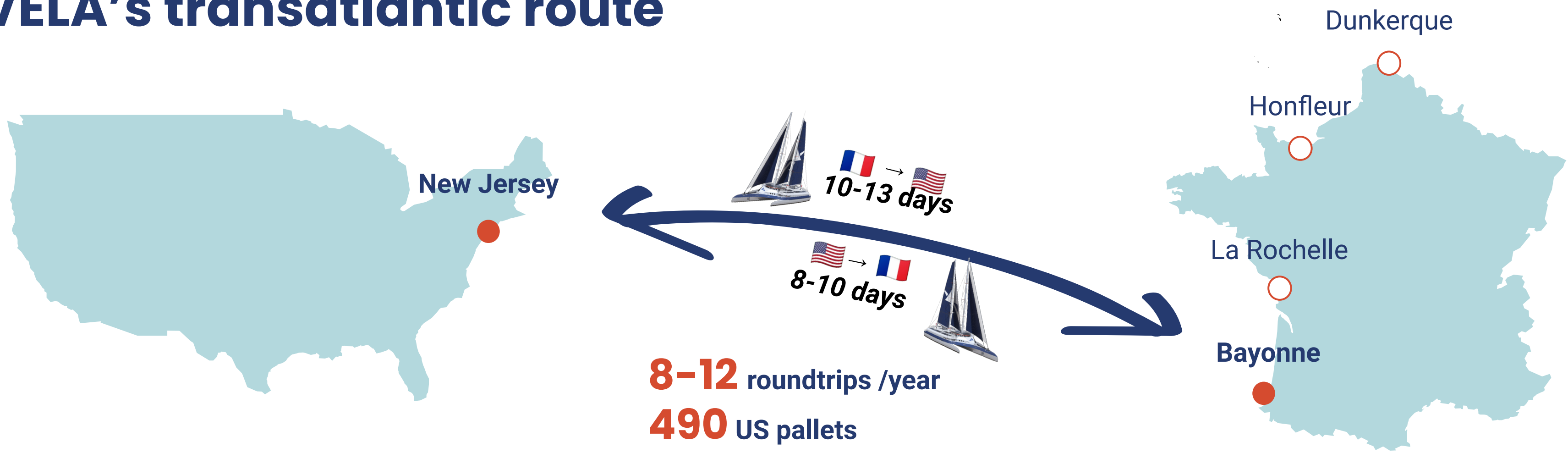
Safety

Air freight systems inside the locked hold

An easy-and-fast-to-load horizontal platform

Case study

VELA's transatlantic route



8–12 roundtrips /year

490 US pallets

360 tons capacity

Safe operations

Guaranteed integrity and 24/7 warehouse security

Reliable lead time

10 years back-testing via weather routing

Fast unloading

Innovative vessels accessing secondary ports[1]

Main port

Alternative Port

(1) designed for unloading small vessels and located near rail and road networks, resulting in a reduced carbon impact.


FAST
RELIABLE
CARBON FREE
VELA

Thank you!

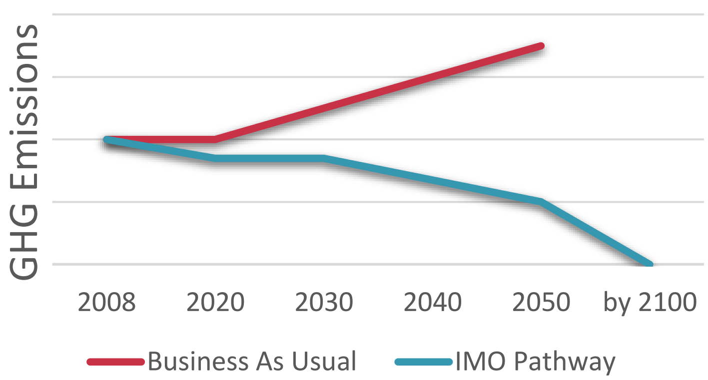
www.vela-transport.com

Nuclear Reactors for Decarbonized Civil Maritime Transportation

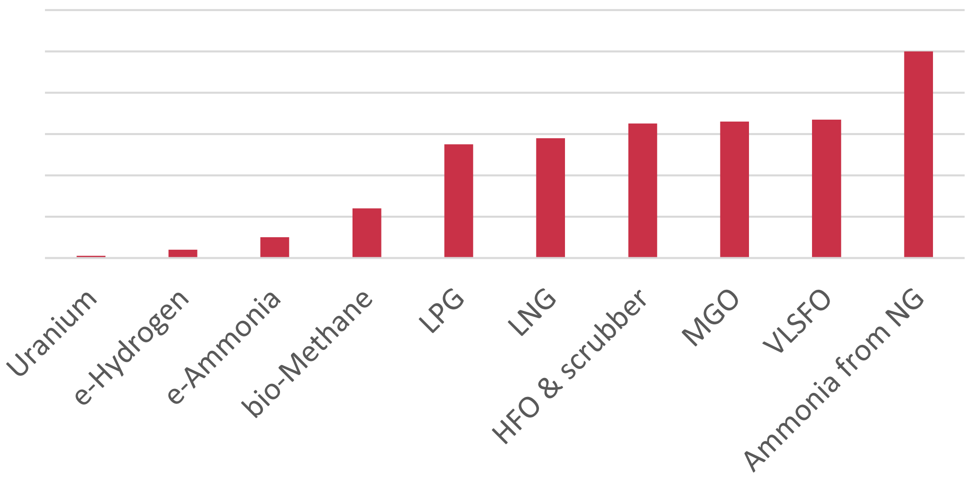
Jonathan E. Stephens, P.E.
JEStephens@bwxt.com
BWXT Advanced Technologies, LLC

Decarbonizing maritime transportation is an extraordinary challenge…

IMO Decarbonization Strategy



Typical Well-to-Wake CO_2 Emissions of Marine Fuels
(normalized per unit energy produced)

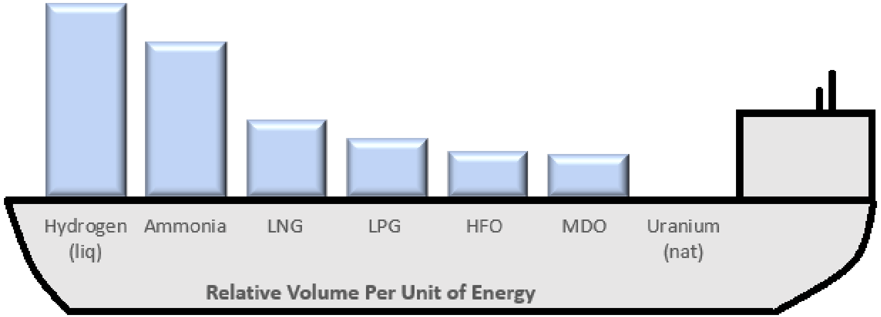


SOLUTION OPTIONS:

1. **e-fuels generated via zero-carbon energy**
2. **On-ship clean energy generation**

IMO objectives can be achieved with existing nuclear technology!

- Production of e-fuels using nuclear energy
  - Zero-emission
  - High power density needed for sufficient fuel volumes
  - Consider fuel volume and safety



- or, on-board nuclear electric plant
  - Zero-emission, low noise
  - Small footprint
  - Stable operational costs
  - Potential for higher ship speed
  - Ability to redirect electric power to shore
  - Legal and regulatory challenges

BWXT Company Highlights

BWXT is one of the world's most prolific nuclear technology innovation companies and the sole manufacturer of naval nuclear reactors for U.S. submarines and aircraft carriers.

6,600
highly skilled employees

$2.1 billion USD
in 2021 revenues

12
major manufacturing facilities totaling 3.9 million square feet

60+
years manufacturing naval nuclear components and reactors

300+
commercial nuclear steam generators manufactured

1.5 million+
Canada Deuterium Uranium (CANDU) fuel bundles provided

13
U.S. Department of Energy laboratories, environmental cleanup projects and NASA sites

8,000+
fuel elements delivered to U.S. national laboratories, universities and international customers

165-Year History of Innovation
75-Year History of Nuclear Technology

1856
Stephen Wilcox patented the water tube boiler

1907
Teddy Roosevelt's Great White Fleet powered by B&W boilers

1946
Awarded first U.S. Navy contract for propulsion systems

1953
Designed and fabricated components for world's first nuclear powered submarine

1956
Manufactured components for first commercial nuclear power plant in the U.S.

1962
Designed and furnished commercial nuclear reactor systems for Indian Point

1966
Initiated design and fabrication of nuclear components for Nimitz-class aircraft carriers

1994
Awarded first major DOE site management and operating contract at Idaho National Engineering and Environmental Laboratory

1997
Awarded first prime contract from DOE

2015
Selected for design and manufacturing contracts for HPR1000 nuclear plant

2017
Awarded NASA Nuclear Thermal Propulsion Reactor Design contract

2018
Announced disruptive medical isotope manufacturing technology

2019
Introduced FDA-approved medical isotope In-111 generic for diagnostic imaging to the U.S. market

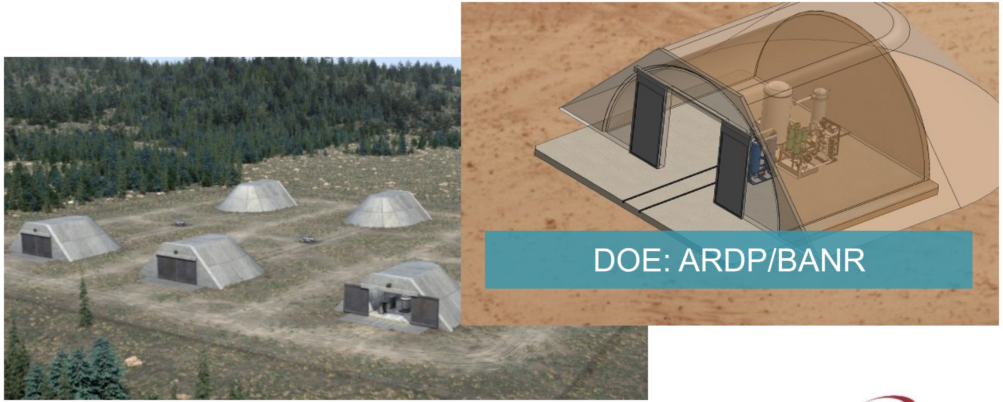
2020
Restarted TRISO advanced nuclear fuel manufacturing for future DoD and NASA missions

2020
Awarded DoD contract for mobile nuclear reactor design

NON-NUCLEAR	NUCLEAR		BWXT ERA
1856	1946	1994	2015

BWXT

Ongoing Projects in BWXT Advanced Technologies



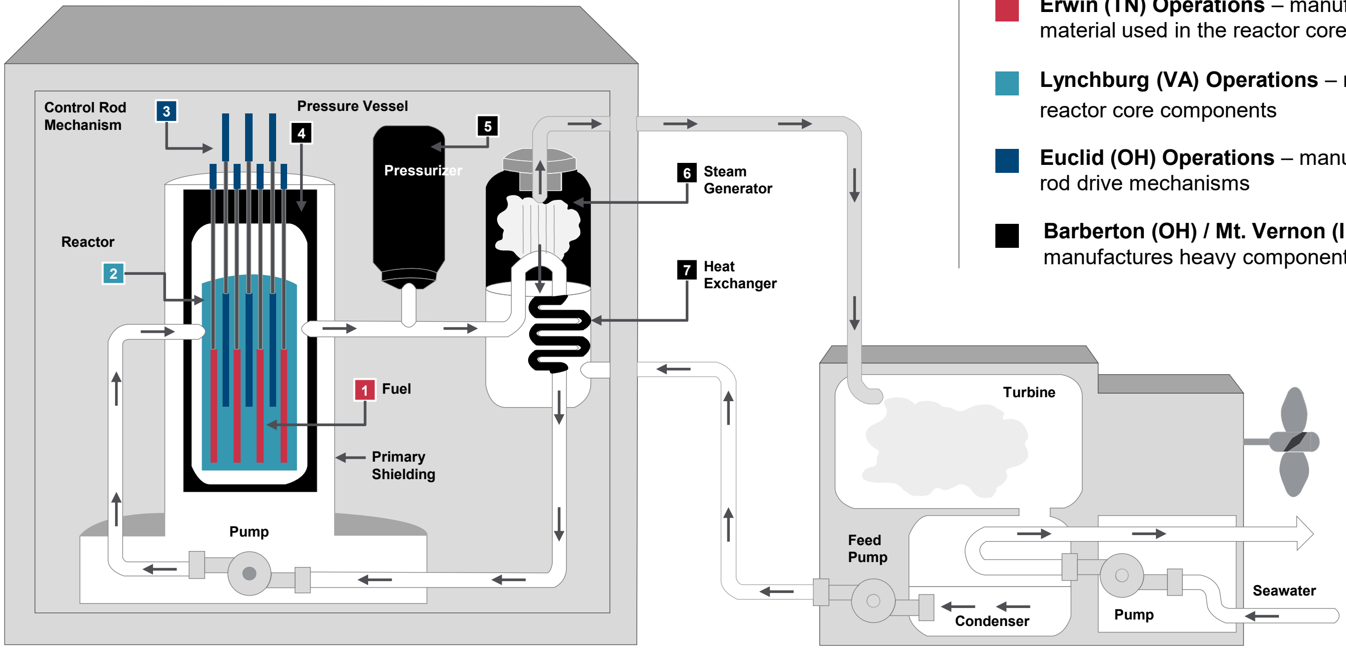
Marine nuclear, even civilian, is not new!

Sevmorput (Rosatom) – 61,000 dwt cargo/icebreaker, 1988-present

NS Savannah (US) – civilian passenger-cargo liner operated from 1962-1965

Reactor technology is continuously improving, but the big catalyst today is the DRIVE FOR DECARBONIZATION

Naval Nuclear Steam Supply System



Erwin (TN) Operations – manufactures fuel material used in the reactor core

Lynchburg (VA) Operations – manufactures reactor core components

Euclid (OH) Operations – manufactures control rod drive mechanisms

Barberton (OH) / Mt. Vernon (IN) Operations – manufactures heavy components

What do we mean by “Nuclear Safety”?

- SUB-CRITICALITY – the ability to “shut down” the self-sustaining nuclear fission reaction
  - Chernobyl disaster exemplifies failure to control nuclear criticality
  - American reactor designs utilize configurations that ensure this type of accident is <u>impossible</u> per the laws of physics; e.g. “negative reactivity feedback”
- DECAY HEAT REMOVAL – the ability to keep reactor components below melting temperatures during fission product decay in a shutdown reactor
  - Three Mile Island & Fukushima exemplify failure to remove decay heat
  - Advanced reactors make use of “passive cooling” concepts
  - In HTGRs like BANR (for example), maximum temperatures possible during accident scenarios remain below the melting points of advanced materials
- RADIATION SHIELDING – minimizing radiation dose during and after operation

Considerations for commercial maritime nuclear systems

- Many reactor technologies exist, though TRL (Technical Readiness) varies

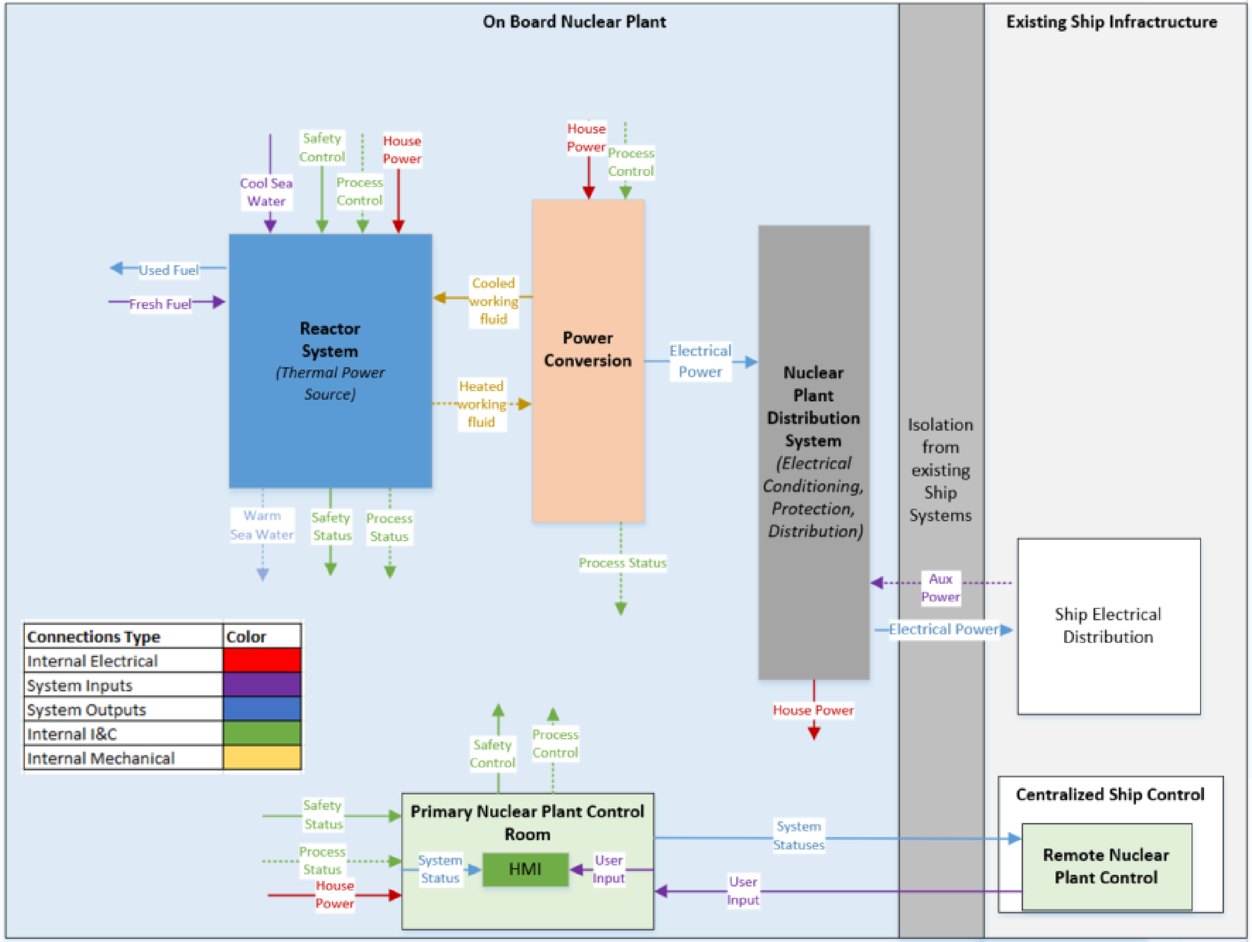
Mature Technologies
- Pressurized Water Reactor (PWR)
- Boiling Water Reactor (BWR)
- High Temperature Gas Reactor (HTGR)

Industry Research Focus Areas
- Molten Salt Reactor (MSR)
- Fusion

- Civil maritime nuclear will likely differ from naval propulsion:
  - Commercial maritime reactors will not utilize HEU fuel (>20% U-235)
  - Commercial maritime nuclear plants will produce power to drive electric motors, rather than direct mechanical propulsion

- Nuclear and wind solutions are not mutually exclusive!

Example System Architecture – On-ship Nuclear Plant



The biggest challenges to moving forward are not technical ones!

Regulatory
- Outdated or missing laws
- Jurisdictional questions

Infrastructure
- Reactor handling
- Uranium enrichment

Port Access
- Emergency planning
- Stakeholder education, acceptance

Personnel
- Operators
- Security
- Training programs

Economics
- Capital cost
- Insurance

Waste Mgmt
- Spent fuel removal
- Ship decom.

Tackling these challenges will require close collaboration between industries & their trade groups, and government(s).

For more information on commercial maritime nuclear developments, check out the NRIC Maritime Nuclear Application Group at: https://nric.inl.gov/maritime/

Questions?