Natural Ship Propulsion Conference

Table of Contents

Destination: Decarbonisation........ 2-16
ROGER STREVENS, Wallenius Wilhelmsen

Natural Propulsion for Transport & Shipping: Potential and Expectations in the Present Context........ 17-49
GUILHEM GAILLARDE, Head of SHIPS department Marin Institute

Aero- and Hydrodynamics with Wind Propulsion........ 50-100
ROGIER EGGERS, Senior Project Manager Marin Institute

Maneuvering & Seakeeping with Wind Propulsion........ 101-134
ROGIER EGGERS, Senior Project Manager Marin Institute

Natural Propulsion for Transport & Shipping: Performance Assessment........ 135-157
GUILHEM GAILLARDE, Head of SHIPS department Marin Institute

Wind Assisted Ship Propulsion........ 158-211
GERARD DYKSTRA, Founder Dykstra Naval Architects

Viability of Bulk Cargo Merchant Sailing Ships........ 212-228
SERGIO PEREZ, USMMA

Solutions for the Design and Operation of Wind Assisted Vessels........ 229-260
MAXIME DUPUY, Route optimization specialist D-Ice Engineering

A Start Up to Decarbonize Shipping........ 261-292
LUDOVIC GERARD, CEO of Ayro

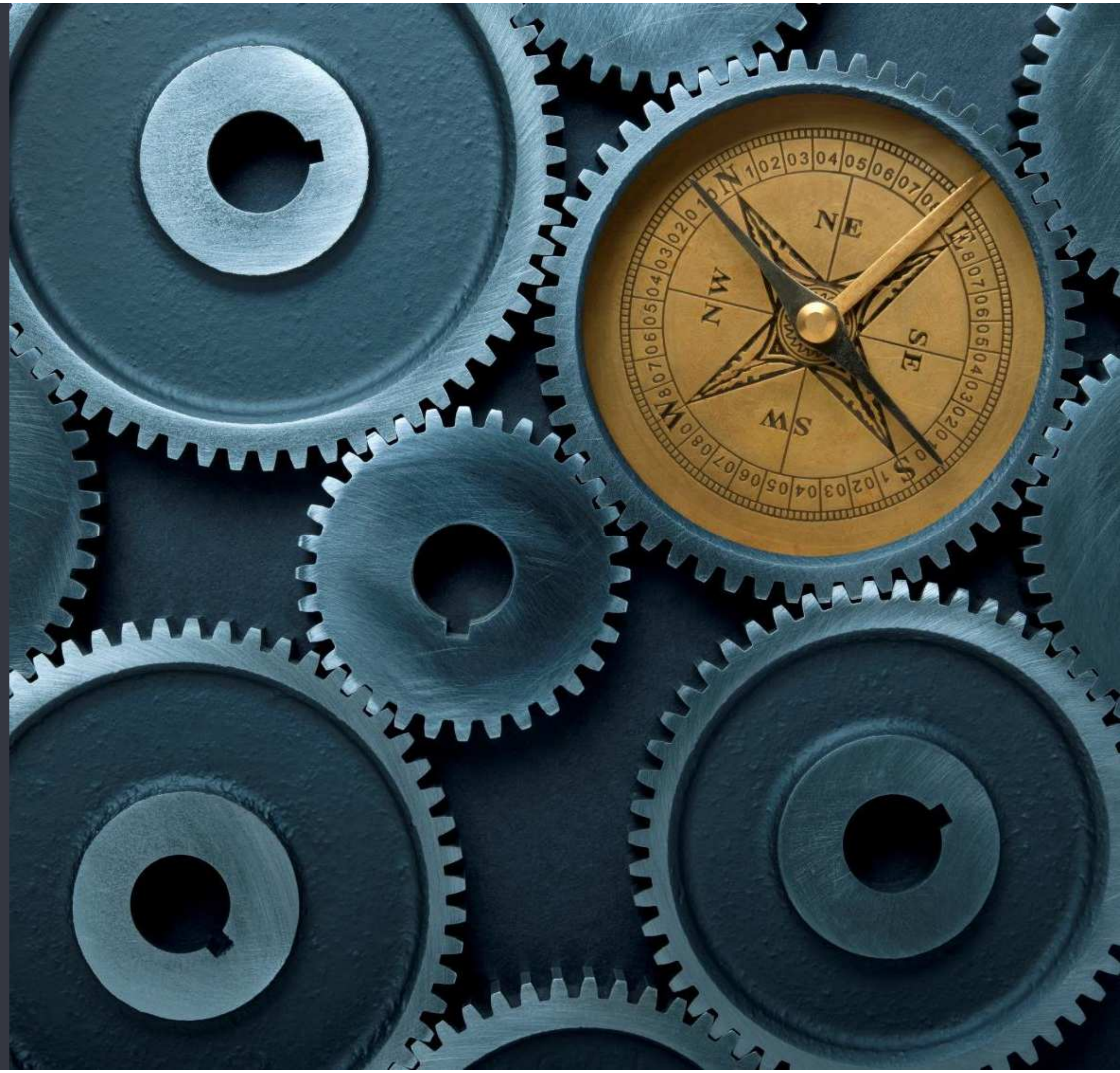
The Contribution of Wind........ 293-340
FRANK NIEUWENHUIS, CEO of Econowind and GUUS VAN DER BLES, Director of development at Conoship

The Neoline Project, a case study into an innovative, low-carbon transportation alternative........ 341-353
JEAN ZANUTTINI, CEO of Neoline

Sail Cargo Inc........ 354-380
DANIELLE DOGGETT, CEO of Sail Cargo Inc.

Wallenius
Wilhelmsen
Ocean

Destination: decarbonisation



Roger Strevens, November 16th 2021

Wallenius Wilhelmsen in brief

VALUE CHAIN AND PRODUCT OFFERING

Landbased – Upstream

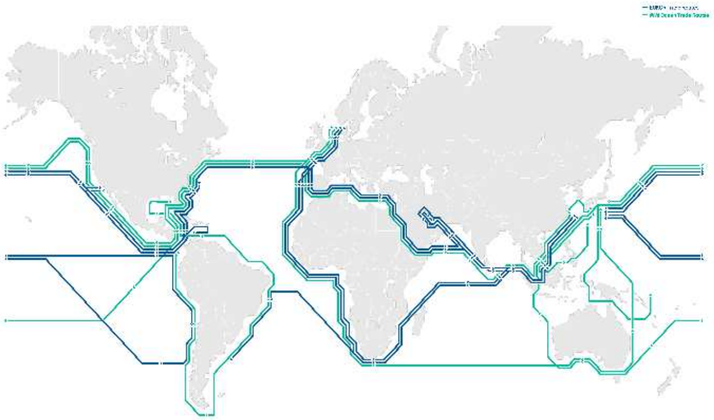
1. DISTRIBUTION TO PORT
2. PLANT-BASED TECHNICAL SERVICES
3. MARINE TERMINAL SERVICES

Landbased - Downstream

3. MARINE TERMINAL SERVICES
2. PORT-BASED TECHINCAL SERVICES
1. DISTRIBUTION TO DEALER

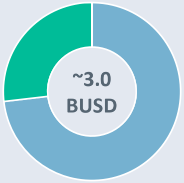
Ocean

OCEAN TRANSPORTATION



KEY FACTS AND FIGURES

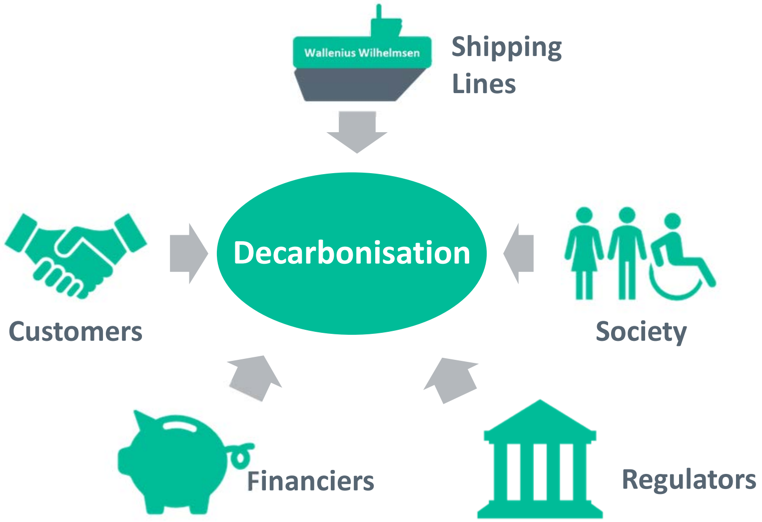
EMPLOYEES	FLEET	INFRASTRUCTURE	MAIN BRANDS	L12M REVENUE	Annual CO2e Emissions
~9,400 ACROSS 29 COUNTRIES	~ 140 VESSELS IN OPERATION	11 TERMINALS; 121 PROCESSING CENTERS	Wallenius Wilhelmsen Solutions; Wallenius Wilhelmsen Ocean; American Roll-On Roll-Off Carrier; Armacup; EUKOR	~3.0 BUSD	4-5m tonnes



Destination decarbonisation

- A 21st century smokestack industry
- Climate change urgency rising fast
- Disruptive momentum building

➔ Change in status-quo inevitable



A big and varied industry: so many different needs / opportunities

Short or Deep sea
- Energy storage and sourcing

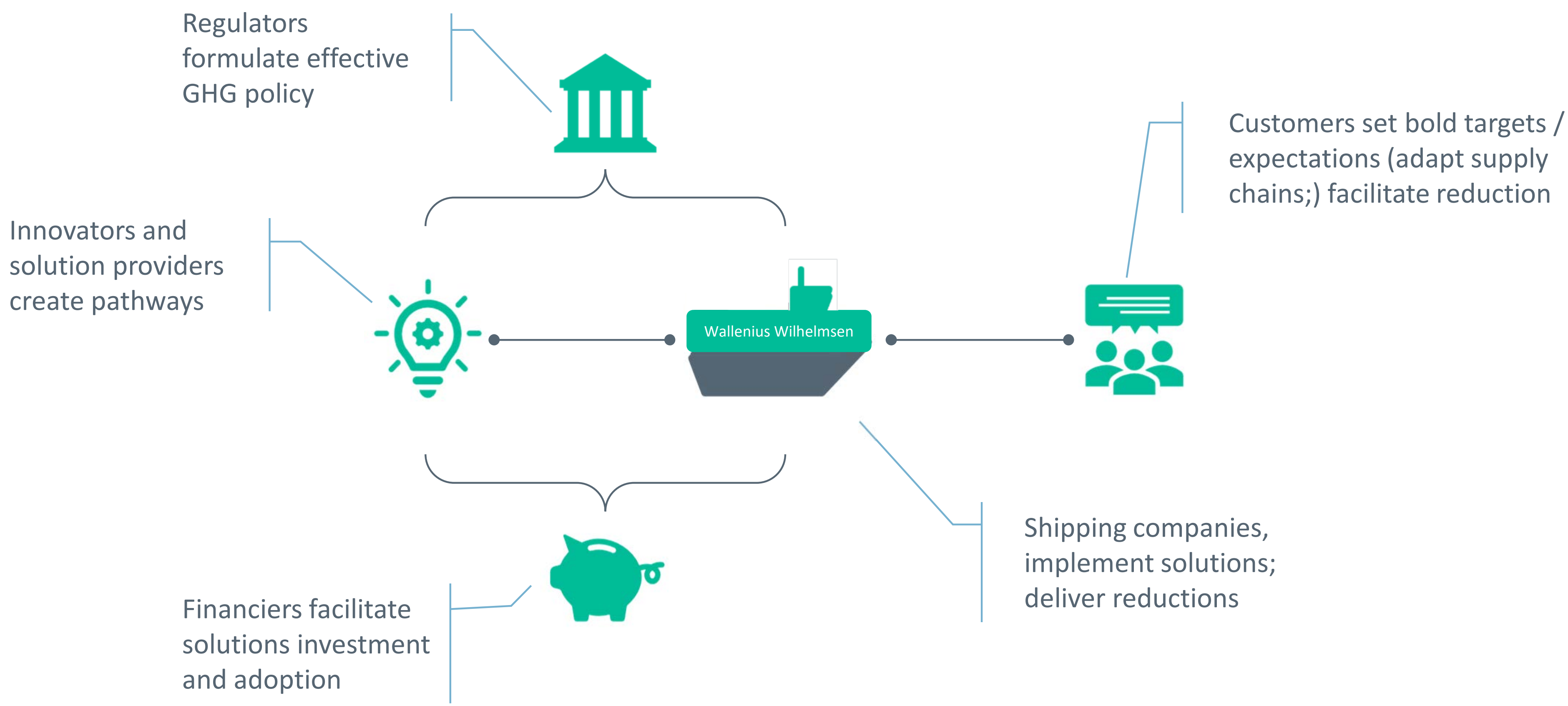
Vessel type
- Architecture, size
- New build / existing

Vessel Ownership
- Owned or chartered

Operational mode
- At-berth or underway?

Business model
- Liner or tramp

All hands on deck

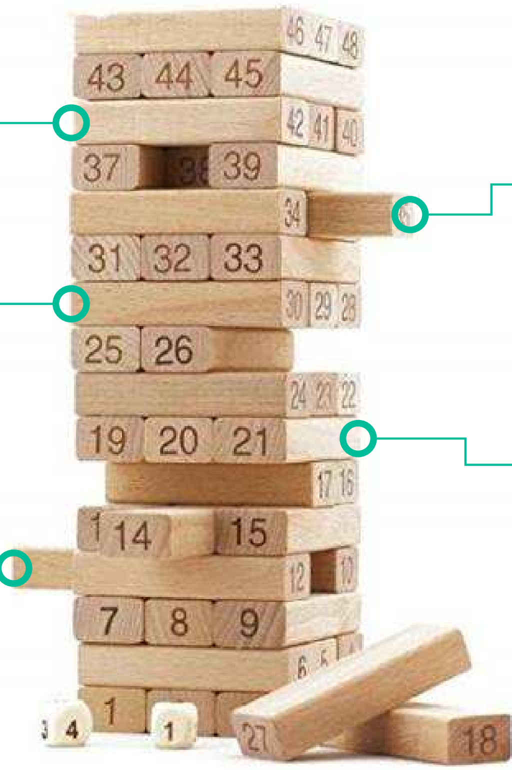


What makes a new solution stack up?

Financial

Operational

Commercial



Technical

Regulatory

… and remember:

Regulation: making green competitive

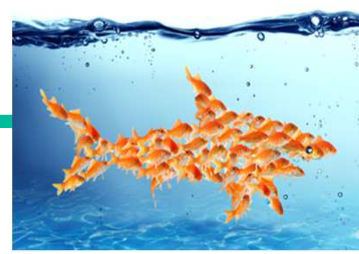
Innovation: transition vs. steady state costs

Demand: beware the rising floor

The **frame of reference** determines the propulsions solutions that remain / will become viable

Key elements of our approach to decarbonistion


Be **curious;** take **initiative**


Seek **partnerships**

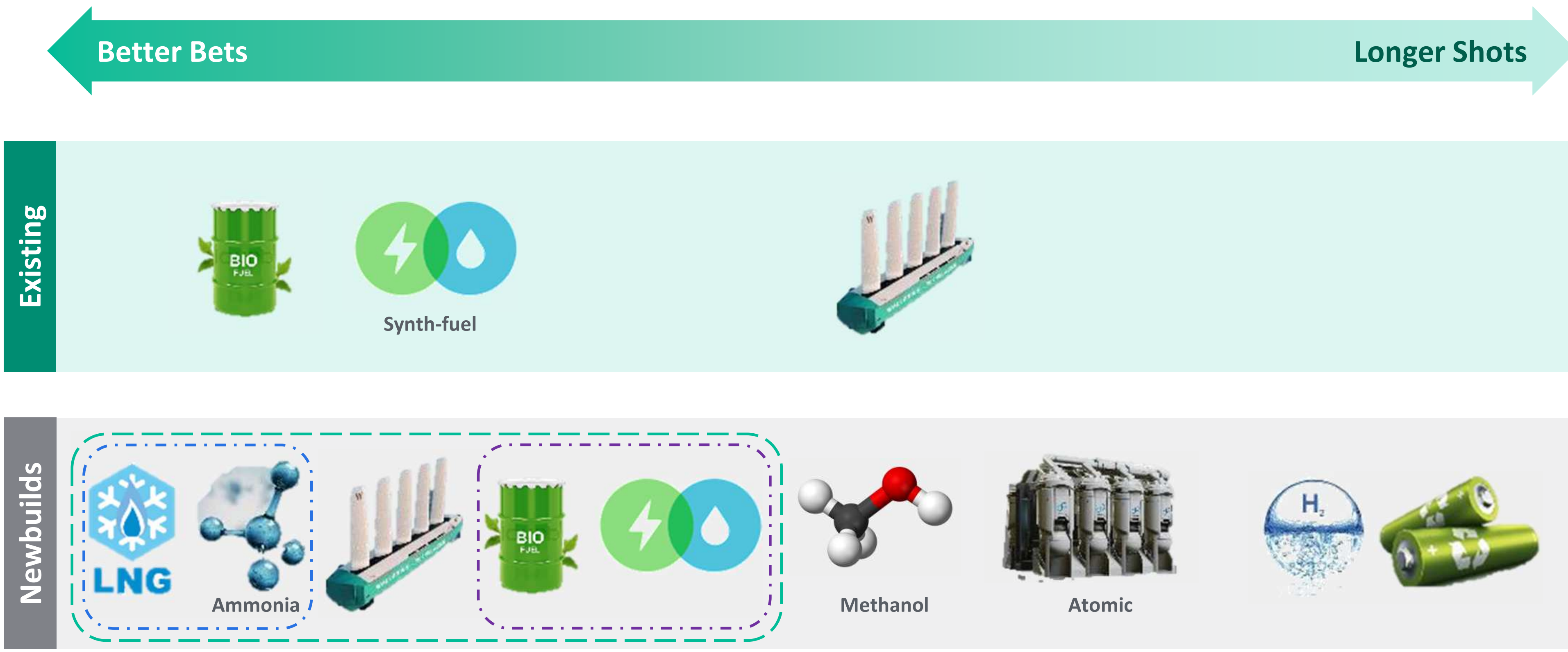

Prepare for the **long-haul**


Lean:Green thinking


Attract innovators


Engage in **advocacy**

Propulsion Prospects



Wallenius Wilhelmsen

Orcelle Wind

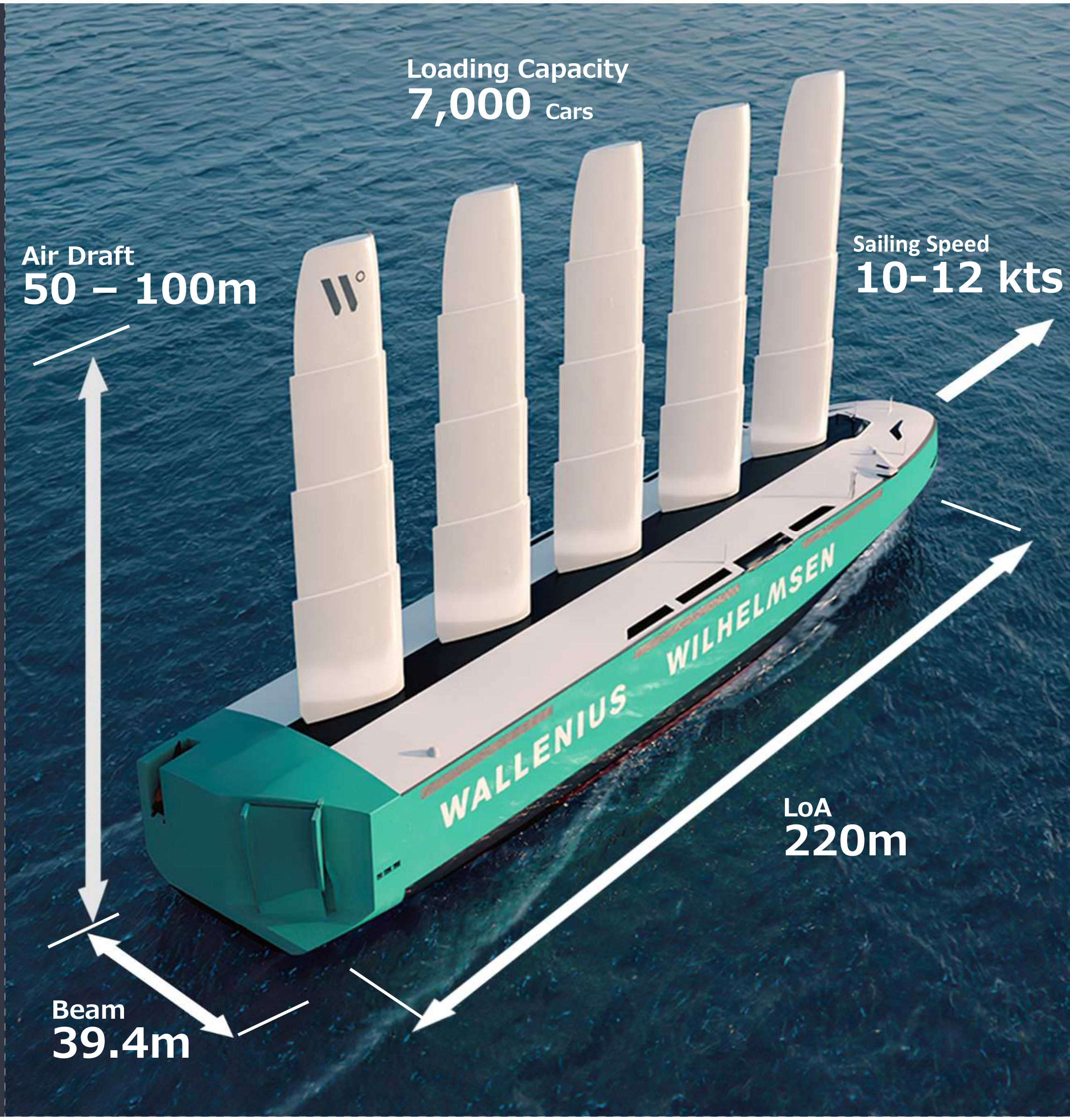
E/S Orcelle – still guiding our course

- Debuted at the World EXPO in 2005,
  - Original zero emissions concept vessel
  - Envisaged a combination of novel technologies
  - Signal effect
- Huge progress (-33% CO_{2e}/tkm 2008:19), but decarbonizing means embracing change on a grander scale
- We still believe in the Orcelle concept and so we introduce the Orcelle Wind….

Orcelle Wind – progress from concept to solution

- One of WW's leading decarbonisation initiatives
- Est. up to -90% GHG emissions v's current best
- Provisional plan:

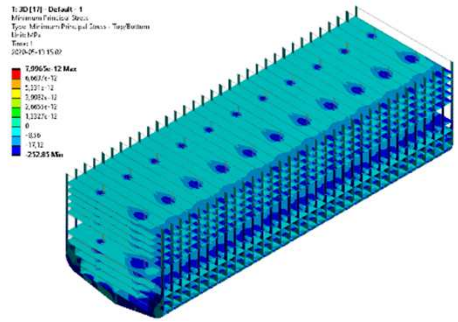
Apr 2022		**Internal Vessel Design Finalization**
Jan 2023		**Yard Contract Finalization**
2025		**Delivery of Orcelle Wind**



Investing to succeed

Initial design, analysis and testing

Aerodynamic analysis



Structural analysis

Tank testing

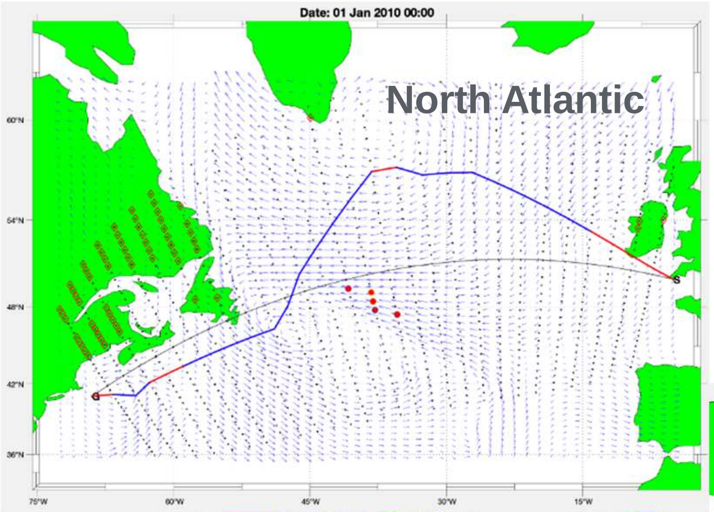
Model and full-scale prototype testing

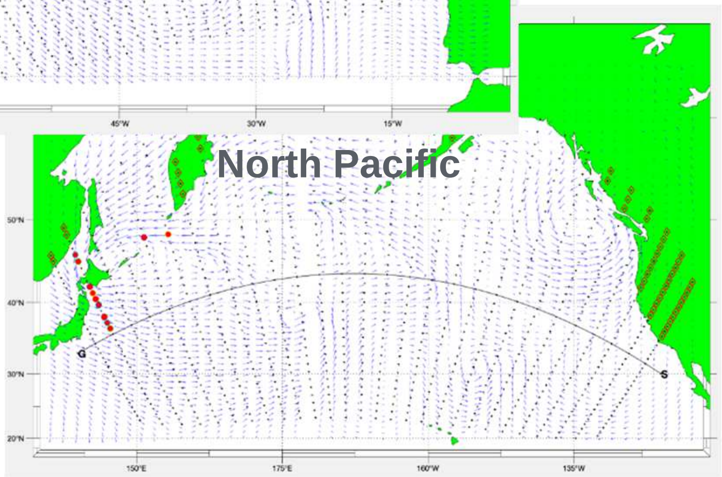
Model testing

Land-based full-scale wing trials

Vessel-based wing testing

A global evaluation for a global network





- Analysis of multiple trade routes because deployment flexibility is critical to achieving network efficiency
- Being considered: geographical and seasonal variation in winds and currents, port access & fuel availability

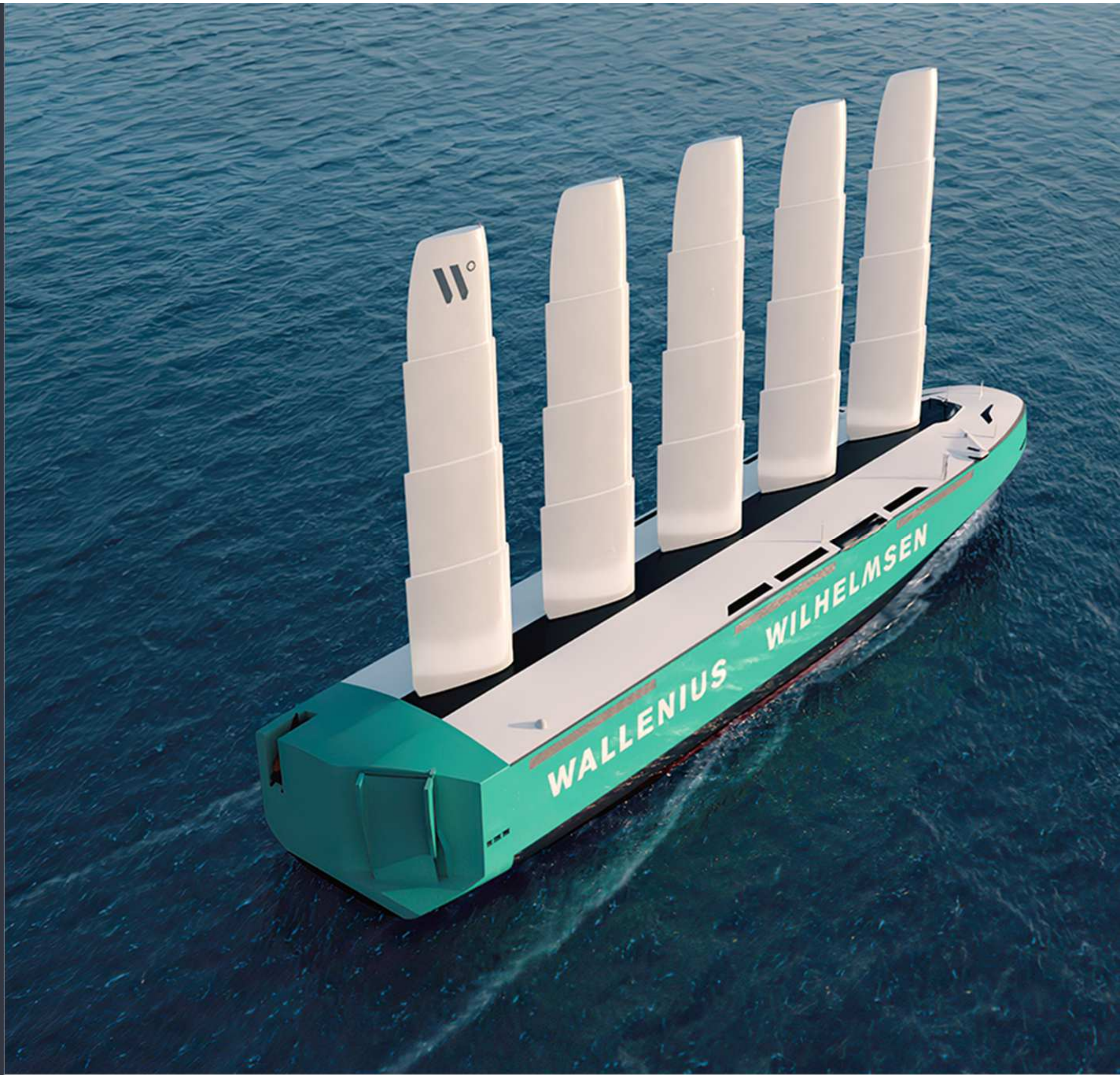
→ In search of a **green corridor**

Decarbonisation: the ultimate test of resilience

- Status quo will not remain
- Disruptor or ‘disruptee’?
- Opportunity in disguise
- Solutions stack
- Orcelle Wind: bold enough?

Sustainable logistics for a world in motion

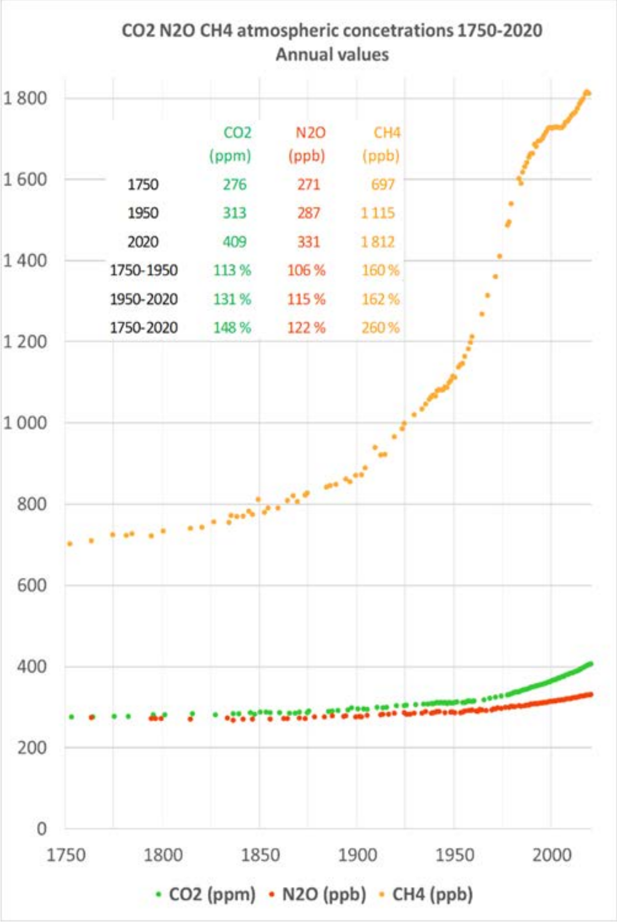
Thank you for your attention.

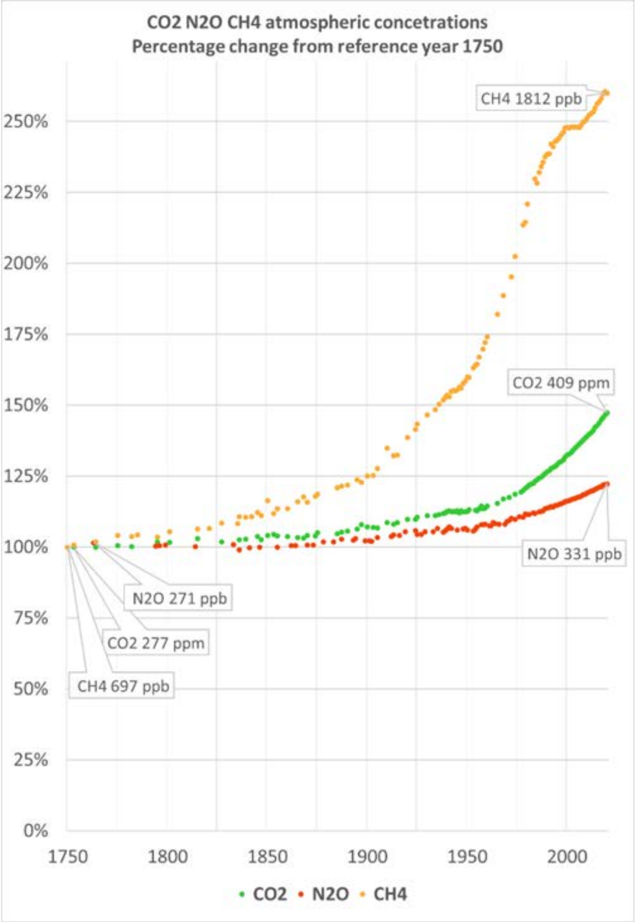


Natural propulsion for Transport & Shipping: potential and expectations in the present context

Guilhem Gaillarde
Head of Ships department, MARIN

Atmospheric gas concentrations of CO_2, N_2O and CH_4 from 1750 to 2020:

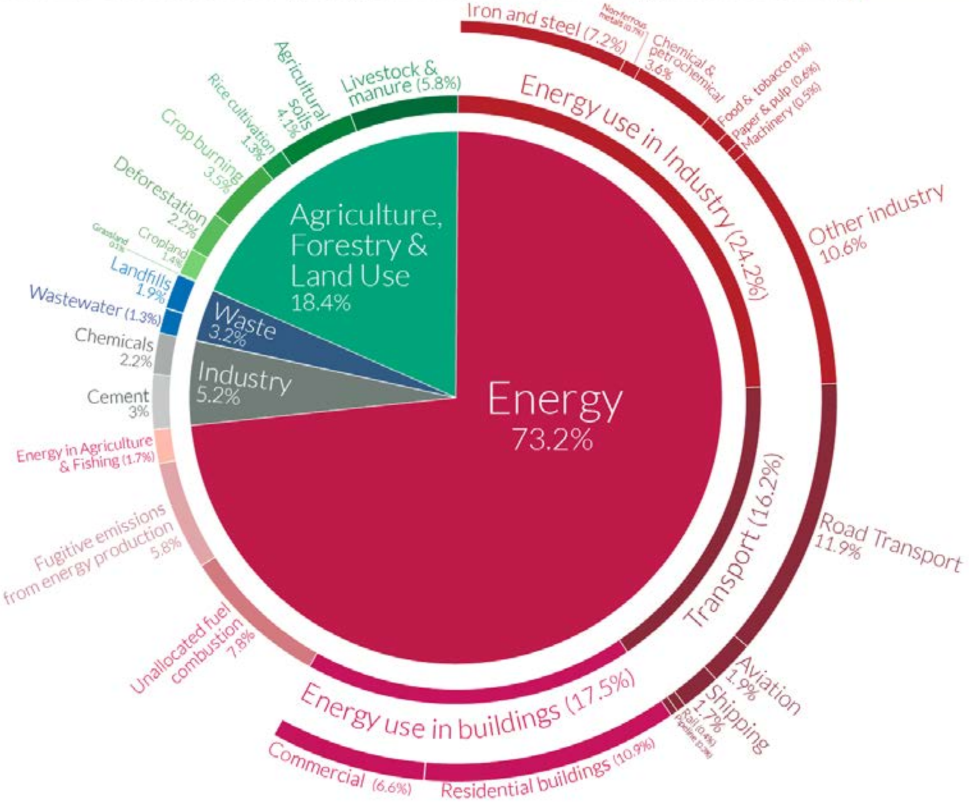




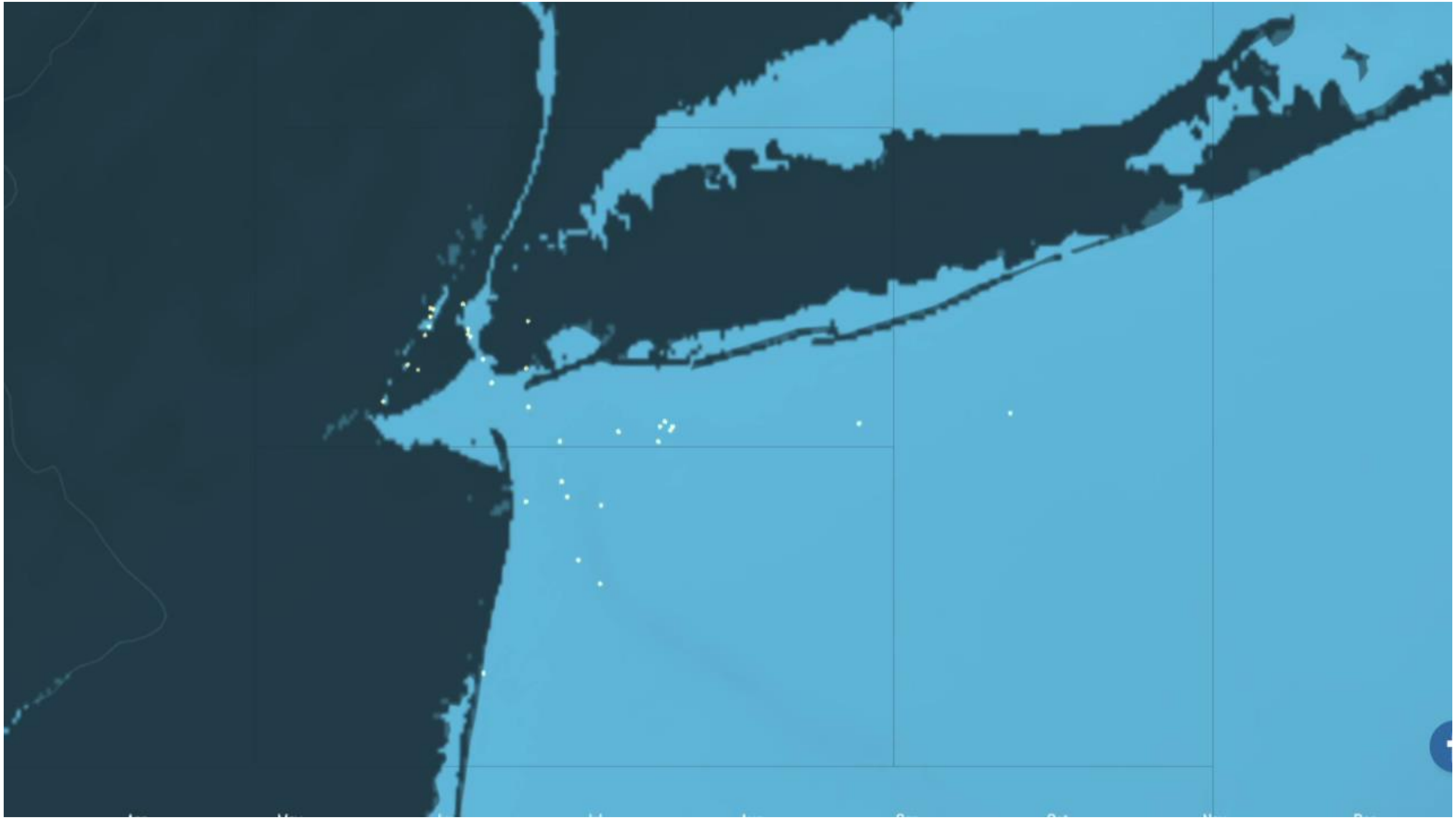
Data sources: Lindstad et al 2020 compiled based on MacFarling-Meure, C., et al. (2006); CSIRO Oceans & Atmosphere and the Australian Bureau of Meteorology (2020).

Global greenhouse gas emissions by sector

This is shown for the year 2016 – global greenhouse gas emissions were 49.4 billion tonnes CO_2eq.



OurWorldinData.org – Research and data to make progress against the world's largest problems.
Source: Climate Watch, the World Resources Institute (2020).



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

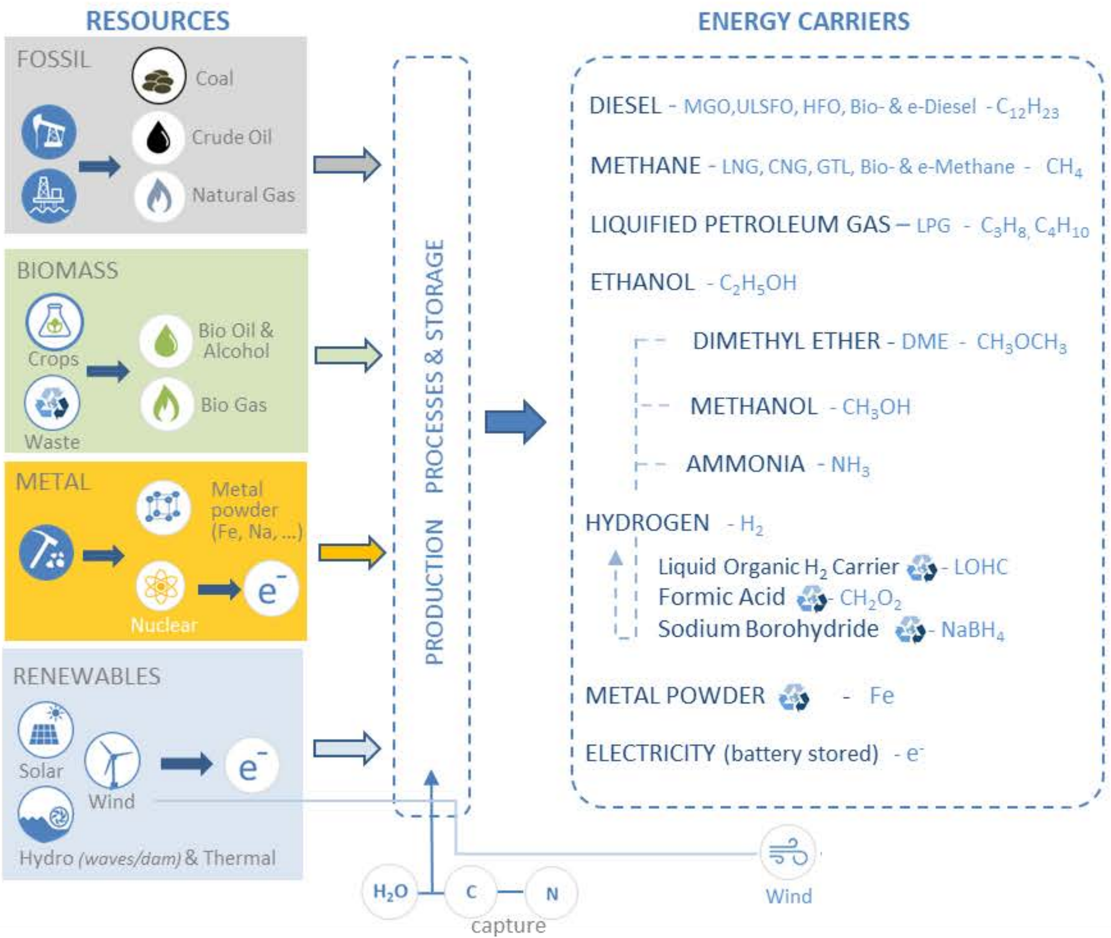
HYDROGEN - H_2

Liquid Organic H_2 Carrier - LOHC
Formic Acid - CH_2O_2
Sodium Borohydride - $NaBH_4$

METAL POWDER - Fe

ELECTRICITY (battery stored) - e^-

Wind


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
Hydro (waves/dam) & Thermal
e⁻
PRODUCTION PROCESSES & STORAGE
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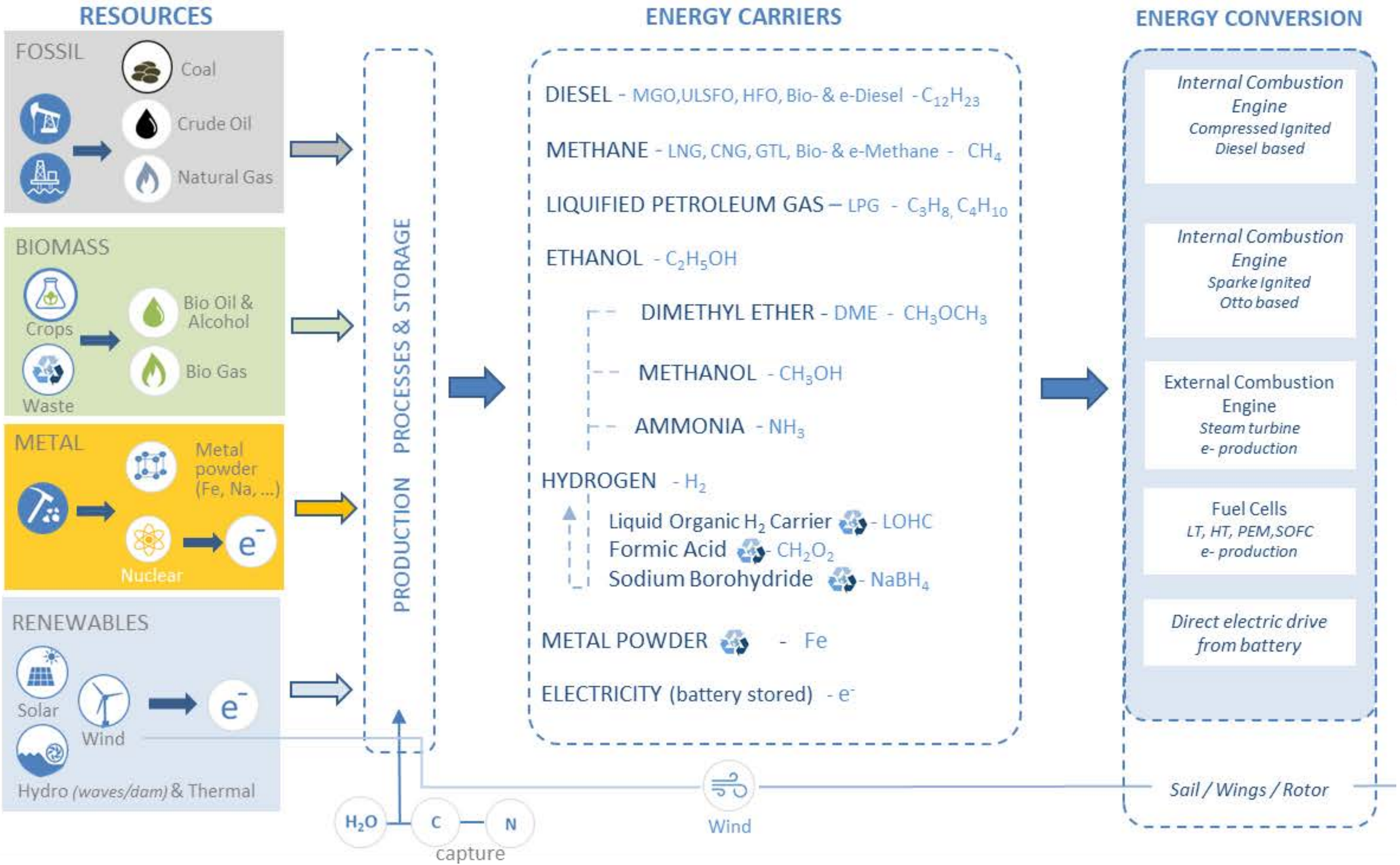
METAL POWDER - Fe
ELECTRICITY (battery stored) - e⁻
H_2O
C
N
capture
Wind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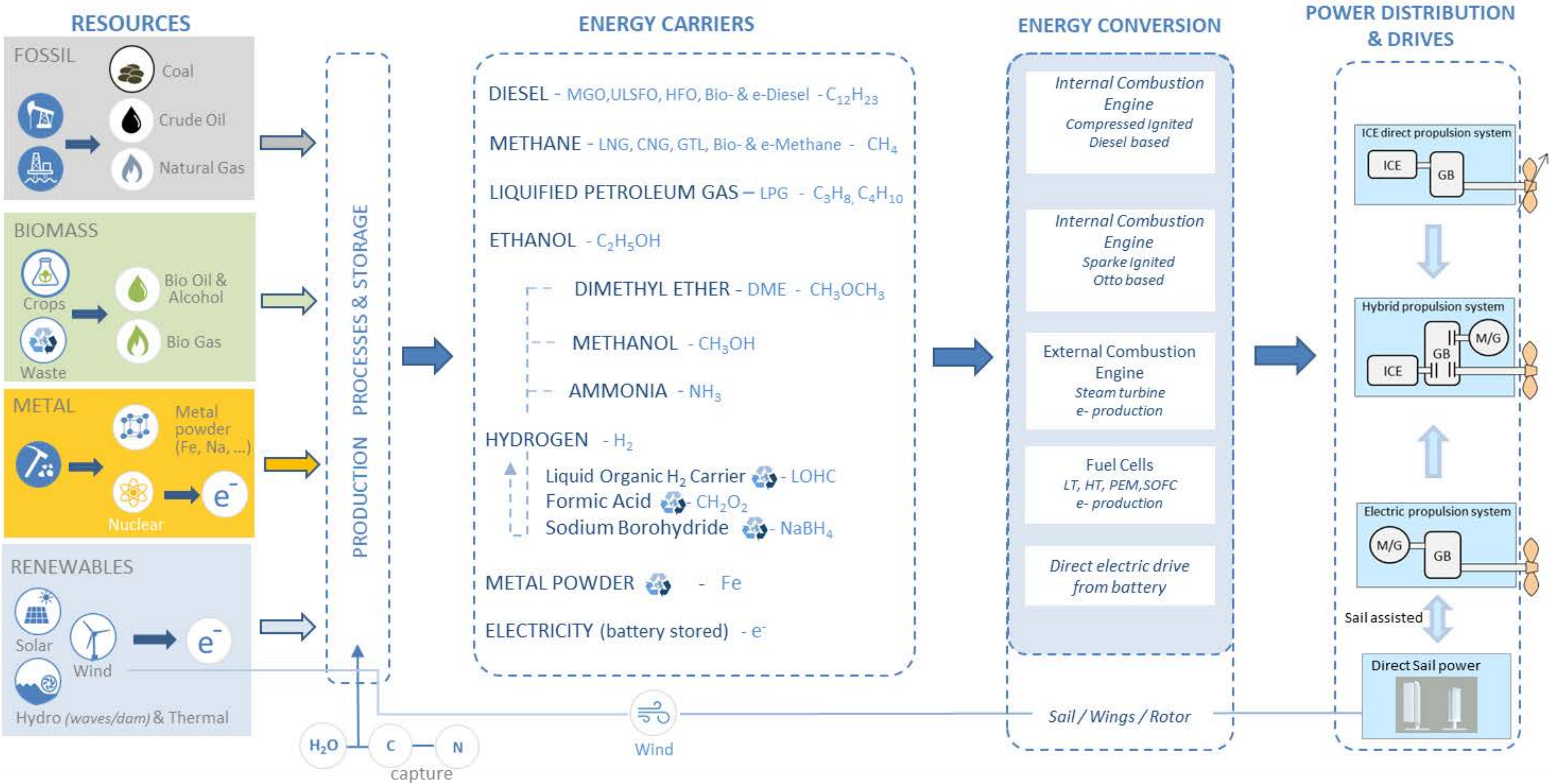
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AMMONIA - NH3
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Formic Acid - CH2O2
Sodium Borohydride - NaBH4
METAL POWDER - Fe
ELECTRICITY (battery stored) - e⁻
Wind
ENERGY CONVERSION
Internal Combustion Engine
Compressed Ignited
Diesel based
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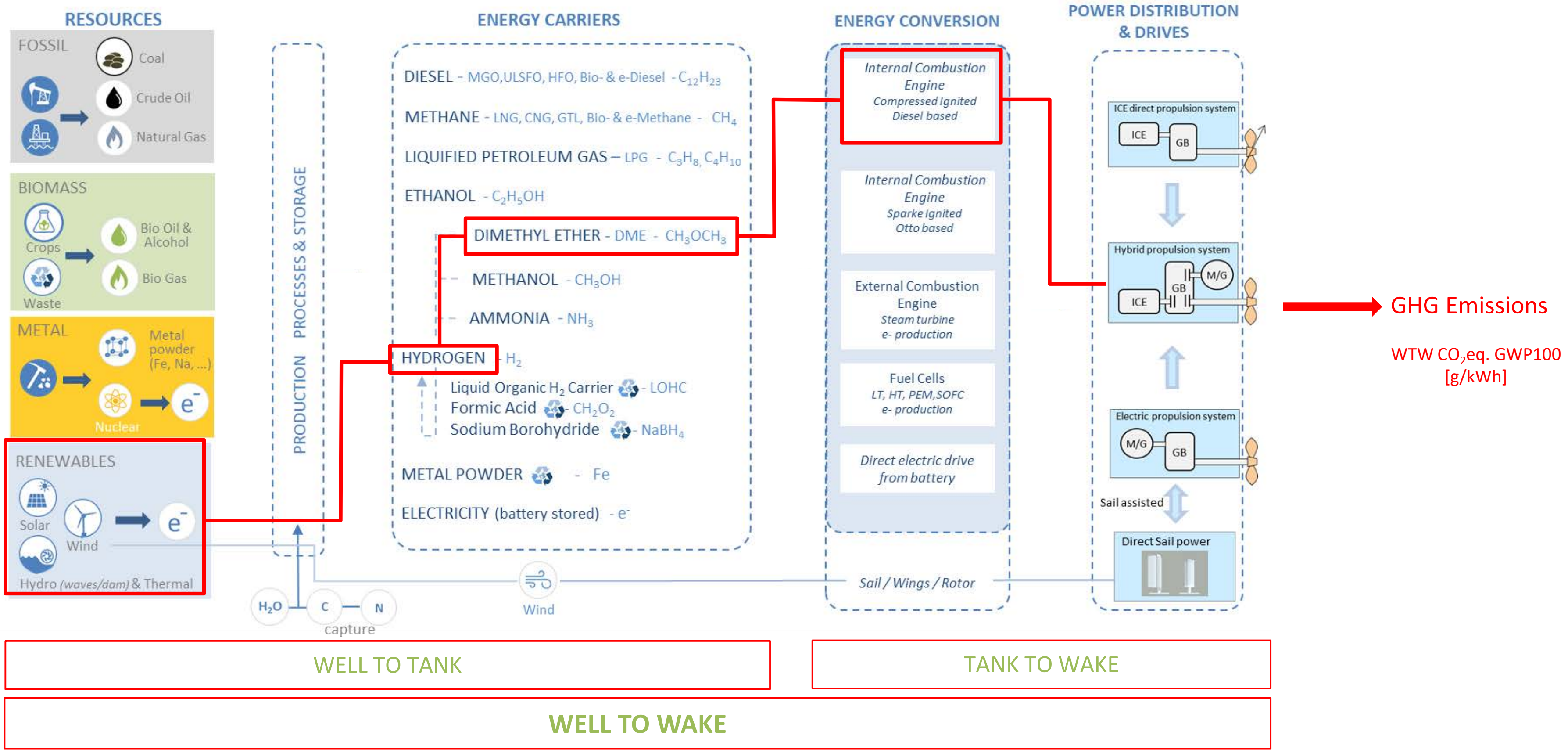
Sparke Ignited
Otto based
External Combustion Engine
Steam turbine
e- production
Fuel Cells
LT, HT, PEM,SOFC
e- production
Direct electric drive from battery
Sail / Wings / Rotor
POWER DISTRIBUTION & DRIVES
ICE direct propulsion system
ICE
GB
Hybrid propulsion system
GB
M/G
ICE
Electric propulsion system
M/G
GB
Sail assisted
Direct Sail power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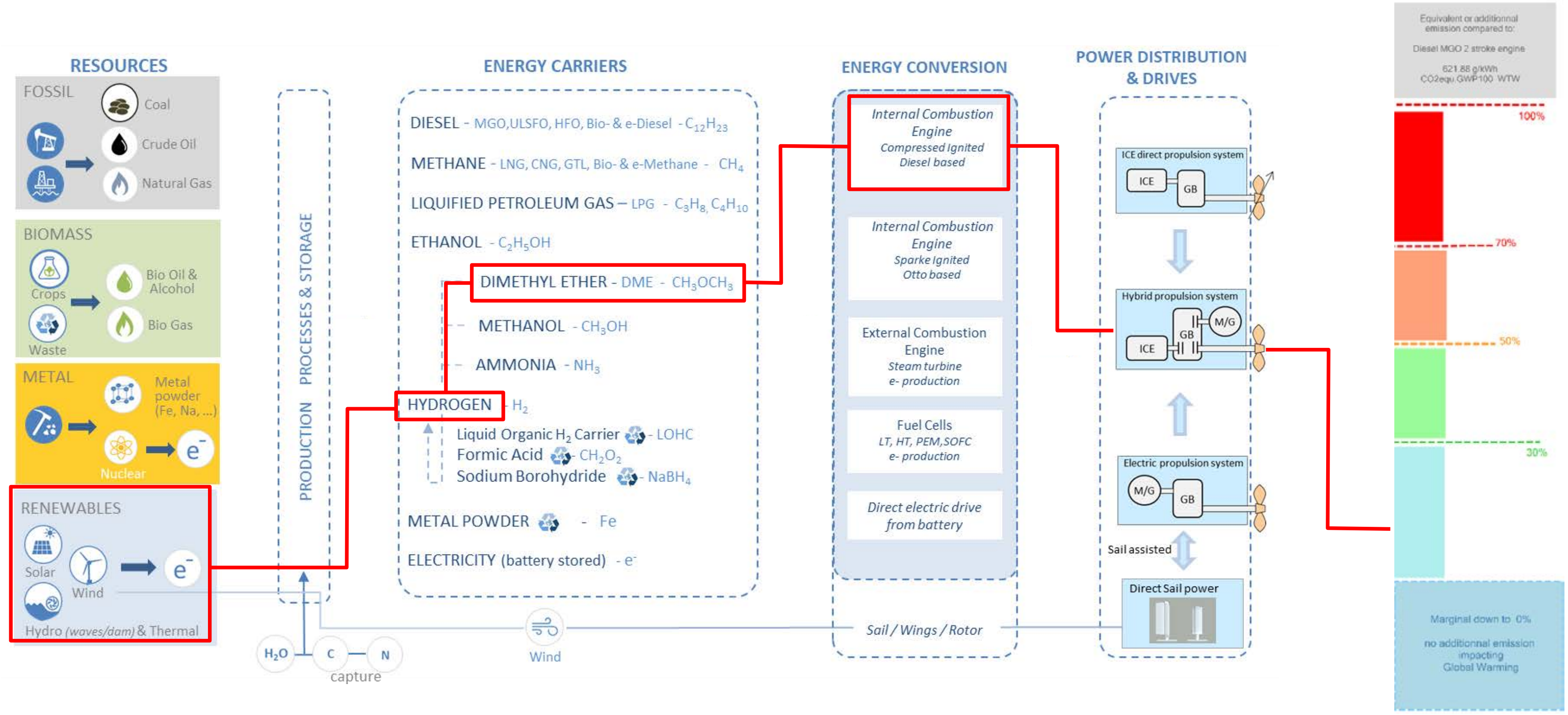
Direct Sail power
GHG Emissions
WTW CO_2eq. GWP100 [g/kWh]
WELL TO TANK
TANK TO WAKE
WELL TO WAKE



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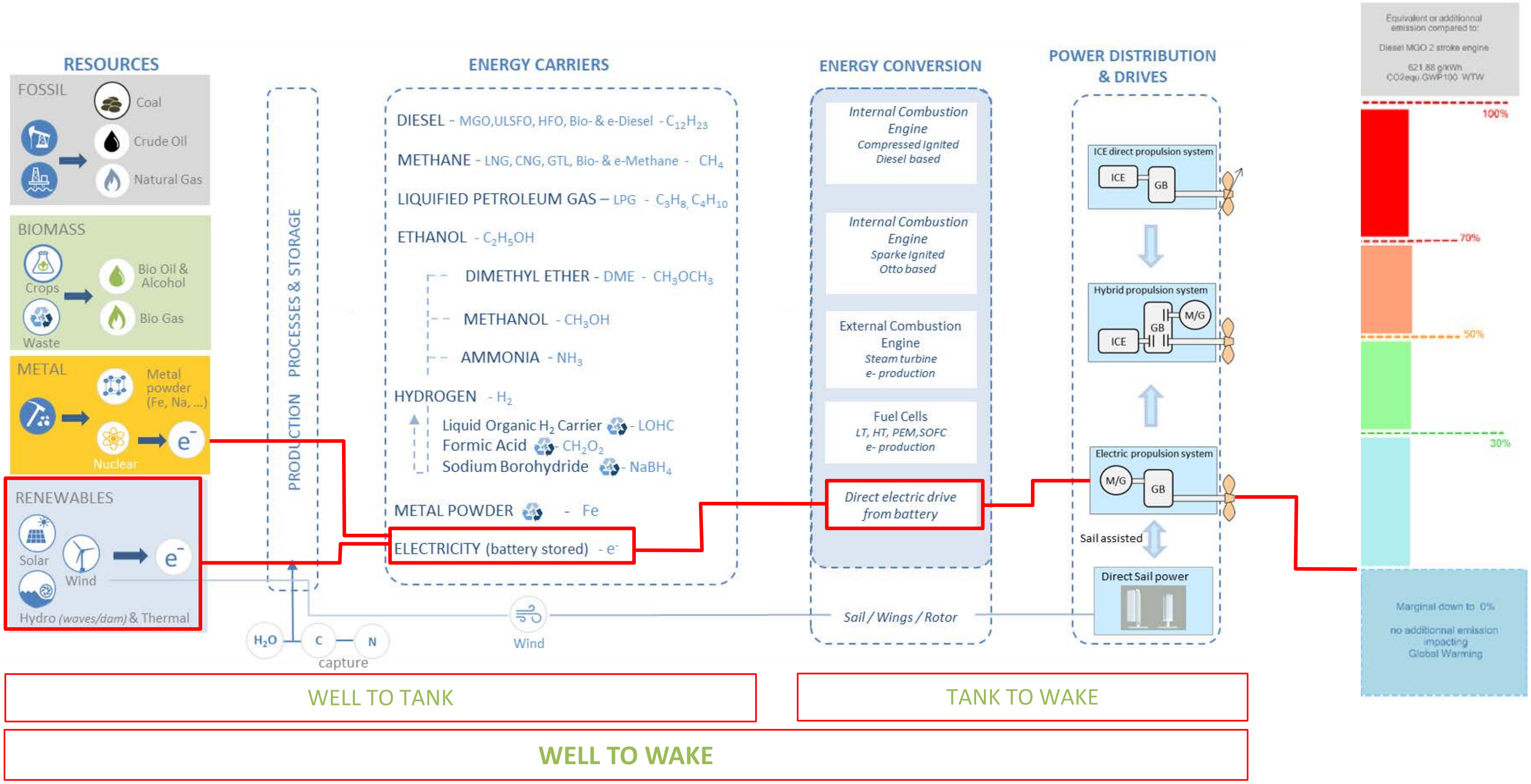
Marginal down to 0%
no additionnal emission impacting Global Warming



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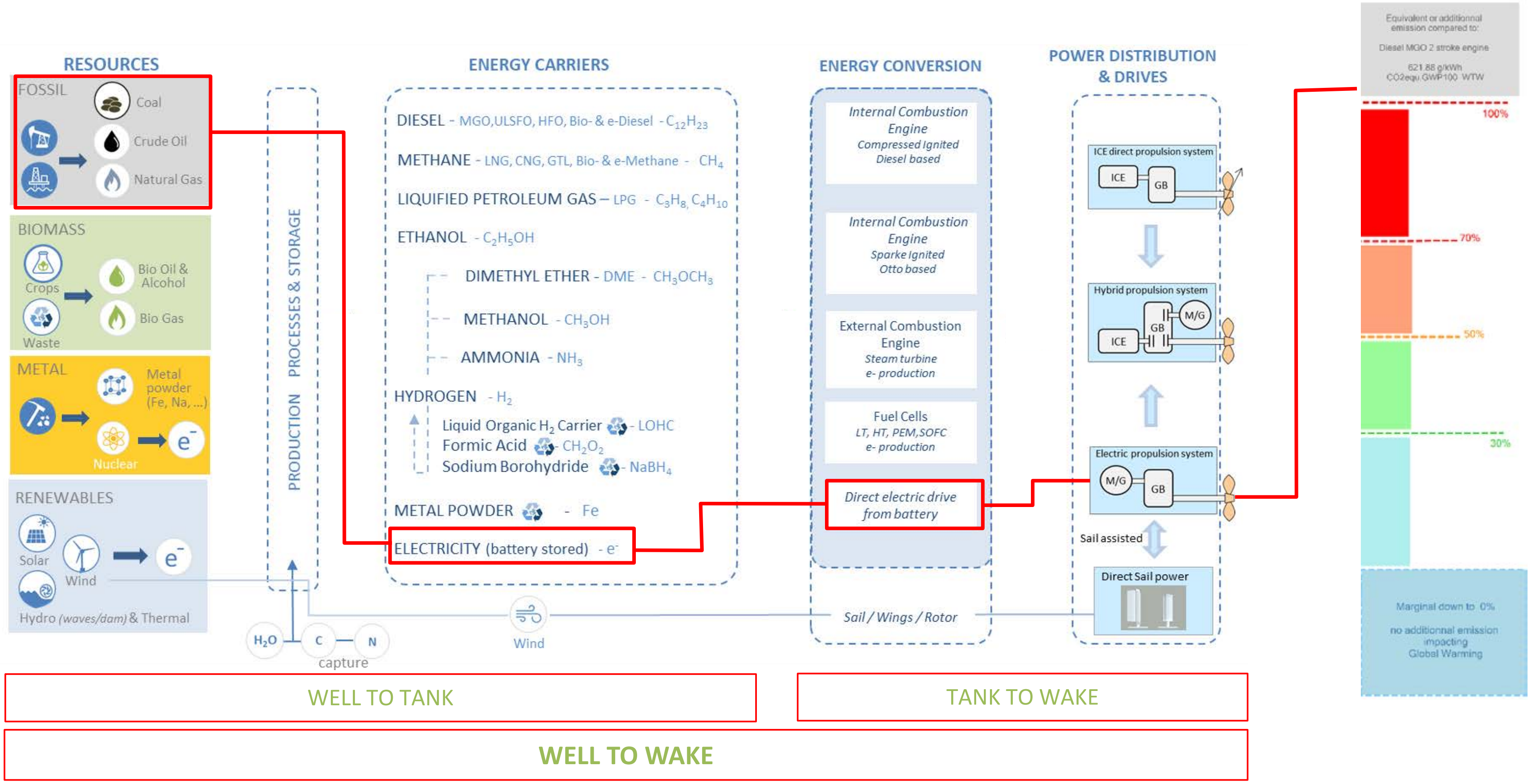
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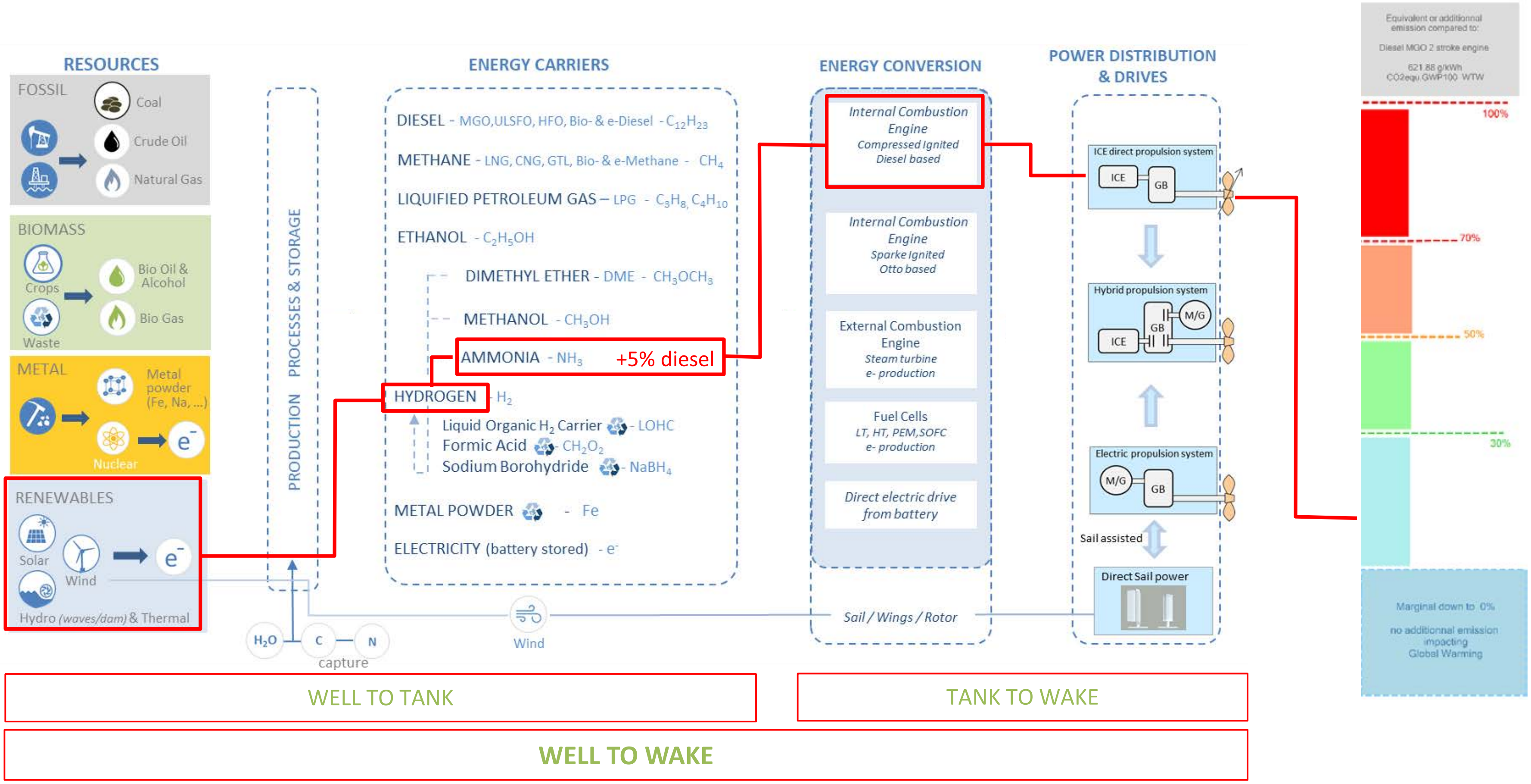

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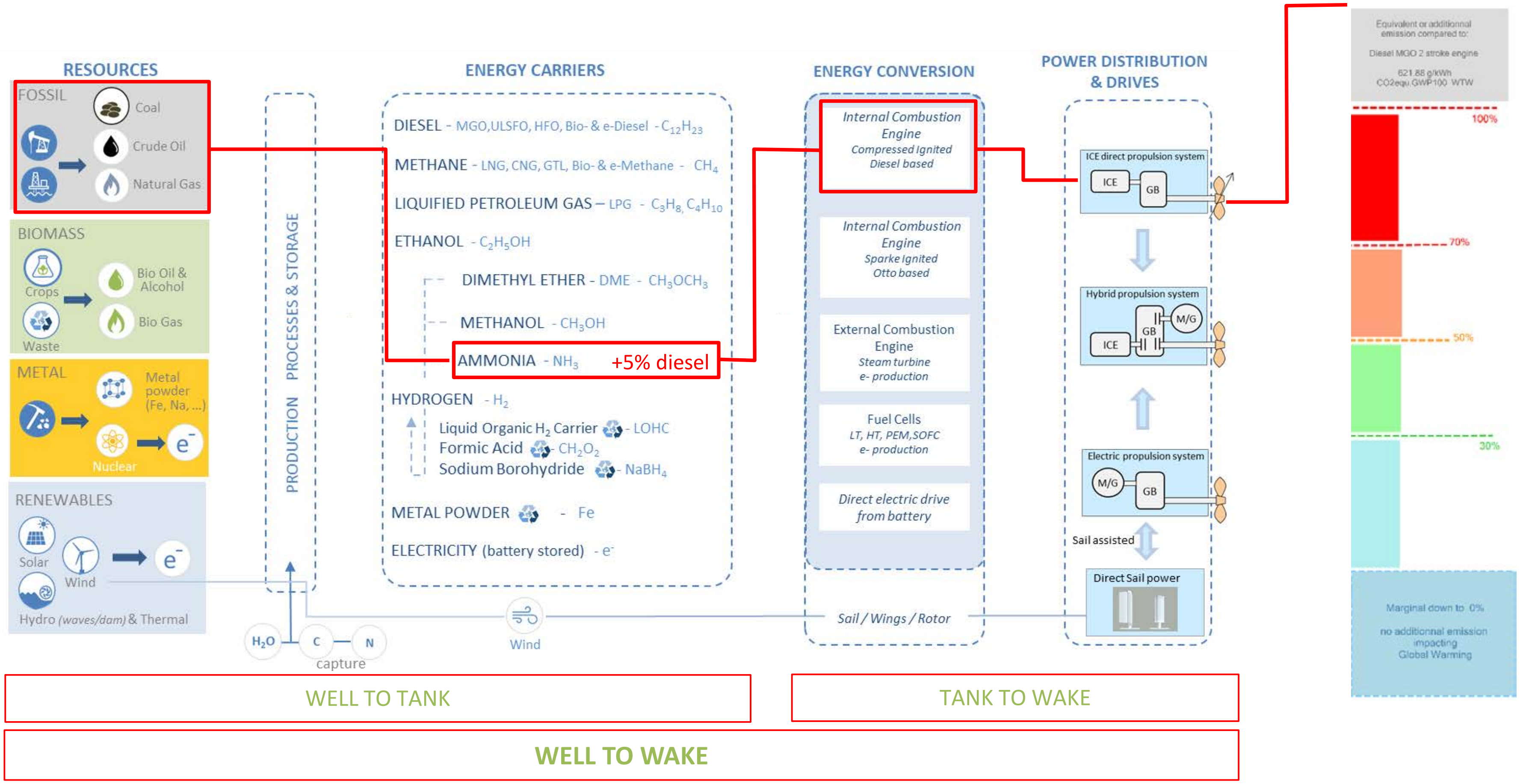
PRODUCTION PROCESSES & STORAGE
H₂O
C
N
capture
Wind
ENERGY CARRIERS
DIESEL - MGO,ULSFO, HFO, Bio- & e-Diesel - C₁₂H₂₃
METHANE - LNG, CNG, GTL, Bio- & e-Methane - CH₄
LIQUIFIED PETROLEUM GAS – LPG - C₃H₈, C₄H₁₀
ETHANOL - C₂H₅OH
DIMETHYL ETHER - DME - CH₃OCH₃
METHANOL - CH₃OH
AMMONIA - NH₃
+5% diesel
HYDROGEN - H₂
Liquid Organic H₂ Carrier - LOHC
Formic Acid - CH₂O₂
Sodium Borohydride - NaBH₄
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
M/G
GB
ICE
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
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 H2 Carrier - LOHC
Formic Acid - CH_2O_2
Sodium Borohydride - $NaBH_4$
METAL POWDER - Fe
ELECTRICITY (battery stored) - e⁻
Wind
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Internal Combustion Engine
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Hybrid propulsion system
M/G
GB
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Electric propulsion system
M/G
GB
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Direct Sail power
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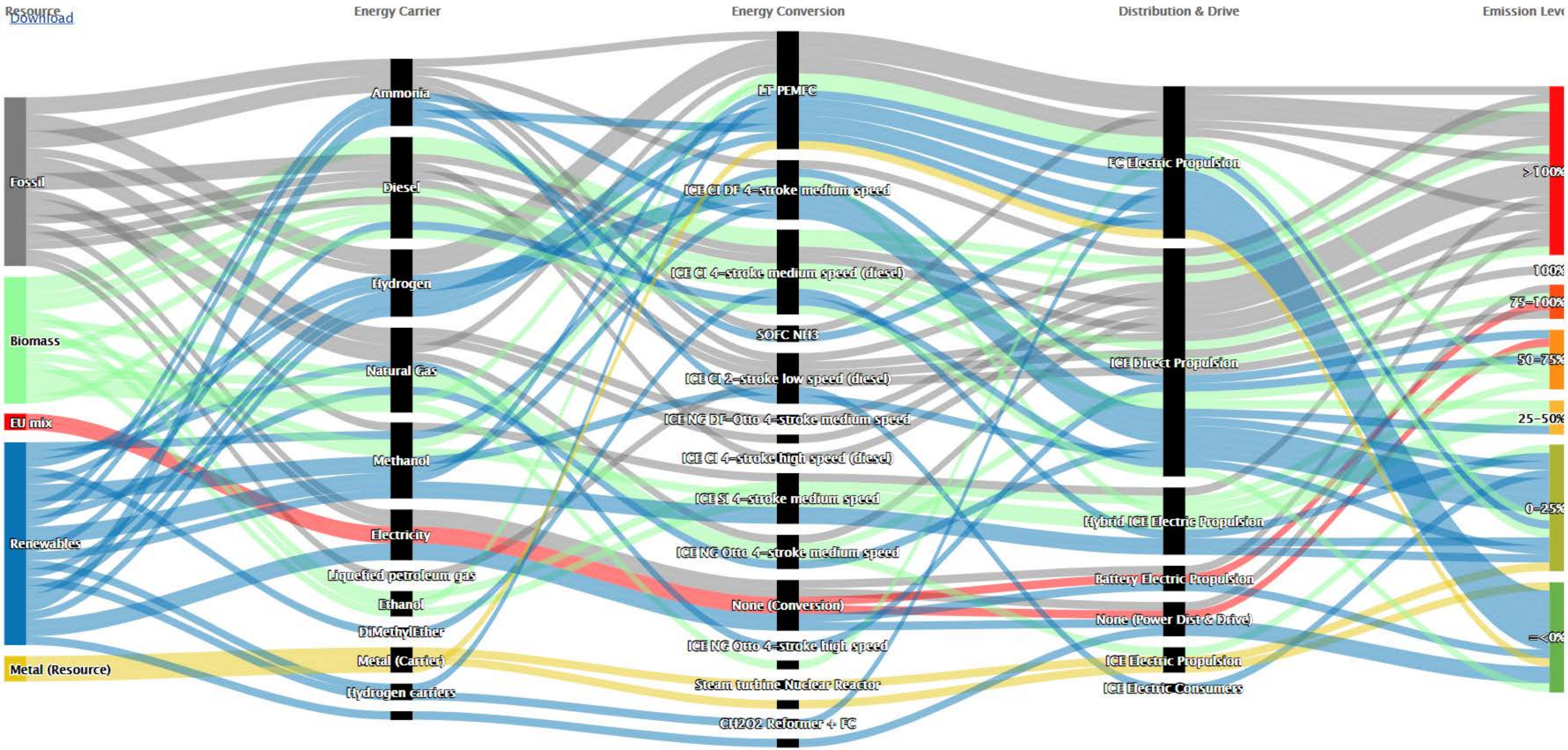
TANK TO WAKE
WELL TO WAKE

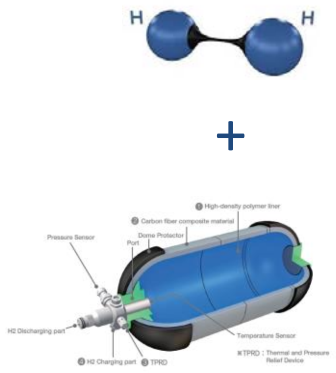

Resource
Download
Energy Carrier
Energy Conversion
Distribution & Drive
Emission Leve
Fossil
Biomass
EU mix
Renewables
Metal (Resource)
Ammonia
Diesel
Hydrogen
Natural Gas
Methanol
Electricity
Liquefied petroleum gas
Ethanol
DiMethylEther
Metal (Carrier)
Hydrogen carriers
LT PEMFC
ICE CI DF 4-stroke medium speed
ICE CI 4-stroke medium speed (diesel)
SOFC NH3
ICE CI 2-stroke low speed (diesel)
ICE NG DF-Otto 4-stroke medium speed
ICE CI 4-stroke high speed (diesel)
ICE SI 4-stroke medium speed
ICE NG Otto 4-stroke medium speed
None (Conversion)
ICE NG Otto 4-stroke high speed
Steam turbine Nuclear Reactor
CH2O2 Reformer + FC
FC Electric Propulsion
ICE Direct Propulsion
Hybrid ICE Electric Propulsion
Battery Electric Propulsion
None (Power Dist & Drive)
ICE Electric Propulsion
ICE Electric Consumers
>100%
100%
75-100%
50-75%
25-50%
0-25%
=<0%

ENERGY CARRIER MAIN PHYSICAL PROPERTY

ENERGY DENSITY

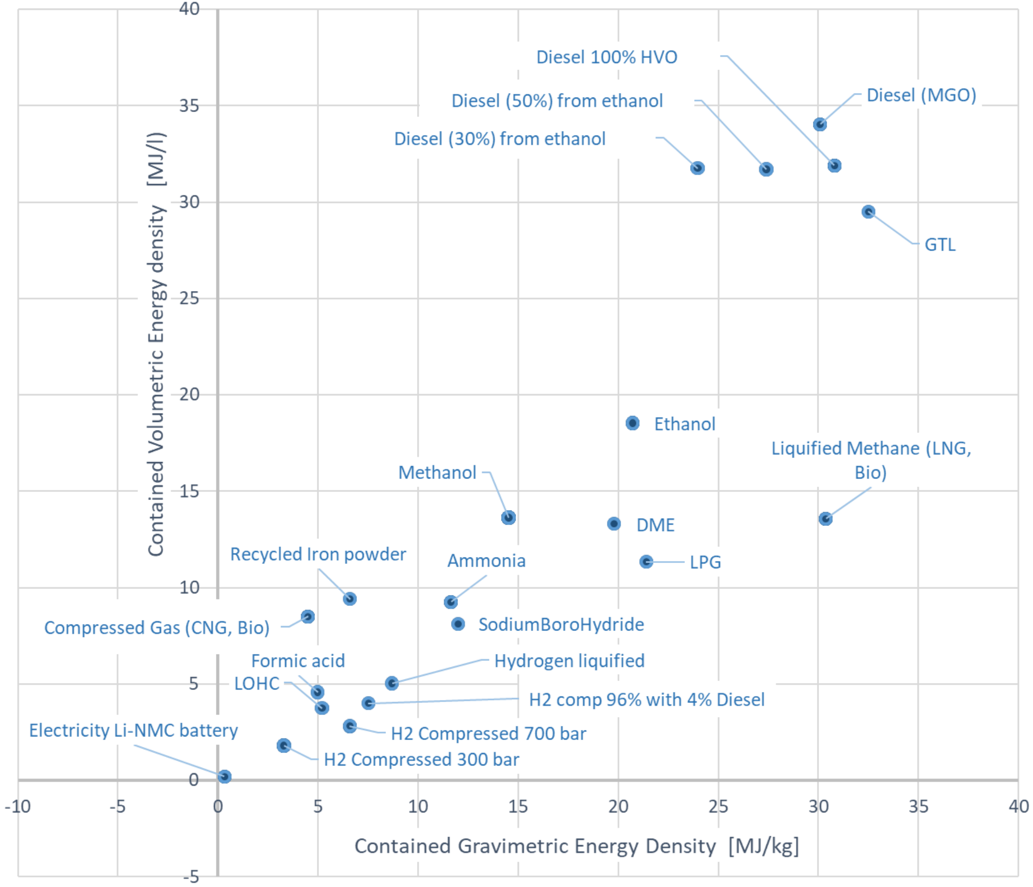
<u>Contained</u> energy density:

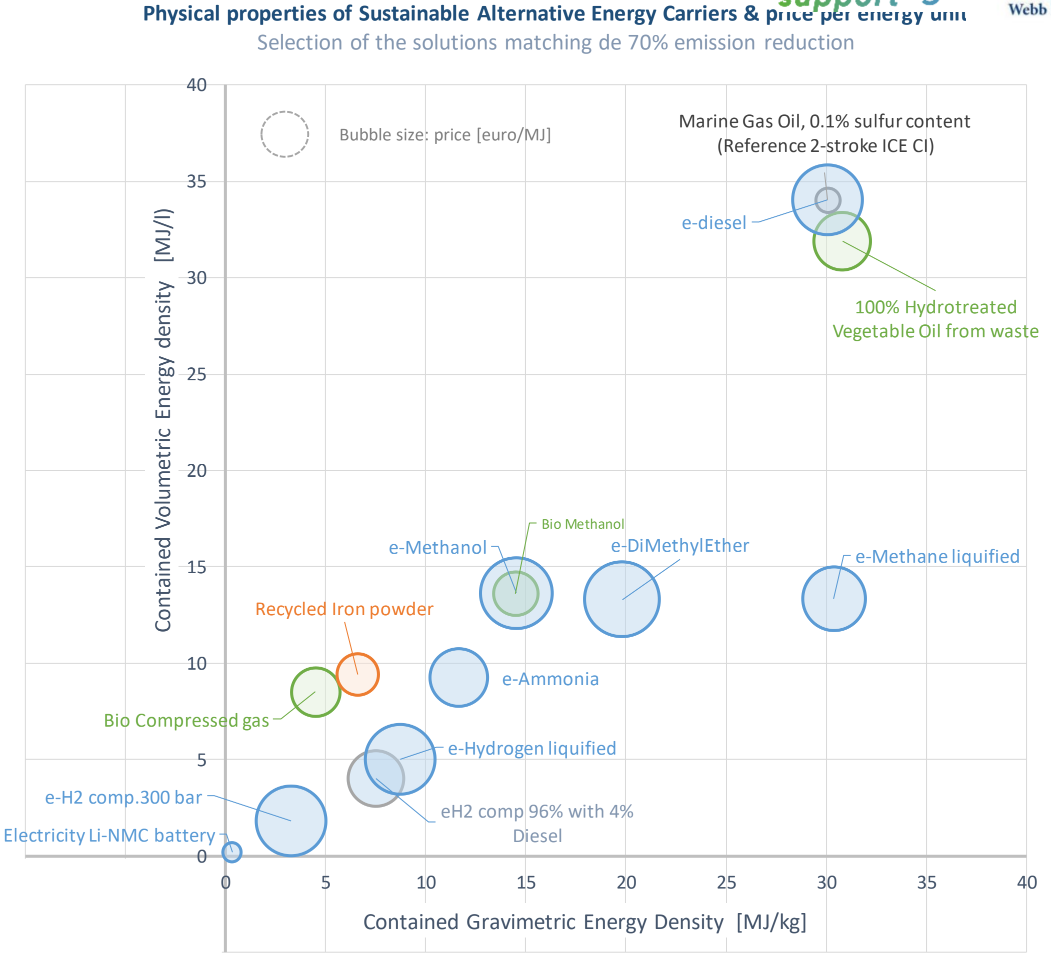
Weight (or volume) of the molecule & its containment system

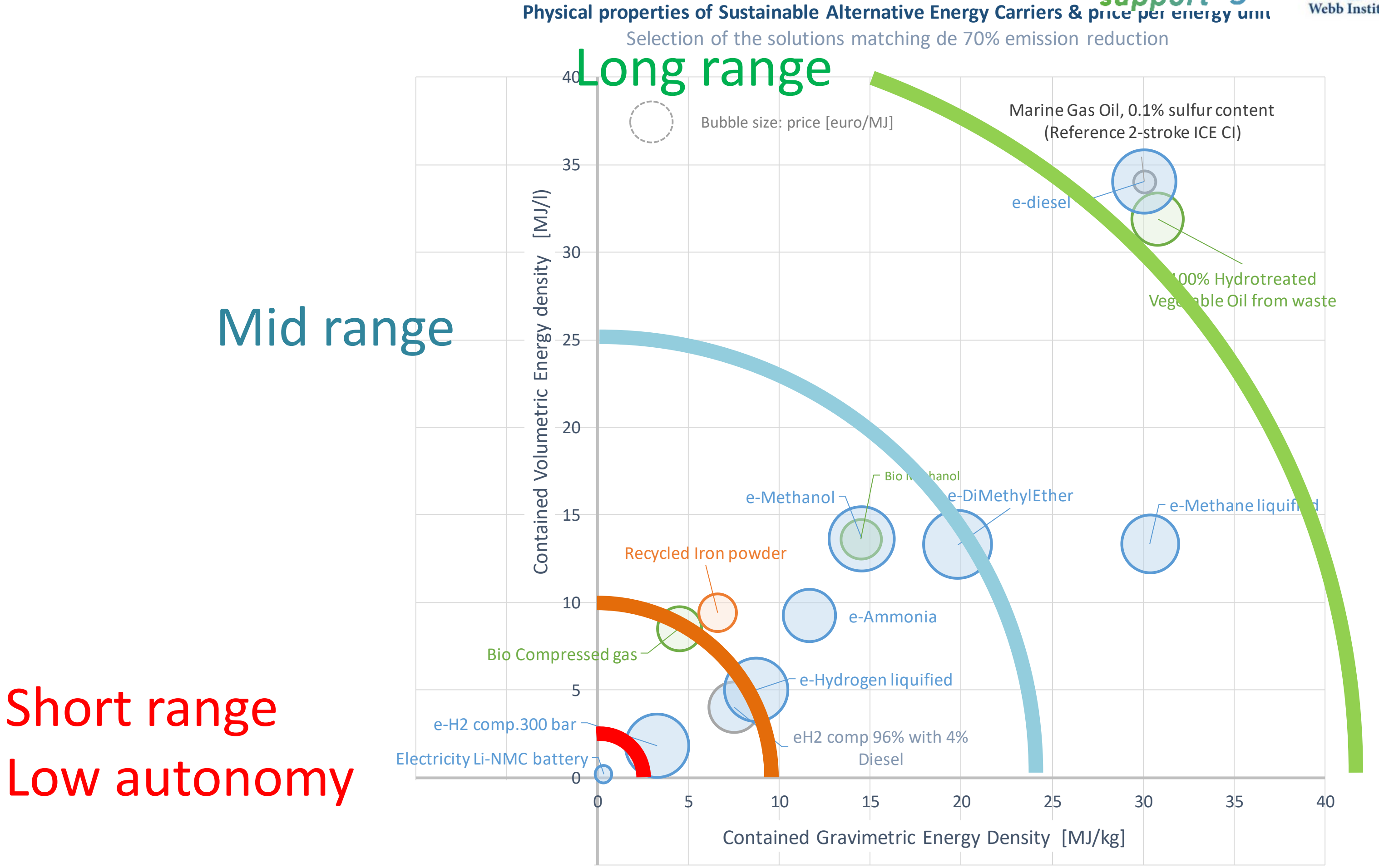


Contained Energy Density of energy carriers (volumetric & gravimetric)

Weight & Volume of the containment system is included in the density




Physical properties of Sustainable Alternative Energy Carriers & price per energy unit
Selection of the solutions matching de 70% emission reduction
Bubble size: price [euro/MJ]
Marine Gas Oil, 0.1% sulfur content (Reference 2-stroke ICE CI)
e-diesel
100% Hydrotreated Vegetable Oil from waste
Bio Methanol
e-Methanol
e-DiMethylEther
e-Methane liquified
Recycled Iron powder
e-Ammonia
Bio Compressed gas
e-Hydrogen liquified
e-H2 comp.300 bar
eH2 comp 96% with 4% Diesel
Electricity Li-NMC battery
Contained Volumetric Energy density [MJ/l]
Contained Gravimetric Energy Density [MJ/kg]
0
5
10
15
20
25
30
35
40



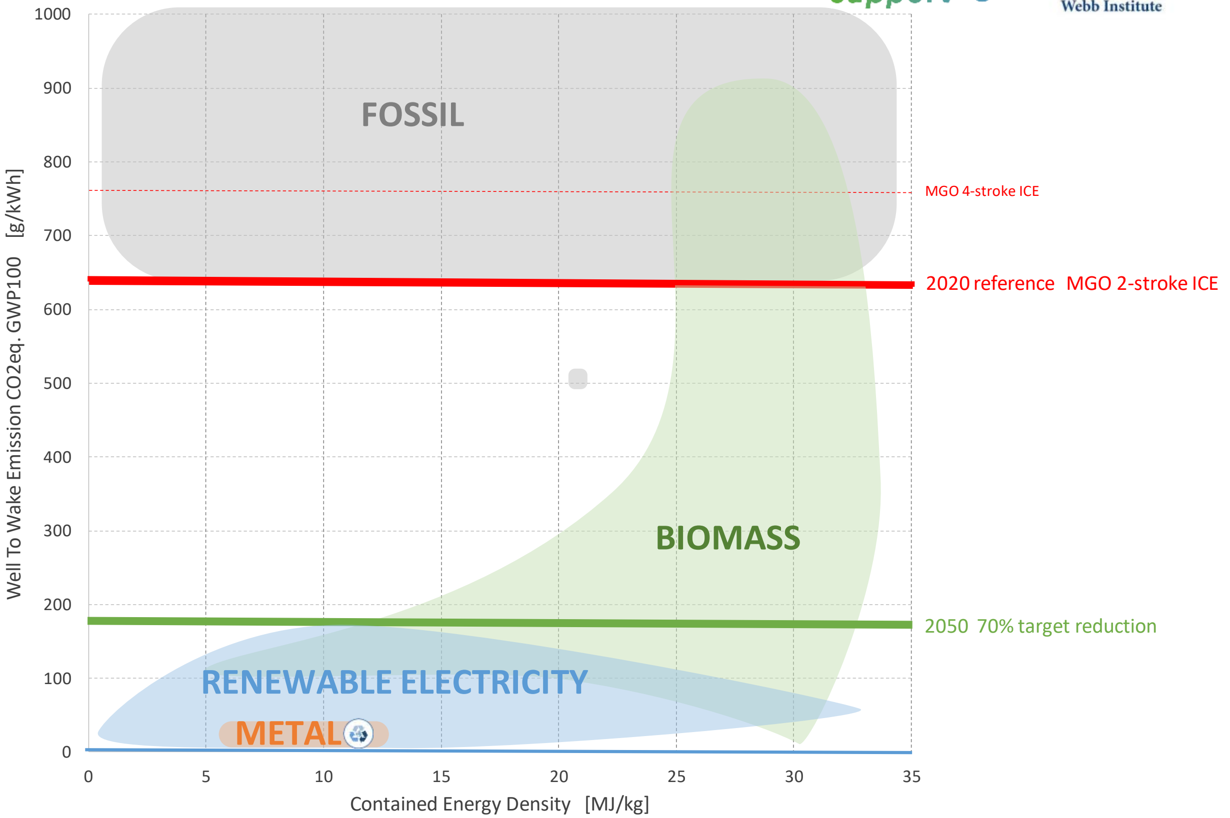
Physical properties of Sustainable Alternative Energy Carriers & price per energy unit
Selection of the solutions matching de 70% emission reduction
Long range
Mid range
Short range
Low autonomy
Bubble size: price [euro/MJ]
Marine Gas Oil, 0.1% sulfur content
(Reference 2-stroke ICE CI)
e-diesel
100% Hydrotreated
Vegetable Oil from waste
e-Methanol
Bio Methanol
e-DiMethylEther
e-Methane liquified
Recycled Iron powder
e-Ammonia
Bio Compressed gas
e-Hydrogen liquified
e-H2 comp.300 bar
eH2 comp 96% with 4%
Diesel
Electricity Li-NMC battery
Contained Volumetric Energy density [MJ/l]
Contained Gravimetric Energy Density [MJ/kg]
0
5
10
15
20
25
30
35
40

ENERGY CARRIER PRODUCTION PATHWAYS & CONVERSION SYSTEMS

&

WTW EMISSIONS

Global results per type of resource



Short range (autonomy), possible for small / medium ships only. Likely too heavy to carry the required energy content for ocean going or short sea shipping operations as sole energy source

Long range (autonomy) possible for Ocean going or Short-sea Shipping with current bunker or adapted strategy

Wind as range extender for all ships (consumption reduction)

ENERGY CARRIER:

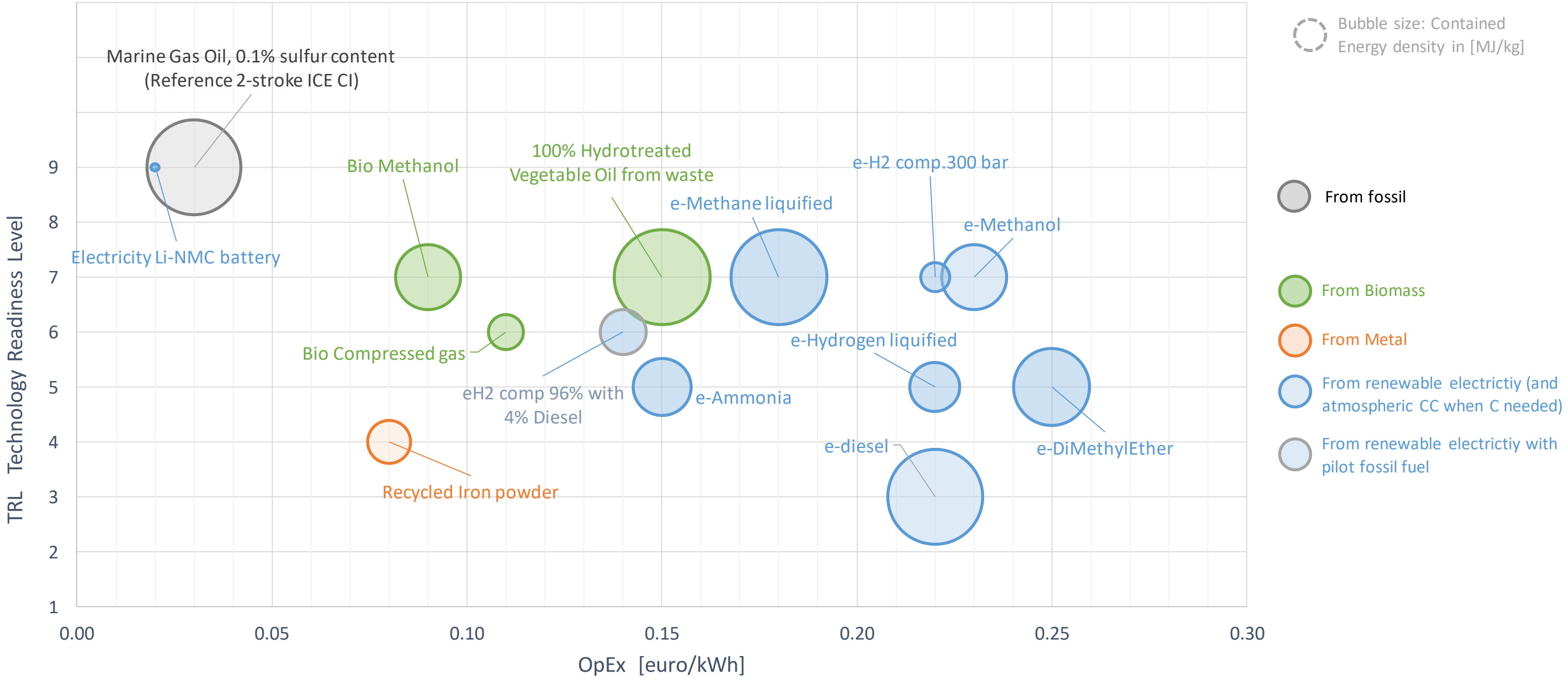
ENERGY DENSITY

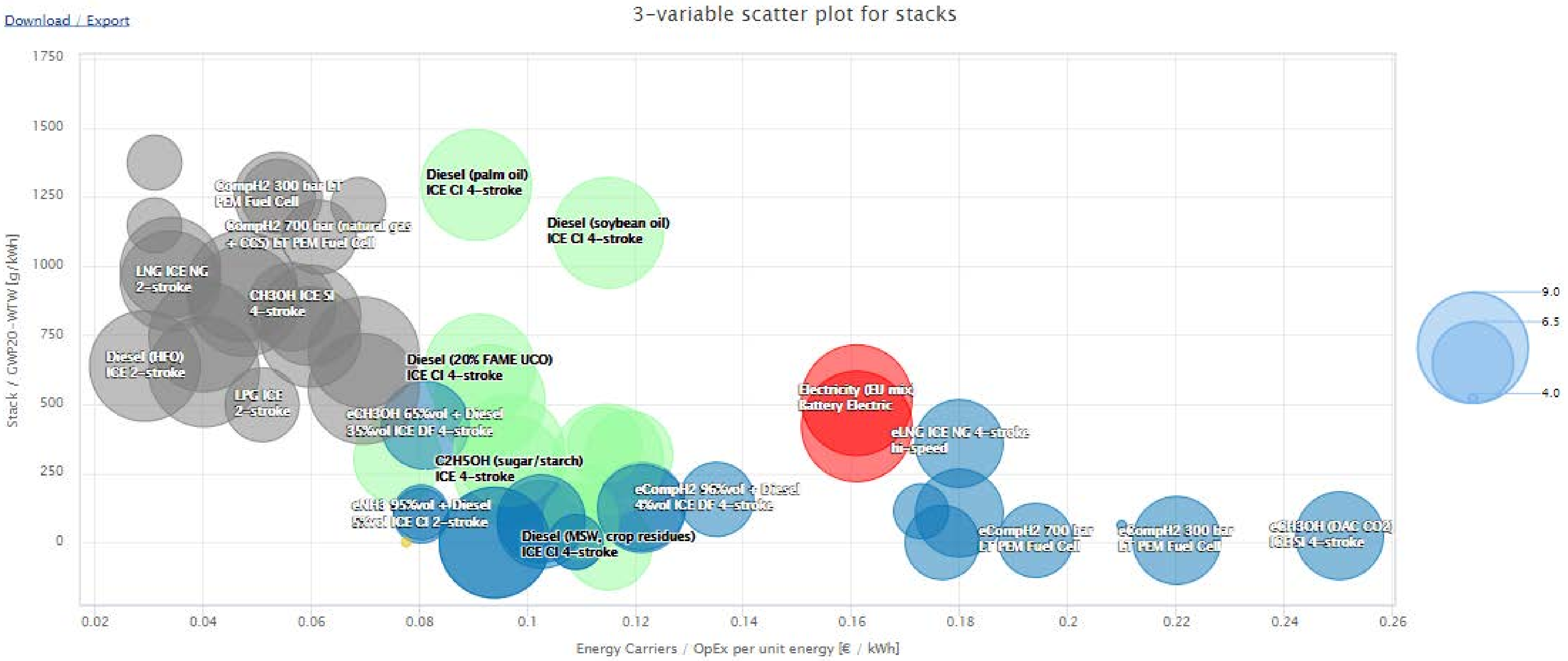
&

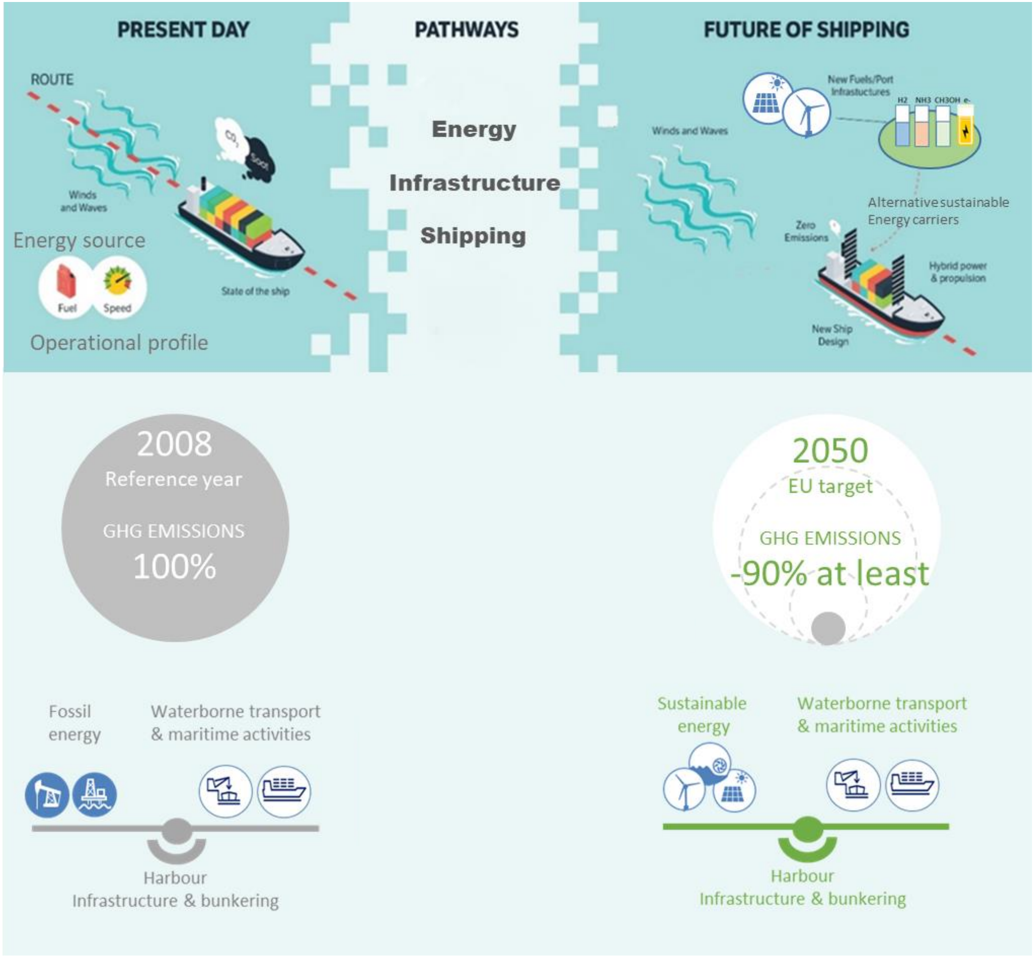
TRL + COST (OpEx)

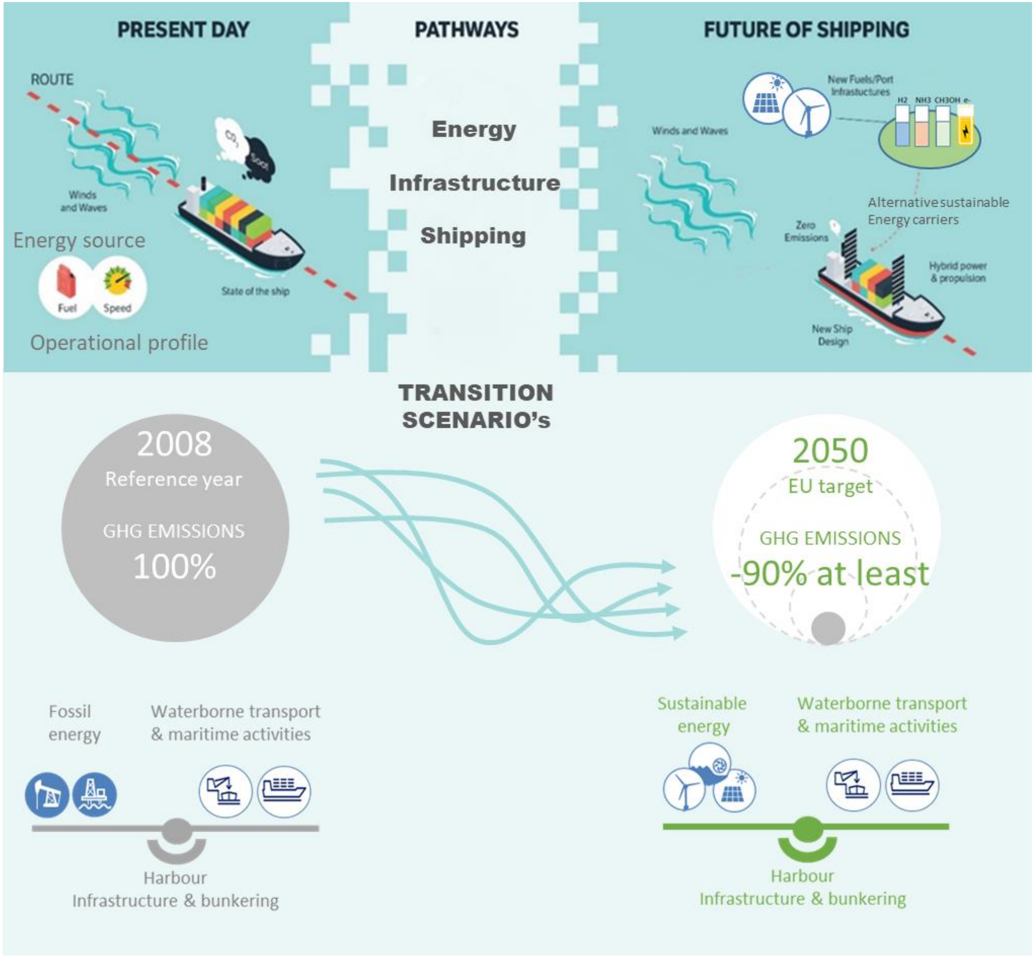
Properties of alternative sustainable powering solutions compared to Diesel MGO in 2-stroke ICE

Selection of carriers combined with power distribution systems, meeting 2050 targets (at least 70% reduction of CO2 eq. GWP100 in [g/kWh])




Download / Export
3-variable scatter plot for stacks
Stack / GWP20-WTW [g/kWh]
Energy Carriers / OpEx per unit energy [€ / kWh]
1750
1500
1250
1000
750
500
250
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
0.18
0.2
0.22
0.24
0.26
CompH2 300 bar LT PEM Fuel Cell
CompH2 700 bar (natural gas + CCS) LT PEM Fuel Cell
LNG ICE NG 2-stroke
CH3OH ICE SI 4-stroke
Diesel (HFO) ICE 2-stroke
LPG ICE 2-stroke
Diesel (palm oil) ICE CI 4-stroke
Diesel (soybean oil) ICE CI 4-stroke
Diesel (20% FAME UCO) ICE CI 4-stroke
eCH3OH 65%vol + Diesel 35%vol ICE DF 4-stroke
C2H5OH (sugar/starch) ICE 4-stroke
eNH3 95%vol + Diesel 5%vol ICE CI 2-stroke
Diesel (MSW, crop residues) ICE CI 4-stroke
eCompH2 96%vol + Diesel 4%vol ICE DF 4-stroke
Electricity (EU mix) Battery Electric
eLNG ICE NG 4-stroke hi-speed
eCompH2 700 bar LT PEM Fuel Cell
eCompH2 300 bar LT PEM Fuel Cell
eCH3OH (DAC CO2) ICE SI 4-stroke
9.0
6.5
4.0


PRESENT DAY
PATHWAYS
FUTURE OF SHIPPING
ROUTE
Winds and Waves
Energy source
Fuel
Speed
State of the ship
Operational profile
Energy
Infrastructure
Shipping
New Fuels/Port Infrastuctures
H2 NH3 CH3OH e-
Winds and Waves
Alternative sustainable Energy carriers
Zero Emissions
Hybrid power & propulsion
New Ship Design
2008
Reference year
GHG EMISSIONS
100%
2050
EU target
GHG EMISSIONS
-90% at least
Fossil energy
Waterborne transport & maritime activities
Harbour Infrastructure & bunkering
Sustainable energy
Waterborne transport & maritime activities
Harbour Infrastructure & bunkering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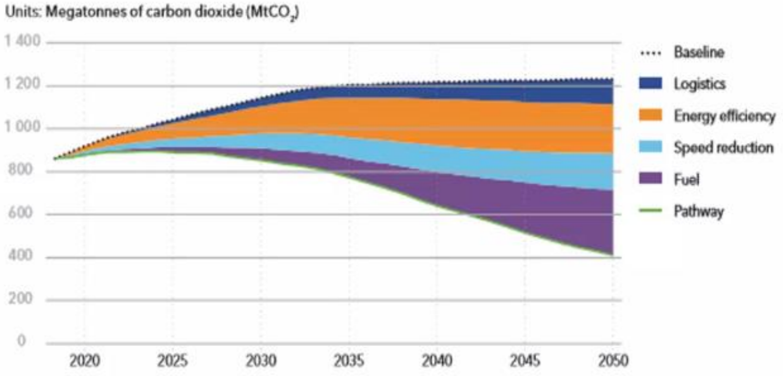
GHG EMISSIONS
-90% at least
Fossil energy
Waterborne transport & maritime activities
Harbour Infrastructure & bunkering
Sustainable energy
Waterborne transport & maritime activities
Harbour Infrastructure & bunkering

Ways to reduce maritime emissions

Meeting the climate targets would require significant progress on two aspects:

- Improvement of energy efficiency (covering logistics, design, technical improvements and operations) – ***i.e. using less fuel***
- Greater use of renewable and low carbon fuels – *i.e.* ***using cleaner fuels***



DNV-GL (2019) | Maritime Forecast to 2050

European Commission | Mobility and Transport

Take aways

(part 1 – context energy transition)

- There are many technical solutions to power ships with ultra low emission level, from wheel to wake. It is the choice which is currently difficult.

- Scalability of the supply of sustainable alternative energy carrier is an issue for the coming decades (we need more renewable electricity, probably incl. nuclear…).

- Energy supply logistics and bunkering, as well as role of harbor, will be key in the energy transition (large impact upcoming).

- Energy carriers and power conversion systems providing zero emission solutions will not allow to keep the current autonomy and range of ships. Additional power source and energy use reduction are going to be key in new designs (because of scarcity of sustainable energy and lower energy density of alternative energy carriers)

- There are many technical solutions to power ships with ultra low emission level, from wheel to wake. It is the choice which is currently difficult.
- Scalability of the supply of sustainable alternative energy carrier is an issue for the coming decades (we need more renewable electricity, probably incl. nuclear…).
- Energy supply logistics and bunkering, as well as role of harbor, will be key in the energy transition (large impact upcoming).
- Energy carriers and power conversion systems providing zero emission solutions will not allow to keep the current autonomy and range of ships. **Additional power source and energy use reduction are going to be key in new designs** (because of scarcity of sustainable energy and lower energy density of alternative energy carriers)

and here the wind begins to blow …

ENERGY CARRIERS

DIESEL - ~~MGO,ULSFO, HFO~~, Bio- & e-Diesel

GAS - ~~LNG, CNG, GTL~~, Bio- & e-Methane

LIQUIFIED PETROLEUM GAS - LPG

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

ELECTRICITY (battery stored) - e^-

Wind

Engine/propeller as prime mover & wind assistance

wind: 5 to 15% total power supply

Possible refit on existing ships, no hull or appendages modifications

Hybrid engine / wind propulsion

Wind: 15 to 40% of total power supply

Requirements for additional appendages (drift/leeway)

Main wind propulsion & engine assistance

Wind: up to 100% of total power supply

Dedicated hull form & appendages


Decade of
Wind Propulsion
Home
Upcoming Activities
Decade of
Wind Propulsion
2021-2030

Natural propulsion for Transport & Shipping: potential and expectations in the present context

Thank you for your attention!

Aero- and hydrodynamics with wind propulsion

Rogier Eggers (MARIN)

Natural Propulsion Conference, Webb, 16-11-2021

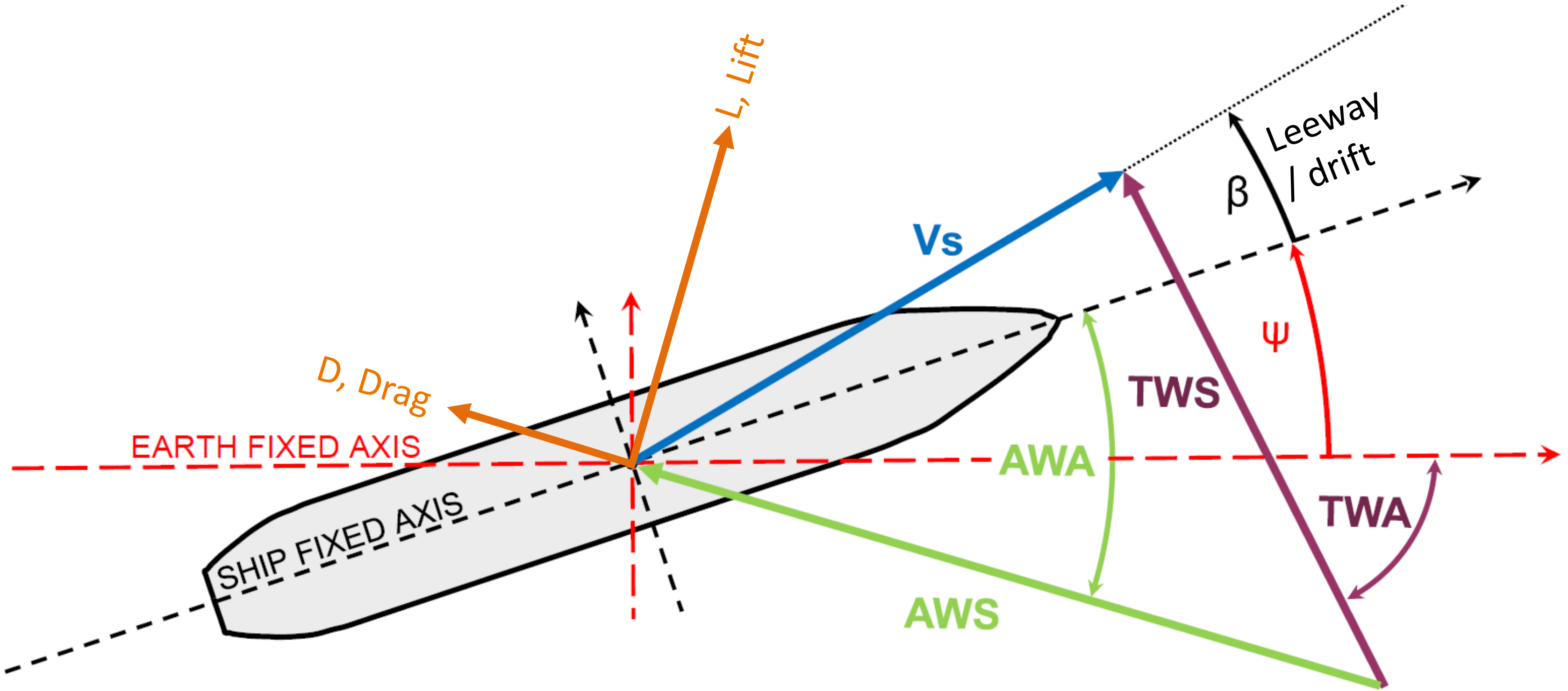
Outline

- Aerodynamics
- What changes in hydrodynamics?
- How to design (and operate)?
- Modelling and measurements

BETTER SHIPS, BLUE OCEANS

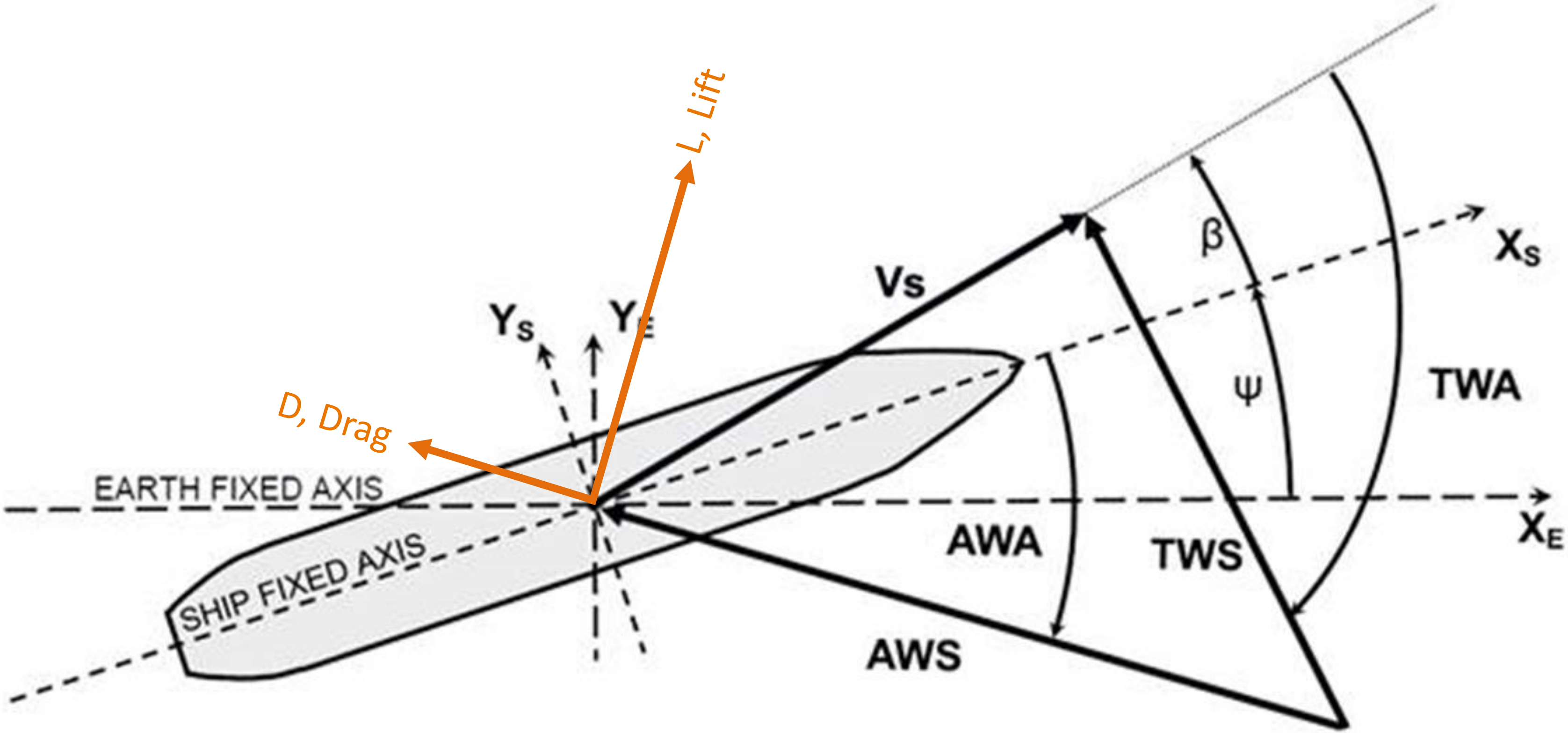
Aerodynamics

Wind definitions

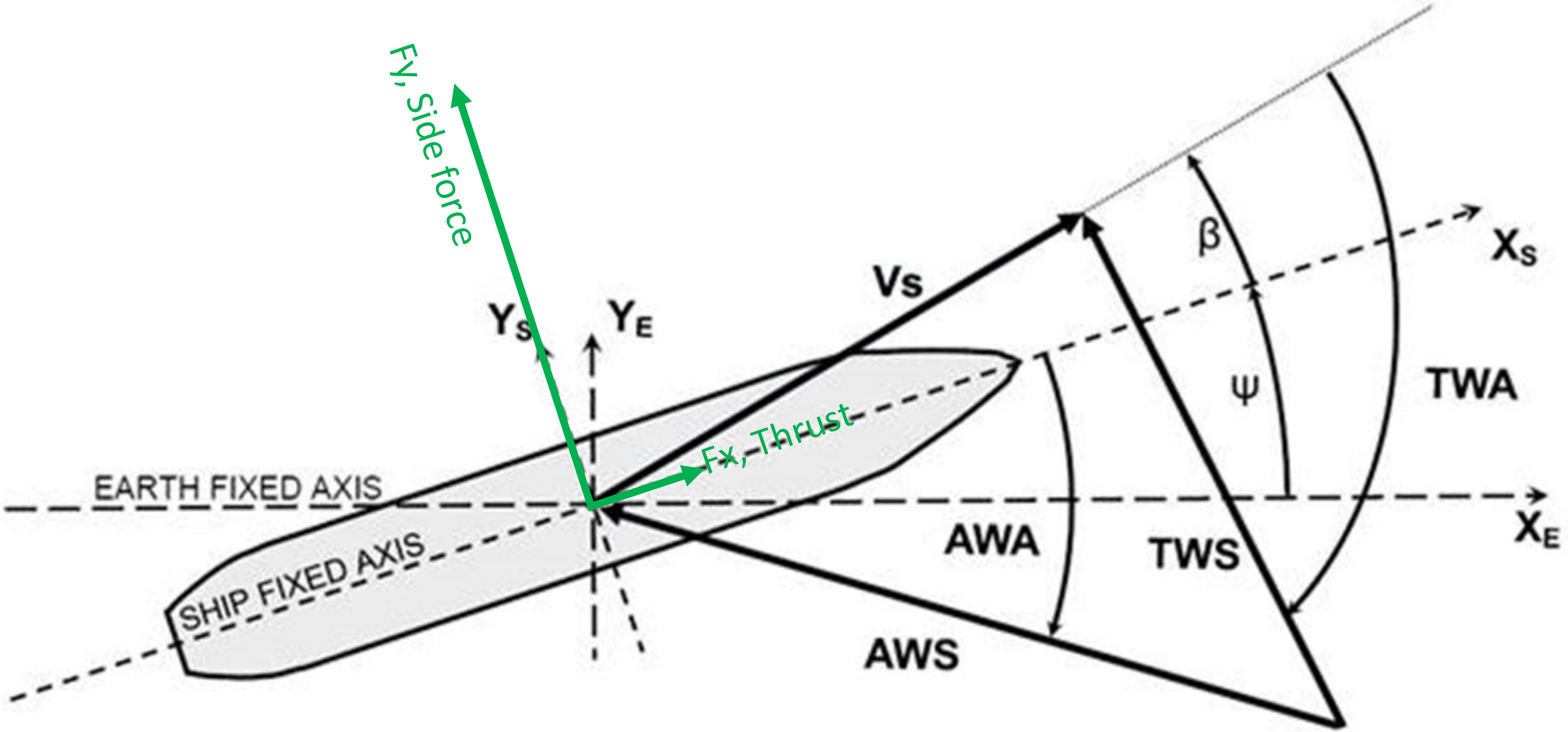


TWS: True Wind Speed
TWA: True Wind Angle
AWS: Apparent Wind Speed
AWA: Apparent Wind Angle

Lift and drag



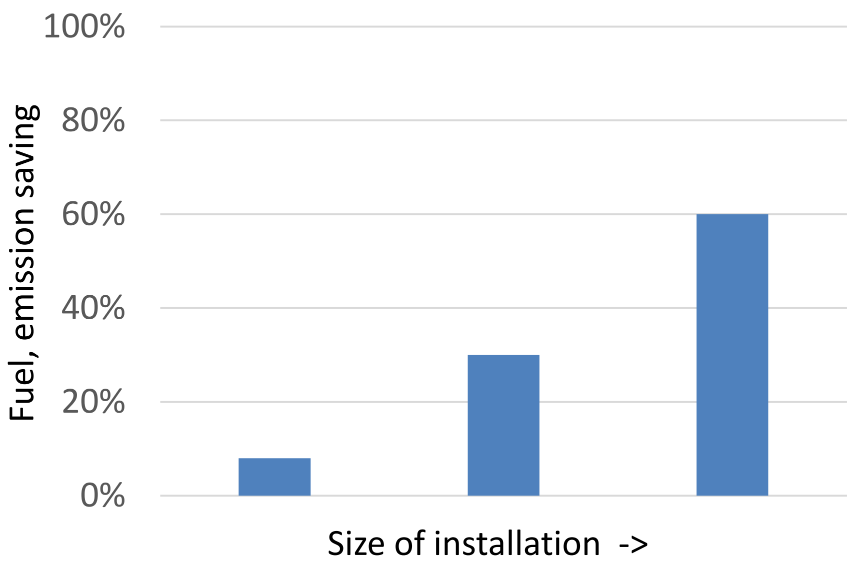
Thrust (and side force)



Thrust (and side force)

- The thrust is what we're after, leading to savings (or complete replacement of ship propulsion)

- The side force has some knock-on effects (discussed later)



Dimensionless numbers

Discarding influence of wind speed (AWS), projected area (A) and air density (ρ):
Allows a "fair" comparison of device types

Lift coefficient $$C_L = \frac{L}{\frac{1}{2} \cdot \rho \cdot AWS^2 \cdot A}$$

Drag coefficient $$C_D = \frac{D}{\frac{1}{2} \cdot \rho \cdot AWS^2 \cdot A}$$

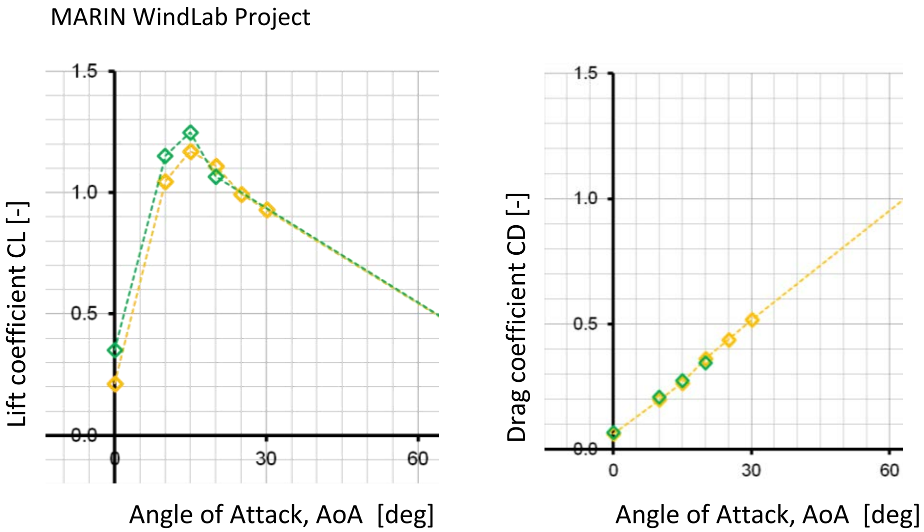
Thrust, driving force coefficient $$C_X = \frac{F_X}{\frac{1}{2} \cdot \rho \cdot AWS^2 \cdot A}$$

Side force coefficient $$C_Y = \frac{F_Y}{\frac{1}{2} \cdot \rho \cdot AWS^2 \cdot A}$$

Lift and drag curves (sails and wing sails)

Dependent on:

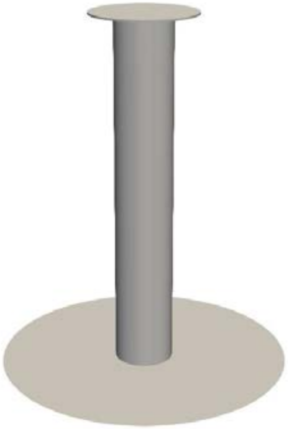
- Angle of attack
- (Reef/Retract)
- (Flap angle/ Camber

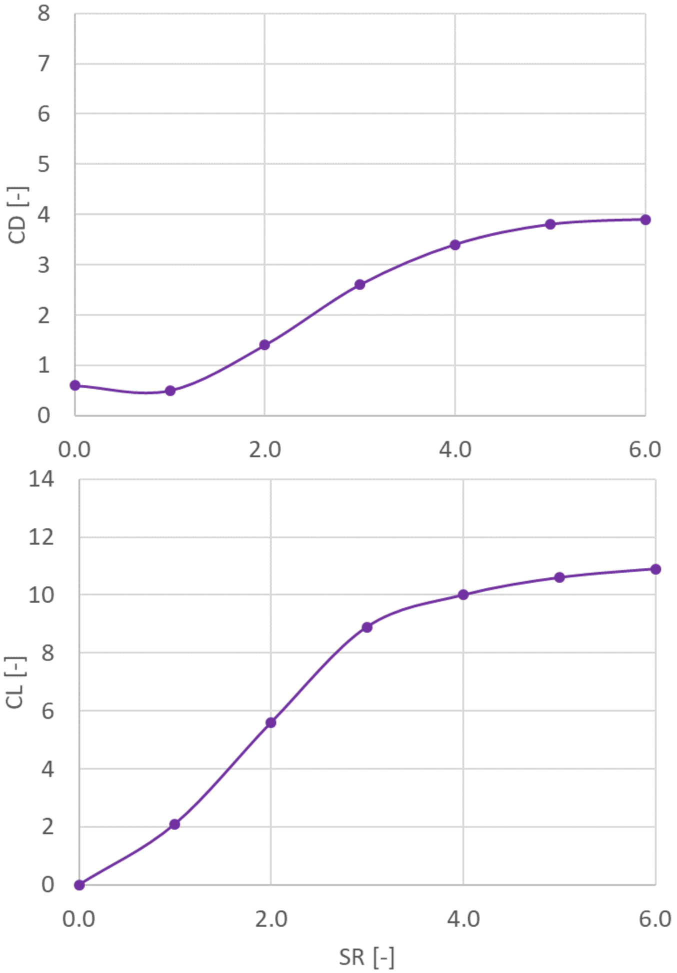


Lift and drag curves (Flettner rotor)

Dependent on:

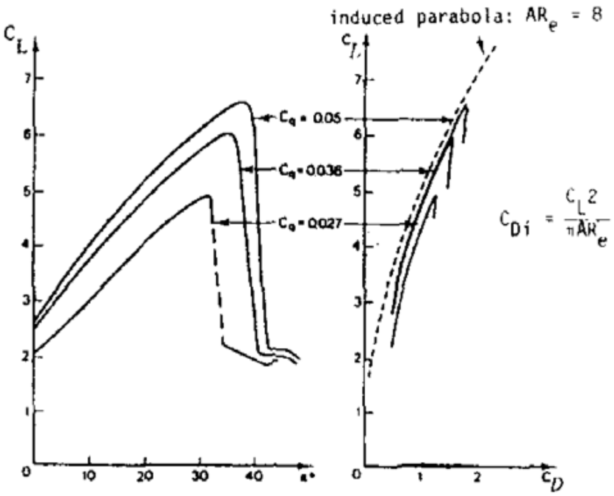
- Spin ratio, $SR = \frac{n \cdot \pi \cdot D}{AWS}$ $[-]$





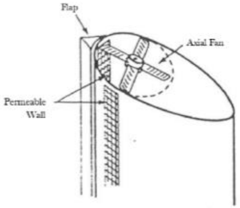
Lift and drag curves (suction sail)

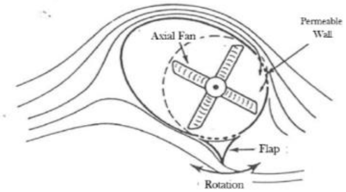
L. Malavard, “Un nouveau propulseur éolien de navire, La vie des sciences,” CR Ser. Générale, 1984



Dependent on:

- Angle of attack
- Aspiration (suction), $C_Q = \frac{Q}{AWS \cdot A}$
- Flap angle

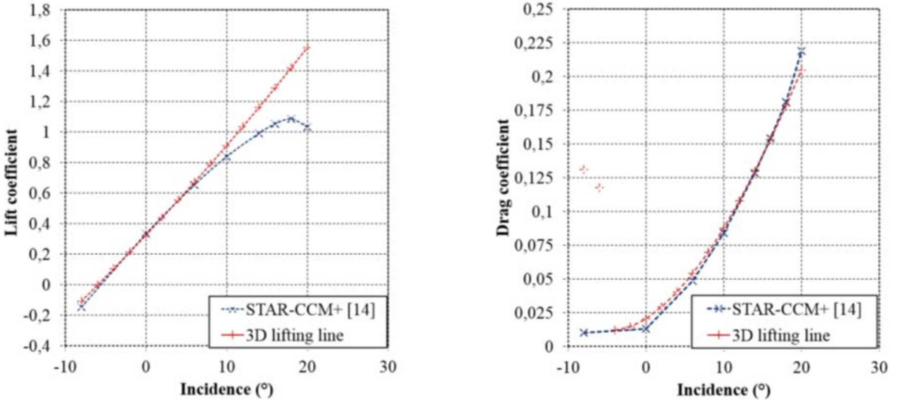


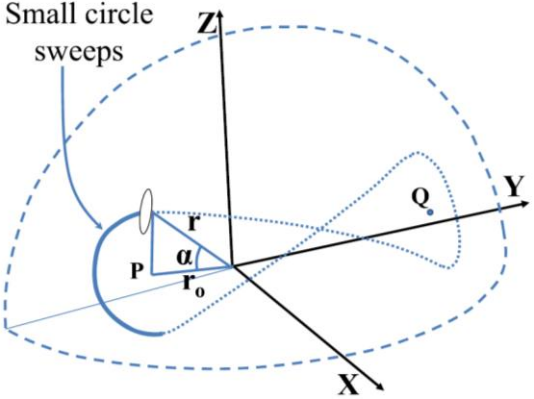


Lift and drag curves (kite)

- Dependent on:
  - Height (wind speed and angle)
  - Angle of Attack
  - Flight pattern (can magnify forces by factor ~25)

Leloup, Richard, et al. "Estimation of the lift-to-drag ratio using the lifting line method: Application to a leading edge inflatable kite." Airborne wind energy, 2013.

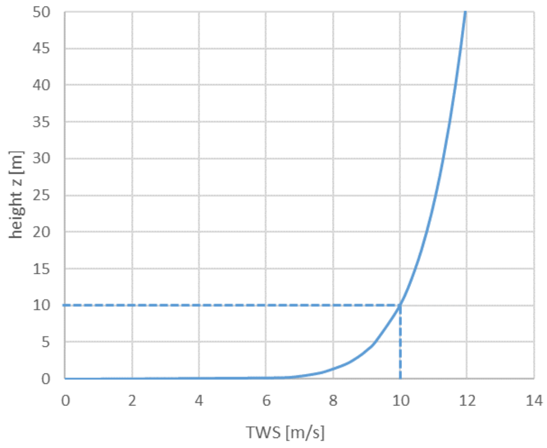




G. M. Dadd, D. A. Hudson, and R. A. Shenoi, "Determination of kite forces using three-dimensional flight trajectories for ship propulsion," Renewable Energy, vol. 36, no. 10,

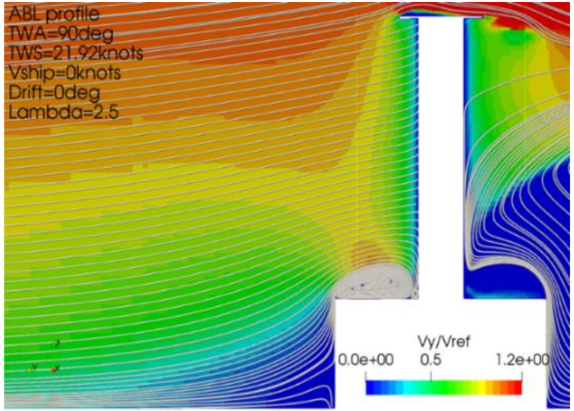
Incoming air flow

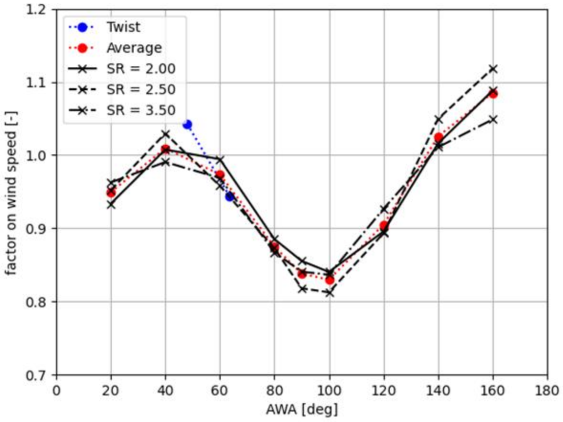
- Wind speed lower at sea surface than higher above: Atmospheric Boundary Layer (ABL)
- Common reference for wind speed at 10m height
- Combined with ship speed, as you go higher:
  - The apparent wind speed increases ("shear")
  - The apparent wind angle moves aft ("twist")

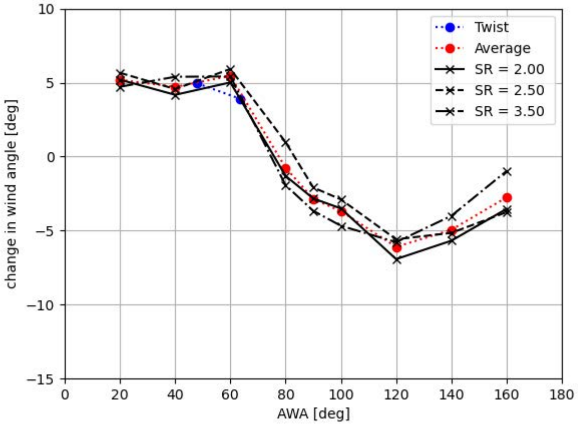


Disturbance of ship

- Ship hull and superstructures affect the flow
- Dependent on apparent wind angle
- Dependent on position on board







M. Garenaux and J. J. A. Schot, “Flettner rotors performance and interaction effects on the MARIN Hybrid Transition Coaster,” 2021.

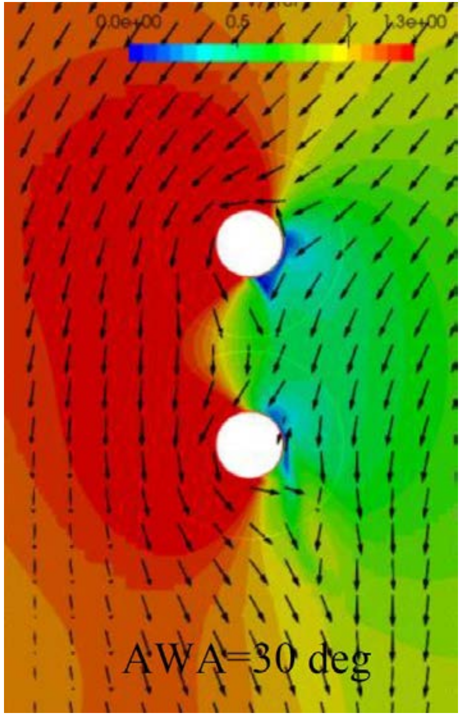
Interaction effects

With wind propulsors closely positioned together

(~ < 12 times chord or diameter):

- Mutual influence on each other’s performance due to change in flow speed and angle
- Generally a reduction of overall thrust

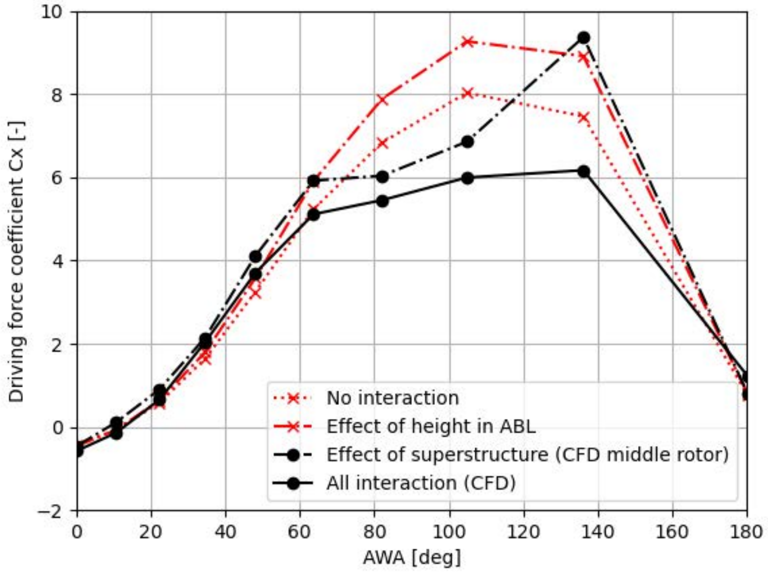
  (some exceptions with closely positioned wings/sails)



M. Garenaux and J. J. A. Schot, “Flettner rotors performance and interaction effects on the MARIN Hybrid Transition Coaster,” 2021.

Full (interaction) scenario

- Combined interaction effects can yield overall forces significantly different from just the wind propulsor in “clean” wind



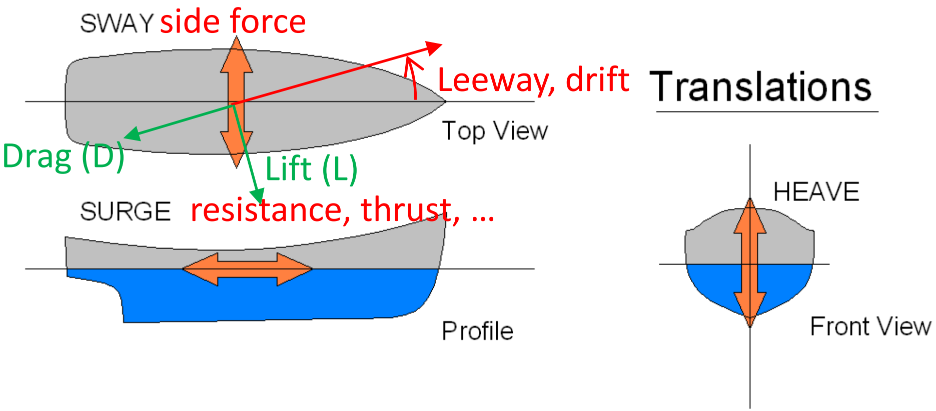
M. Garenaux and J. J. A. Schot, “Flettner rotors performance and interaction effects on the MARIN Hybrid Transition Coaster,” 2021.

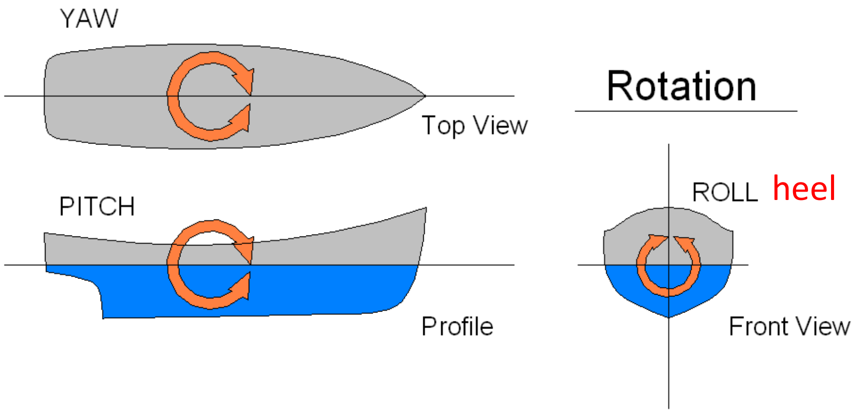
MARIN

BETTER SHIPS, BLUE OCEANS

What changes (in hydrodynamics) with wind propulsion?

Definitions





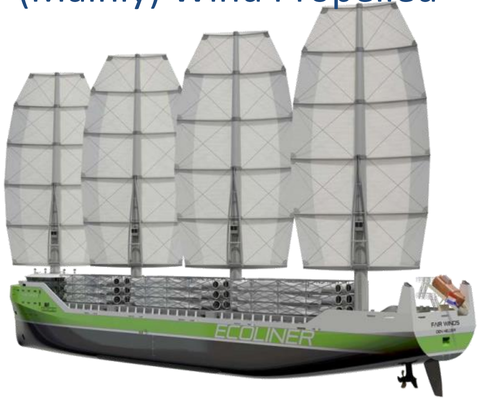
How much wind propulsion?

Not only dependent on design, but also operations (speed) and routes (wind) !

Reference:
Conventionally propelled

Fully sailing

Wind Assisted <-> (Mainly) Wind Propelled

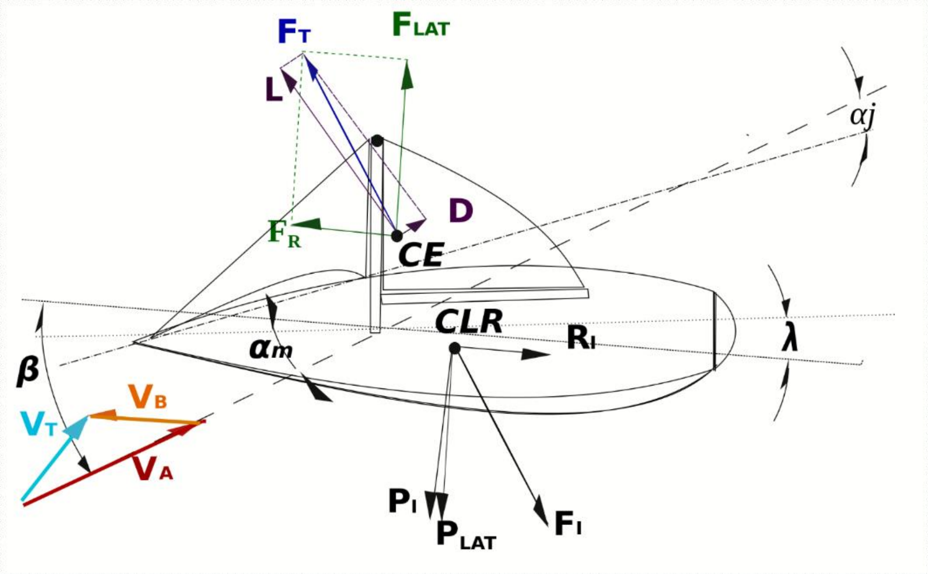


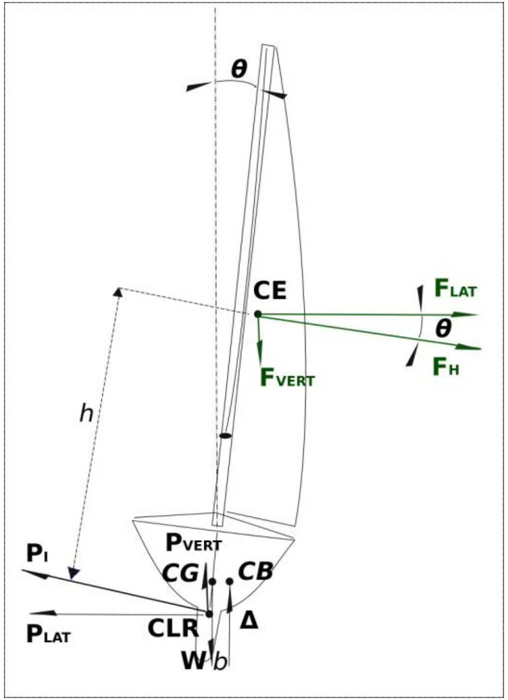
Reference without wind propulsion

- Calm water
- Resistance – a force as function of speed
- (Propeller) propulsion – function of propeller rotation rate
- ➢ All of that only in **longitudinal direction, wind normally discarded**

What changes with wind propulsion?

What changes?

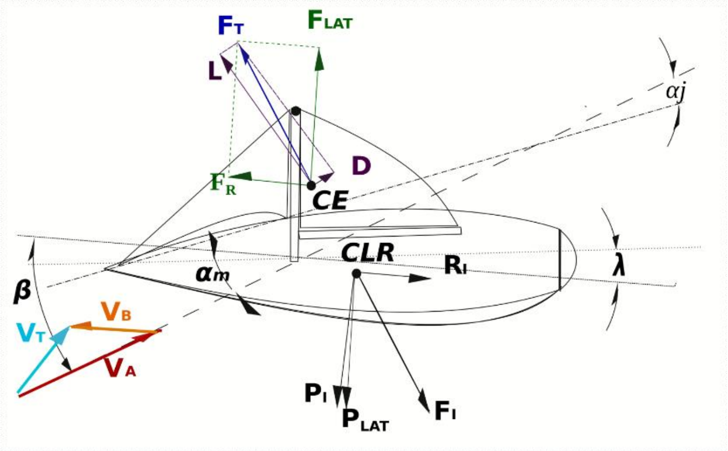


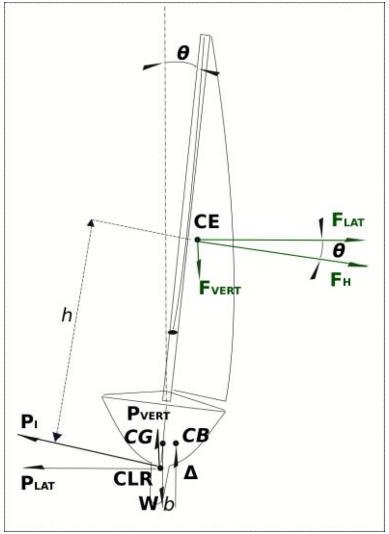


Source: [Bcebul] / Wikipedia

What changes?

- Aerodynamic thrust -> Savings on fuel consumptions & emissions
- Side force - > Leeway
- Rolling moment -> Heel
- Yawing moment -> Non-zero rudder angle
- Aerodynamic thrust -> Lower loading on propeller and engine

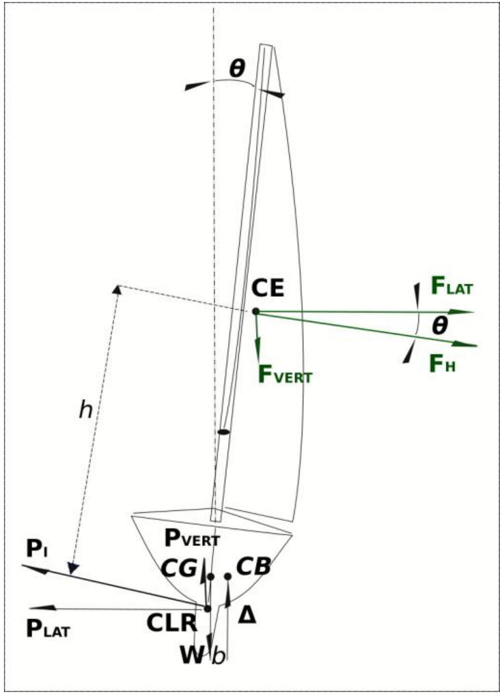




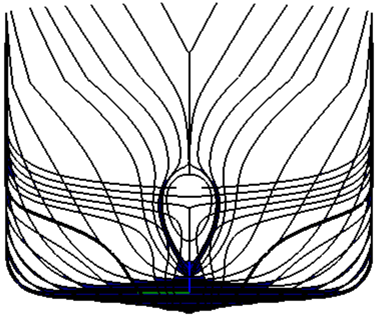
Heel

How much heel?

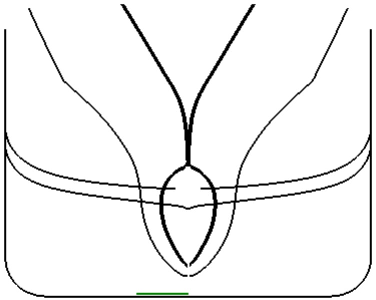
What is acceptable? No common reference yet. But published maxima vary between 5 to 10 degrees.



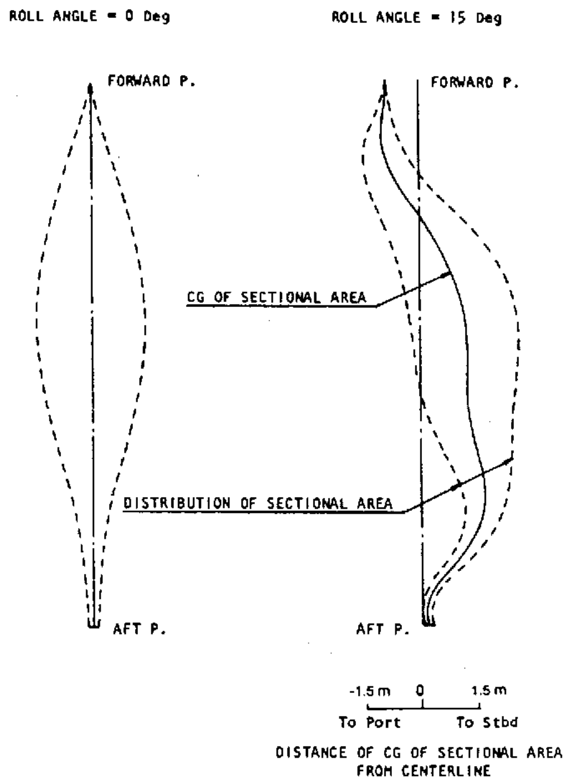
Heel

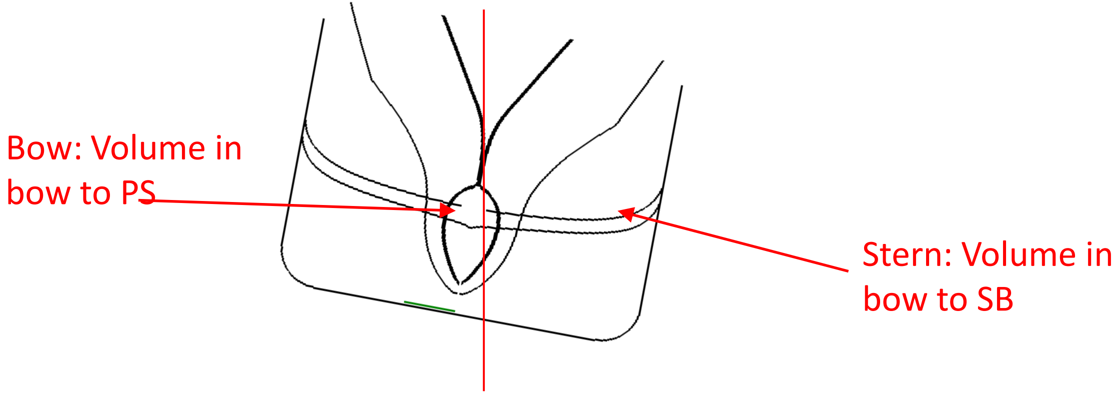


KCS reference hull



Heel

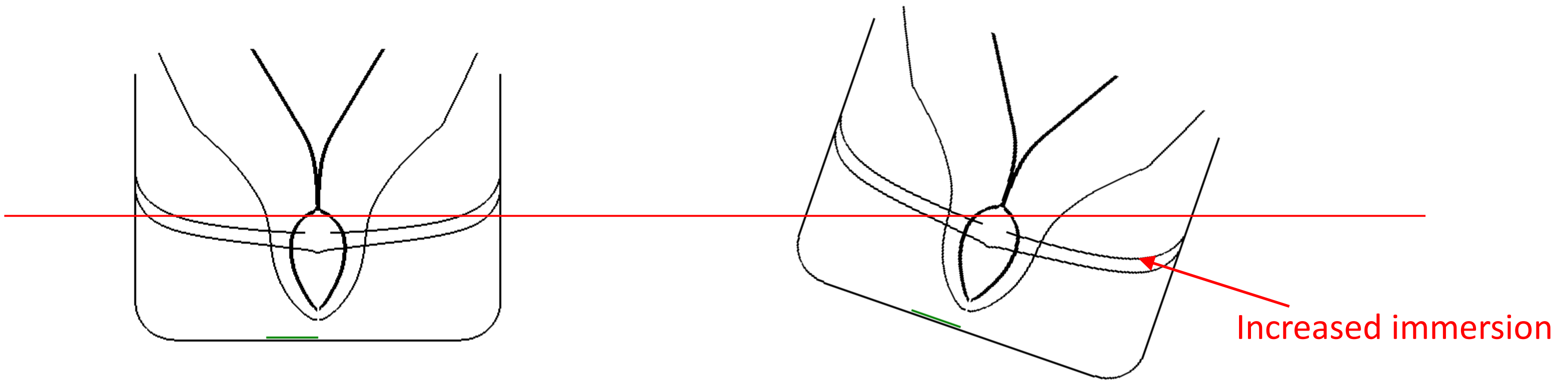




- Underwater shape becomes asymmetric
  - Angle of attack introduced
  - Resulting side force and yaw moment

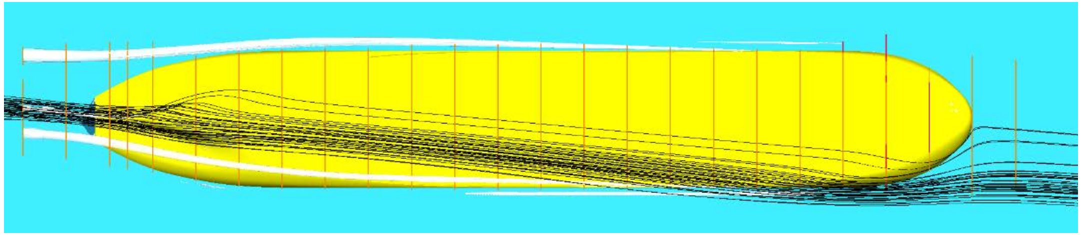
Heel

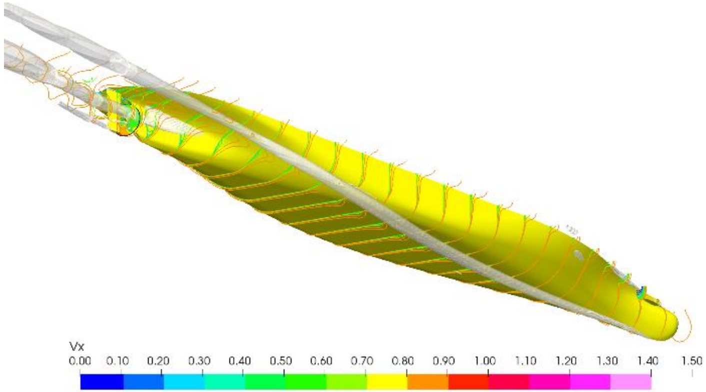
- Change of wetted surface
  - Change in drag
- Transom may locally immerse (more)
  - Increased drag



Leeway

- Change in flow, pressures, waves; starboard and port side different
- Generates required side force
- But comes with consequences
    - Increased resistance
    - Changed flow (and vortices) through propeller



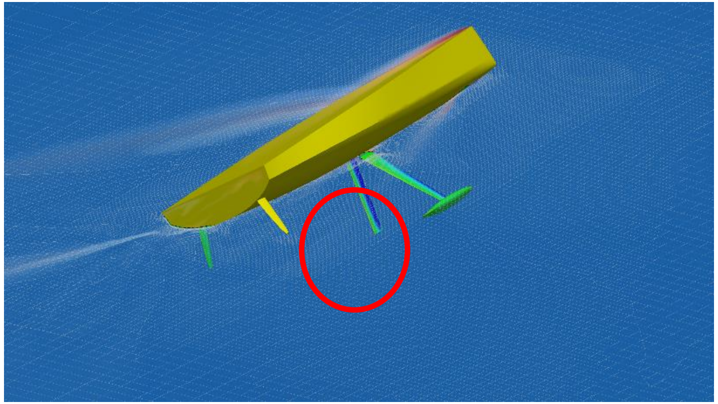


J. J. A. Schot and R. Eggers, "The Effect of Leeway Angle on the Propeller Performance," London, United Kingdom, 2019.

Yaw balance

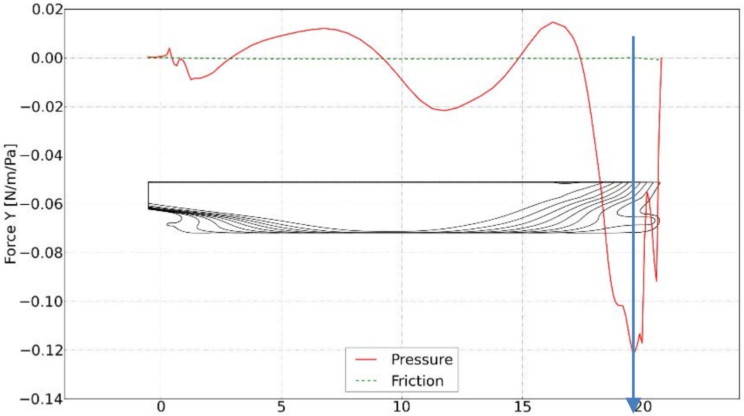
- Side force on vessel without keel or *boards applies far forward !

Yacht: Keel carries majority of side force close to mid ship



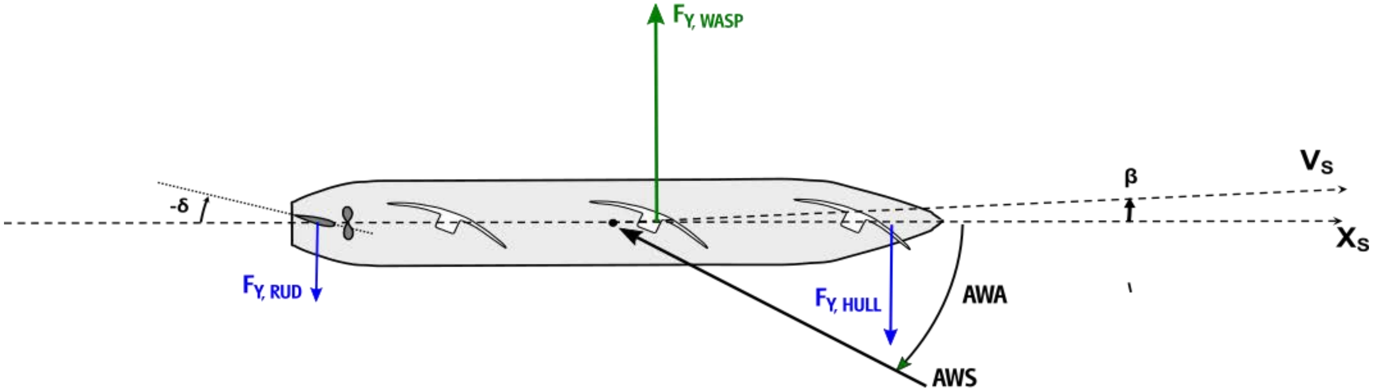
R. Eggers, "Prediction Methods for Team Akzonobel in the Volvo Ocean Race and Wind Assisted Ship Propulsion for Merchant Vessels," 2018.

Merchant vessel: Majority of side force close to bow



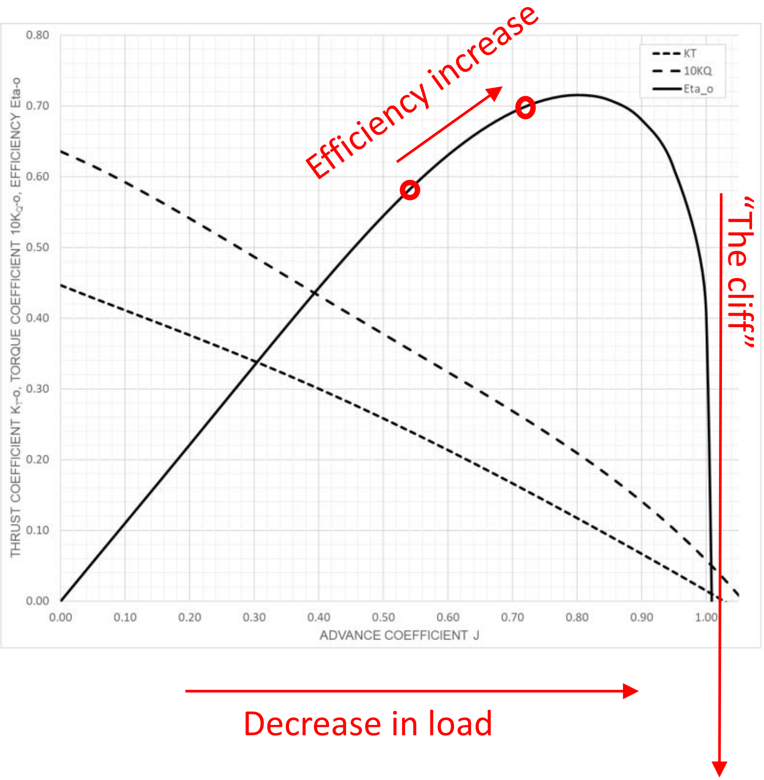
Yaw balance

- A rudder angle is generally required
- Rudder can easily be overloaded (excessive drag)
- Demanding for vessels without additional appendages



Propeller load

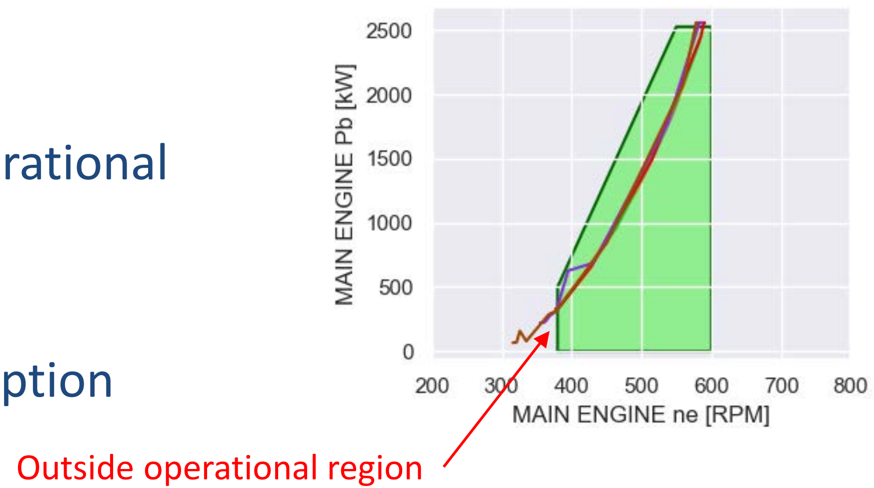
- Propeller is *generally* overloaded from efficiency perspective
- Wind propulsion can improve effiency by reducing load
- But don’t fall of “the cliff”!
  - Windmilling/retract/feather
  - Power generation (with



Engine load

- When using a (single) combustion engine:
  - On edges of common operational conditions
  - Wear and tear
  - Poor **specific** fuel consumption (g/kWh)

WiSP Joint Industry Project



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BETTER SHIPS, BLUE OCEANS

How to design (and operate)?

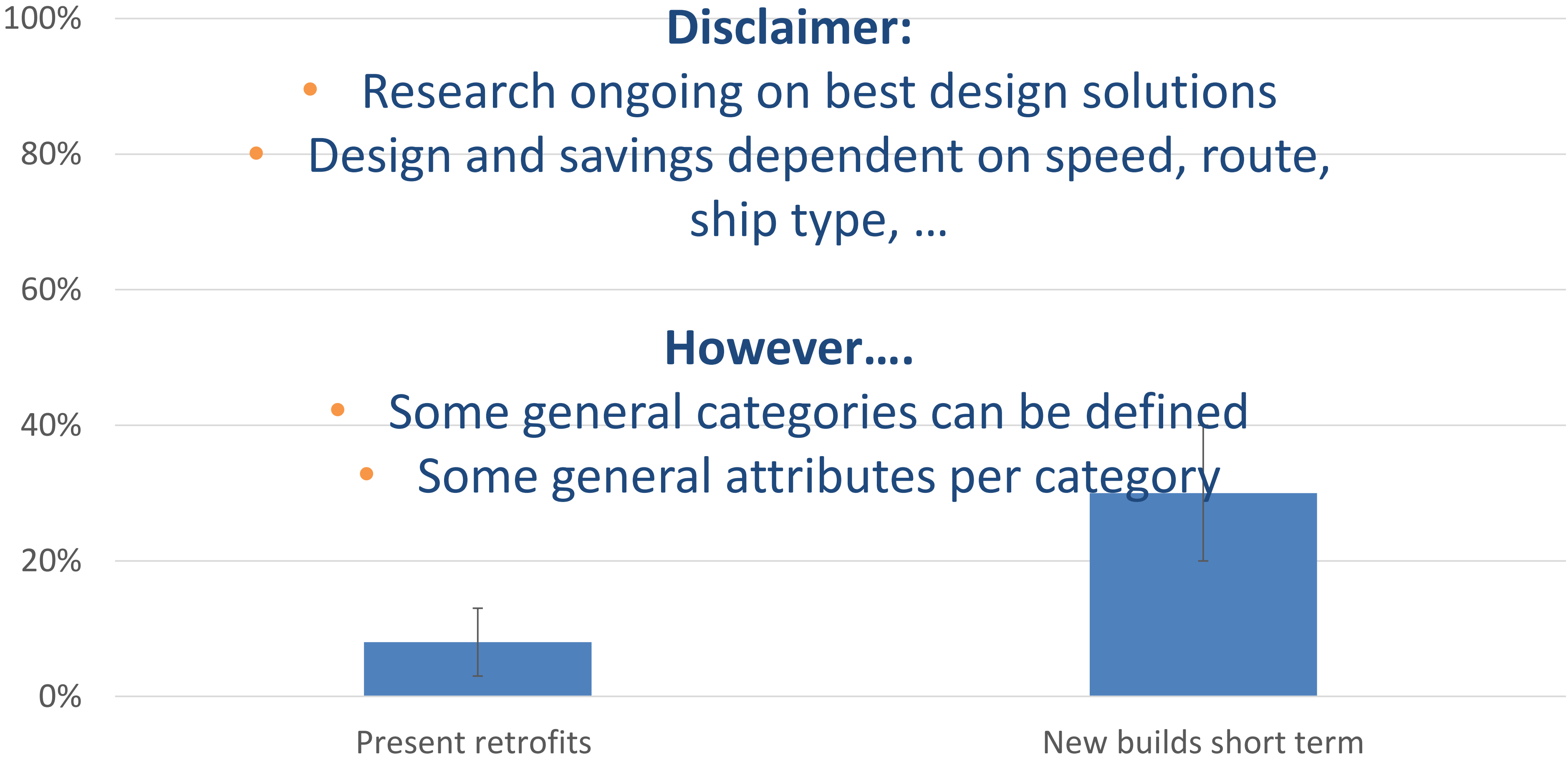
Design

Disclaimer:

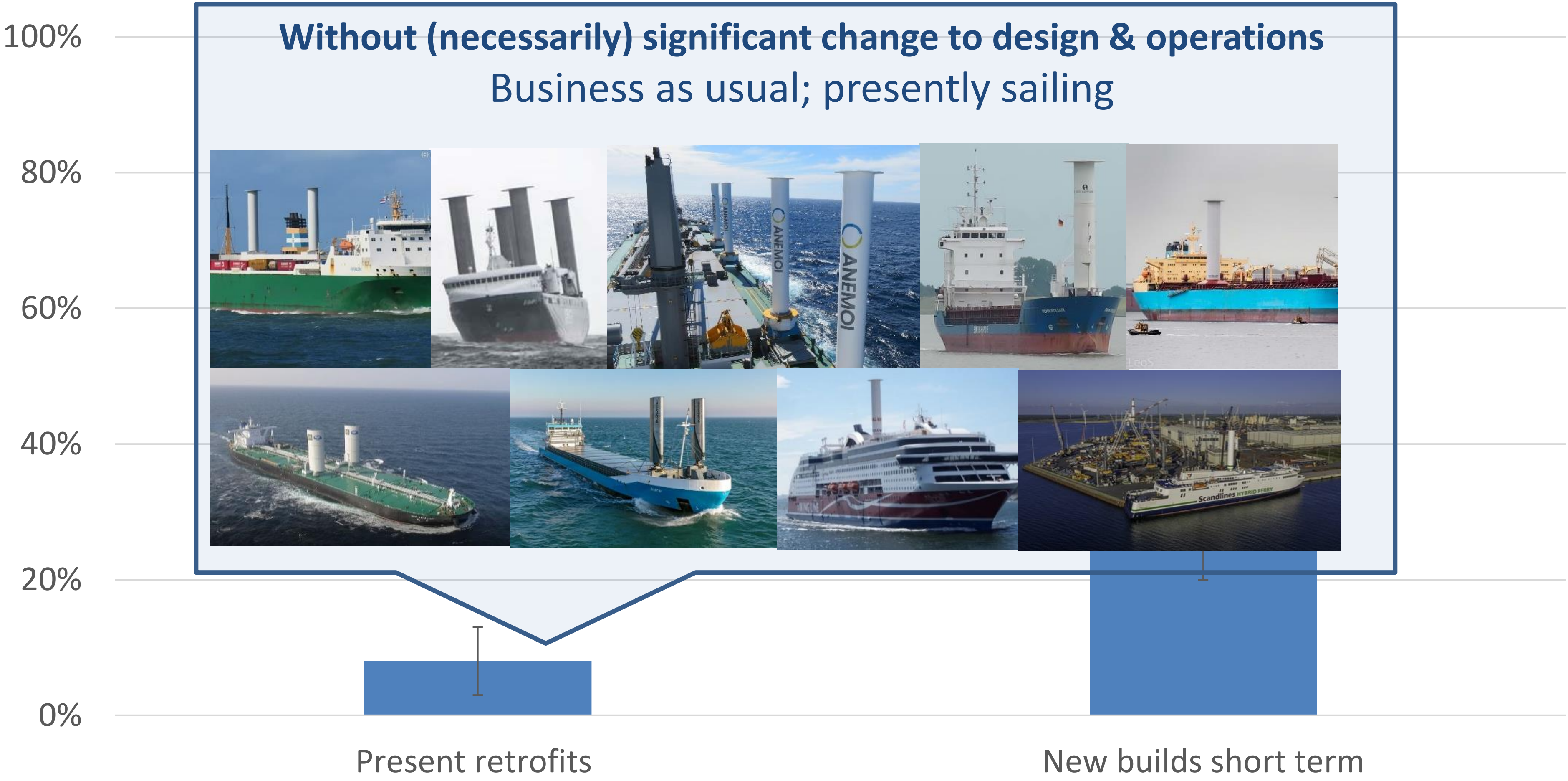
- Research ongoing on best design solutions
- Design and savings dependent on speed, route, ship type, …

However….

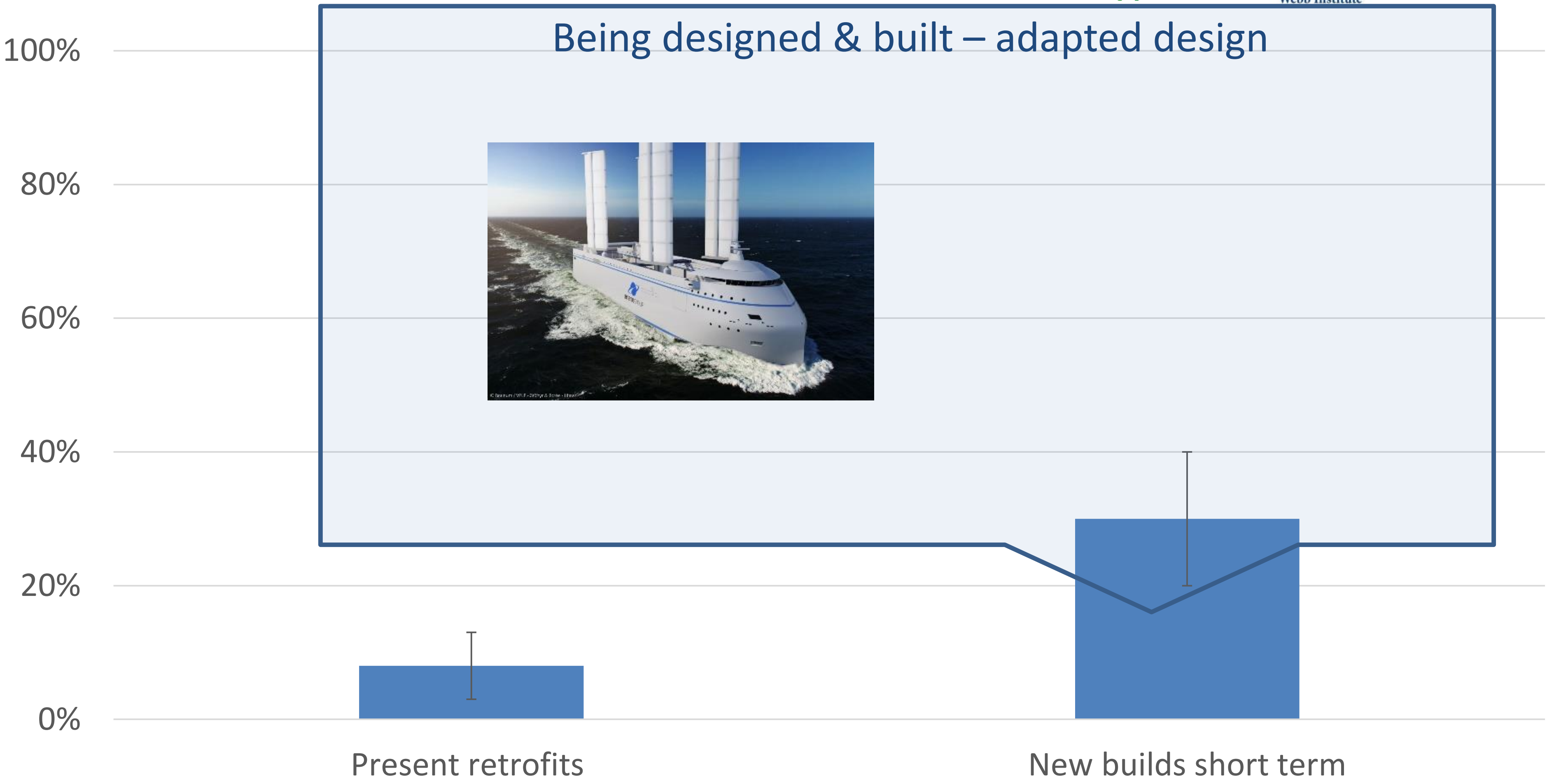
- Some general categories can be defined
- Some general attributes per category



Design – retrofits / business as usual

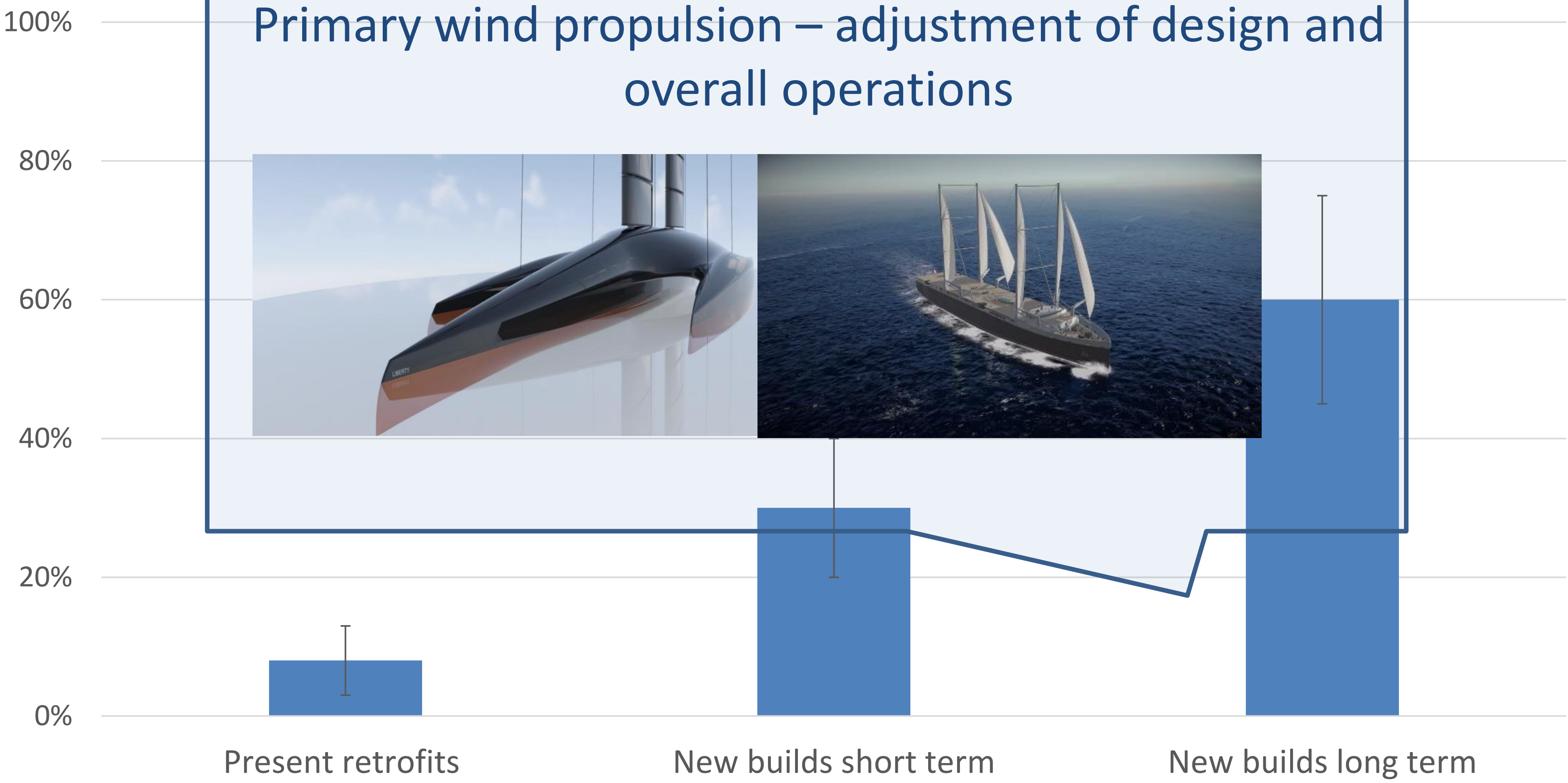


Design – new builds short term



Design – new builds long term

Primary wind propulsion – adjustment of design and overall operations



Aerodynamics - Design

- Select suitable type of wind propulsor !
- Clear area on deck with substantial separation between wind propulsors and superstructures
- New frontier: flow optimisation for drag reduction and good inflow
  - Adjusted deck edges, coamings
  - Fairing / end plates

Aerodynamics - Operation

- Local wind conditions at each wind propulsors not trivial !
- May specifically affect wind propulsors with a stall angle
- Dedicated measurements and/or ship specific corrections can help
- Direct force measurement can also help (but not trivial)

Hull & rudder

- For better ultimate sailing performance:
  - Aim for best lift-to-drag ratio
  - Bring the hydrodynamics side force aft (to reduce the rudder angle)

Hull & rudder

- The toolbox:
  - 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.

Propeller

Propeller characteristics and design to be updated for overall wind assistance profile.

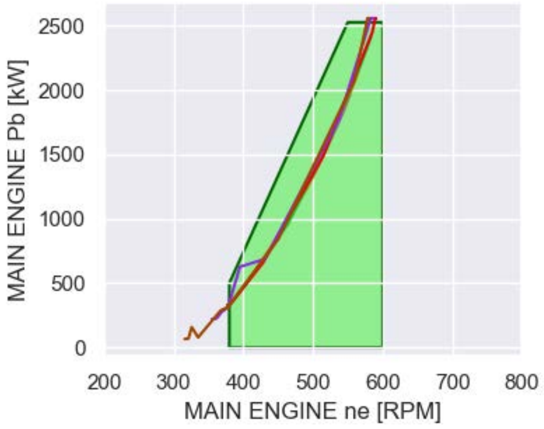
Two strategies when the ship sails only on wind power:

1. Fold, retract or weathervane propeller to reduce drag
2. Keep propeller in place; use propeller as turbine (regeneration)

Development required to optimize and verify performance at the scale of common commercial ships

Power generation - engines

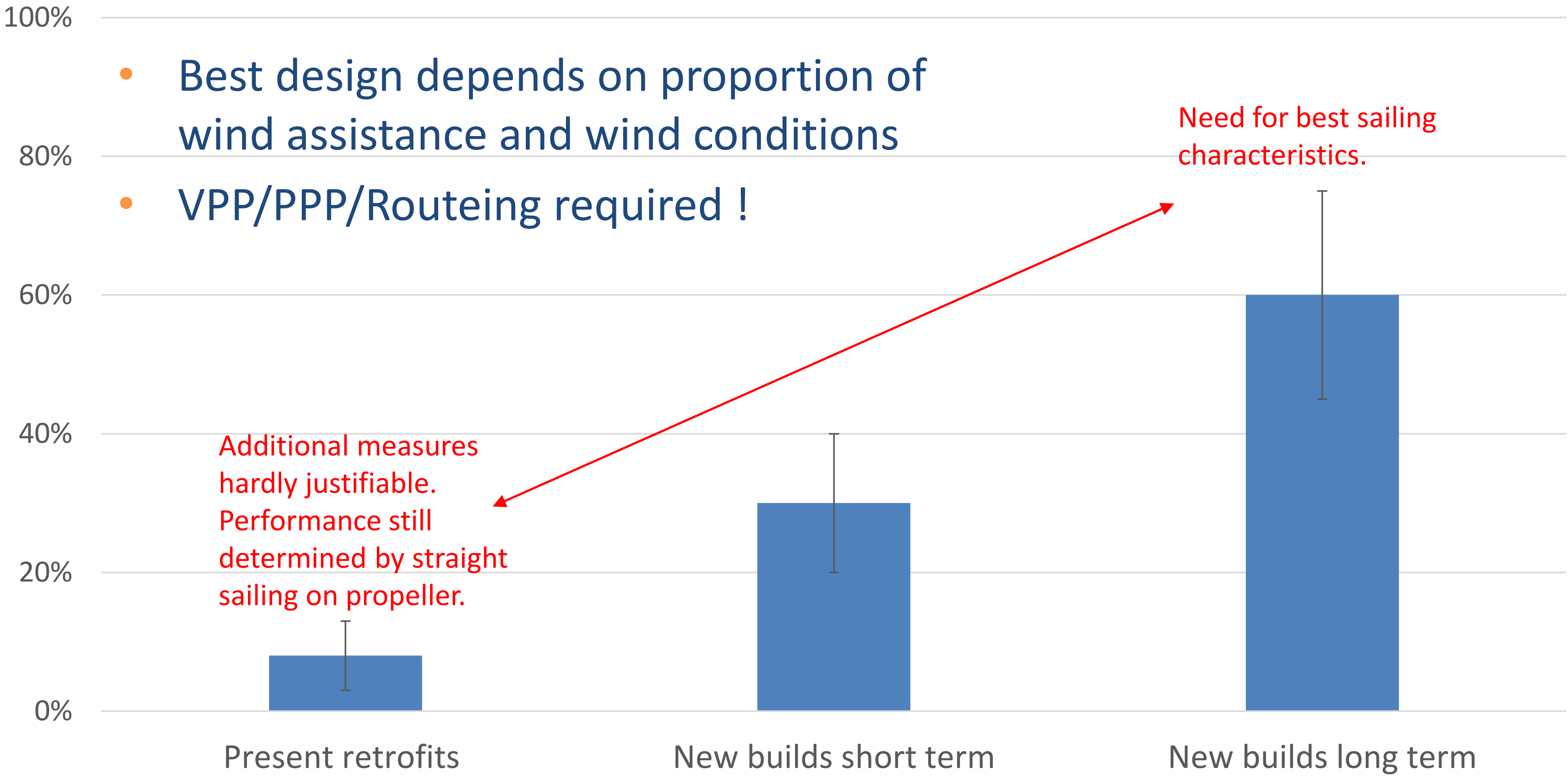
- A single combustion engine is *still* most cost effective (and directly available at scale)
- But larger load variations cannot be handled, so
  - Multiple engines mechanically coupled
  - Generator sets and electric drive
  - Fuel cell
  - ….
  - Hybrids !



- Of course dependent on general ambitions in project ! Diesel still acceptable?

Trade-off

- Best design depends on proportion of wind assistance and wind conditions
- VPP/PPP/Routeing required !



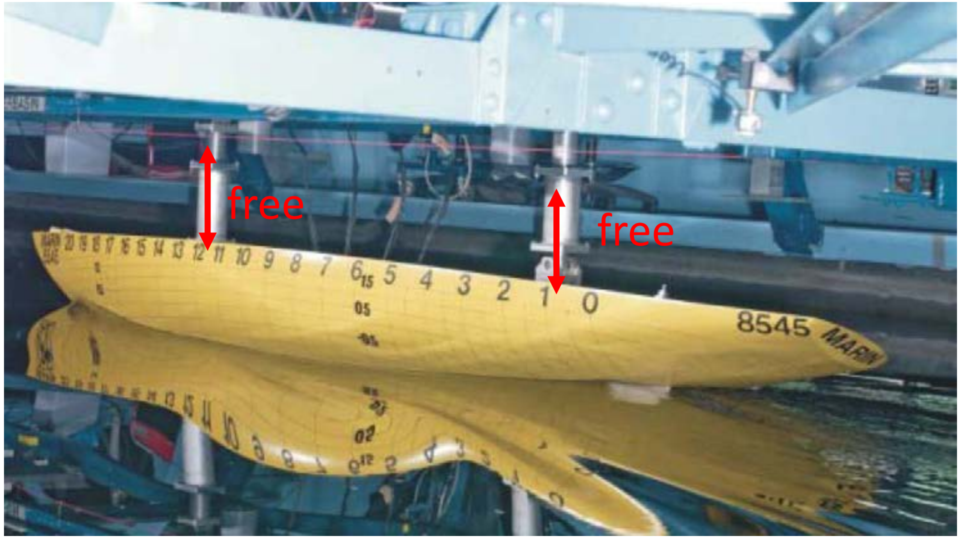
Modeling and measurements

Steps in performance prediction

1. Initial performance prediction (estimates)
2. Derivation of expected equilibrium conditions
3. Predict aero- and hydro forces
4. Refined (final) performance

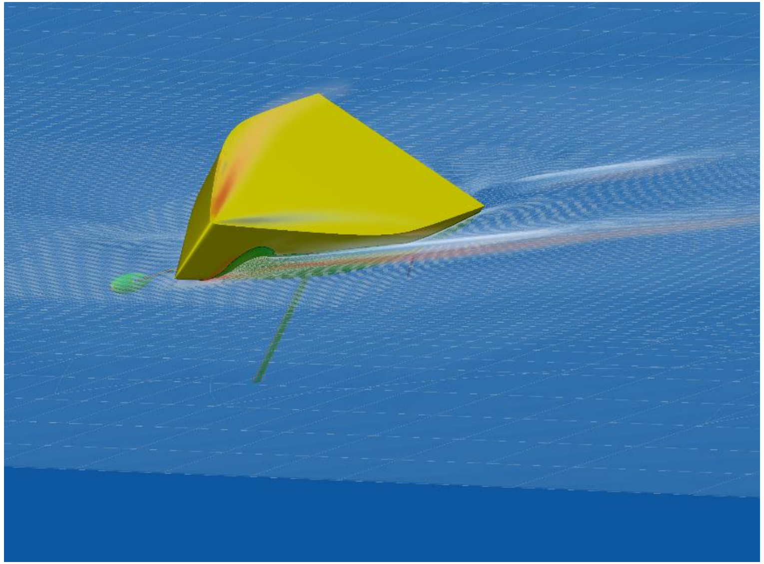
Model tests – a traditional "towing tank"

- Set-up:
  - Fixed in surge, sway roll and yaw
  - Free in heave and pitch
- Tests
  - Speeds
  - Heel angles
  - Leeway angles
  - Rudder angles
- Measured
  - Forces in surge, sway, roll and yaw
  - Forces in rudders, keels, …
  - Heave and pitch
  - Video
  - ….
- "Extrapolation" required for move from "model scale" to "full scale"
- But size of model should not be too small !
- Physics happens "automatically"



Computational Fluid Dynamics (CFD)

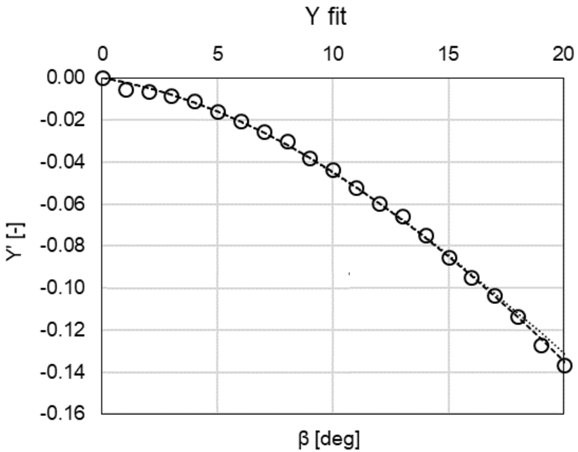
- Same approach as tests!
- However:
  - Directly at “full scale” (no extrapolation)
  - Insight in flow
  - (Start-up) cost lower
  - But, still sensitive to the right assumptions and methods (turbulence modesl, grids, …) to get the physics right!



Numerical model – “fitting”

Performance prediction needs “smooth” curves, for instance:

(Modular) forces in **surge, sway, roll and yaw** (4 outputs)
as function of
speed, leeway, heel, rudder angle (4 inputs)



Example fit of side force (Y)
versus leeway (β)

Composition of performance prediction

Aerodynamic forces

+

Hydrodynamic forces

→ Equilibrium

Force equilibrium:
- Speed
- Leeway (drift)
- Heel
- Rudder angle

- Result of final prediction
- But already required for hydro prediction
- Chicken and egg problem!

Optimize, e.g.
- Flettner rotor rotation rate
- Suction wing ventilation
- Sail trim, reefing
- Propeller pitch
- …

Summary

Wind propulsion is already proven to work and provide substantial savings!

However, to get the most out of it:

- Aerodynamics critical to get right
- Hydrodynamics can be influenced by substantial WASP
- Best design for substantial WASP
    - General trends known
    - Elaboration for specific ships ongoing
- Prediction methods available (but validation & standardisation ongoing)

THANK YOU - ANY QUESTIONS ?

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BETTER SHIPS, BLUE OCEANS

R.EGGERS@MARIN.NL

Maneuvering and Seakeeping with wind propulsion

Rogier Eggers (MARIN)

Natural Propulsion Conference, Webb, 16-11-2021

Outline

- Criteria
- Predictions & results

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Maneuvering & Seakeeping criteria

Maneuvering

- For maneuvering there are some quantitative criteria:
- IMO Resolution MSC 137(76)
  - Turning circle test
    - Advance
    - Tactical diameter
  - Zig-zag test
    - 10°/10°
      - Initial turning ability
      - First overshoot angle
      - Second overshoot angle
    - 20°/20°
      - First overshoot angle
  - Crash stop test

Turning ability

Initial turning, yaw checking and course keeping ability

Stopping ability

Maneuvering

Zig-zag test on LCF frigate of Dutch MoD (www.dutchdefencepress.com)

90 m OPV turning circle test (articles.maritimepropulsion.com)

- Required for any ship longer than 100m, or when carrying dangerous goods
- Formally in calm conditions (without wind)
- With wind propulsion, it’s generally interpreted that wind is to be accounted for (important for safe operations)

Seakeeping

- Some binding requirements from IMO (e.g. on stability)
- However, nothing relating to behaviour in operational conditions

- Some projects/ships have their own criteria
- Anyway, the following is generally important for operations:

Added resistance

Course/track keeping

Motions

Comfort/sickness

Slamming

Propulsion

“Green” water on deck

(Structural) loads

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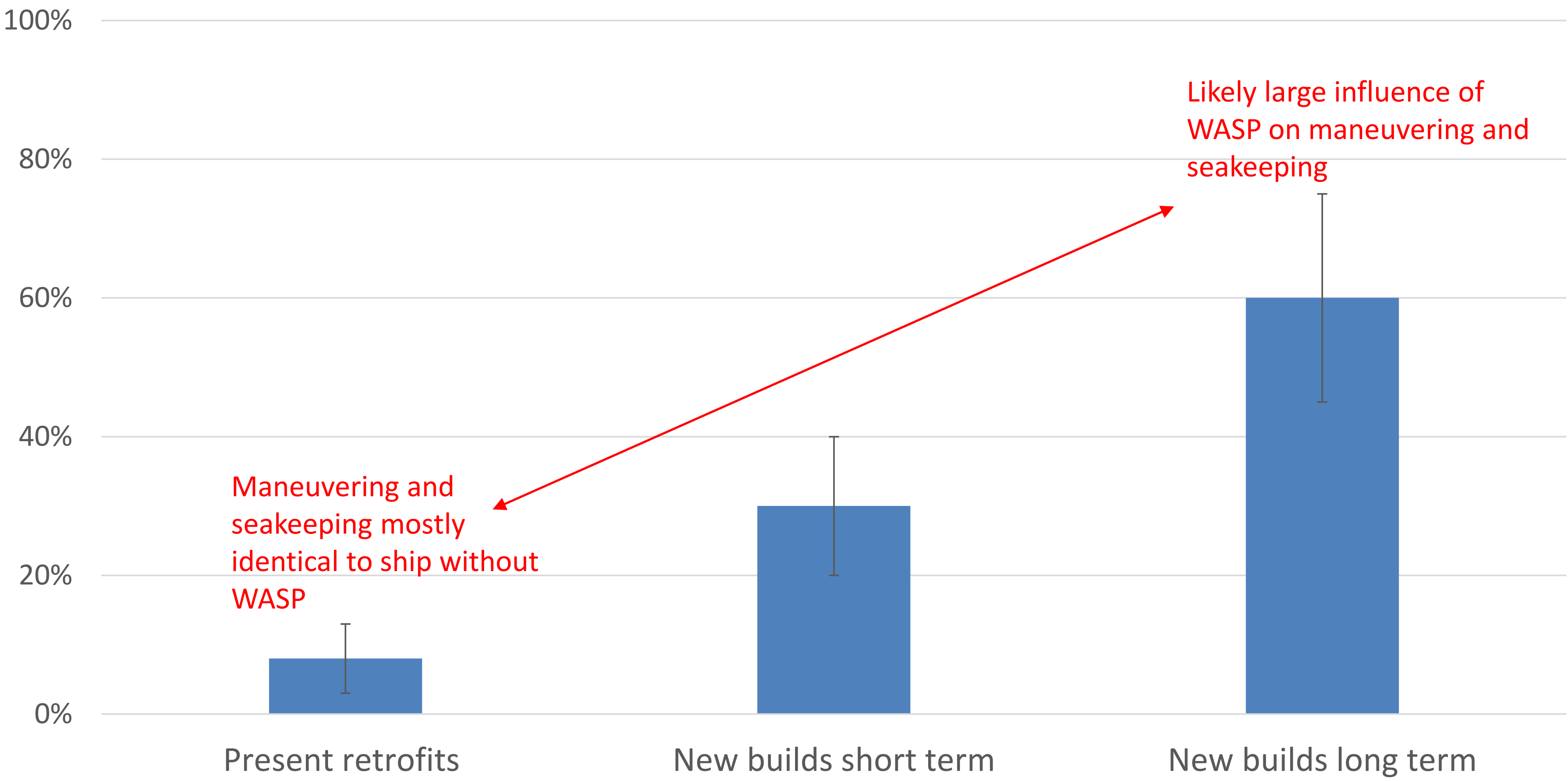
Predictions (calculations & model tests) and results

Relevance



100%
80%
60%
40%
20%
0%
Likely large influence of WASP on maneuvering and seakeeping
Maneuvering and seakeeping mostly identical to ship without WASP
Present retrofits
New builds short term
New builds long term

How to model?

- **Simulations** combining aerodynamic and hydrodynamic forces
  - Hydrodynamic model tests/calculations with forced motions
  - Aerodynamic wind tunnel tests/calculations with forced motions
  - Simulations to merge all modelling
- **Tests** combining hydro and aero
  - Applying motions in a wind tunnel
  - Applying pre determined aerodynamic forces in a hydrodynamic model test:
    - Fans
    - Winches

How to model?

- **Simulations** combining aerodynamic and hydrodynamic forces
  - Hydrodynamic mo
  - Aerodynamic wind
  - Simulations to me
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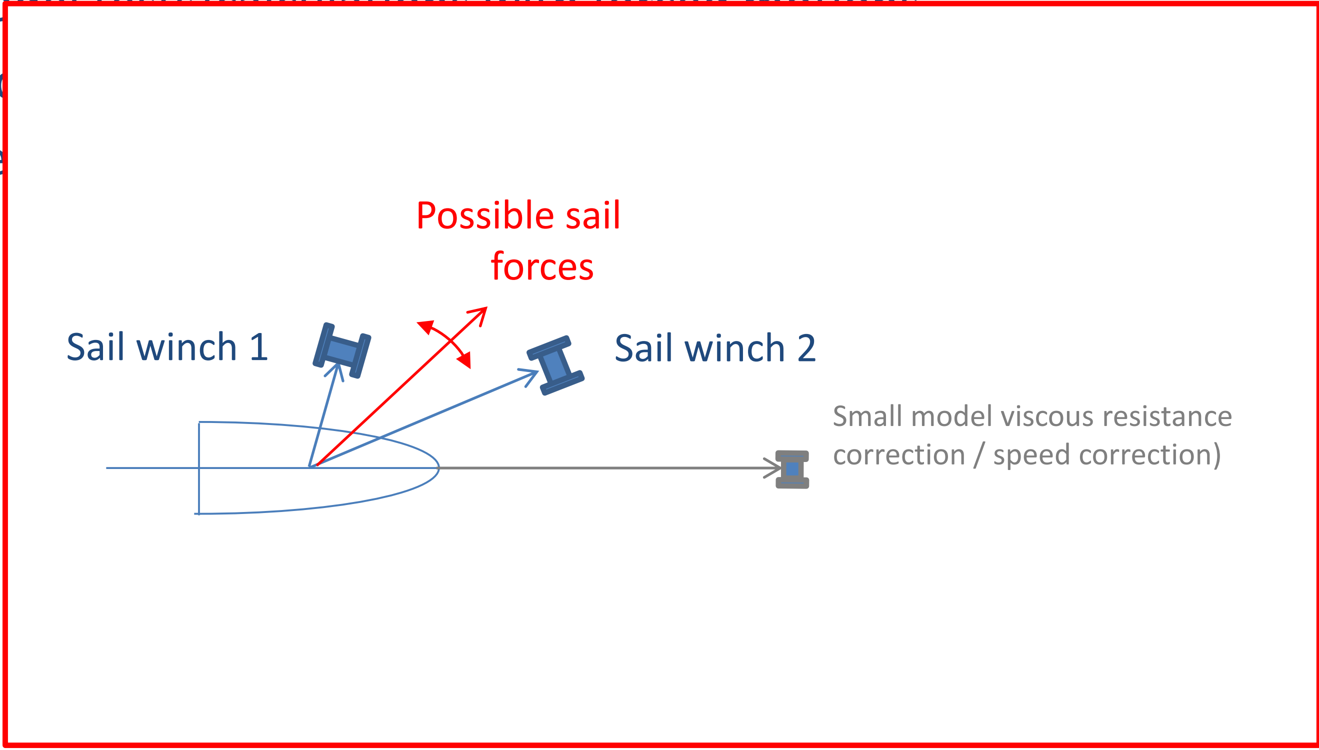

How to model?

- **Simulations** combining aerodynamic and hydrodynamic forces
  - Hydrodynamic model tests/calculations with forced motions
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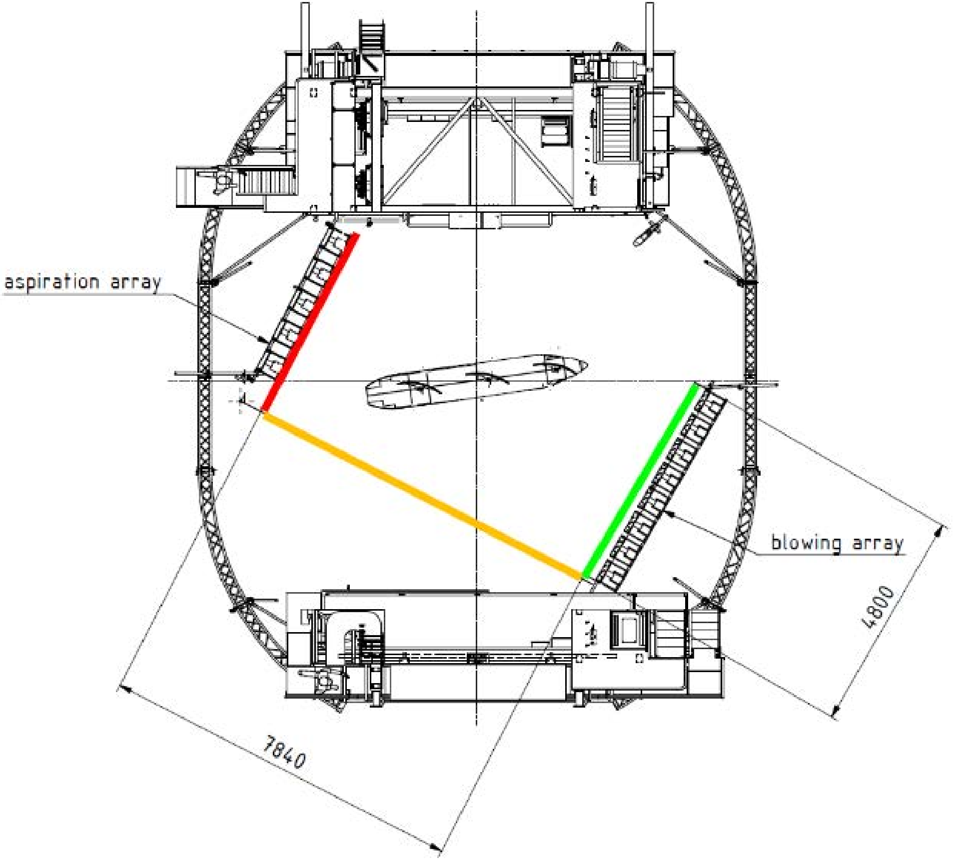
  - Simulations to merge all modelling
- **Tests** combining hydro and aero
  - Applying motions in a wind tunnel
  - Applying pre determined aerodynamic forces in a hydrodynamic model test:
    - Fans
    - Winches
  - **Letting both hydro- and aerodynamics work by itself**

"WindLab" Project

- Aero- and hydrodynamics modelled at the same time in one test-setup
- Experimental research!
- Limitations in wind quality
- Ship speed changes effect not modelled correctly (yet)
- Calculations performed in parallel
- Some first indications of manoeuvring and seakeeping with WASP

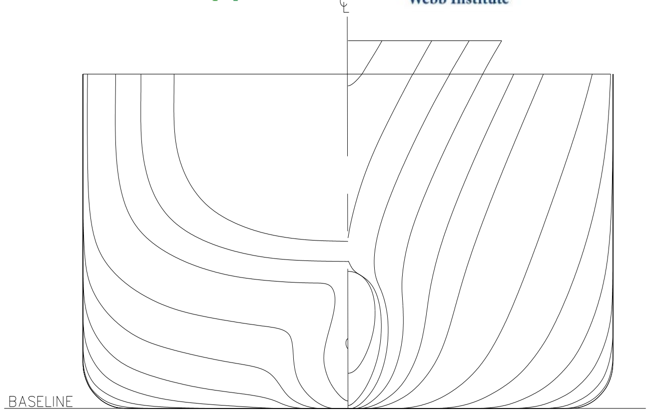
R. Eggers and A. S. Kisjes, "Seakeeping and Manoeuvring for Wind Assisted Ships," London, United Kingdom, 2019-10.

Test set-up



“MARIN Hybrid Transition Coaster”

Length between perpendiculars	L_{PP}	68.7	m
Breadth moulded on WL	B	14.0	m
Draught	T	4.4	m
Displacement mass in seawater	Δ	4146.0	t
Transverse metacentric height Dynarigs	GM	0.69	m
Transverse metacentric height Flettner rotors	GM	0.67	m
Block coefficient	C_B	0.76	-

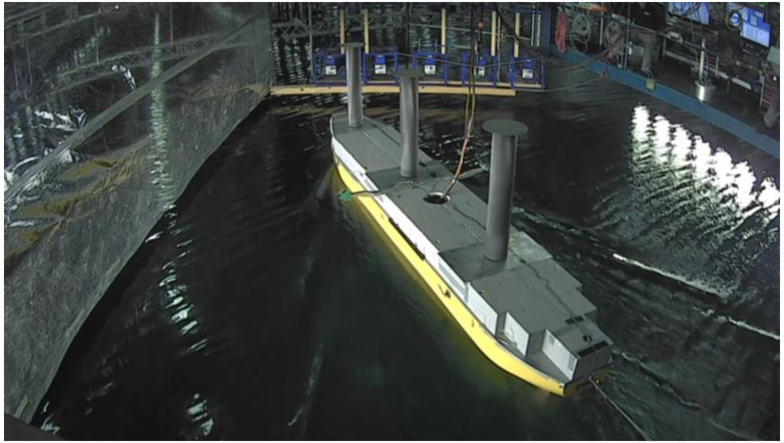


Dynarigs

Span (incl. yards)	s	29.9	m
Average chord	c	16.4	m
Combined projected area	A	1474.5	m^2
Overall air draught from WL	h_{air}	38.4	m

Flettner rotors

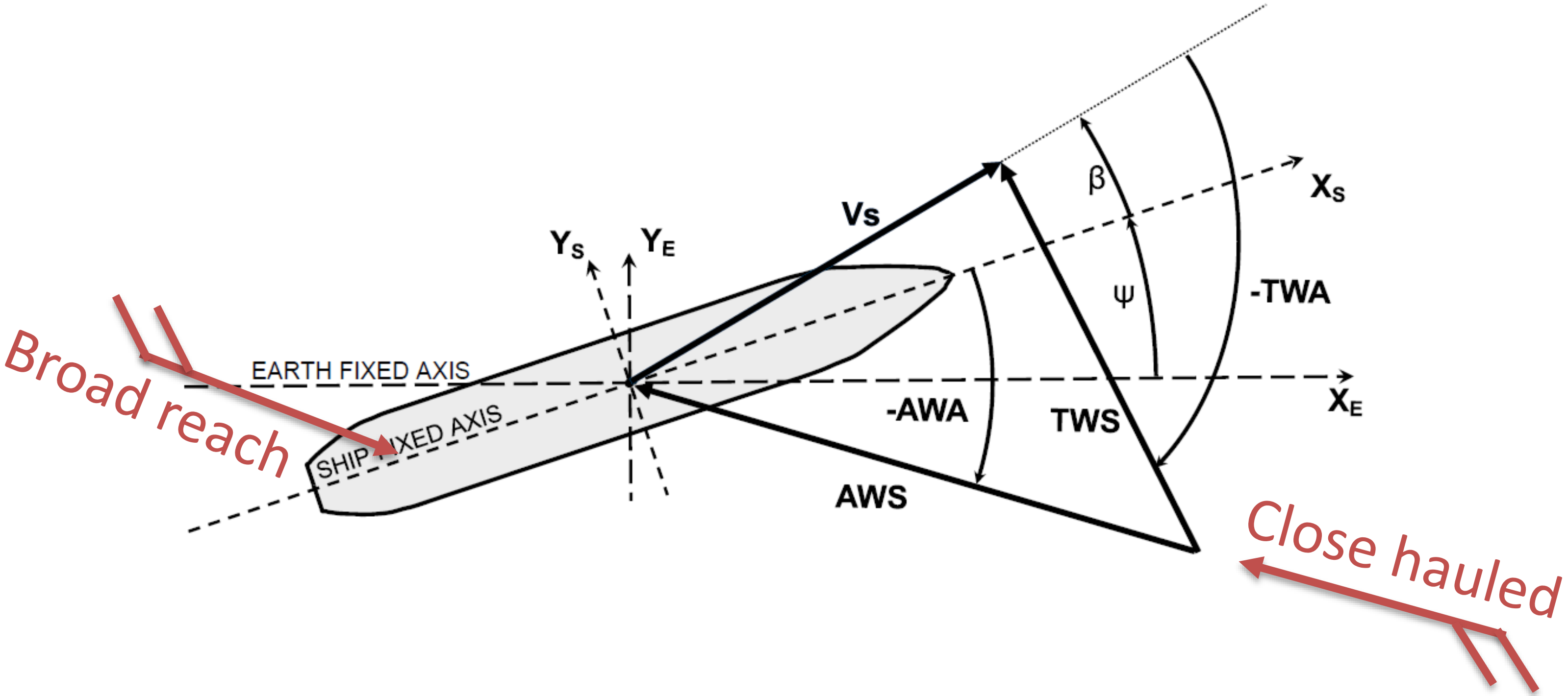
Height	**h**	**18.0**	**m**
Diameter cylinder (disk)	d	3.0 (6.0)	m
Combined projected area	A	162.0	m^2
Overall air draught from WL	h_{air}	25.56	m



Test program

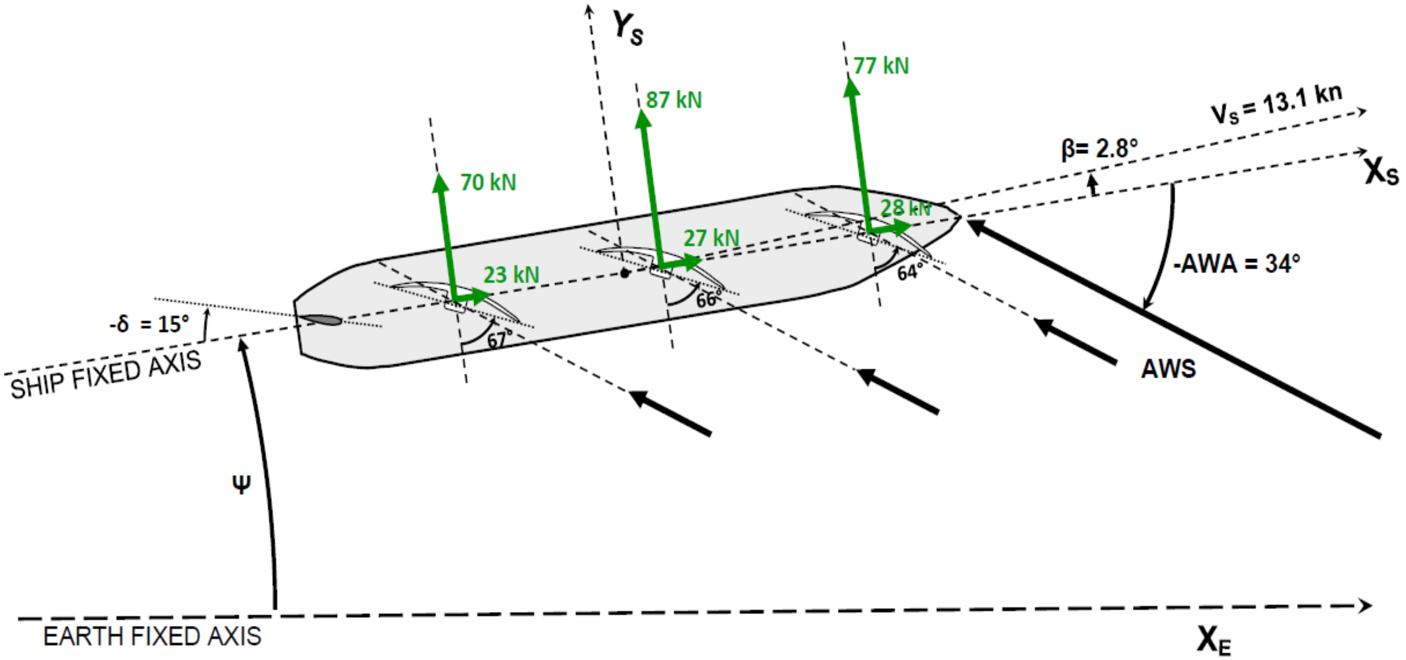
- Tests with Dynarigs in close hauled (bow quartering) wind conditions:
  - Speed runs and roll decay tests
  - Zig-zag tests
  - Seakeeping tests in regular and irregular bow quartering waves
- Tests with Flettner rotors in broad reach (stern quartering) wind conditions:
  - Speed runs and roll decay tests
  - Zig-zag and crash-stop tests
  - Seakeeping tests in regular and irregular stern quartering waves

Definitions (& wind conditions)



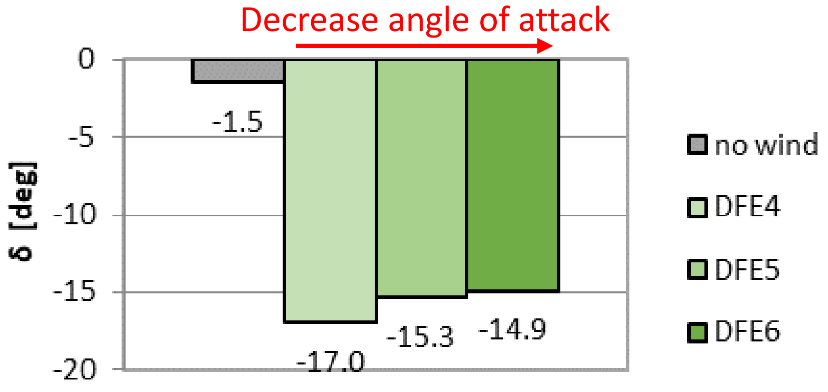
Sailing

Equilibrium condition Dynarigs

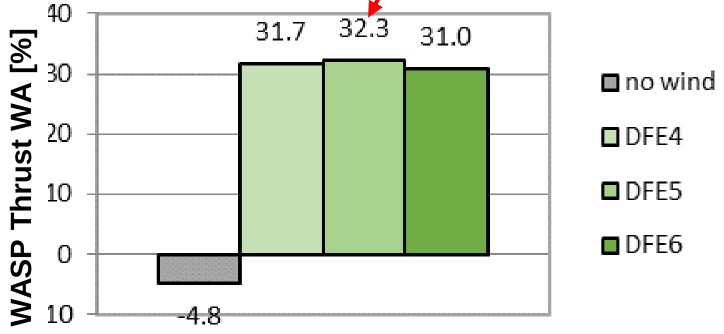


Sailing equilibrium

- Large rudder angles!

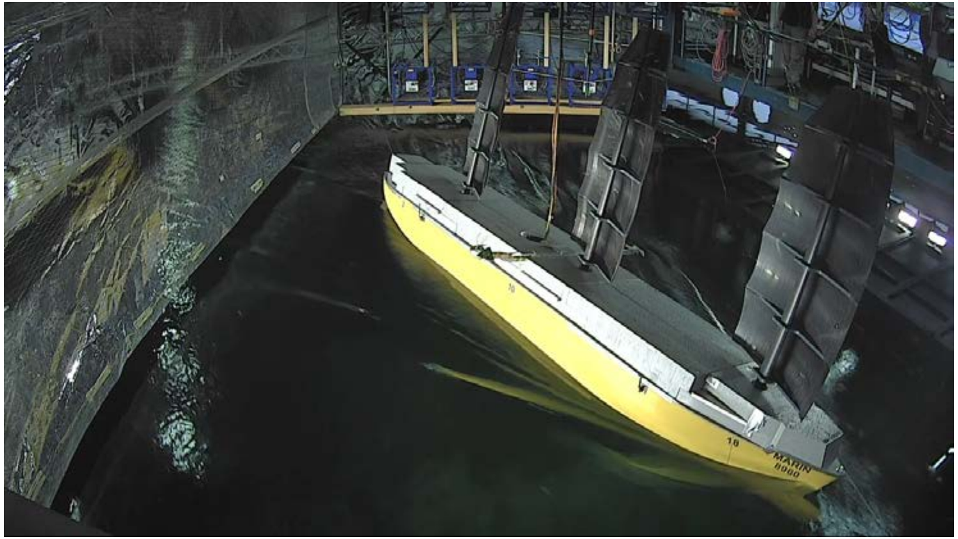


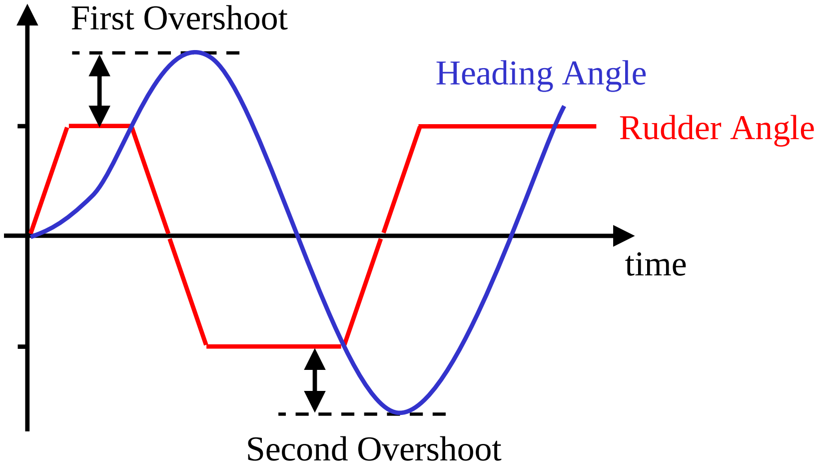
Best performance



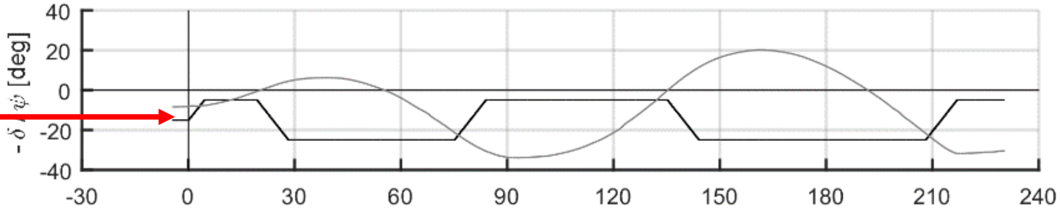
$$WA = \left(\frac{F_{X,sail,tot}}{F_{X,sail,tot} + T} \right) \cdot 100\%$$

Zig-zag tests Dynarig



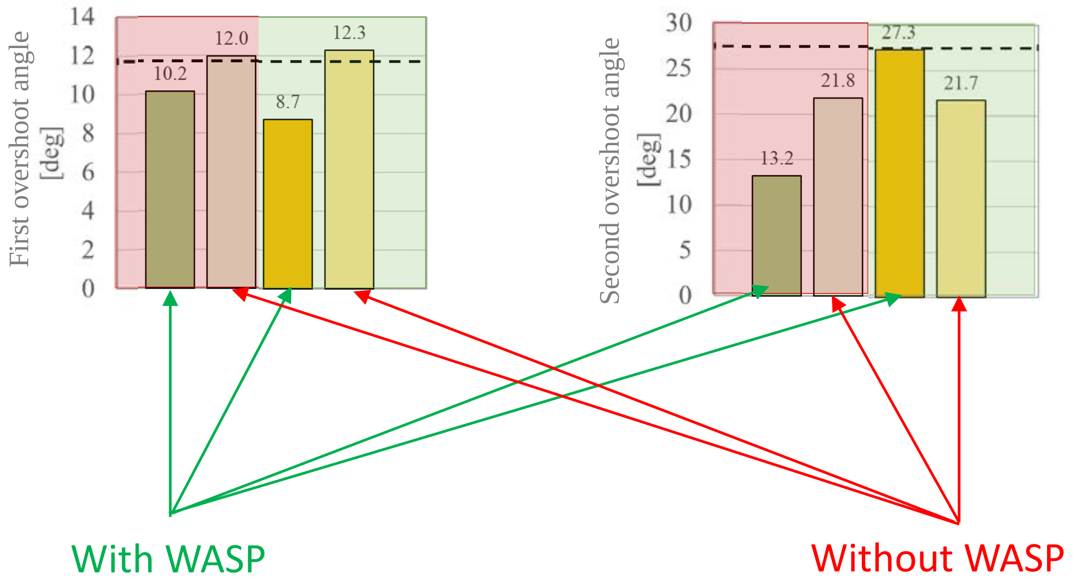


Started with non-zero rudder and leeway/yaw angle

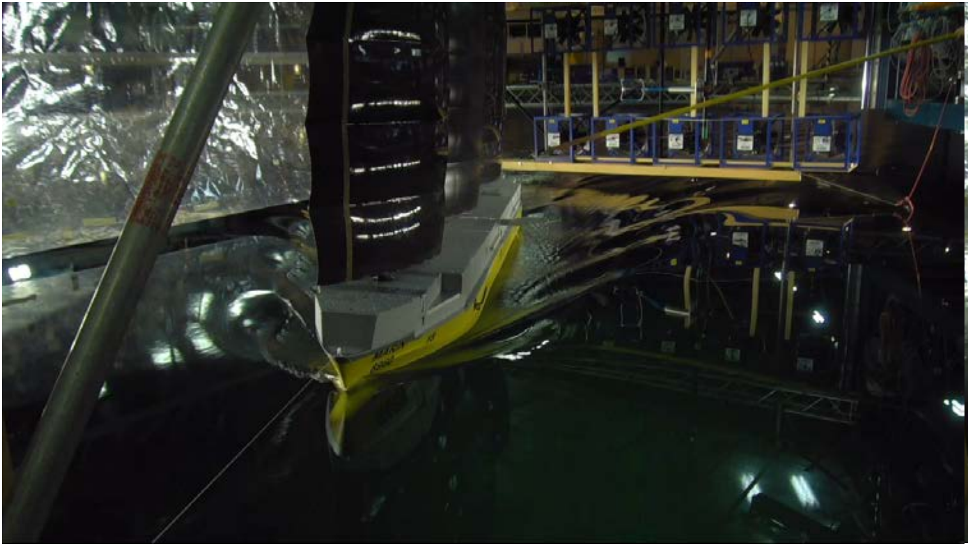
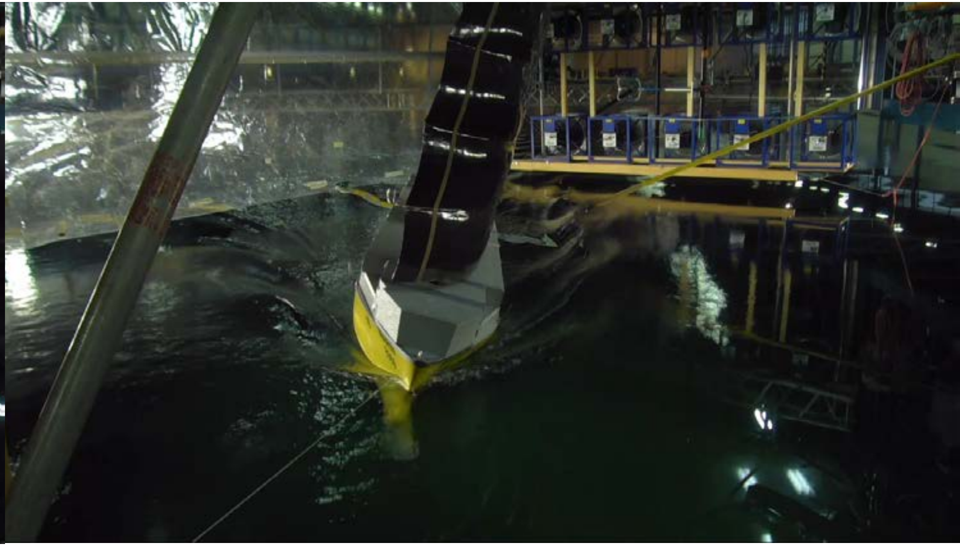


Zig-zag calculations Dynarig

- WASP significantly affects first and second overshoot
- *Generally* it seems to improve for Dynarigs upwind

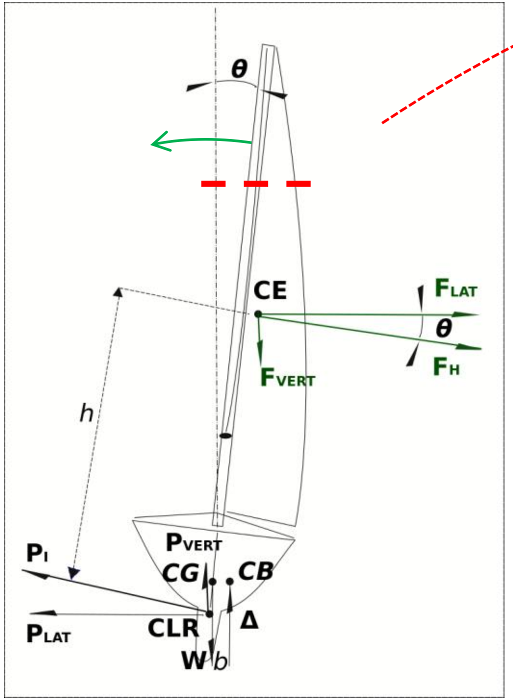


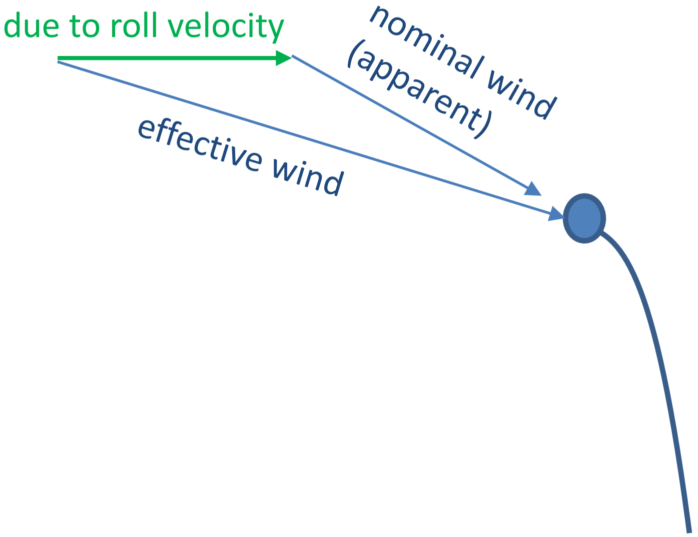
Roll decay tests Dynarig

Without wind	With wind
	

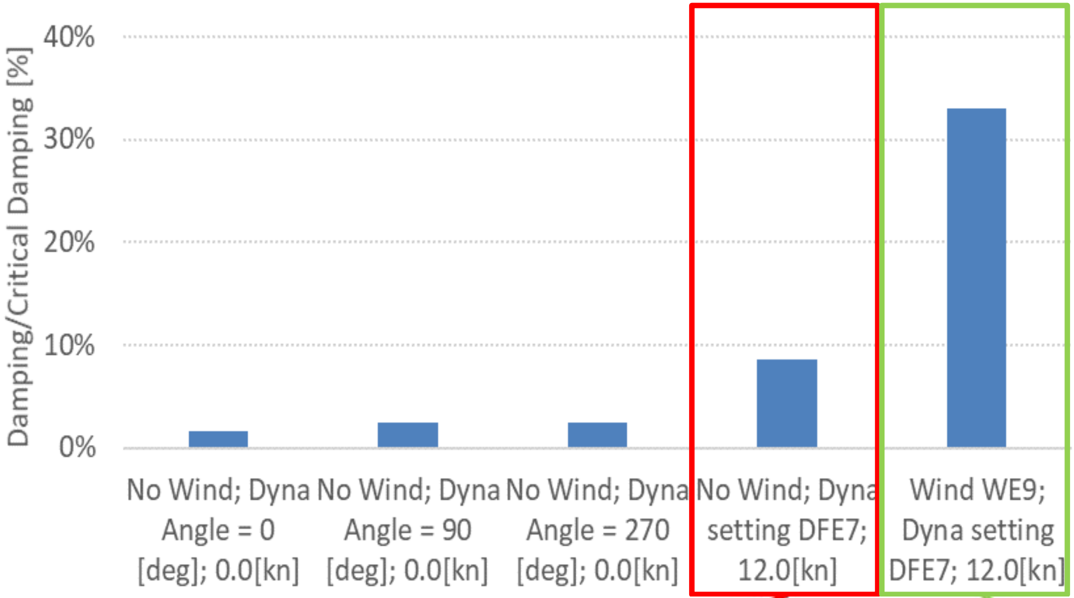
Roll damping with sails – what happens?

- Rolling to windward introduces a larger angle of attack on the sails
- Rolling to leeward introduces a lower (negative) angle of attack on the sails
- Both provide roll damping

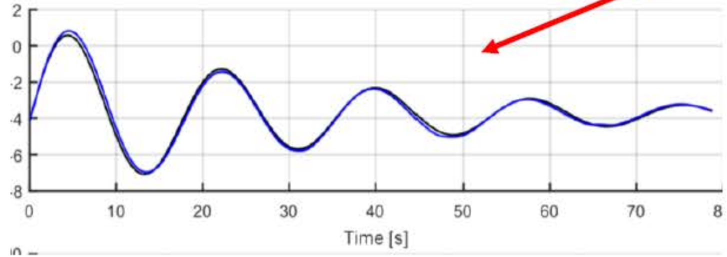




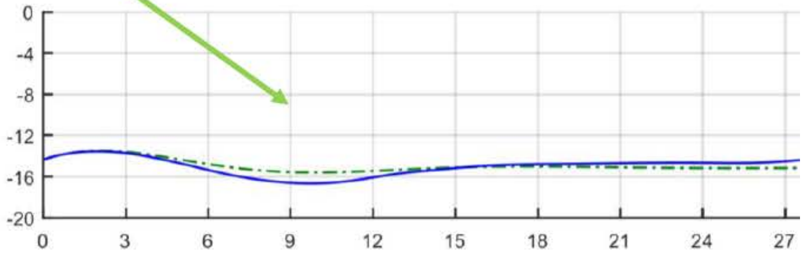
Roll damping Dynarigs



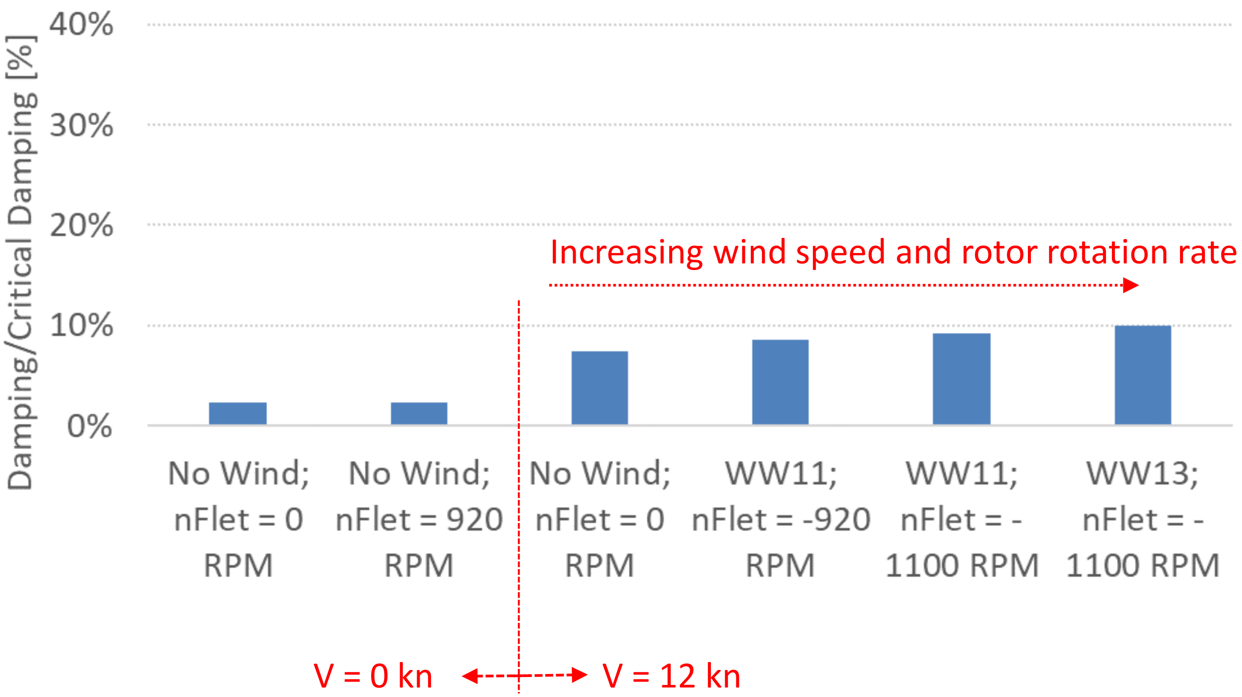
Without wind



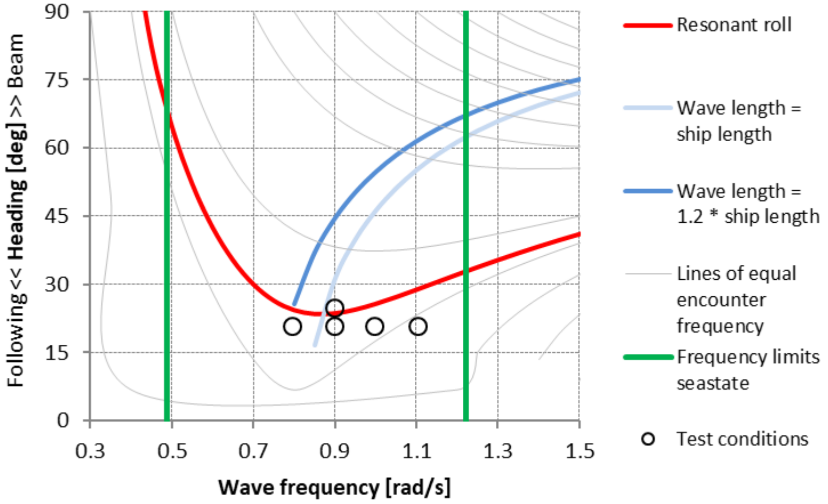
With wind

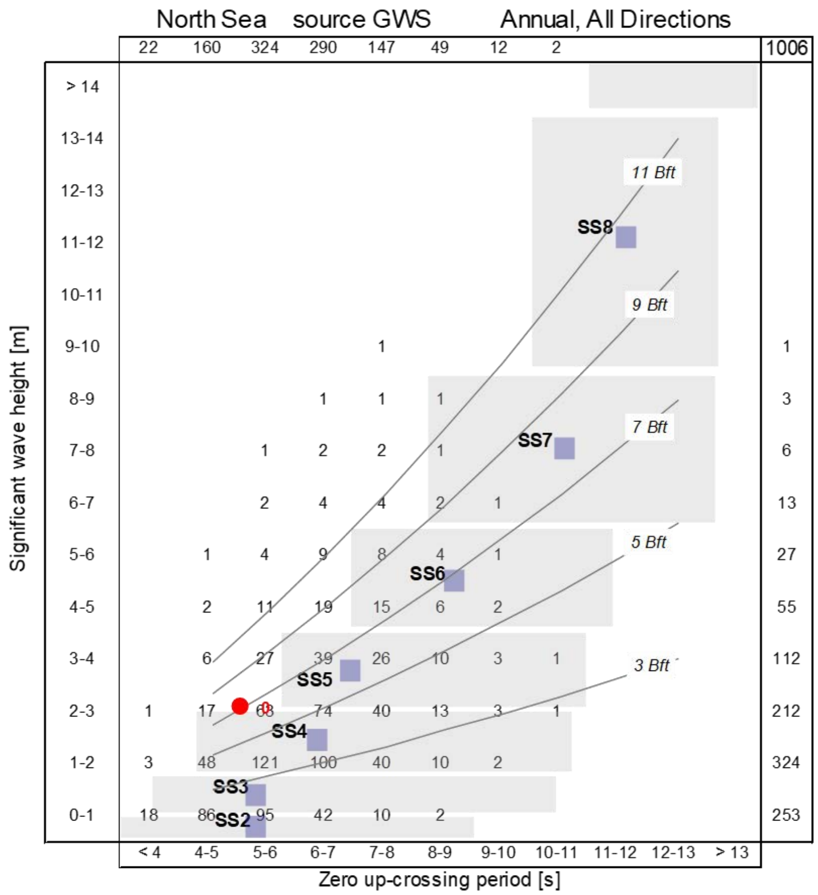


Roll damping Flettner rotors



Seakeeping tests Flettner rotors

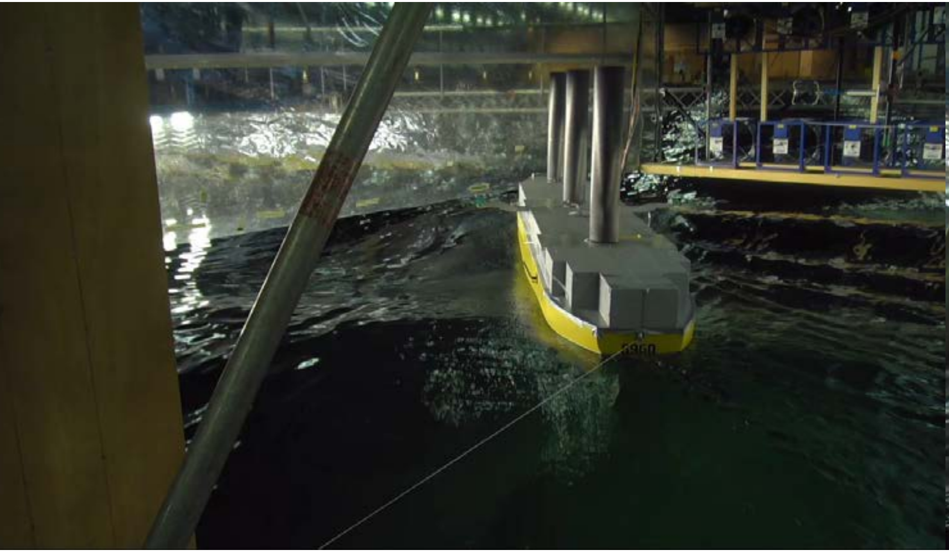




Seakeeping tests Flettner rotors

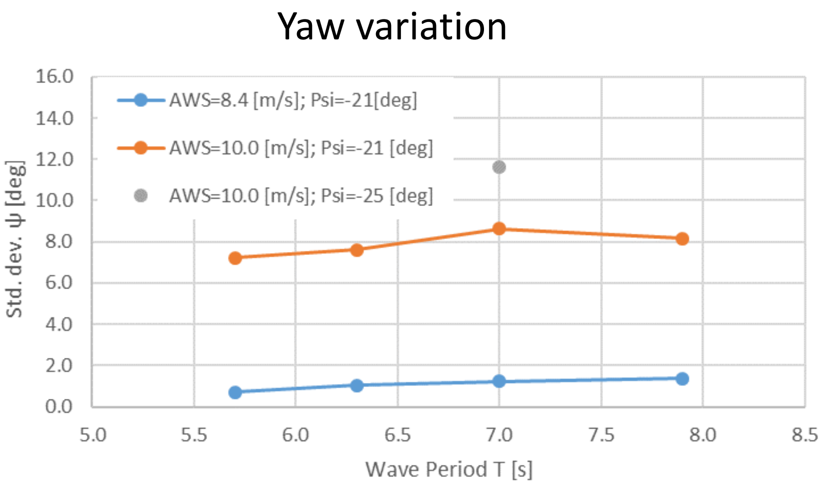
Low wind

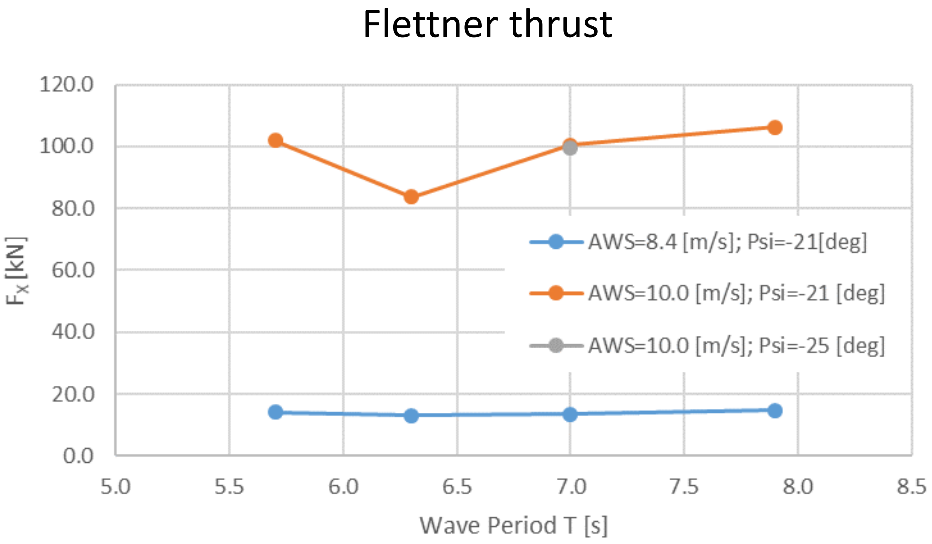
High wind



Seakeeping tests Flettner rotors

- Wind propulsion can substantially reduce the course keeping ability in *demanding* stern quartering wind and waves





What else?

- Stopping tests
- Green water on deck may damage sails
- Dynamic (& fatigue) loads in rigs
- Propeller/rudder ventilation due to heel (twin propeller vessels)
- Which heel is acceptable (crew, cargo, …) ?
- ….

Summary

- Maneuvering & seakeeping can be influenced by substantial wind propulsion
- Prediction methods and specific impact of WASP on maneuvering and seakeeping still in development

THANK YOU - ANY QUESTIONS ?

MARIN



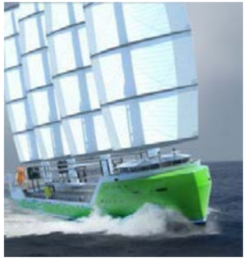

BETTER SHIPS, BLUE OCEANS

R.EGGERS@MARIN.NL

Natural propulsion for Transport & Shipping: Performance assessment

Guilhem Gaillarde
Head of Ships department
Maritime Research Institute Netherlands (MARIN)


E-SHIP 1

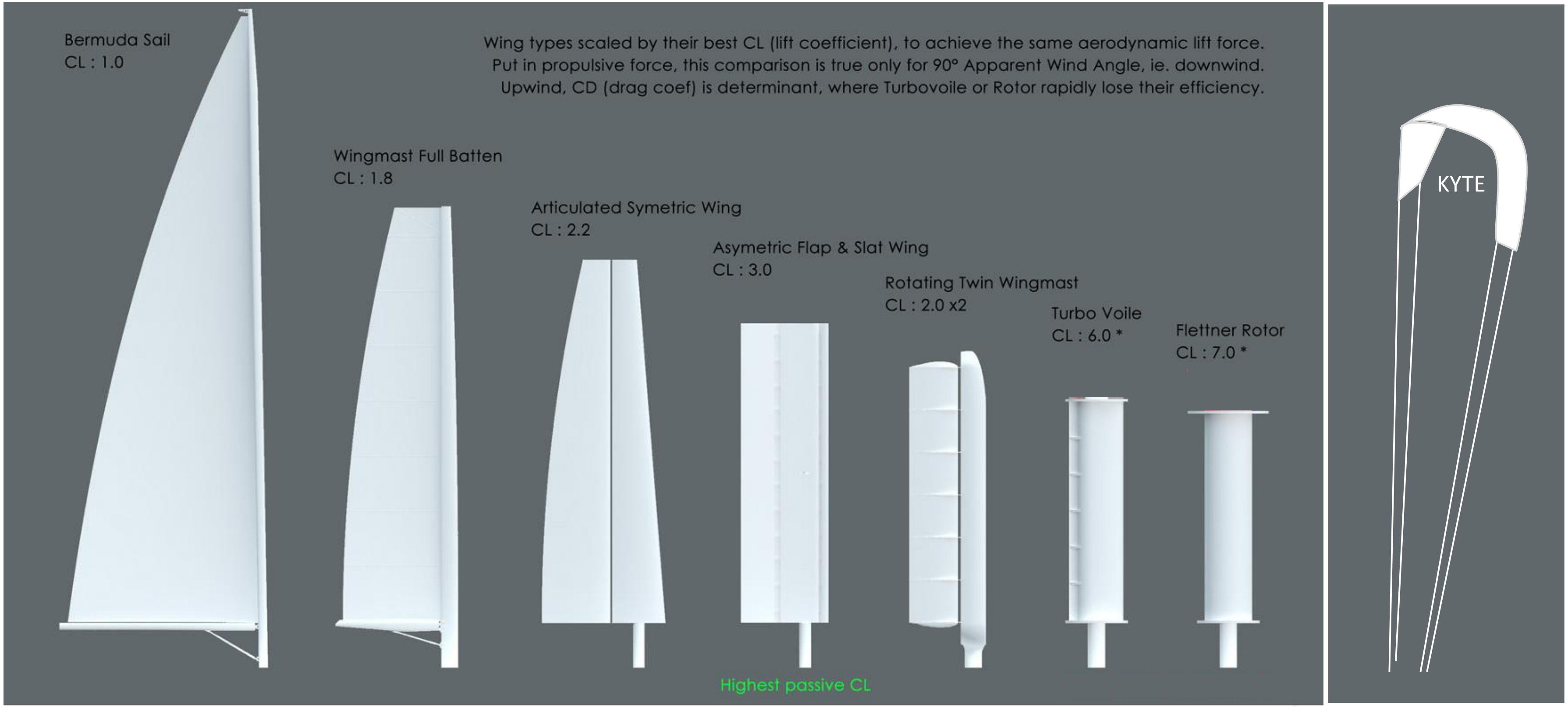



LADY CHRISTINA


OCEANBIRD


ANEMOI

Wing types scaled by their best CL (lift coefficient), to achieve the same aerodynamic lift force.
Put in propulsive force, this comparison is true only for 90° Apparent Wind Angle, ie. downwind.
Upwind, CD (drag coef) is determinant, where Turbovoile or Rotor rapidly lose their efficiency.



Wing types efficiency

Energy production

Wind propulsion

Crane operations

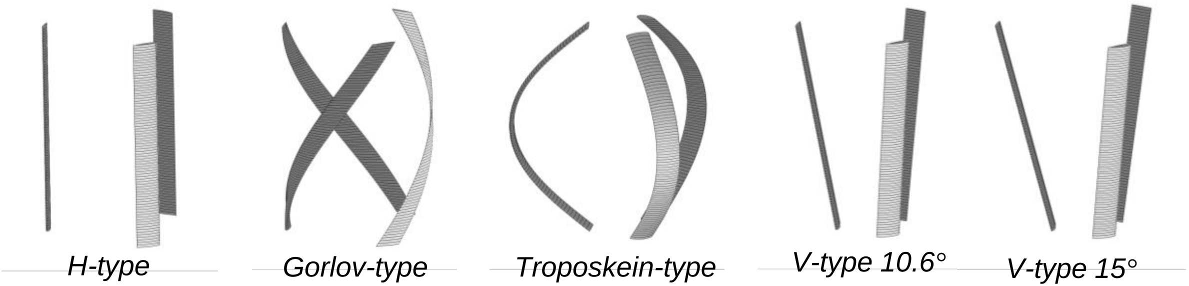
Ship stationary

Ship cruising

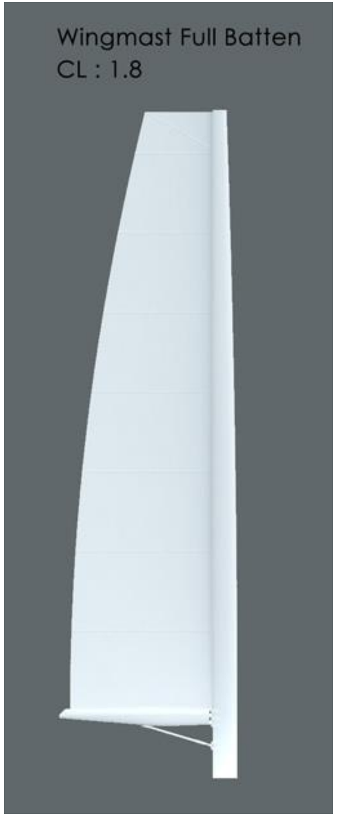
Energy production

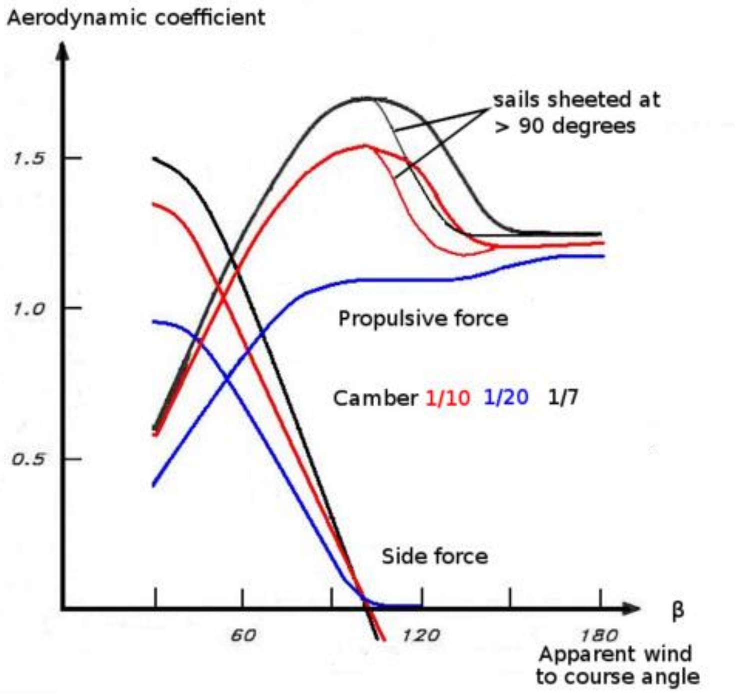
Wind propulsion

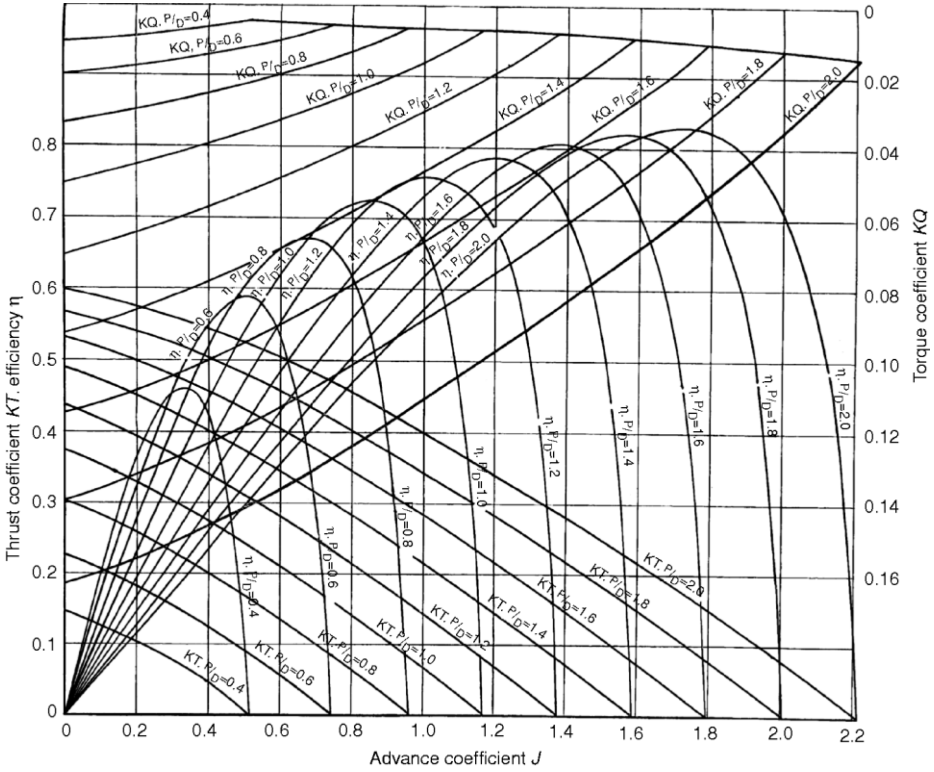
Crane operations

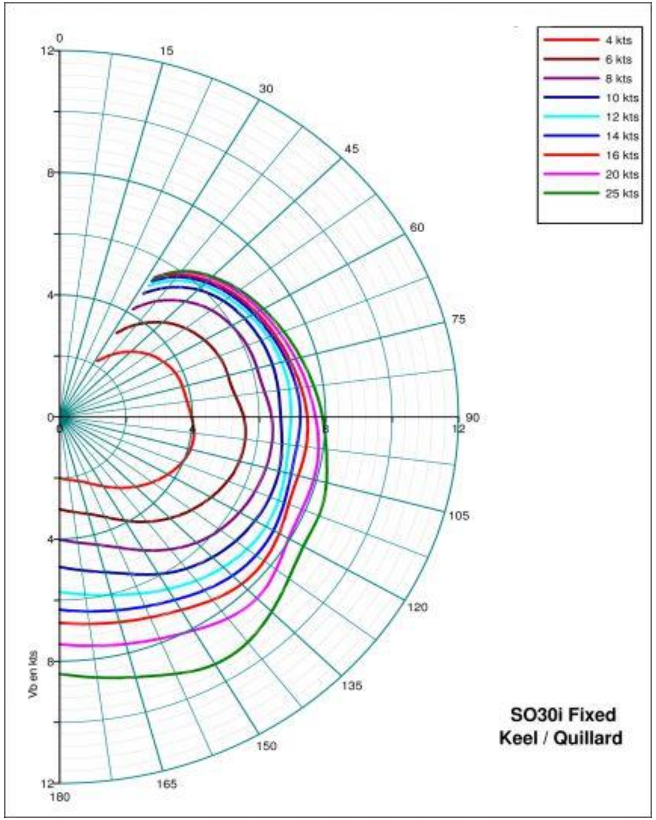


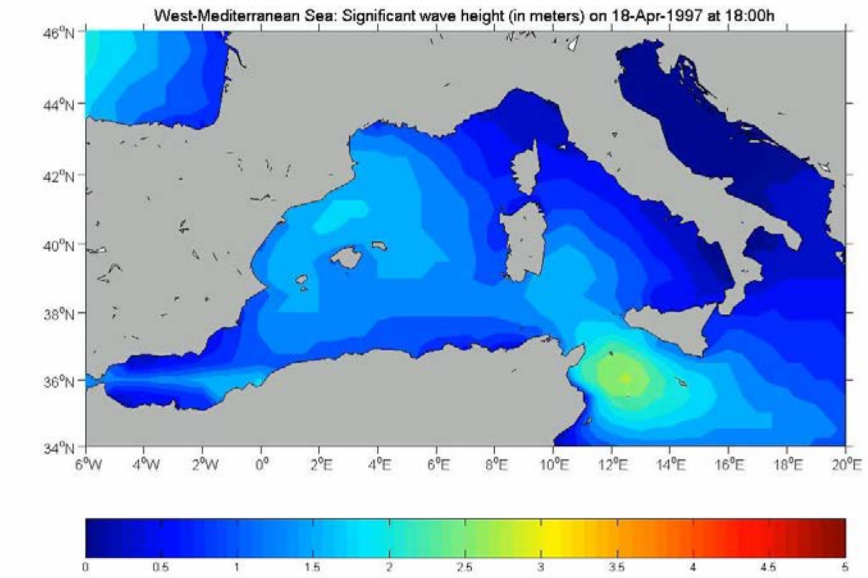
Different types of VAWT made in QBlade

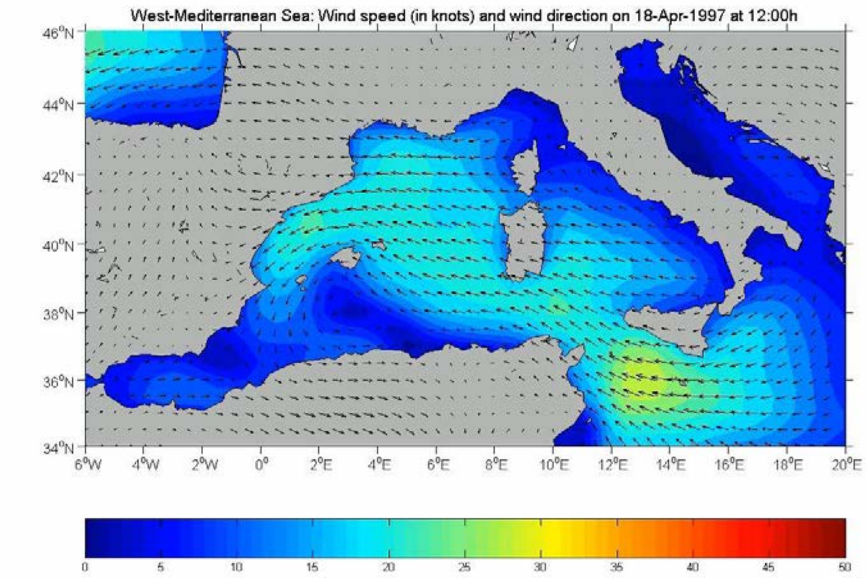

Wingmast Full Batten
CL : 1.8

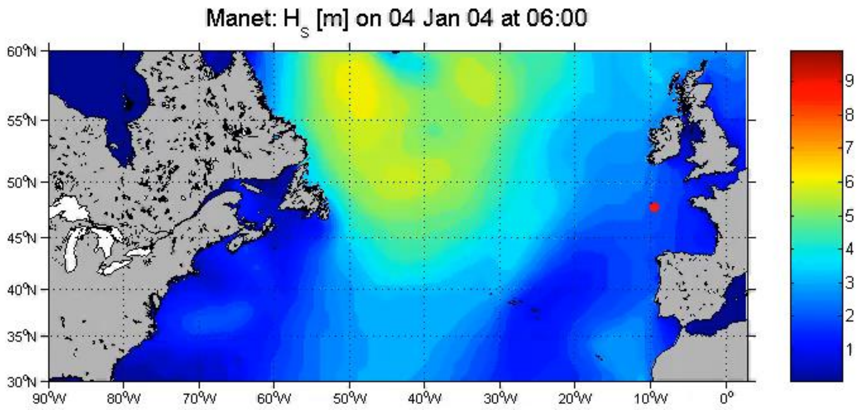

Aerodynamic coefficient
1.5
1.0
0.5
sails sheeted at
> 90 degrees
Propulsive force
Camber 1/10 1/20 1/7
Side force
60
120
180
β
Apparent wind
to course angle


Thrust coefficient KT. efficiency η
Torque coefficient KQ
Advance coefficient J
KQ. P/D=0.4
KQ. P/D=0.6
KQ. P/D=0.8
KQ. P/D=1.0
KQ. P/D=1.2
KQ. P/D=1.4
KQ. P/D=1.6
KQ. P/D=1.8
KQ. P/D=2.0
η. P/D=0.4
η. P/D=0.6
η. P/D=0.8
η. P/D=1.0
η. P/D=1.2
η. P/D=1.4
η. P/D=1.6
η. P/D=1.8
η. P/D=2.0
KT. P/D=0.4
KT. P/D=0.6
KT. P/D=0.8
KT. P/D=1.0
KT. P/D=1.2
KT. P/D=1.4
KT. P/D=1.6
KT. P/D=1.8
KT. P/D=2.0


4 kts
6 kts
8 kts
10 kts
12 kts
14 kts
16 kts
20 kts
25 kts
Vb en kts
SO30i Fixed
Keel / Quillard


West-Mediterranean Sea: Significant wave height (in meters) on 18-Apr-1997 at 18:00h
46°N
44°N
42°N
40°N
38°N
36°N
34°N
6°W
4°W
2°W
0°
2°E
4°E
6°E
8°E
10°E
12°E
14°E
16°E
18°E
20°E
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5


West-Mediterranean Sea: Wind speed (in knots) and wind direction on 18-Apr-1997 at 12:00h
46°N
44°N
42°N
40°N
38°N
36°N
34°N
6°W
4°W
2°W
0°
2°E
4°E
6°E
8°E
10°E
12°E
14°E
16°E
18°E
20°E
0
5
10
15
20
25
30
35
40
45
50



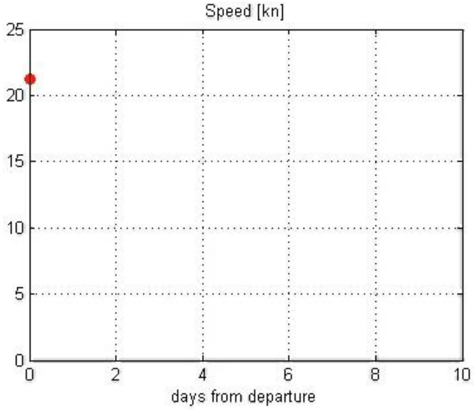
H_s : 1.98 m

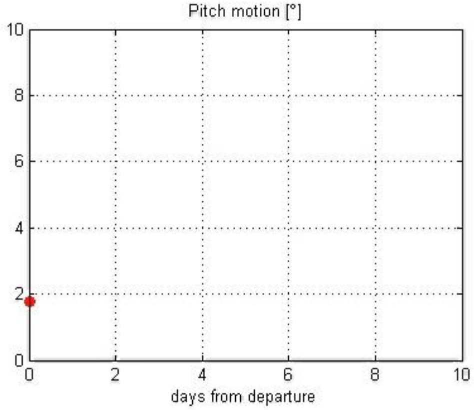
T_p : 11.4 s

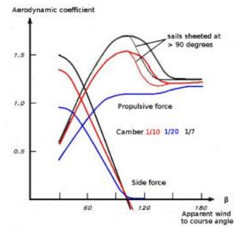
μ_p : 138°

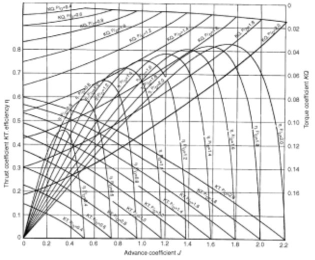
U_{wind} : 5.4 kn

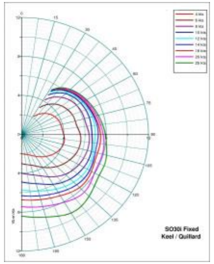
α_{wind} : 79°



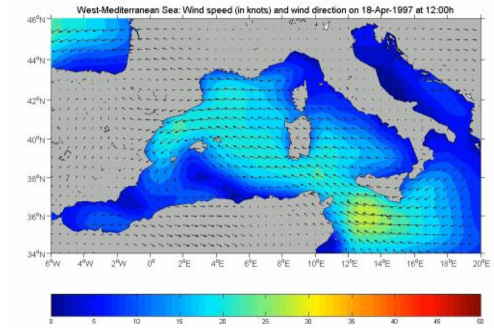


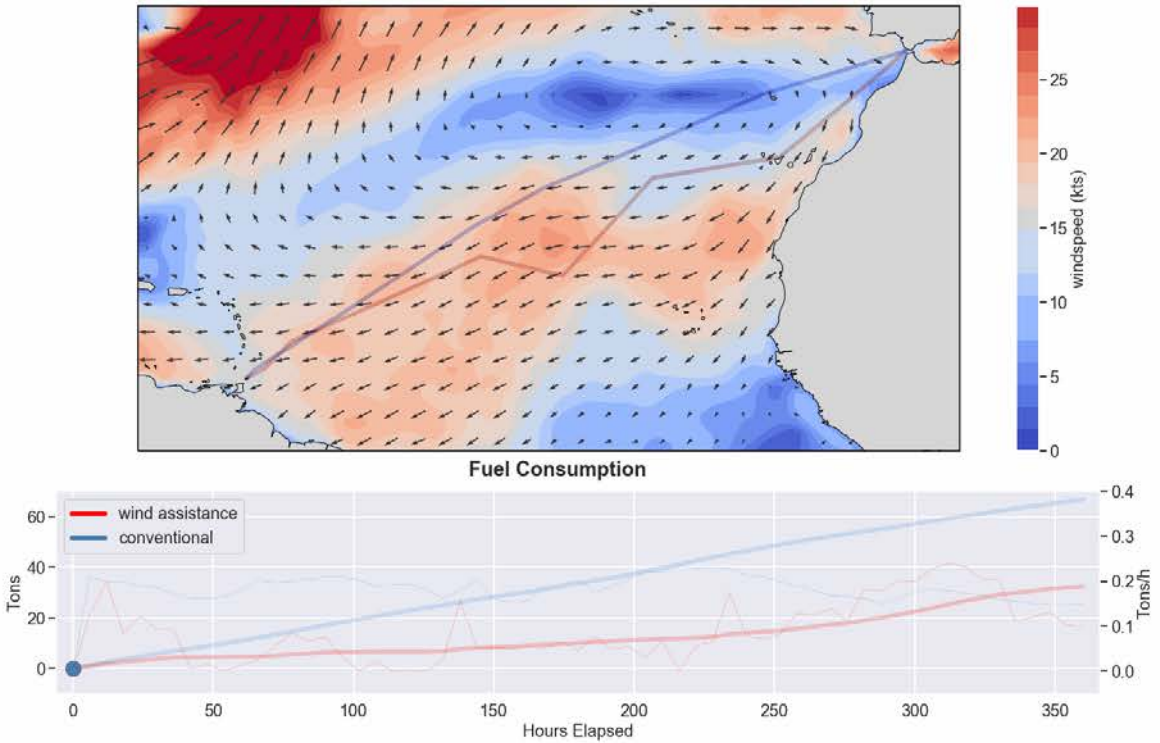






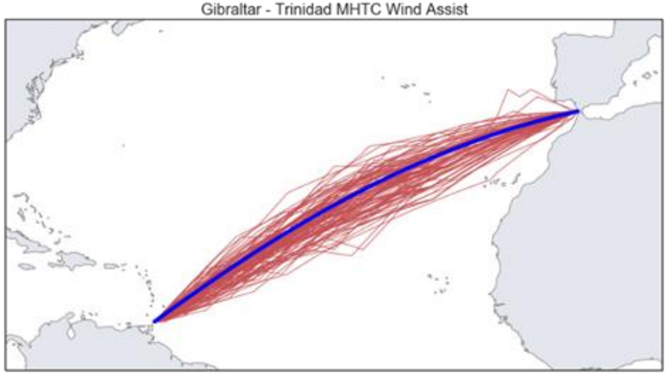
Let’s create voyage simulation

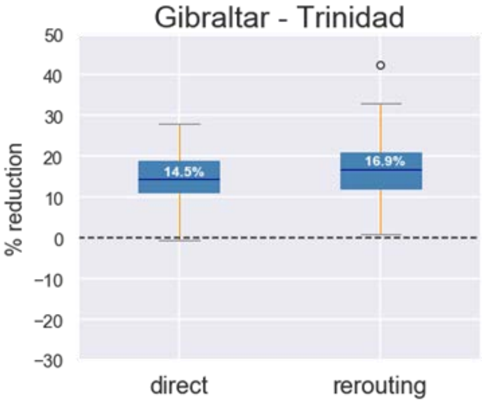


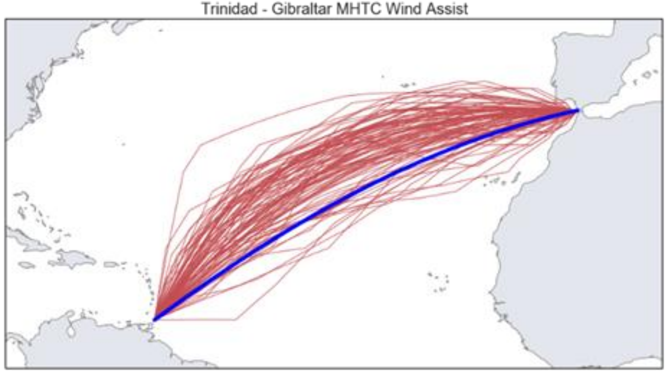

windspeed (kts)
0
5
10
15
20
25
Fuel Consumption
wind assistance
conventional
Tons
Tons/h
Hours Elapsed
0
20
40
60
0.0
0.1
0.2
0.3
0.4
0
50
100
150
200
250
300
350

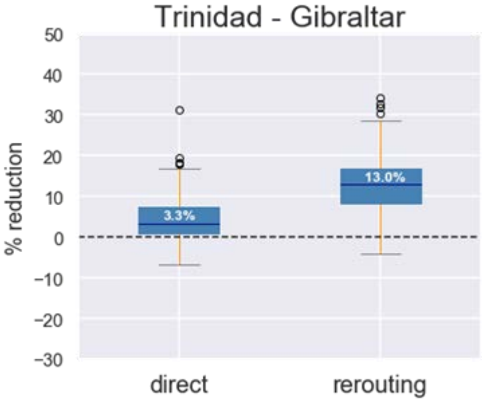
Scenario studies for wind assistance

Impact of rerouting on fuel consumption

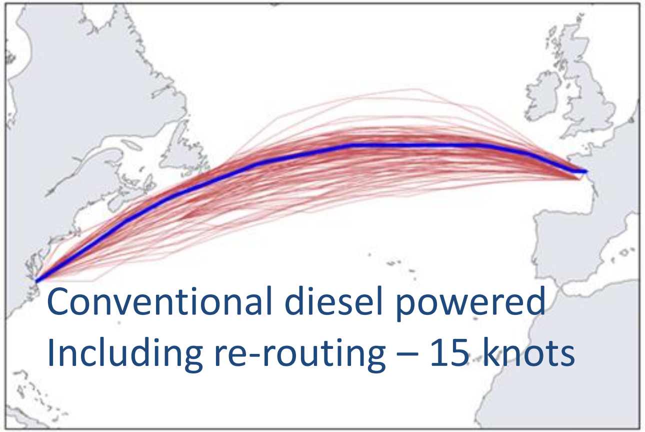


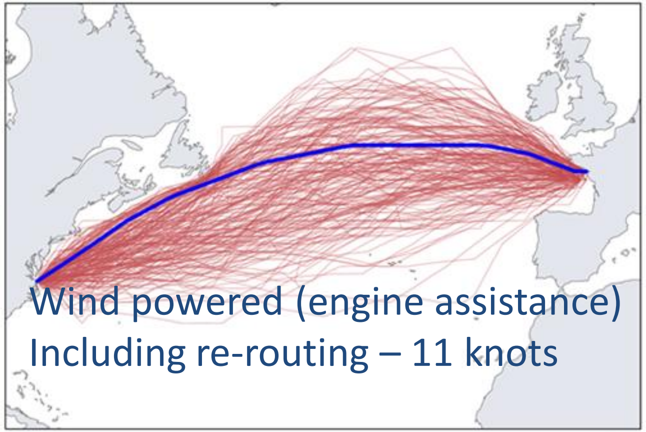


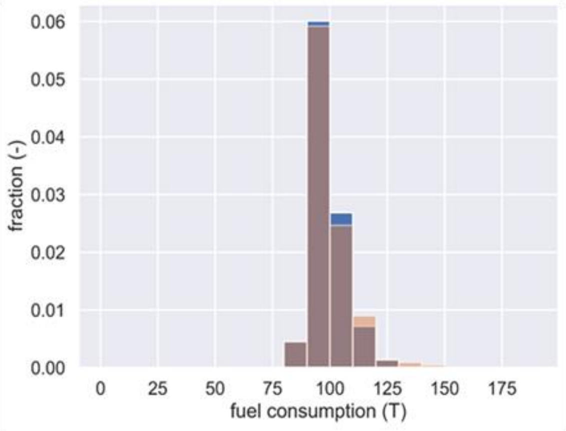


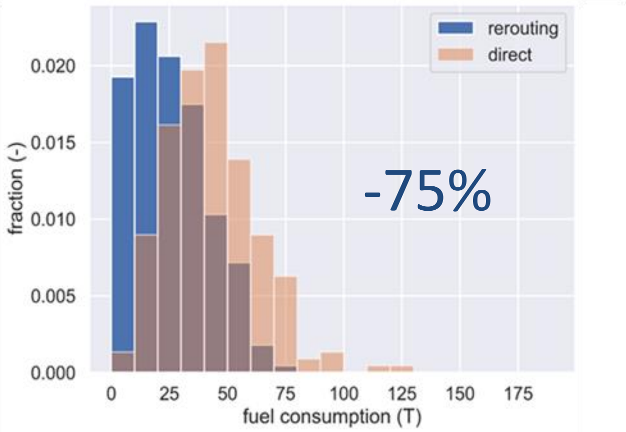


Scenario studies for alternative wind propulsion





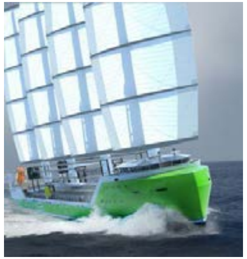




Take aways

- Wind offers a free source of energy that can be captured on almost any kind of ships.
- It can be applied today for refit or new builds. Benefit in terms of energy and emission is immediate.
- It helps compensating the issue of lower energy density, acting as range extender (average value, depending of course on wind conditions).
- Direct gains 5% to 30% emission reduction keeping existing service conditions, and 30 to 100% when adapting operational conditions and logistics (plus dedicated design).
- Todays sail technologies are so far up to 7 times more efficient than (old) soft sail technologies. Further performance is at reach. Do your engineering to optimize solution even further!
- The upcoming decade is going to see a huge development in integrated designs and optimum solutions & operations. You will be, as future naval architect, at the heart of such (r)evolution.


E-SHIP 1




LADY CHRISTINA


OCEANBIRD


ANEMOI

Thank you for your attention!

Upcoming port of call for wind technology and zero emission shipping

BLUE
BlueWeek2022

Rotterdam
The Netherlands
13 – 17 June

www.blueforum.org

Thank you for your attention!

WIND ASSISTED SHIP PROPULSION

DNA involvement, selected test cases and the future

2021, G Dijkstra

DYKSTRA
NAVAL ARCHITECTS

CONTENTS

- INTRODUCTION DNA
- HISTORY
- SAILING SHIPS operational
- SAILING SHIPS under construction/ in design / studies
- DESIGN TOOLS
- TRANSITION AND BARRIERS

DYKSTRA
NAVAL ARCHITECTS

OCEAN RACING 1969-1980

SECOND LIFE 1972 O.S.T.A.R.

DYKSTRA NAVAL ARCHITECTS

YACHT DESIGN 1975 ONWARDS

DYKSTRA
NAVAL ARCHITECTS

LAMINATED WOOD SHIP BUILDING IN INDONESIA
1982-1993

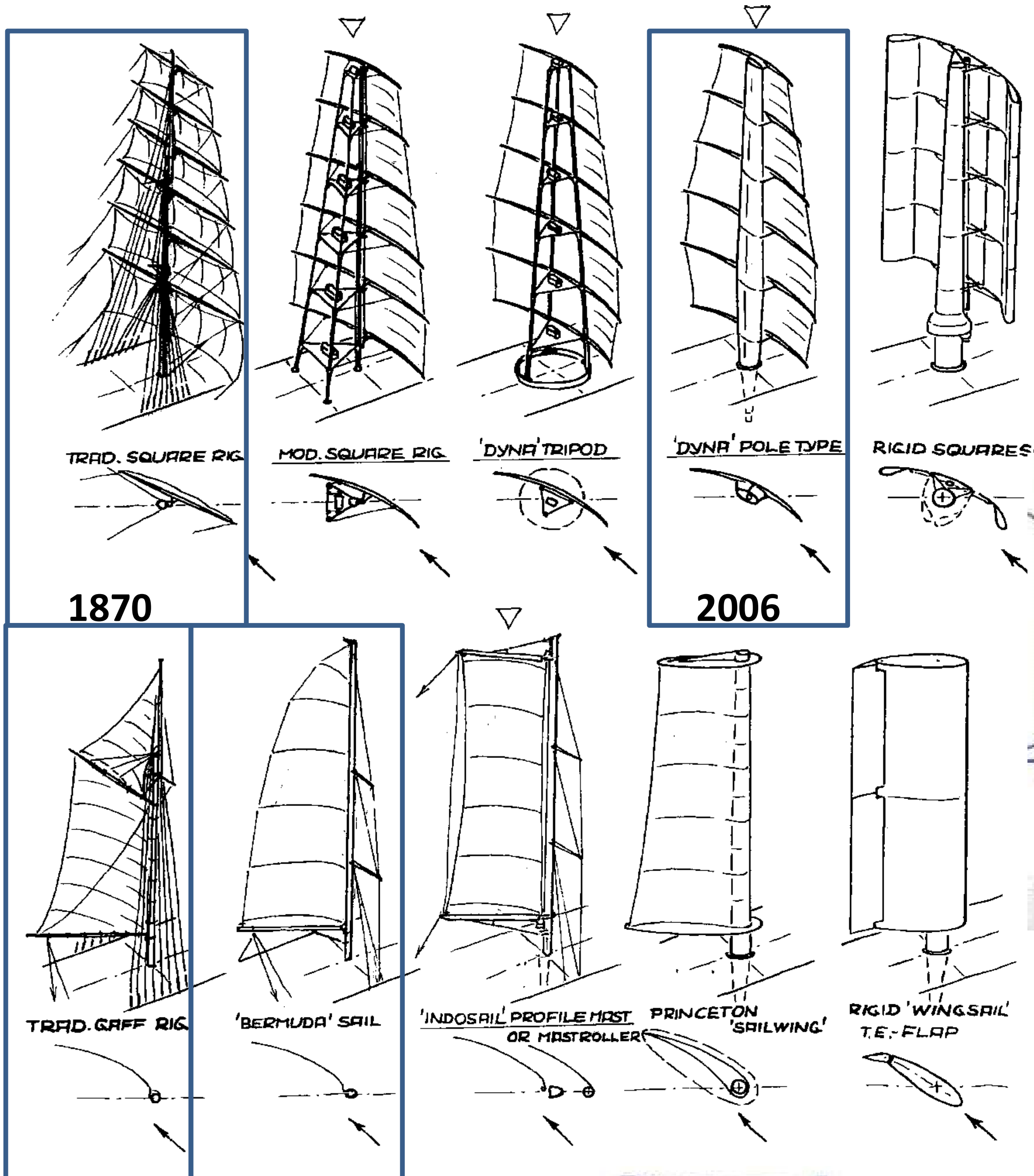
DYKSTRA
NAVAL ARCHITECTS

Student Thesis June 2003: Average 13% fuel reduction, for reductions >40% the soft sail route was developed.

Stichting De Noordzee

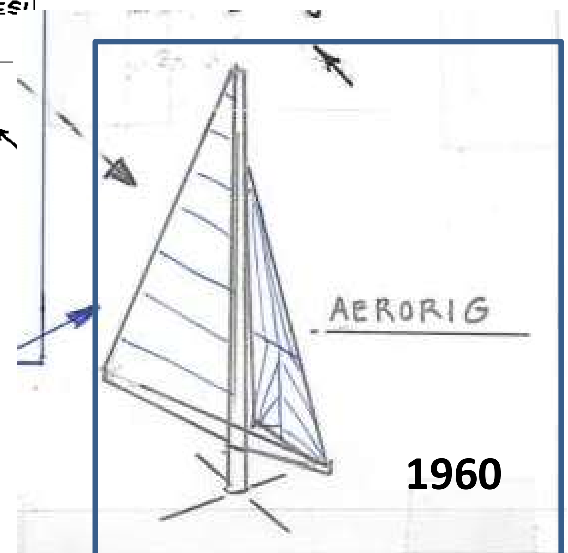
DYKSTRA NAVAL ARCHITECTS

2500 years in the past



SQUARE RIG

ILLUSTRATION
P.SCHENZLE

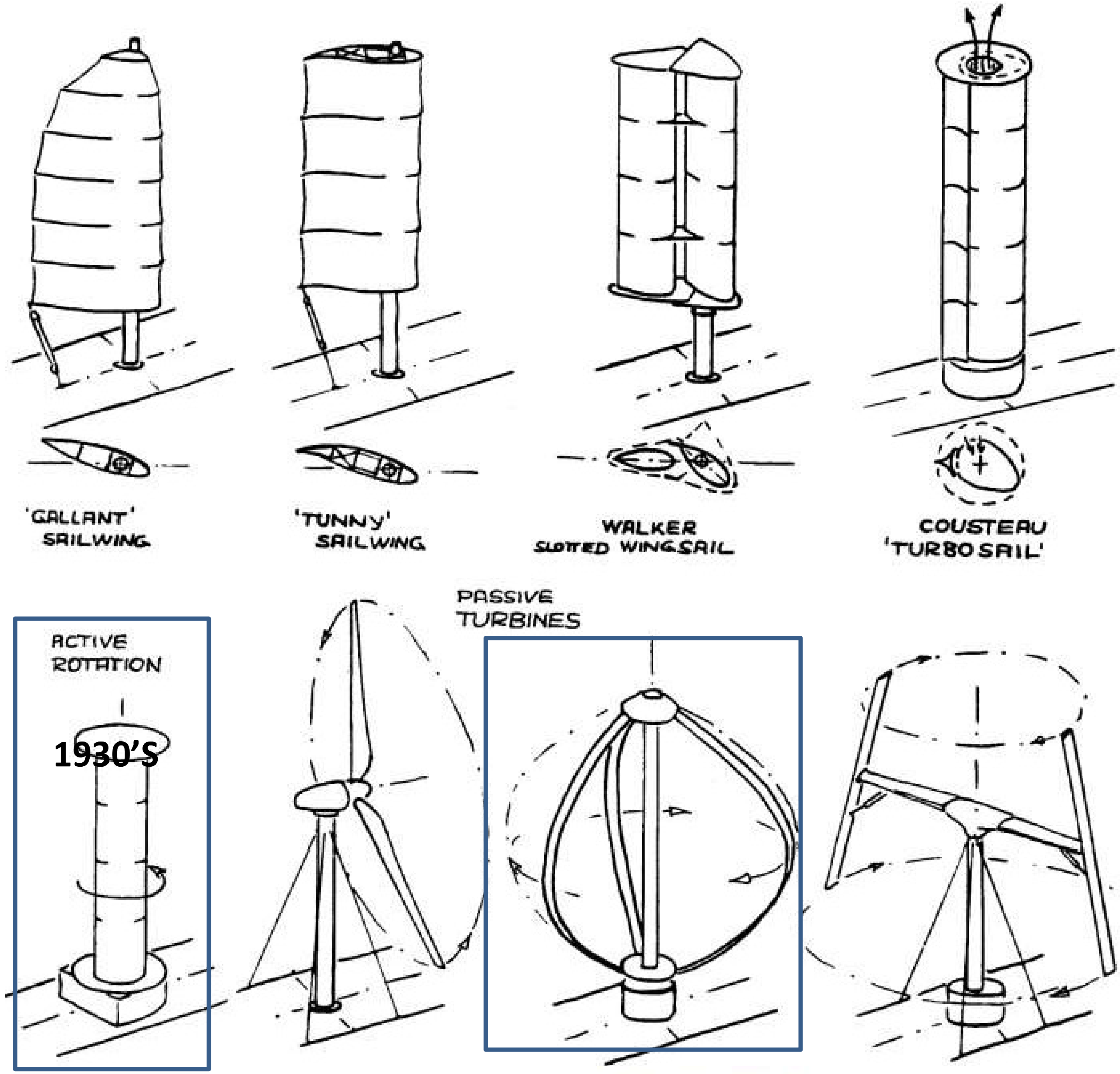


FORE-AND-AFT RIG

DYKSTRA
NAVAL ARCHITECTS

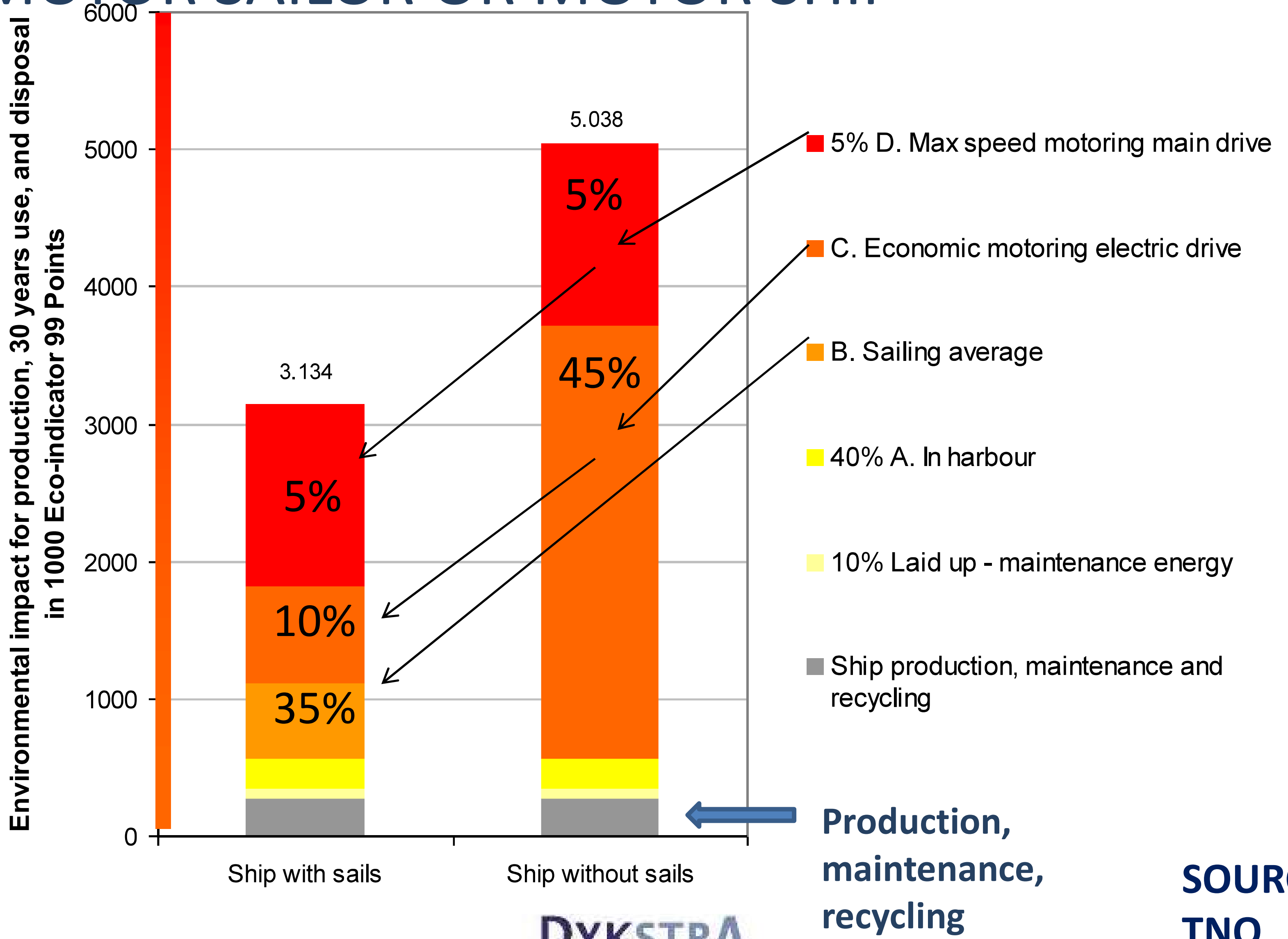
ILLUSTRATION

P. SCHENZLE



DYKSTRA
NAVAL ARCHITECTS

RAINBOW WARRIOR LIFE CYCLE ANALYSIS
MOTOR SAILOR OR MOTOR SHIP



SOURCE: TNO

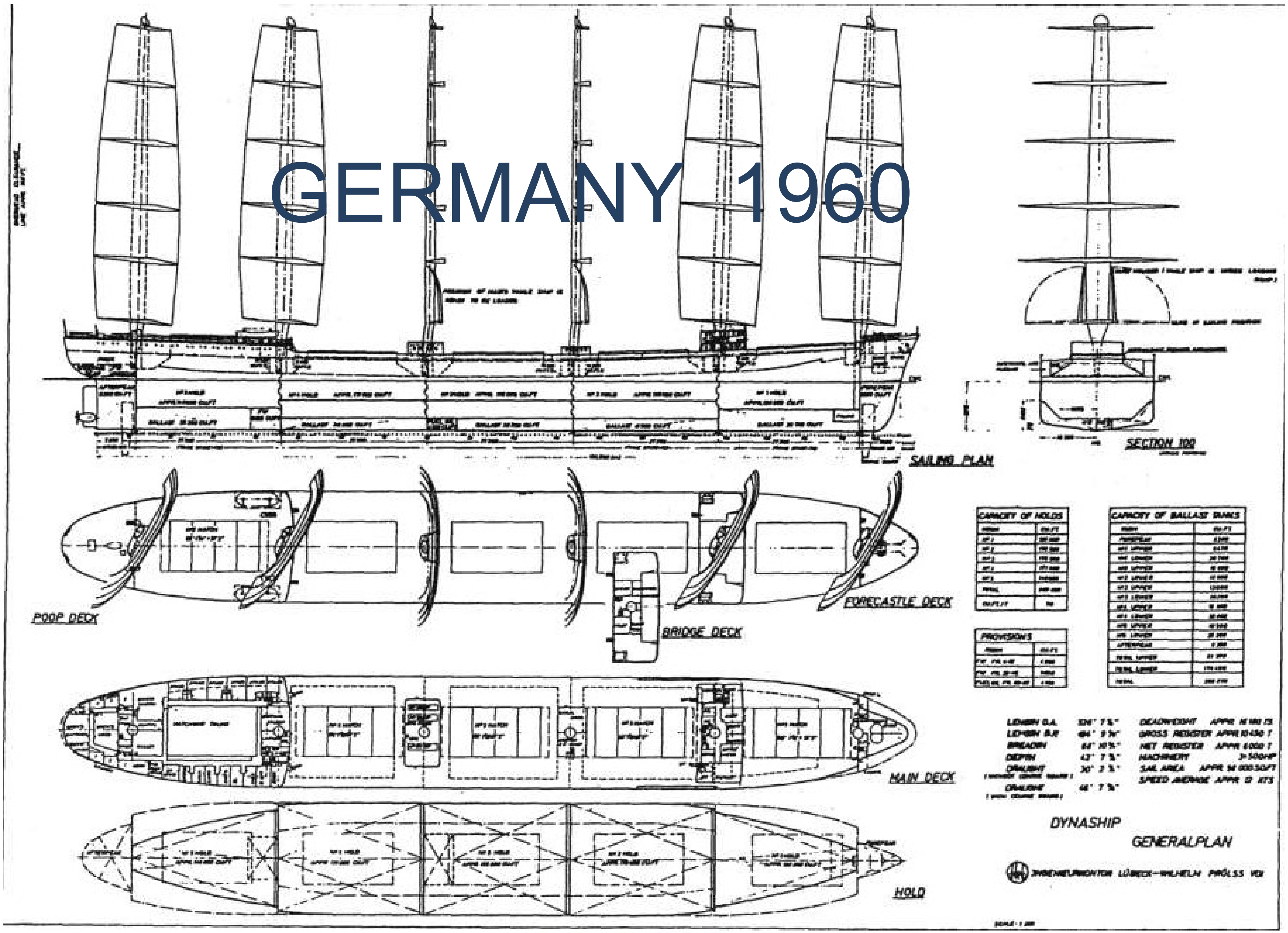
Clipper STAD AMSTERDAM, 2000

DYKSTRA
NAVAL ARCHITECTS

DYKSTRA
NAVAL ARCHITECTS

DYKSTRA
NAVAL ARCHITECTS

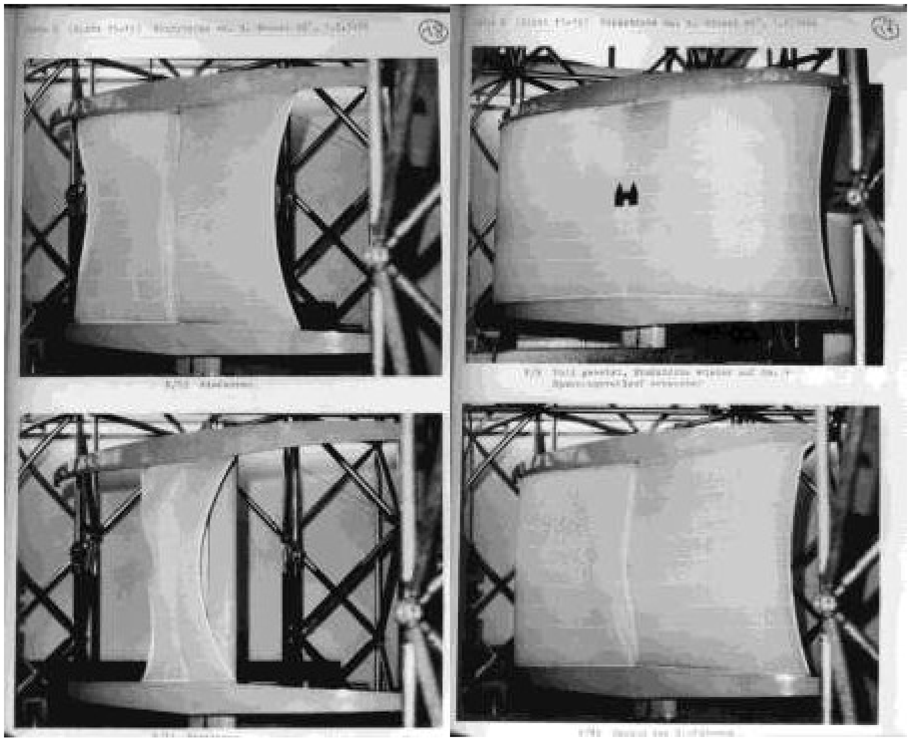
GERMANY 1960



DYKSTRA
NAVAL ARCHITECTS

DYNARIG DEVELOPMENT

1960 HAMBURG



2000 AMSTERDAM

2003
TURKEY

DYKSTRA
NAVAL ARCHITECTS

MALTESE FALCON 2006

Project commenced 2002

Launch 2006, To date (2011):

- 80,000 sea miles ,95% under sail
- 24 knots under sail
- several gales
- 3,000 sail sets
- winner Perini Navi Cup 2008, 2010 and many awards

No issues with the rig

Full data set from Monitoring system

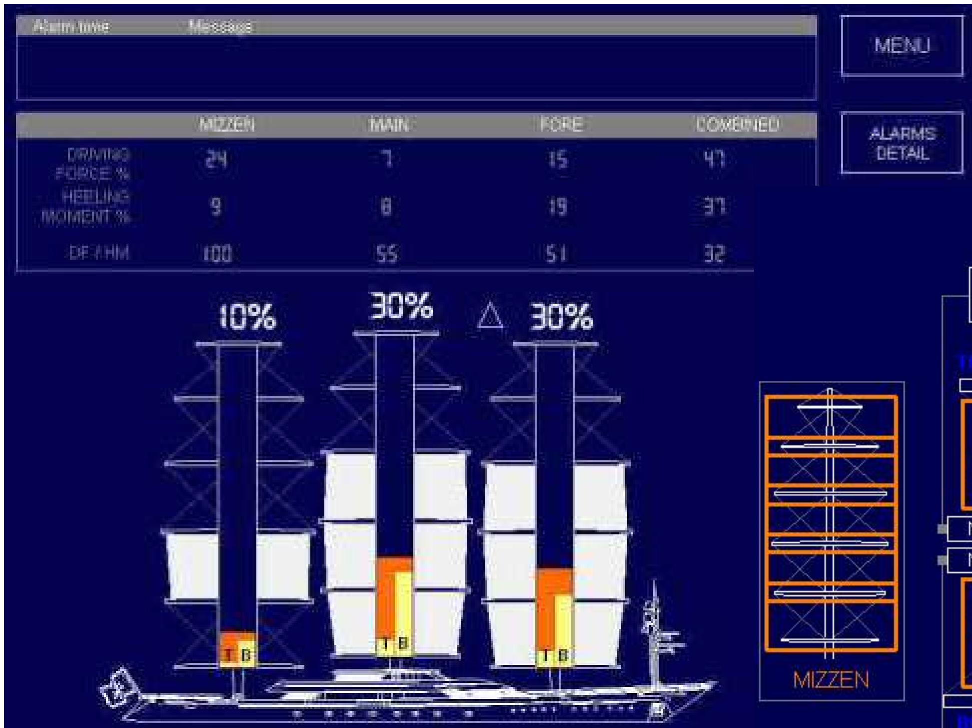
Rigs never removed & no plans to remove rigs

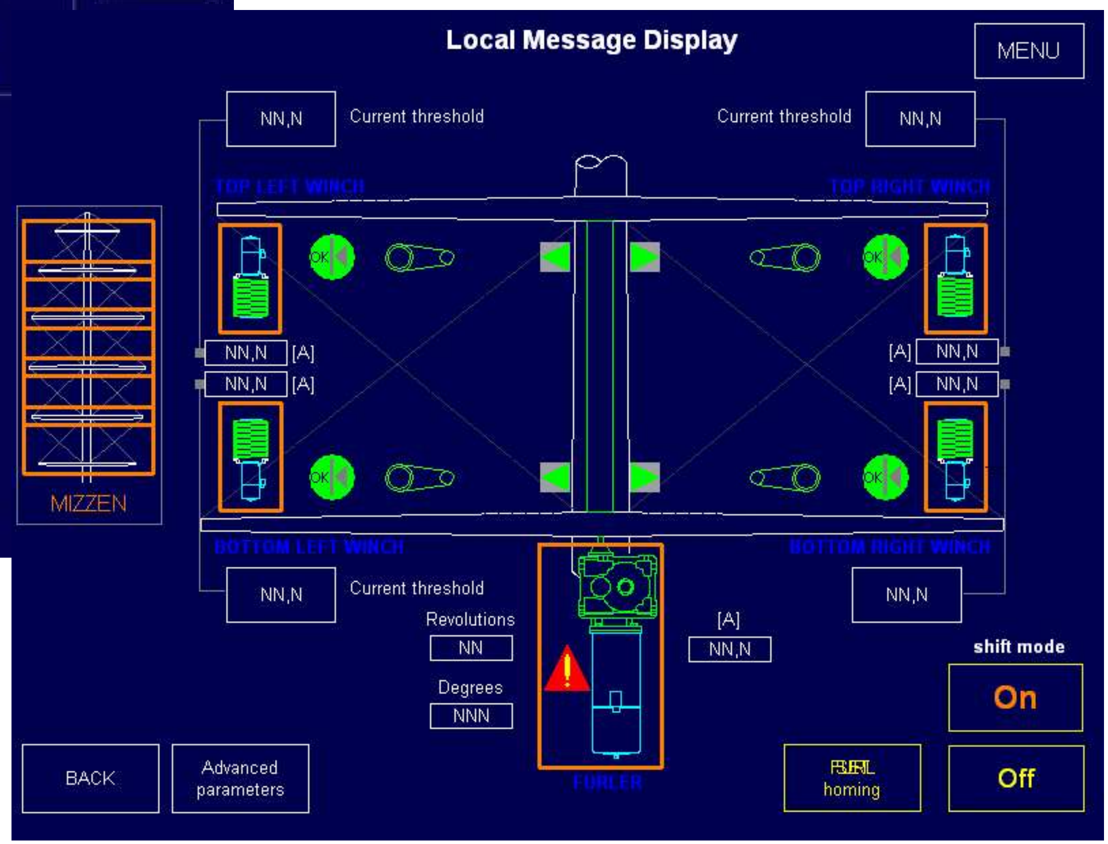
Sold to new owner 2009

Main control panel MALTESE FALCON

DYKSTRA
NAVAL ARCHITECTS

2000 ONWARDS
FIBRE OPTIC STRUCTURAL MONITORING, MagmaStructures
SAIL HANDLING MONITORING SOFTWARE, Caccini

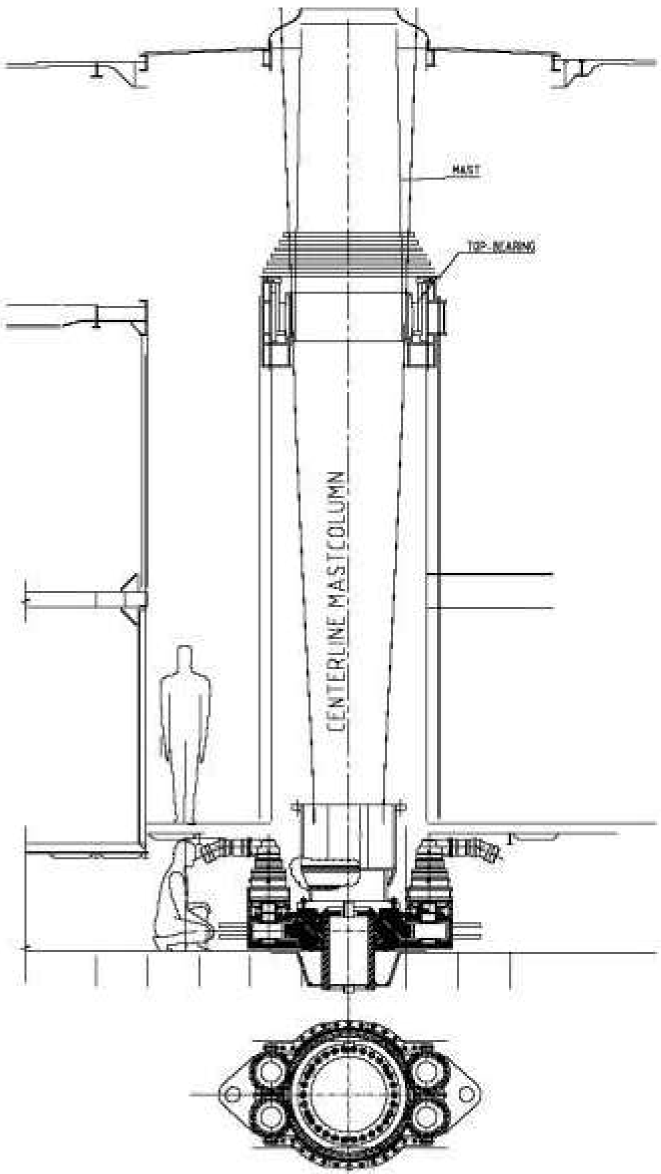




DYKSTRA
NAVAL ARCHITECTS

BACK-UP SAIL HANDLING PANEL

MALTESE FALCON MAST ROTATION SYSTEM



DYKSTRA
NAVAL ARCHITECTS

BLACK PEARL 106m, 2018

DYKSTRA
NAVAL ARCHITECTS

46m AERORIG DWINGER

REFIT AND RIG DESIGN DNA 2002

Hoofdafmetingen:

Lengte = 46 m

Waterverplaatsing = 300 ton

Zeiloppervlak = 780 m2

Bemanning = 4 pers

DYKSTRA
NAVAL ARCHITECTS

ECOLUTION, AERORIG SCHOONER,
a self sustained yacht, 2011

DYKSTRA
NAVAL ARCHITECTS

SOFT SAIL WING
MAST
DNA design 2012
Sea trials and load
Measuring
On a 30 ft hull,
For designing a
1000 m2 rig.

RAINBOW WARRIOR LAUNCHED 2011
2012-2016 150.000 NM SAILED

DYKSTRA
NAVAL ARCHITECTS

DYKSTRA
NAVAL ARCHITECTS

2018 MARIN, MEASUREMENTS ON A FREE SAILING MODEL OF A SAILING SHIP (or YACHT)

ECOLINER 8000 DWT WITH FLETTNER ROTORS OR DYNARIG

Related VPP DEVELOPOMENT reported during this symposium separately by MARIN

DYKSTRA
NAVAL ARCHITECTS

DARIEUX ROTOR, KITE, ENERGY STORAGE, ENERGY GENERATION, ELECTRIC PROPULSION, RETRACTABLE OUTRIGGERS

STUDY DNA

ECOLINER 8000 DWT, 2010

DYKSTRA
NAVAL ARCHITECTS

ECOLINER 2012

FAIR TRANSPORT

- LOA 138m
- B 18m
- T 6.5m
- DW 8200 T
- Multi purpose
- Containers 476

Preliminary Design trade wind Atlantic routes by DNA

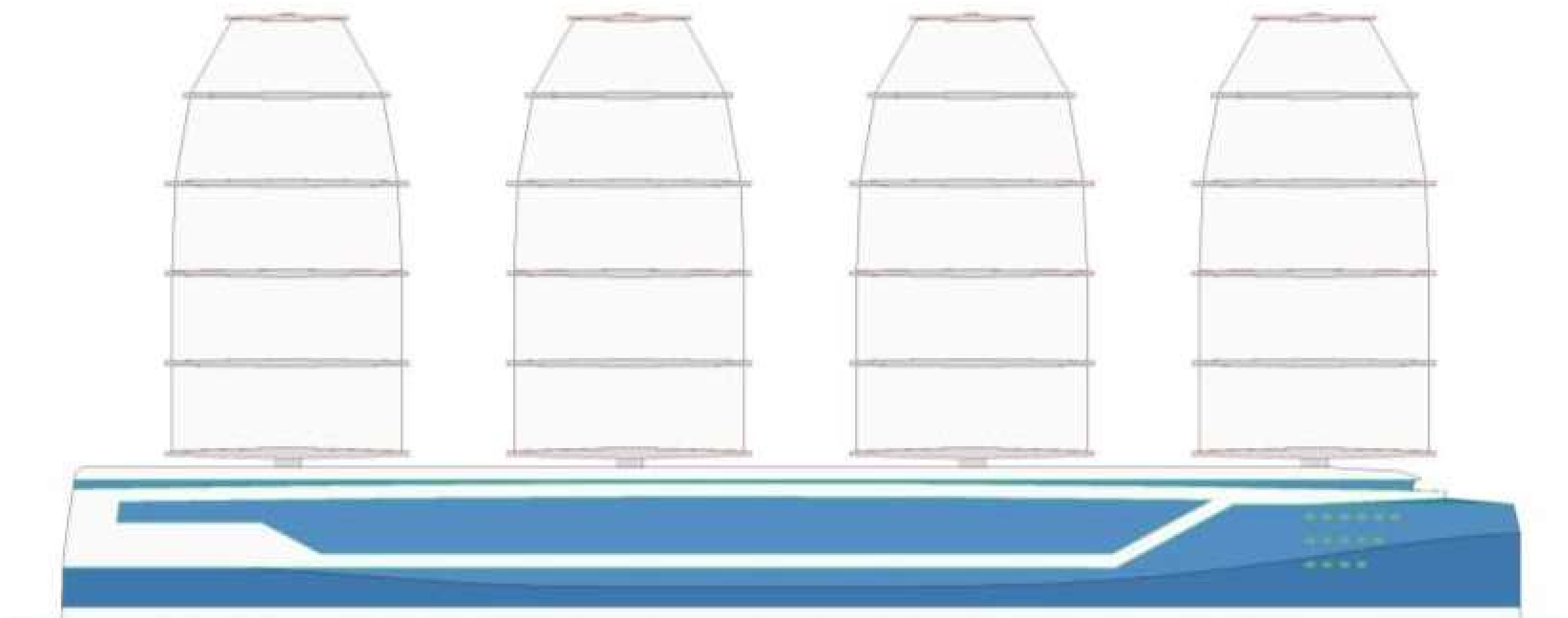
DYKSTRA
NAVAL ARCHITECTS

SAIL CARGO, 2021

HIGHER SPEED, LESS CARGO

DYKSTRA
NAVAL ARCHITECTS

ECO CAR CARRIER 170m
Design study 2016



Main Particulars

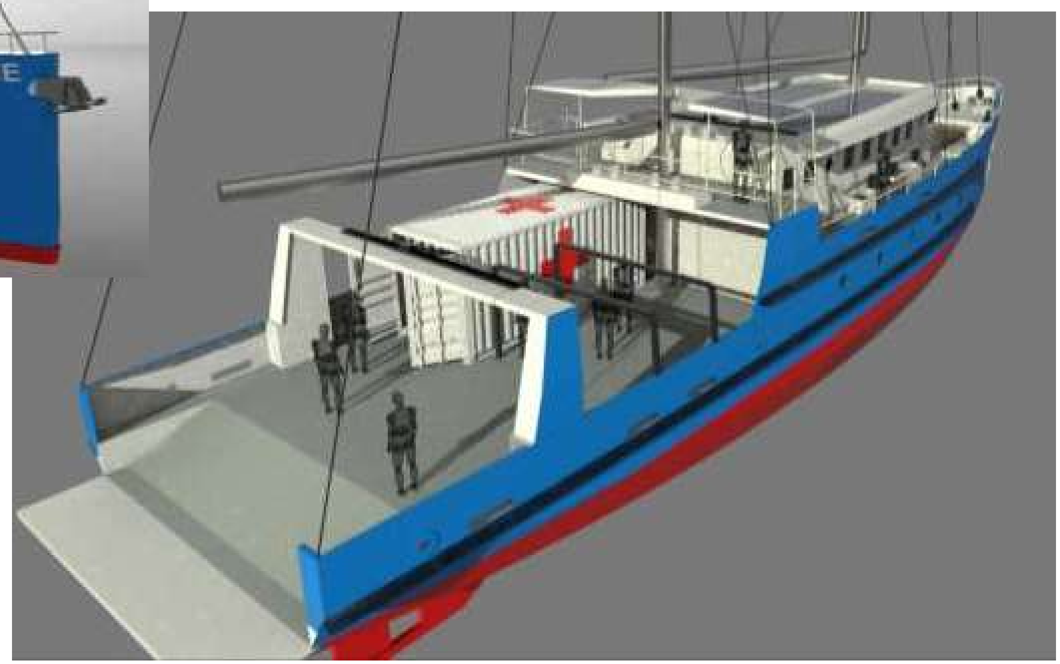
Lengte over alles:	170.0	m	Doorvaarthoogte:	70.8	m
Lengte waterlijn:	170.0	m	Volume:	17676	m3
Breedte max:	25.2	m	Displacement:	18118	ton
Breedte waterlijn:	25.0	m	Deadweight:	8580	ton
Diepgang max:	8.5	m	Windweerstand opp.:	5061	m2
Diepgang romp:	7.2	m	Zeil oppervlak:	5000	m2

DYKSTRA
NAVAL ARCHITECTS

SEABRIDGE ONE 36M
Disaster relief and medical support vessel, in design

DYKSTRA
NAVAL ARCHITECTS

SEABRIDGE ONE 36M
Disaster relief and medical support vessel



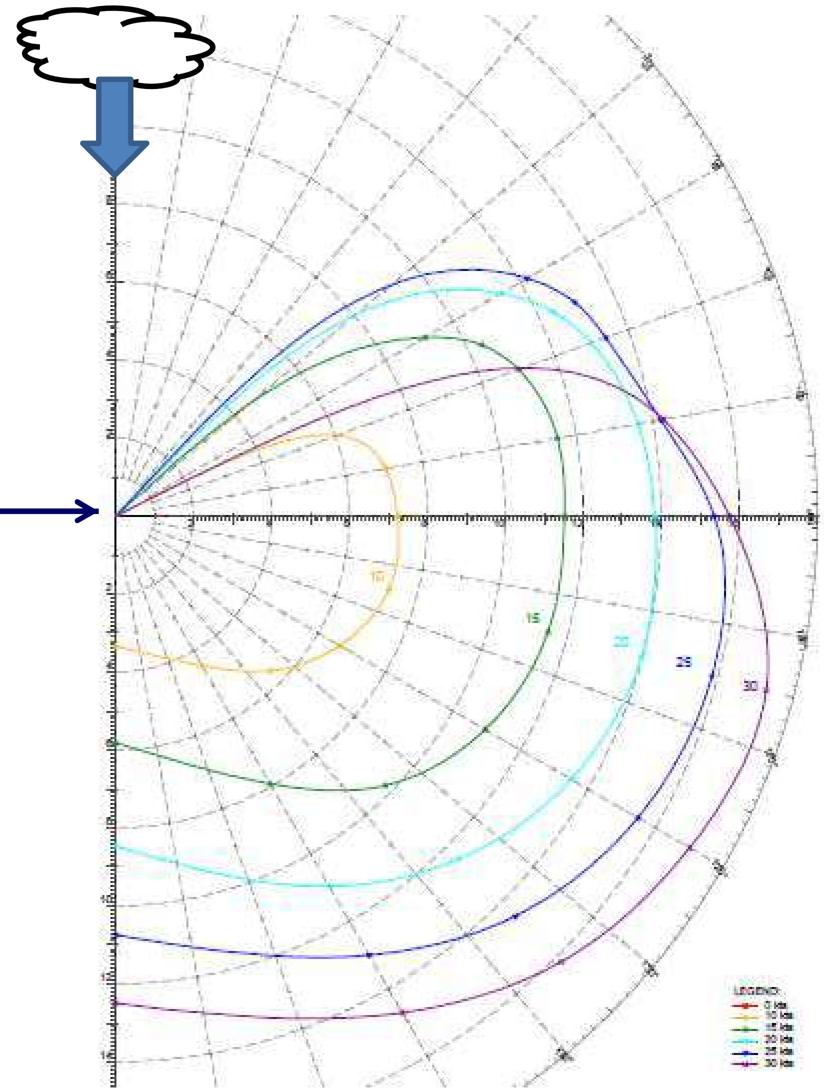
DYKSTRA
NAVAL ARCHITECTS

DESIGN TOOLS

DEVELOPED IN OFFICE

- VPP & TPP
- WASP WEATHER ROUTING
- ABOVE COMBINES TO FUEL SAVING CALCS., WHICH CAN BE LINKED TO AN ECONOMIC MODEL
- IN 2021 A MODULE TO INCLUDE REGENERATION OF ENERGY WHEN SAILING WAS ADDED

Performance calculations

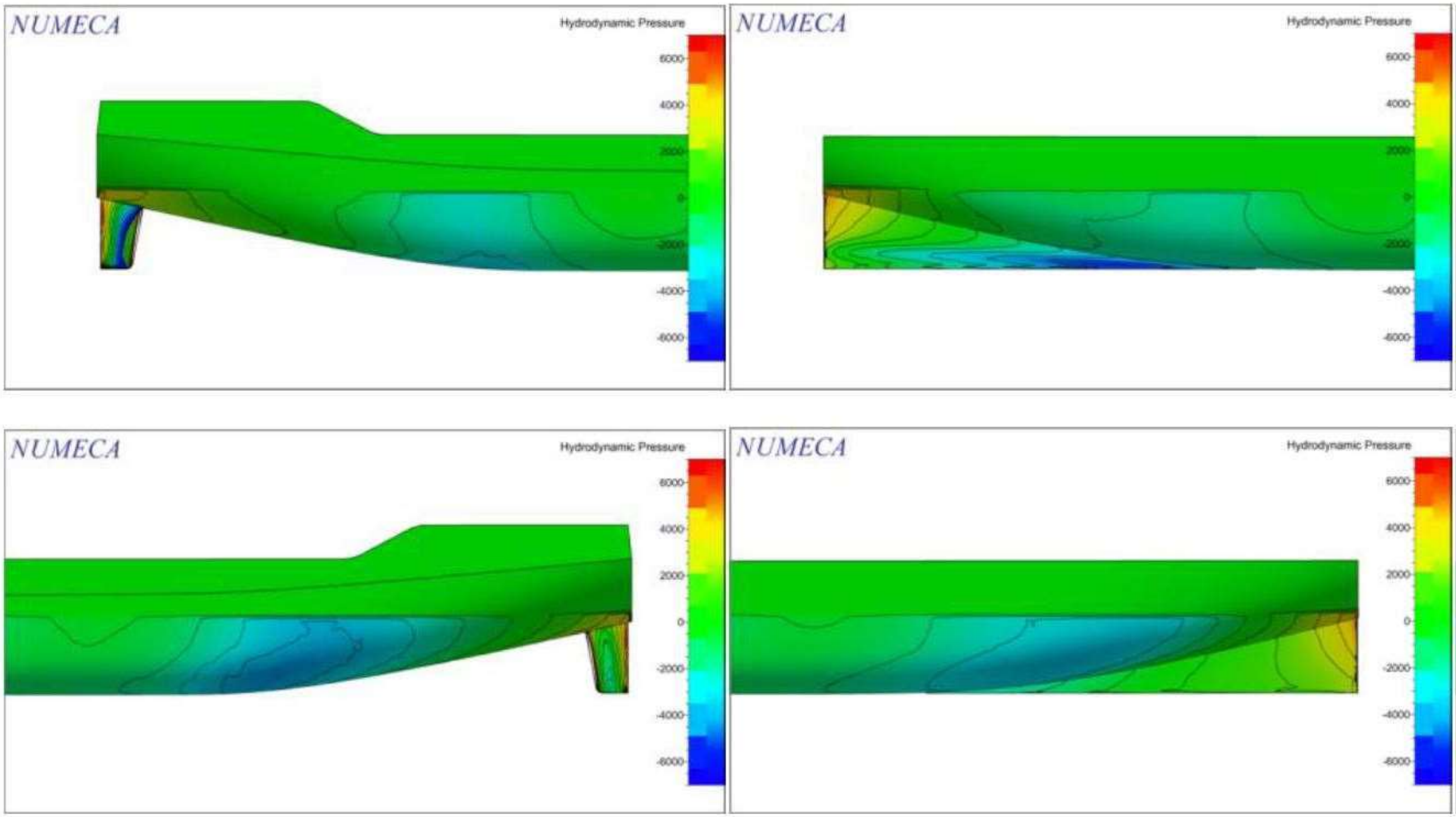


DYKSTRA
NAVAL ARCHITECTS

ECOLINER RUDDER versus SKEG CFD CHECK

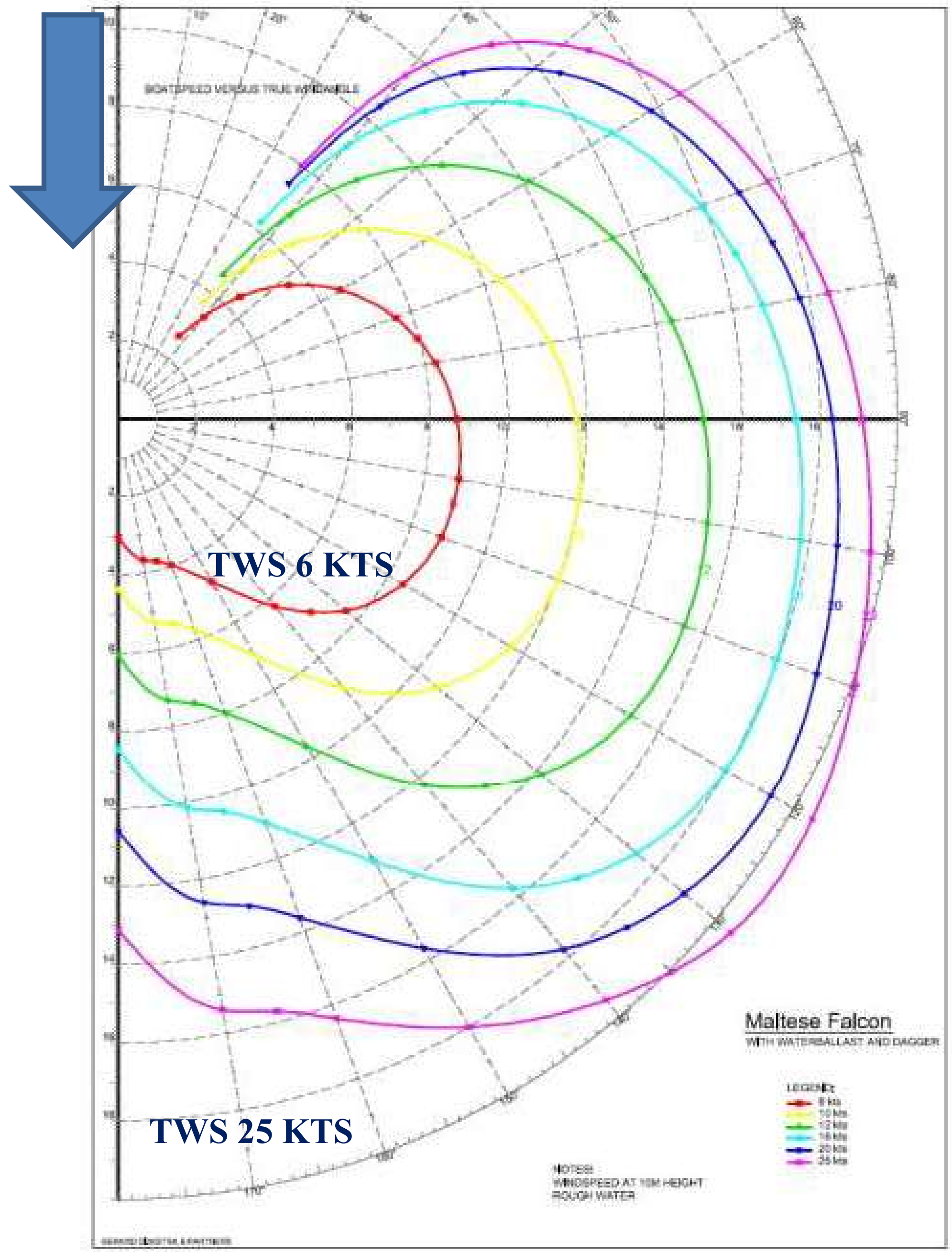
Baseline (Ecoliner)

Eco2 (Simple skeg)



DYKSTRA
NAVAL ARCHITECTS

TRUE WIND
DIRECTION



Polar Diagram – Sailing Performance

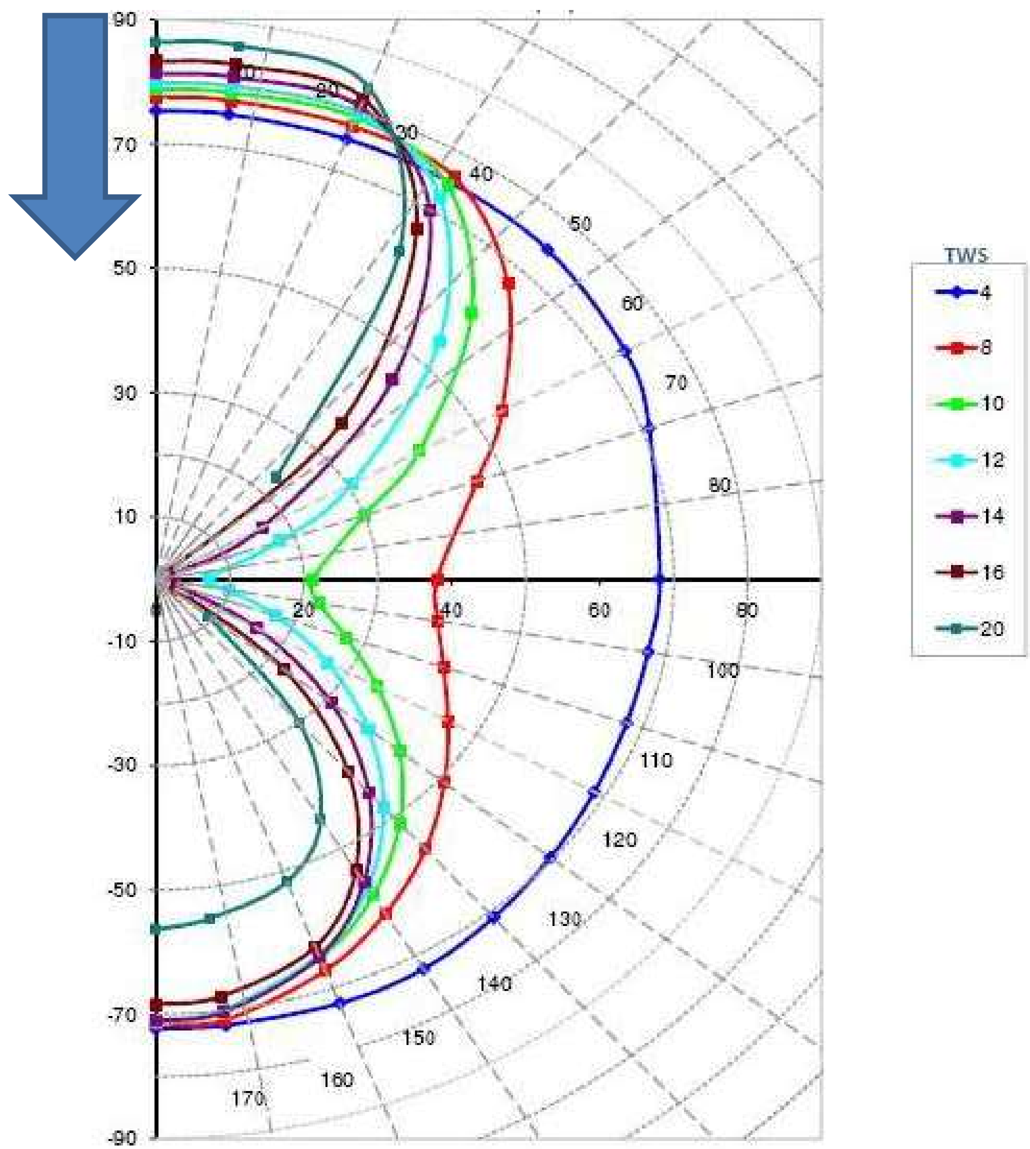
- DNA in office software or
- WIN DESIGN (WOLFSON UNIT) software

DYKSTRA
NAVAL ARCHITECTS

Thrust Prediction Program

- DNA in office software

Showing the required power for constant boat speed at different wind speeds



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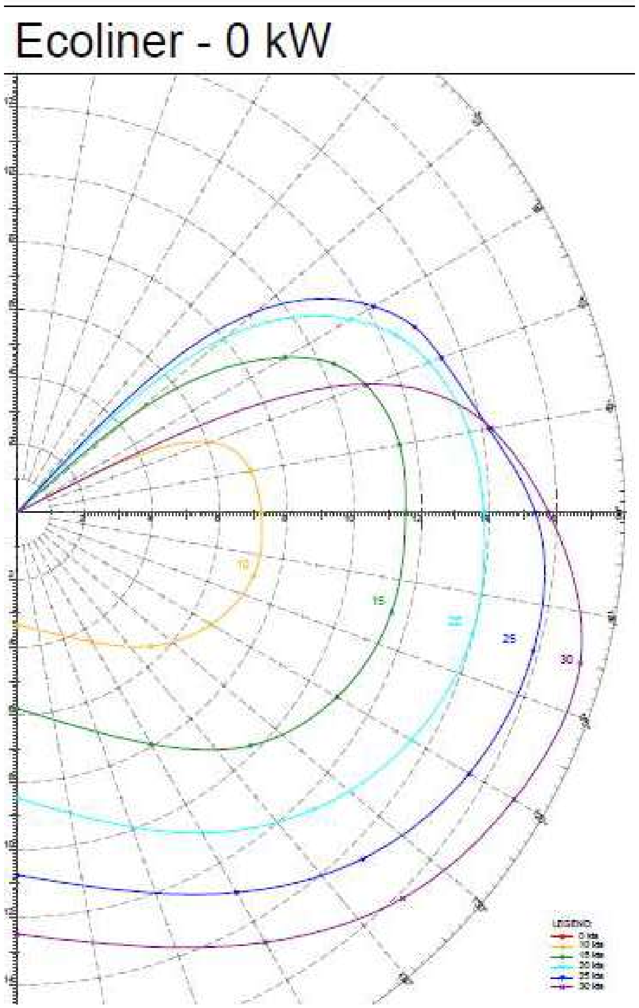
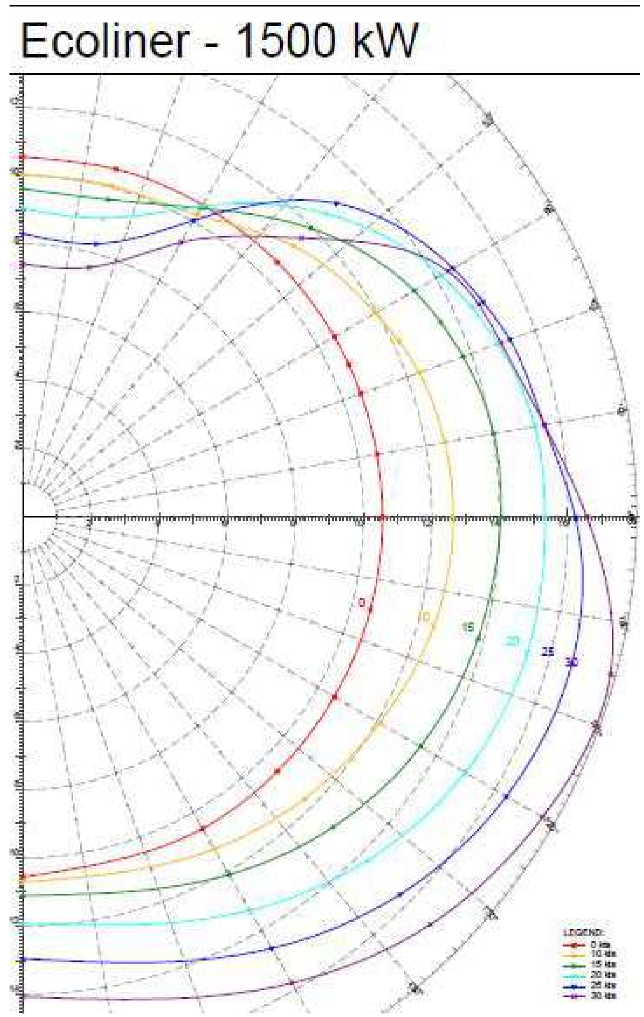
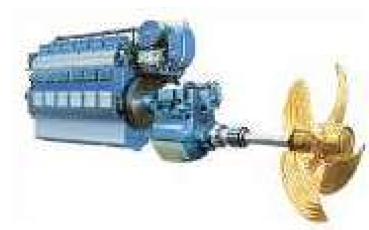
Polair diagram sail and selected thrust







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WEATHER ROUTING DNA

- Existing weather routing programs:
  - Sail only
  - Sailing, minimum speed
  - Motor only
  - 2012: DNA motor sailing
  - New in 2021: DNA power re-generation

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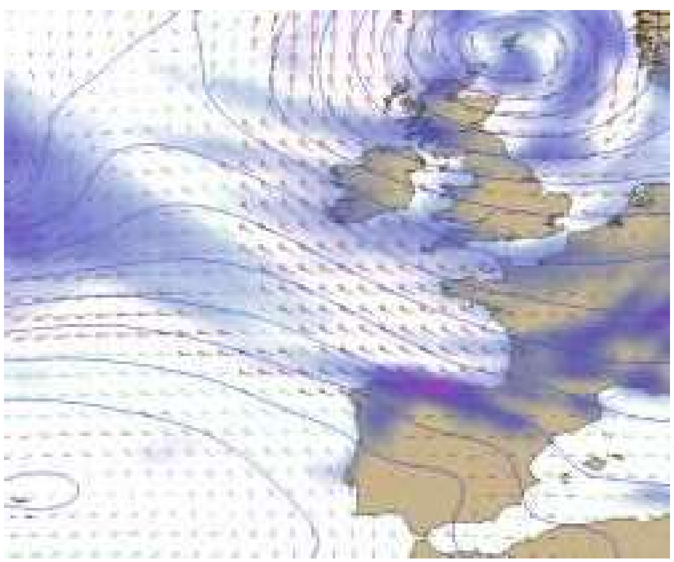
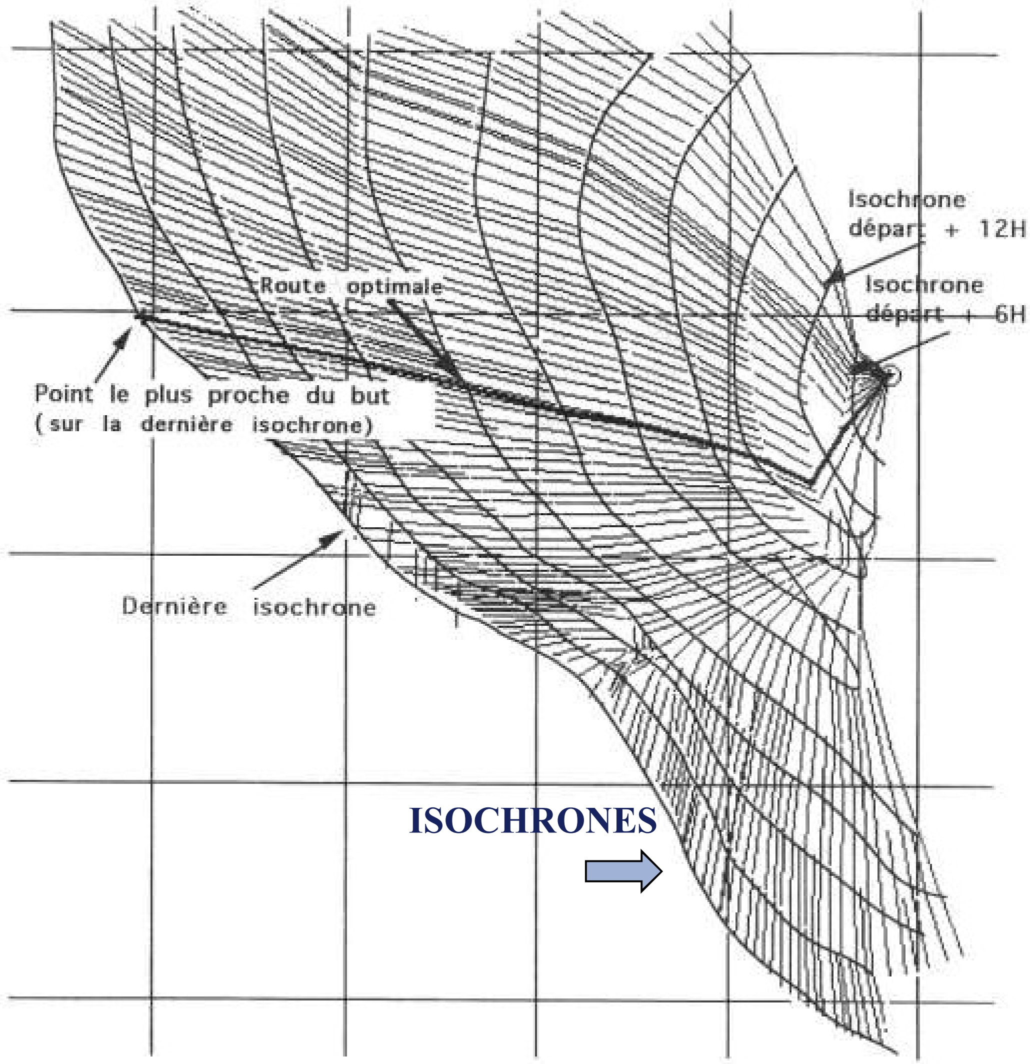
WEATHER ROUTING BASED ON ISOCHRONES
SINGLE OBJECTIVE

- wind info grib files
  - VPP





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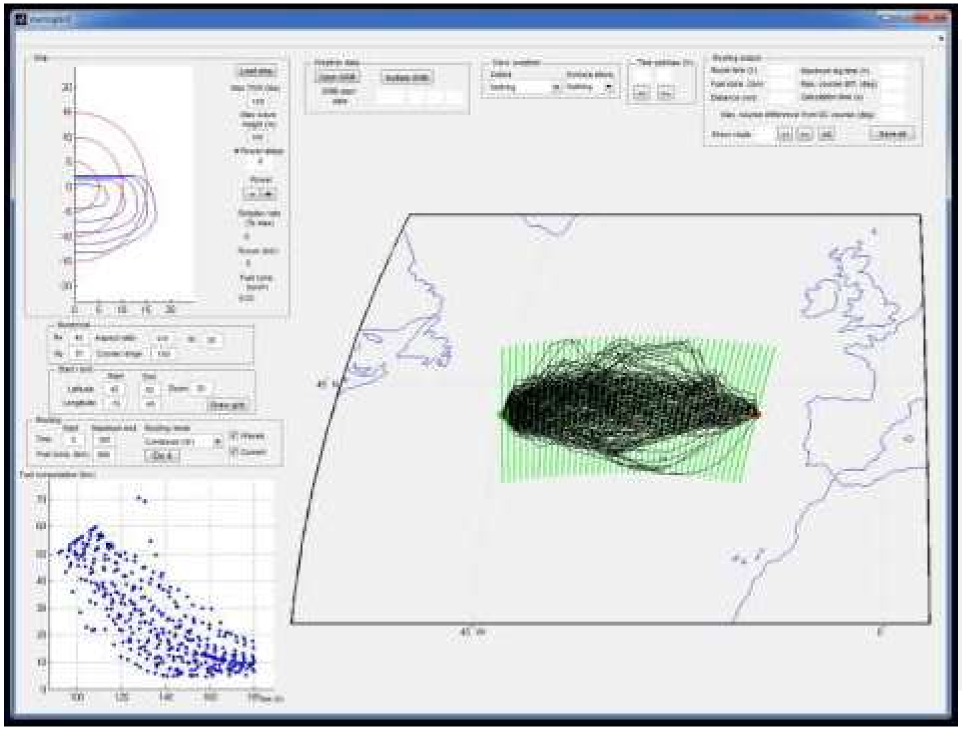
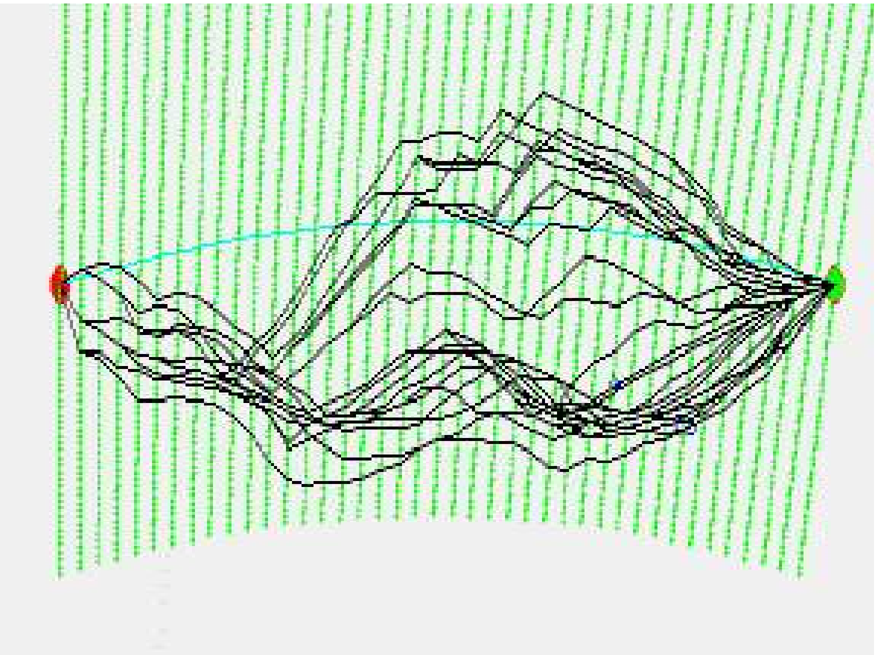
2000 onwards ROUTING FOR MOTOR SAILING
GRID CALCULATIONS, MULTIPLE OBJECTIVES
2012 MULTIPLE ENGINE SETTINGS





DYKSTRA
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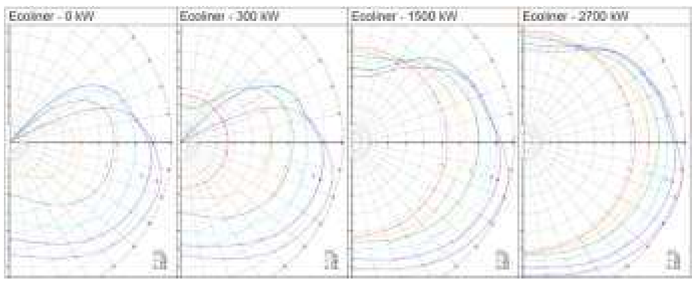
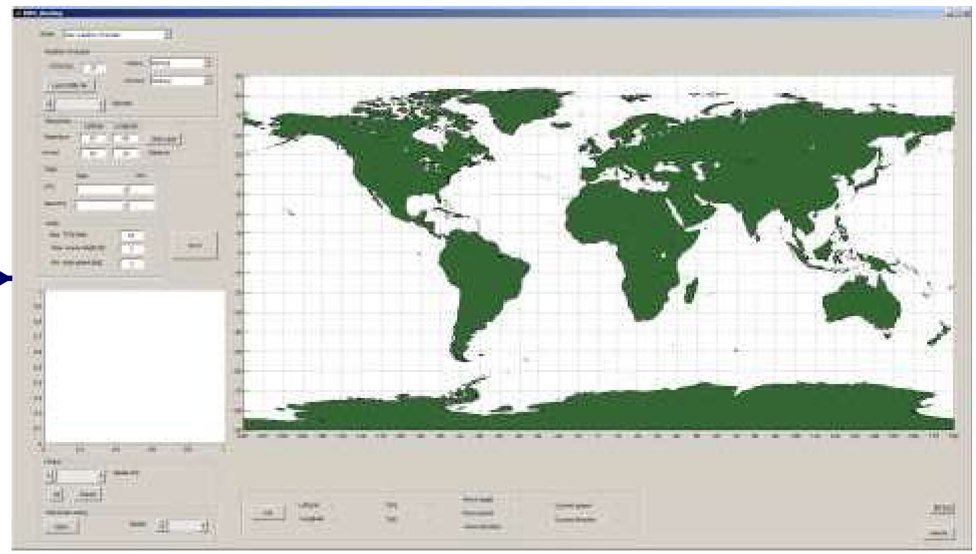
Weather Routing Program input of:

1. Weather information

2. Ship performance





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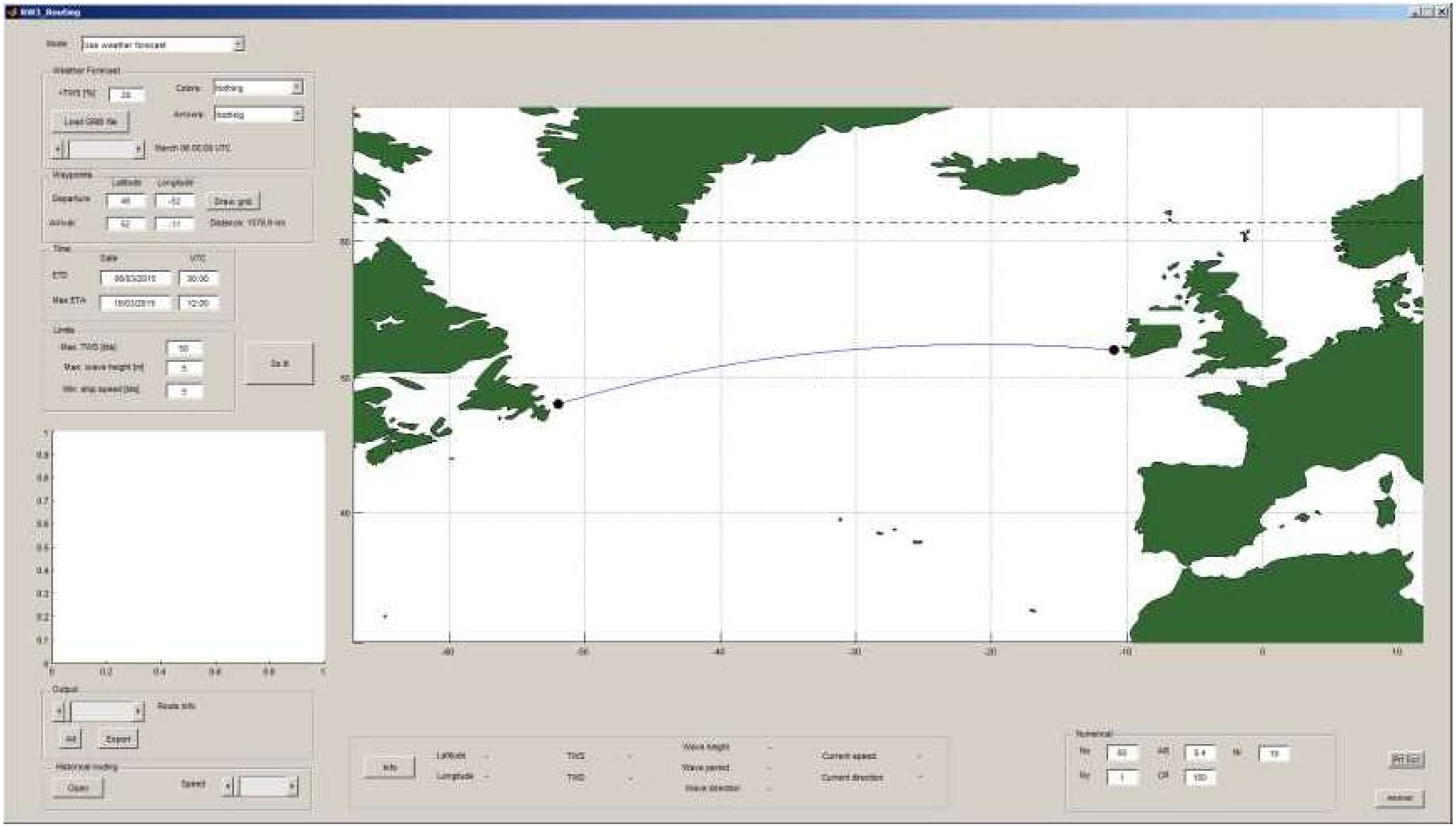
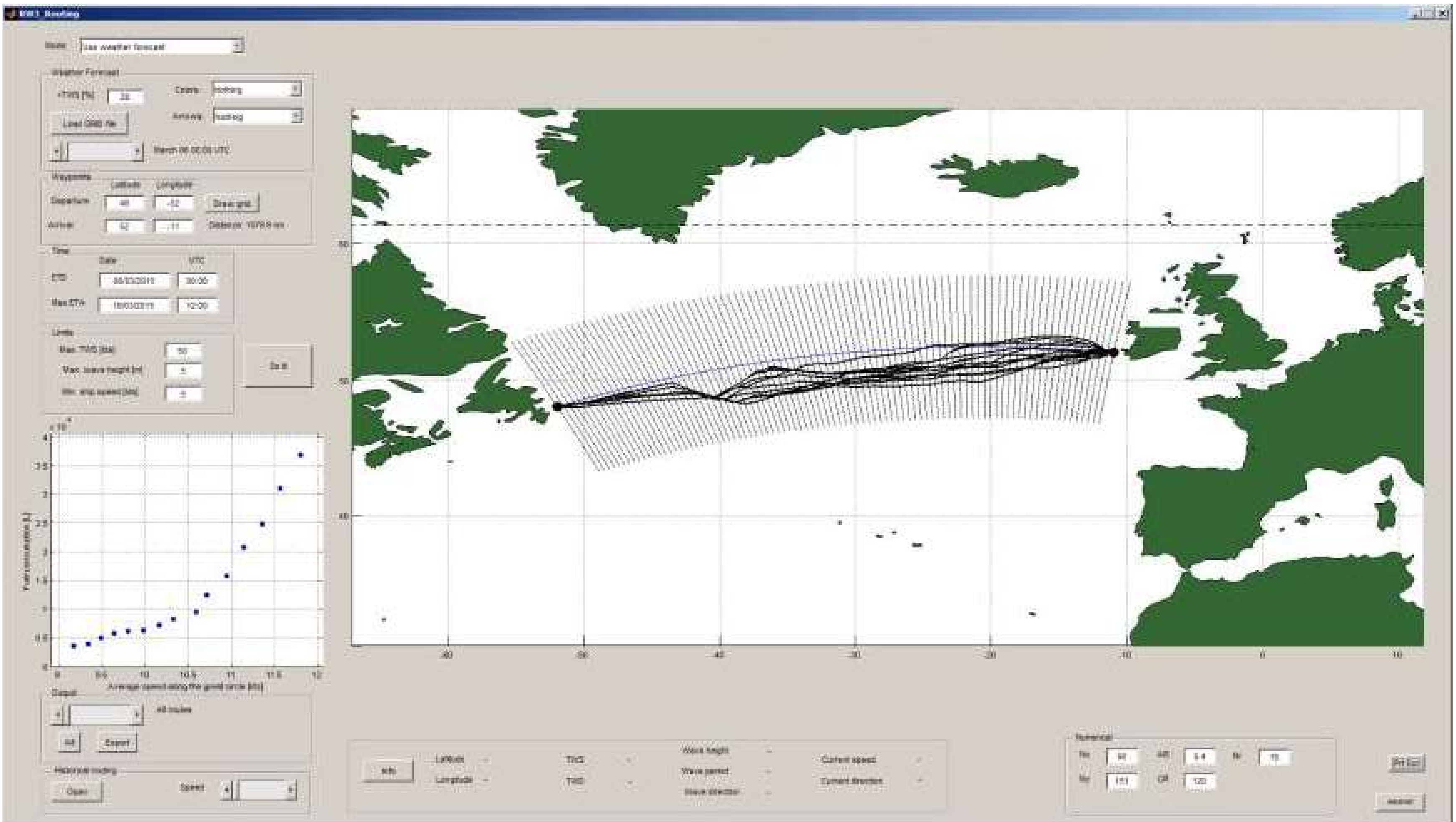
Weather Routing Program selection of route



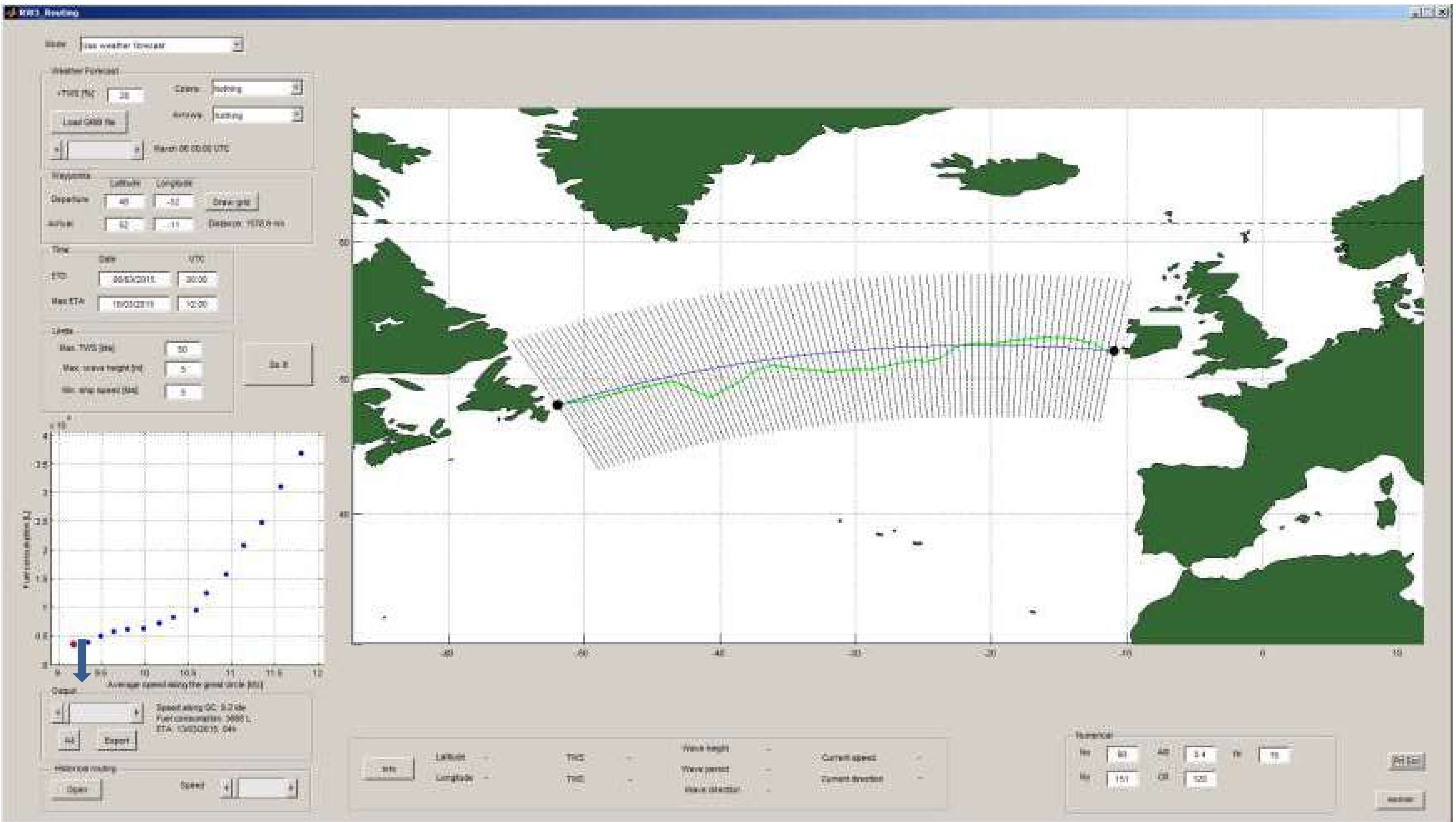
DYKSTRA NAVAL ARCHITECTS

Weather Routing Program optimum routes calculated for a number of selected passage times

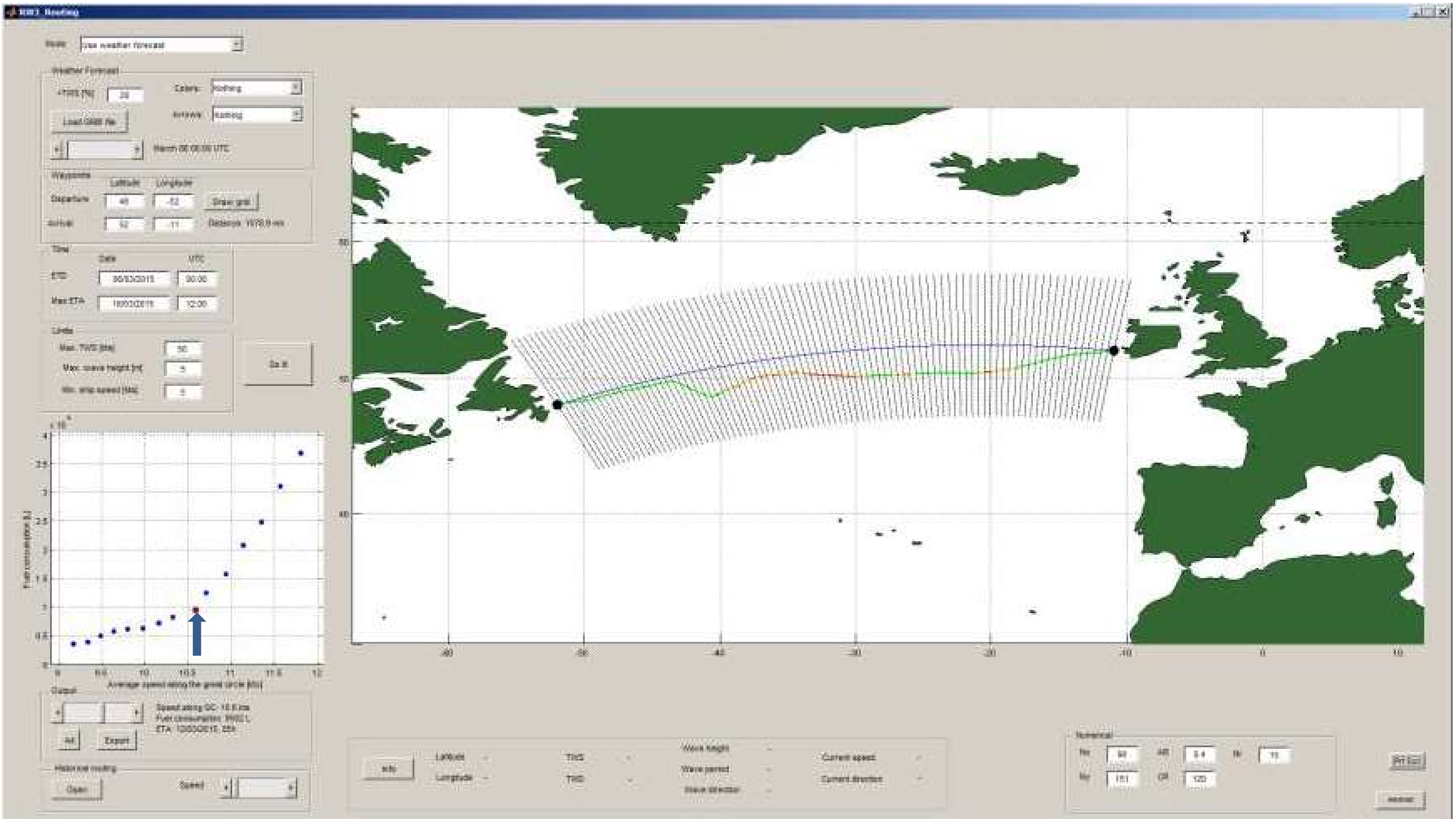


DYKSTRA
NAVAL ARCHITECTS

Weather Routing Program, optimum route sailing only



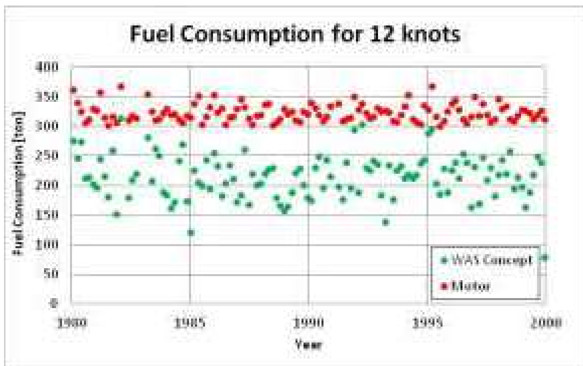
Weather Routing Program, optimum route for a selected passage time using sail and motor

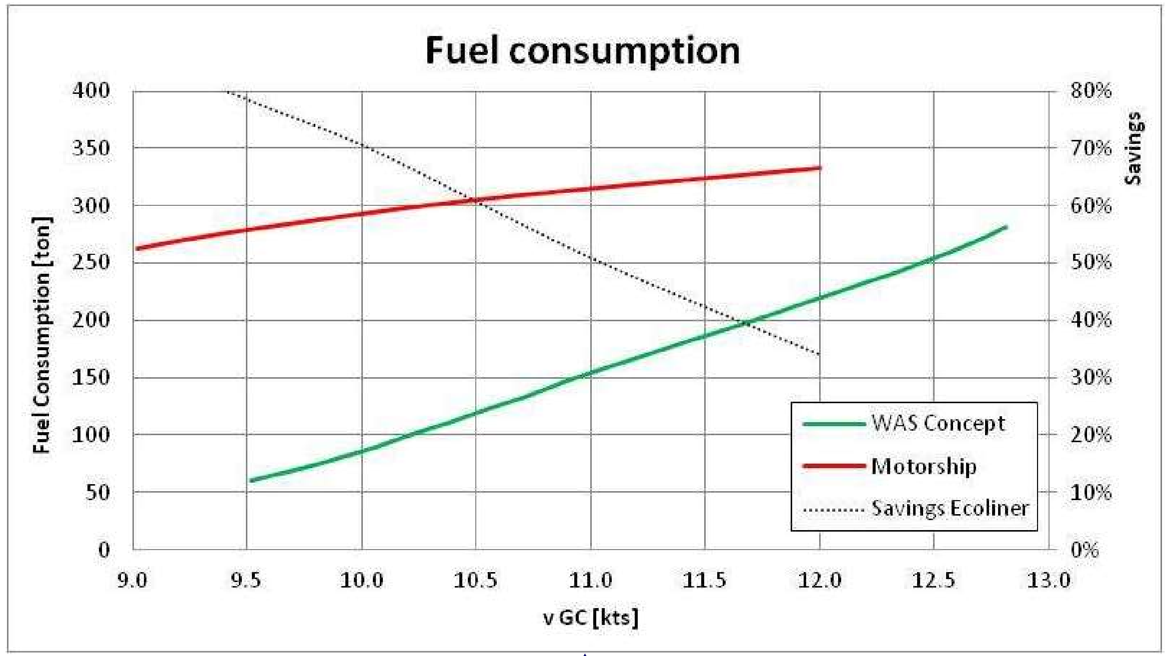


DYKSTRA
NAVAL ARCHITECTS

11 KTS IS A GOOD BOAT SPEED FOR WASP

EXAMPLE CALCULATION FOR A 8000 DWT ECOLINER





Average over 20 years for all speeds

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POWER RE-GENERATION ROUTE ANALYSIS 2021

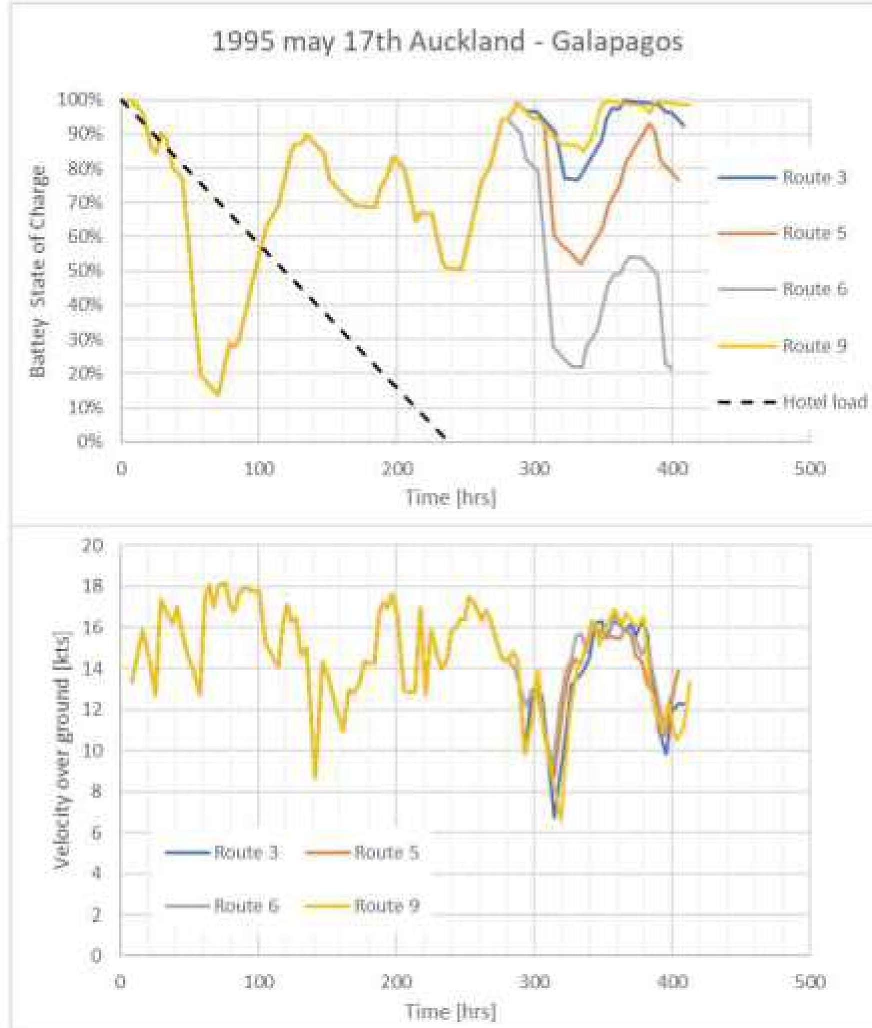
Result for one departure date

Base sails

	Distance	TIME	
	5300 nm	hrs	days
Average Boatspeed	9	589	24.5
	10	530	22.1
	11	482	20.1
	12	442	18.4
	13	408	17
	14	379	15.8
	15	353	14.7

ENERGY CONSUMPTION

AVERAGE SPEED



DYKSTRA NAVAL ARCHITECTS

TRANSITION AND BARRIERS

Why, after all those years, is there hardly any WASP ship operational.

1. CE STUDY 2019, GLOBAL :
   - TRUSTED INFORMATION ON THE WASP TECHNOLOGIES, BOTH CONSTRUCTION, COST AND PERFORMANCE CALCULATIONS
   - INCENTIVES FOR CO2 EMISSION, FUEL COST and others
   - ACCESS TO CAPITAL FOR DESIGNING, BUILDING AND TESTING OF DEMONSTRATORS

2. DNA SPECIFIC BARRIERS TODAY:
   - CONSTRUCTION COSTS COMMERCIAL DYNA RIG
   - CREW & MAINTENANCE REQUIREMENTS DYNA RIG & SOFT SAILS
   - DEMONSTRATOR(S) (LACK OF)

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THE FUTURE IS IN MARKETS SUITABLE FOR WASP

	Speed	Ship size in Deep-sea market	Effect rig on cargo handling	Effect on hull shape	Sustainable awareness	Liners	% of Max.
Importance	4	5	3	3	2	4	
Ro-Ro	3	5	5	4	4	5	100
Passenger	3	5	5	3	5	5	99
Chemical Tanker	4	4	5	3	4	4	91
Dry Bulk	5	3	4	3	3	3	80
Specialized Cargo	3	4	4	3	3	3	77
General Cargo	4	3	4	3	3	3	76
Project Cargo	4	3	4	3	3	3	76
Oil Tanker	5	1	5	3	3	2	68
LNG/LPG	1	3	5	2	4	3	65
Container	2	2	2	3	3	4	60
Refrigerated	1	2	2	3	3	4	55

Figure 24 Qualitative comparison of niche markets (Dunné, 2014)

DYKSTRA NAVAL ARCHITECTS

A FINAL NOTE:

WASP ONLY WORKS OPTIMAL WHEN HULL DESIGN AND RIG DESIGN ARE MATCHED.

RETROFIT: SUITABLE FOR LIMITED CONTRIBUTION WASP SYSTEMS

WASP IS NOT A SOLUTION FOR ALL TRANSITIONS TO A GREENER SHIPPING, IT IS ONE OF THE POSSIBILITIES

DYKSTRA
NAVAL ARCHITECTS

Wind-Propeller Sails Proposed For Liners

Air blast from fan turns windmill mounted on model boat, in demonstration at English inventor's exhibit. At right is artist's conception of ocean liner using the wind-propeller sails.

THANK YOU FOR YOUR ATTENTION

DYKSTRA
NAVAL ARCHITECTS

Viability of Bulk Cargo Merchant Sailing Ships

Sergio Perez, Department of Marine Engineering, USMMA

From paper by S. Perez, Chang Guan, Alexander Mesaros and Atil Talay in Journal of Merchant Ship Wind Energy, August 2021

Summary

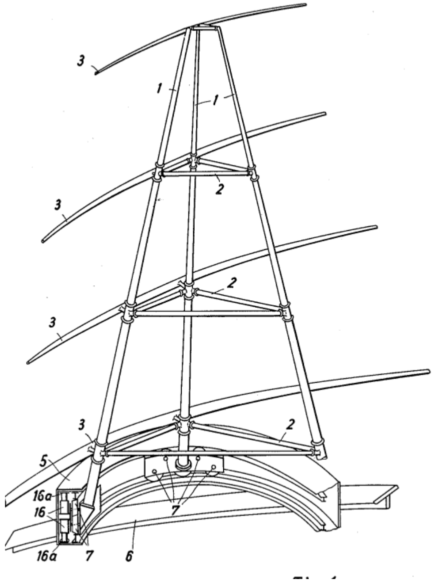
- 1975 Report to MARAD: bulk cargo merchant sailing ships <u>not</u> commercially viable compared to steam vessels
- We update the 1975 Report and find the opposite is now true.

Prior work:

1 

Engineer Wilhelm Prolss, inventor of the Dynarig sailing ship.

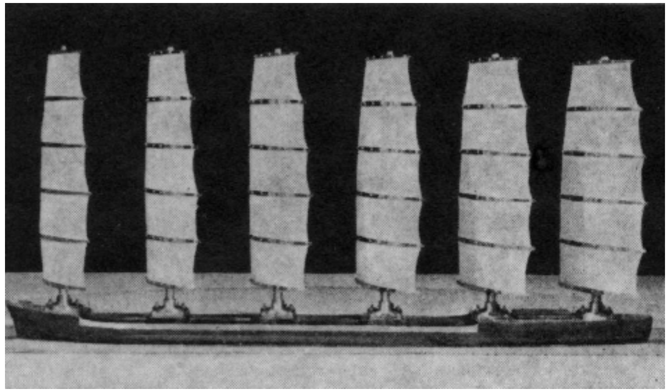
Photo from Sueddeutsche Zeitung, circa 1970.
https://www.sueddeutsche.de/auto/grosssegler-zurueck-in-die-zukunft-1.584119-2

2 

From 1963 Prolss U.S. Patent

Prior work continued:

3 Engineer Von B. Wagner, Technical University of Hamburg



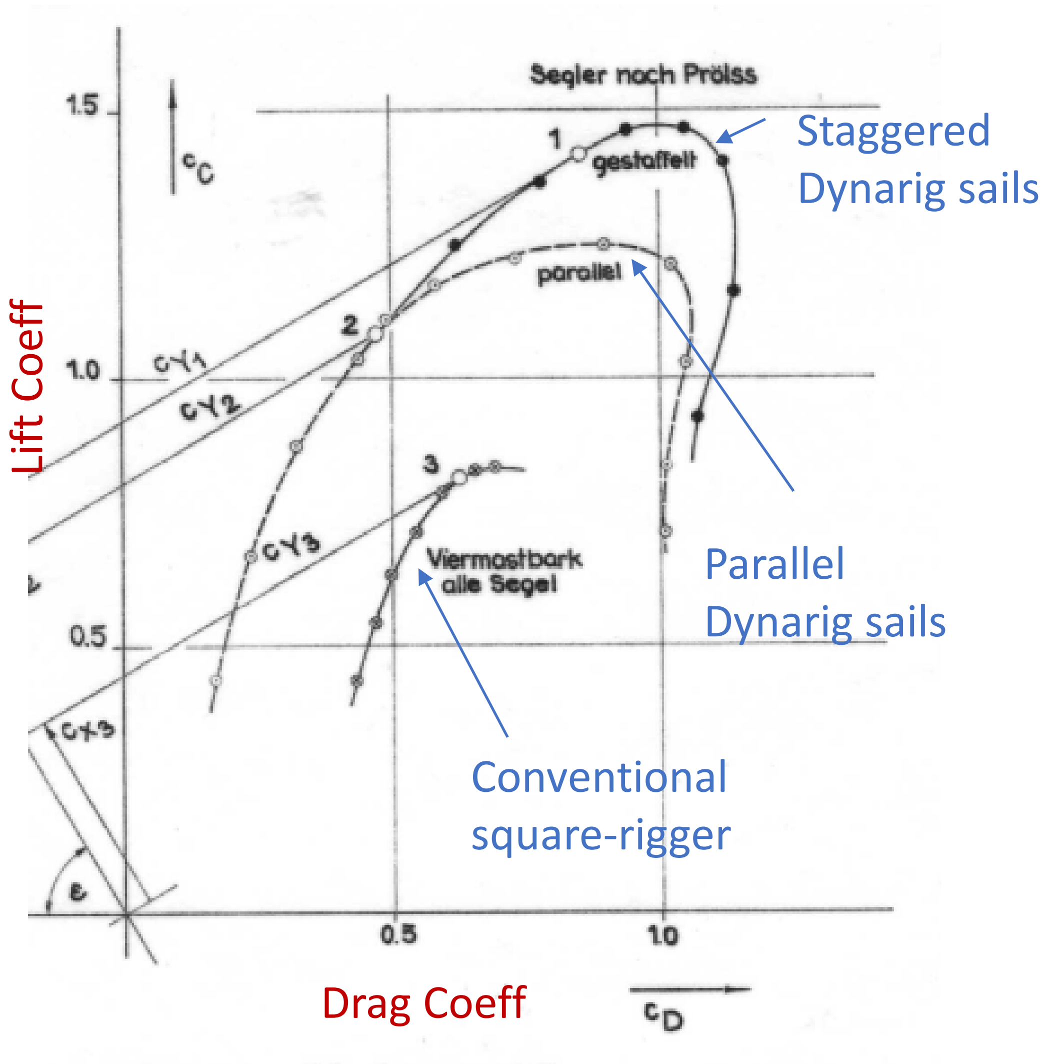


Abb. 8a: ε = 60°

1975 MARAD Report

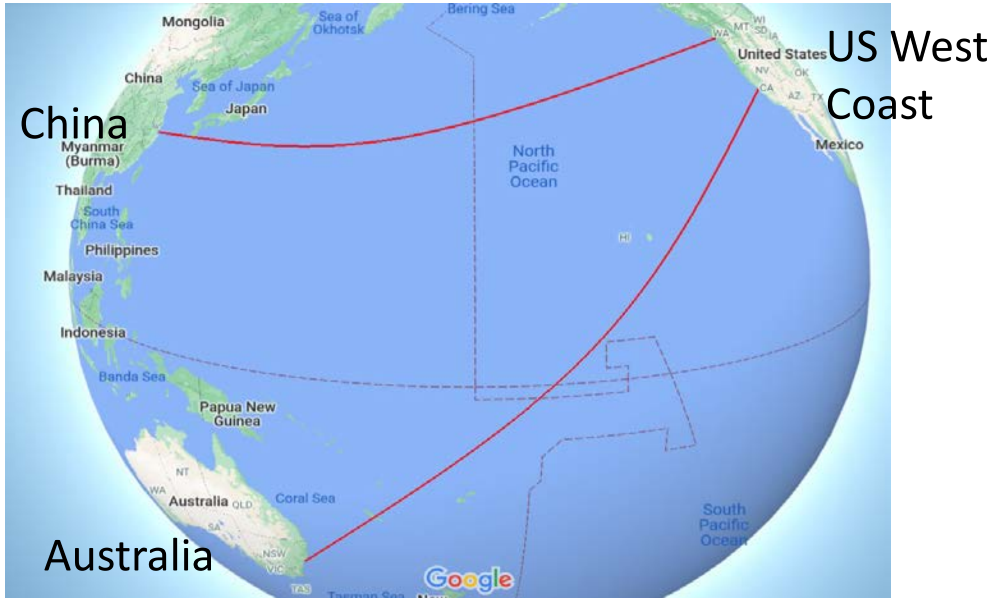
4 Prof. John Woodward, University of Michigan

- Applied Wagner’s data to Dynarig sailing vessels
- 15,000 , 30,000 and 45,000 tons cargo deadweight ships
- Computer Program predicted sailing speeds
- Monte-Carlo routine predicted average crossing times and variance in crossing times
- Compared Required Freight Rates of steamships vs. Dynarig sailing vessels

Photo from University of Michigan web site

Woodward’s 1975 Report:

- Simulated 4 routes:



- Auxiliary engines of 600, 1000 and 1200 HP
- Fuel use strategy: turn engines on if sailing speed < 6 knots
- NY-Liverpool: 29 days R/T (sailing ship 15,000 DWT),

  26 days R/T (sailing ship 30,000 DWT) 25 days R/T (45,000 DWT sailing ship)

Steamship: 21 days

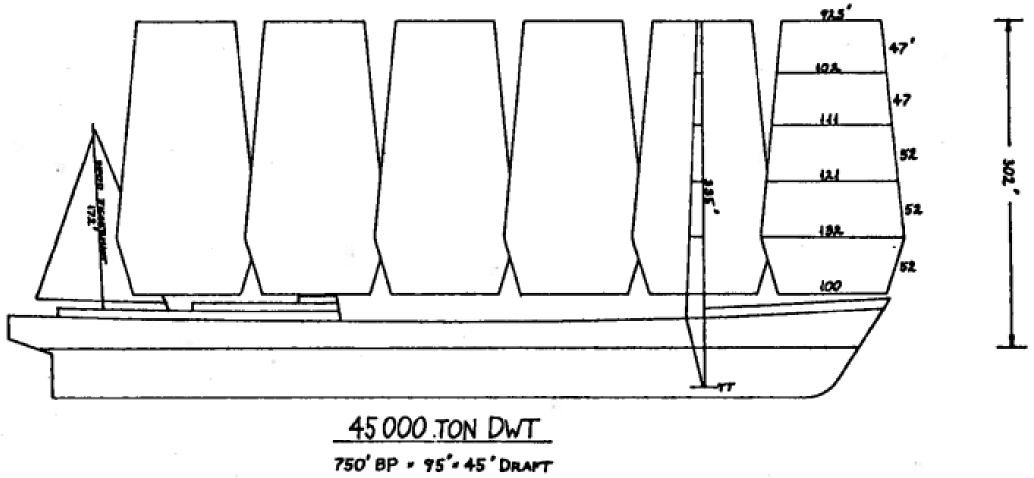
THE VESSELS

Image from 1975 MARAD Report

250 m LOA

Sail area: 16,638 sq. m

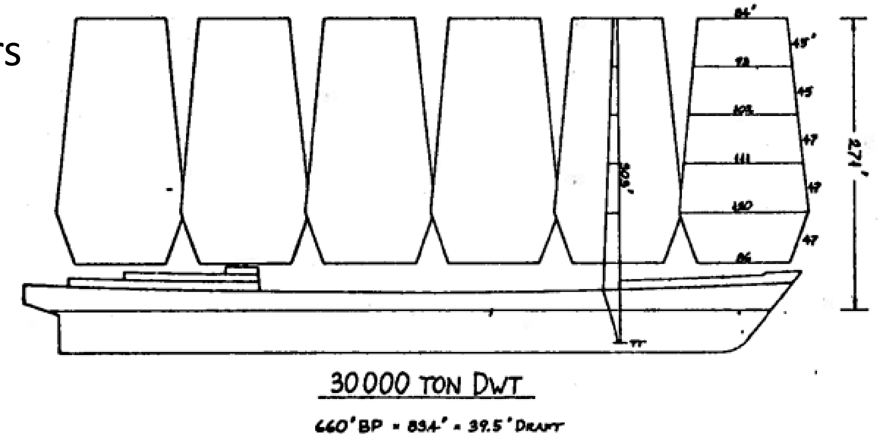
30 crew members (30 steam)



92 m

Sail area: 12,920 sq. m

28 crew members (27 steam)

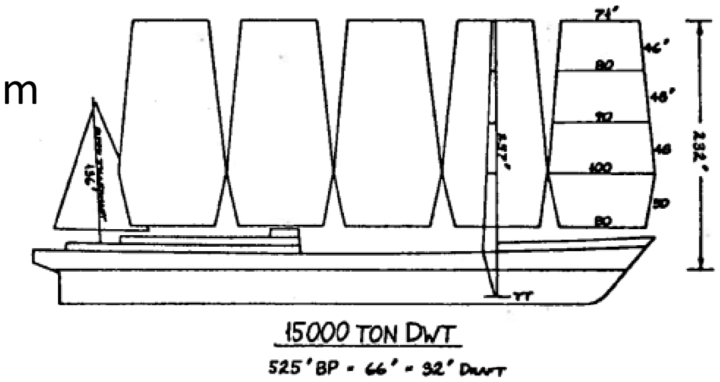


83 m

220 m

Sail area: 8,180 sq. m

28 crew members (24 steam)



71 m

175 m

Result of 1975 MARAD Study: bulk cargo ships sailing vessels had a higher required freight rate (RFR) than engine-driven vessels.

Updating the 1975 MARAD Report:

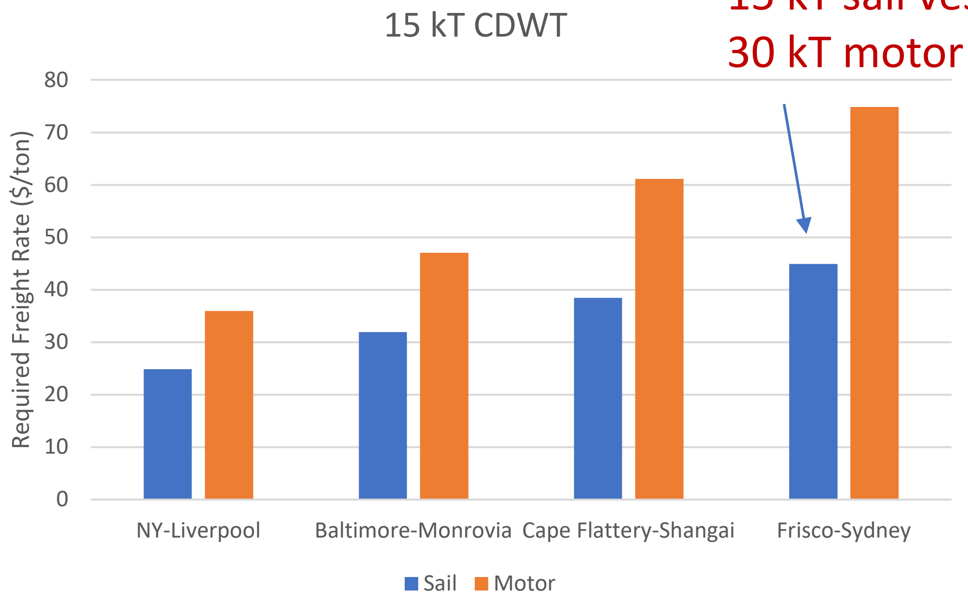
- Use IFO 380 fuel
- Improved fuel efficiency
- Same sailing ship design as 1975 report (Dynarig)
- Chinese manufacture of the vessels, assuming 20% higher construction cost for sailing vessels, as compared to engine-driven vessels. U.S. manufacture also studied.
- Use the 10-year average IFO 380 price ($72/barrel, Rotterdam) to calculate required freight rate (RFR) for sailing and engine-driven vessels.

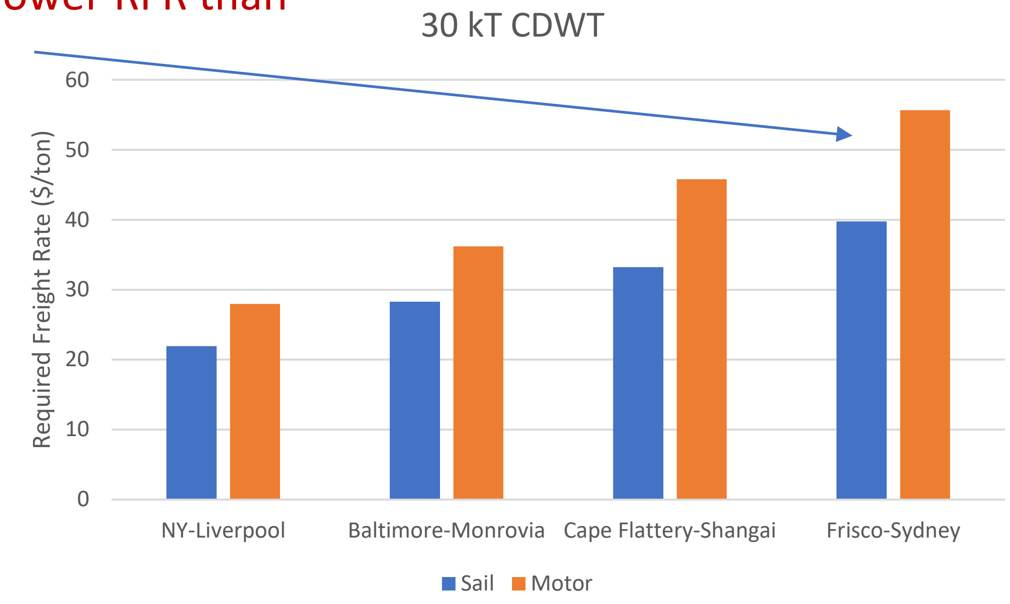
Updated MARAD 1975 Report, continued

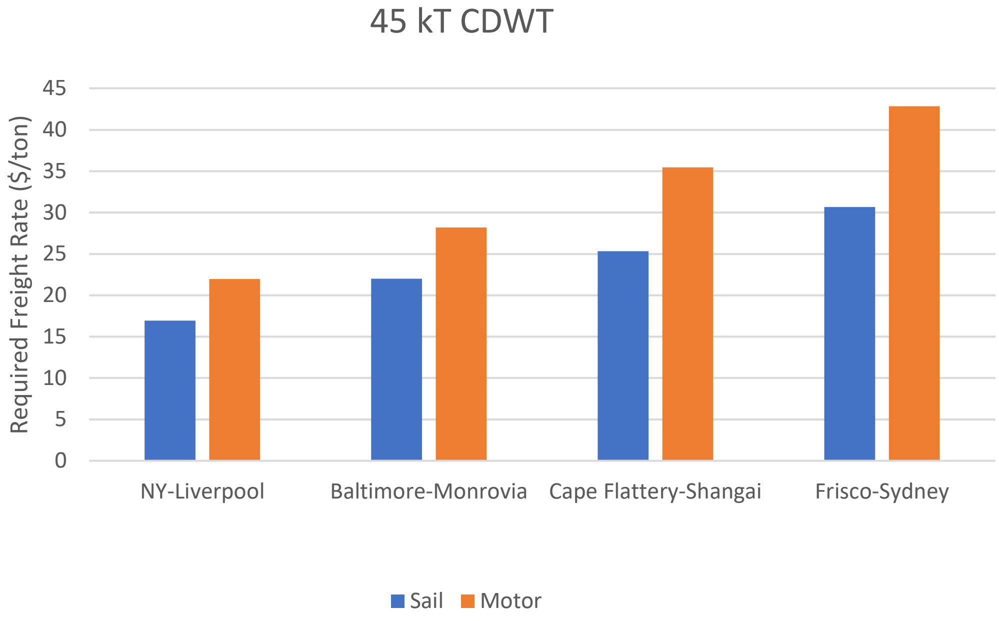
- Updated costs due to crews, sails, stores & lubes, insurance, maintenance and repair, port fees, overhead
- Sails have a 2-year life, with Asian manufacturing cost of \$240K \$379K, \$489K for the 15, 30 and 45 kDWT vessels.
- Engine-driven ship costs: \$11.1 million, \$24.45 million and \$27.8 million for 15, 30 and 45 kDWT vessels, including scrubbers, based on Chinese manufacture.
- US manufacture was assumed 4 times greater cost.

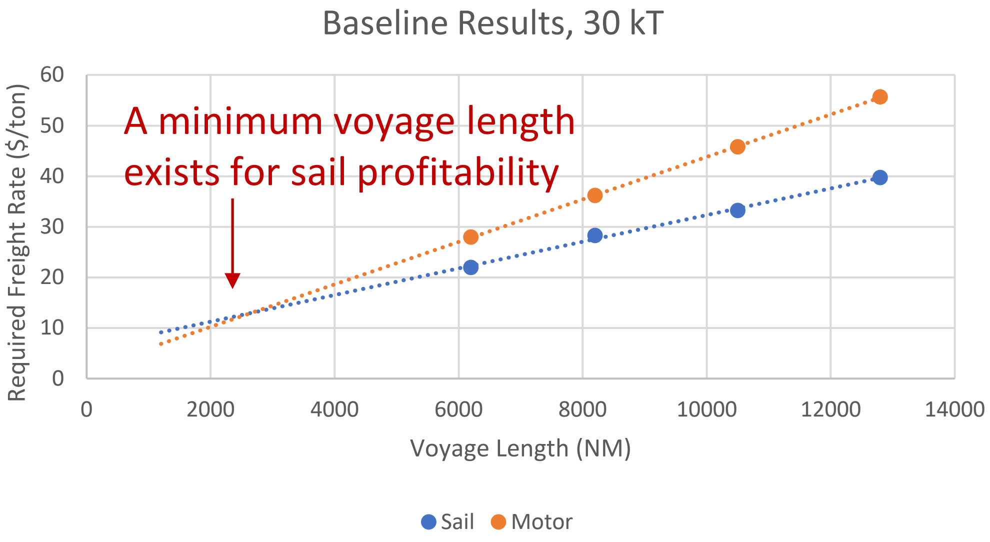
Analysis using IFO 380 10-year av. price, Asian manufacture

15 kT sail vessel has lower RFR than
30 kT motor vessel !



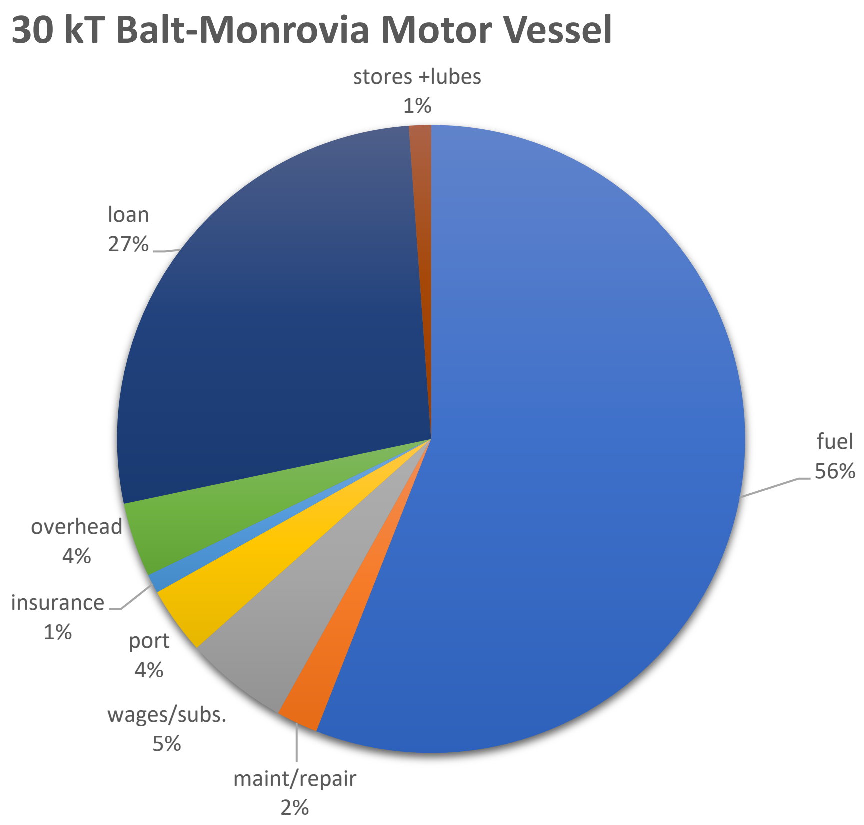


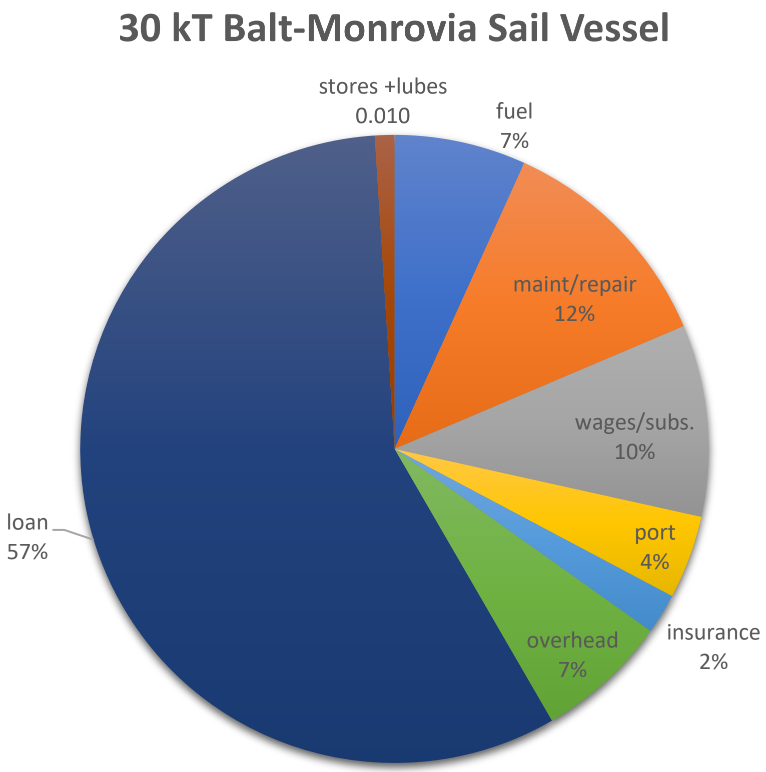




11

What affects totals? (plots based on Asian construction, $72/barrel fuel (recent 10 year-av) and 20% higher build cost for sailing vessel)

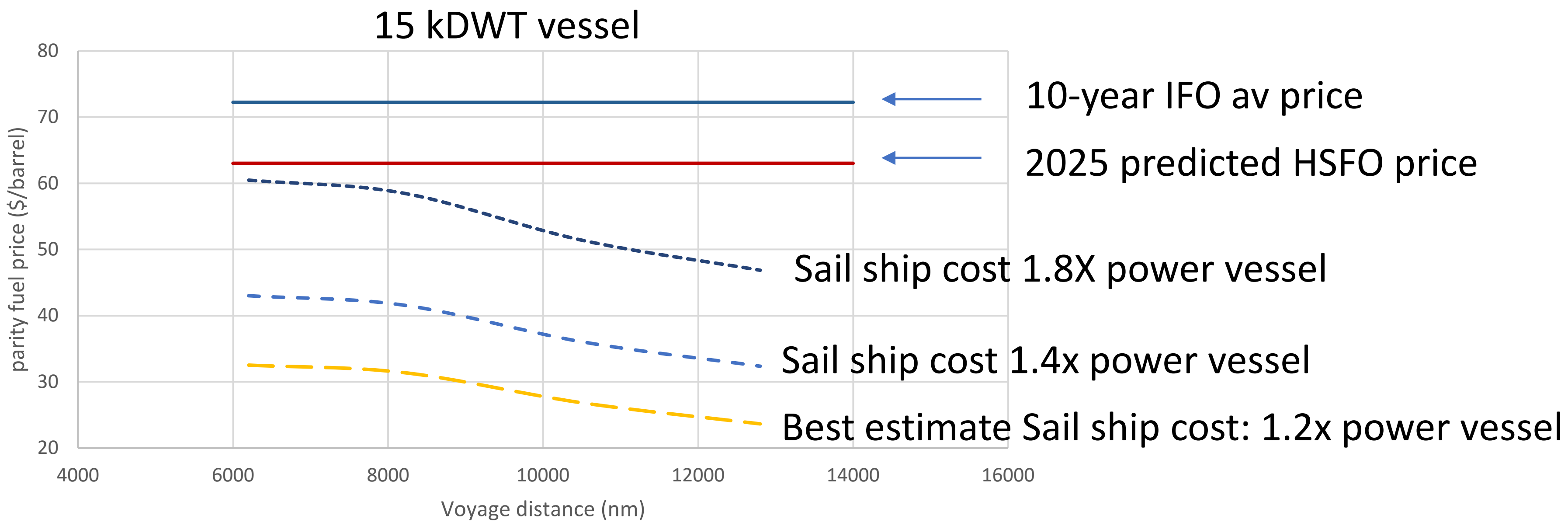


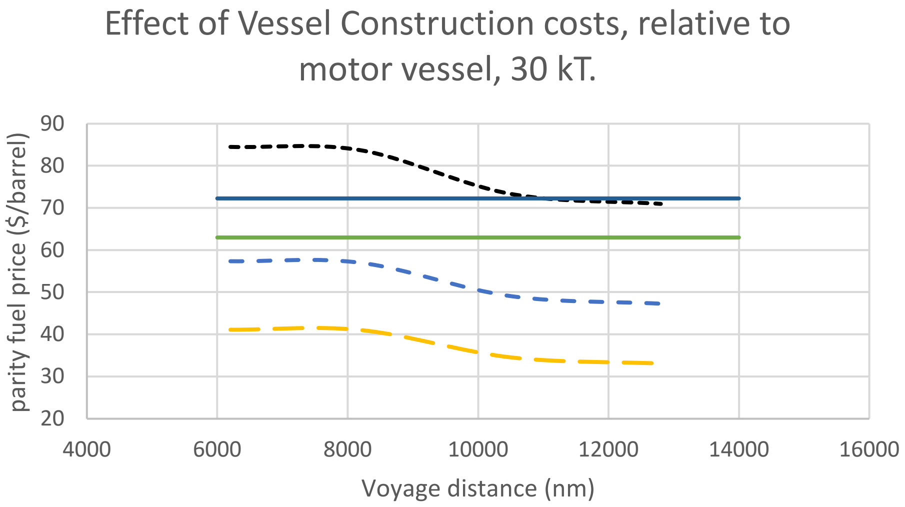


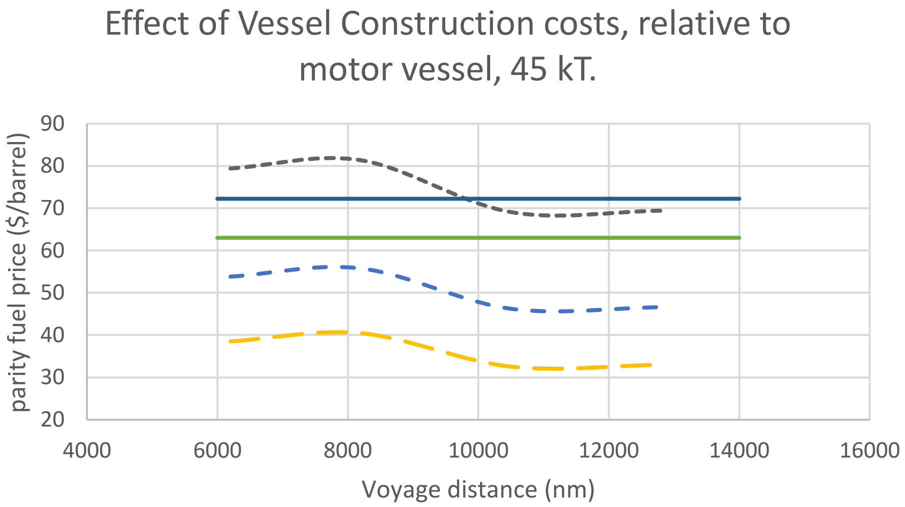
A better way to analyze: the fuel parity price

- Very high fuel prices tend to favor sailing vessels over power vessels
- Very low fuel prices favor power vessels
- At some fuel price between high and low is a price resulting in equal required freight rates (RFR) for both types of vessels. We call this the fuel parity price.
- We calculated fuel parity prices for each voyage and vessel size, and use it to determine at what fuel price the sailing vessel has the economic advantage.
- Fuel prices greater than parity price favor sailing vessels, while those below favor power vessels.

Effect of Vessel Construction Costs : what if estimated sailing ship cost is too low? (estimate is 1.2 times power vessel cost)

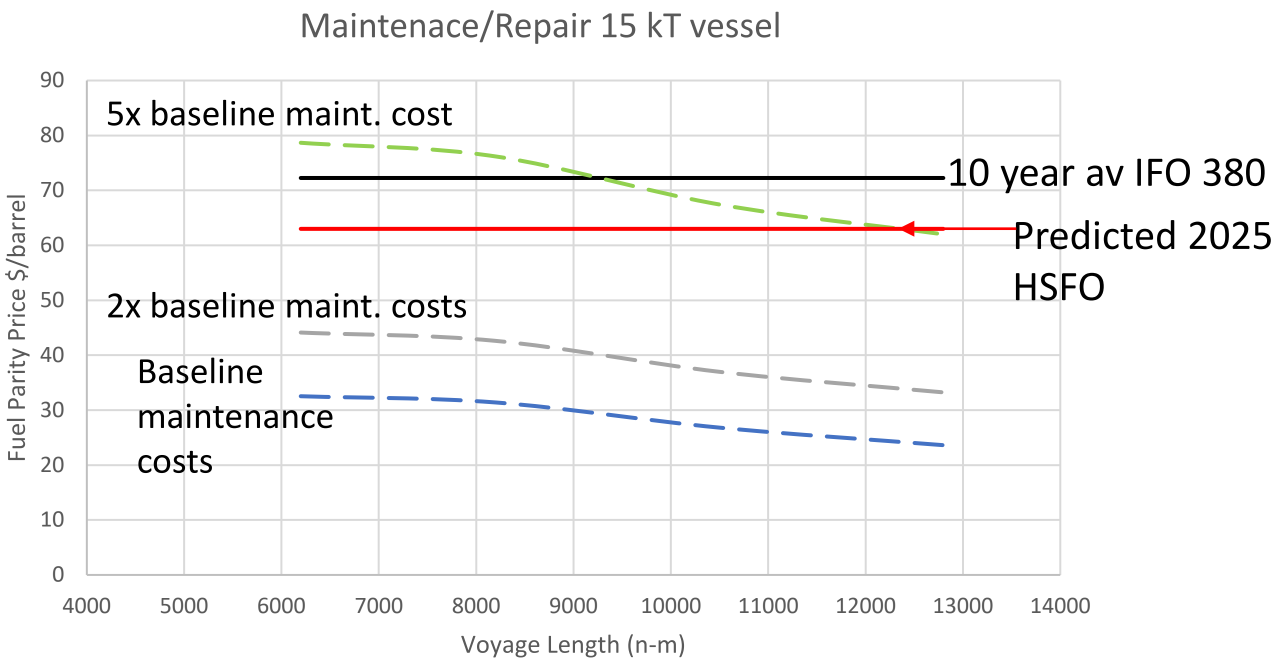






Effect of Maintenance and Repair costs

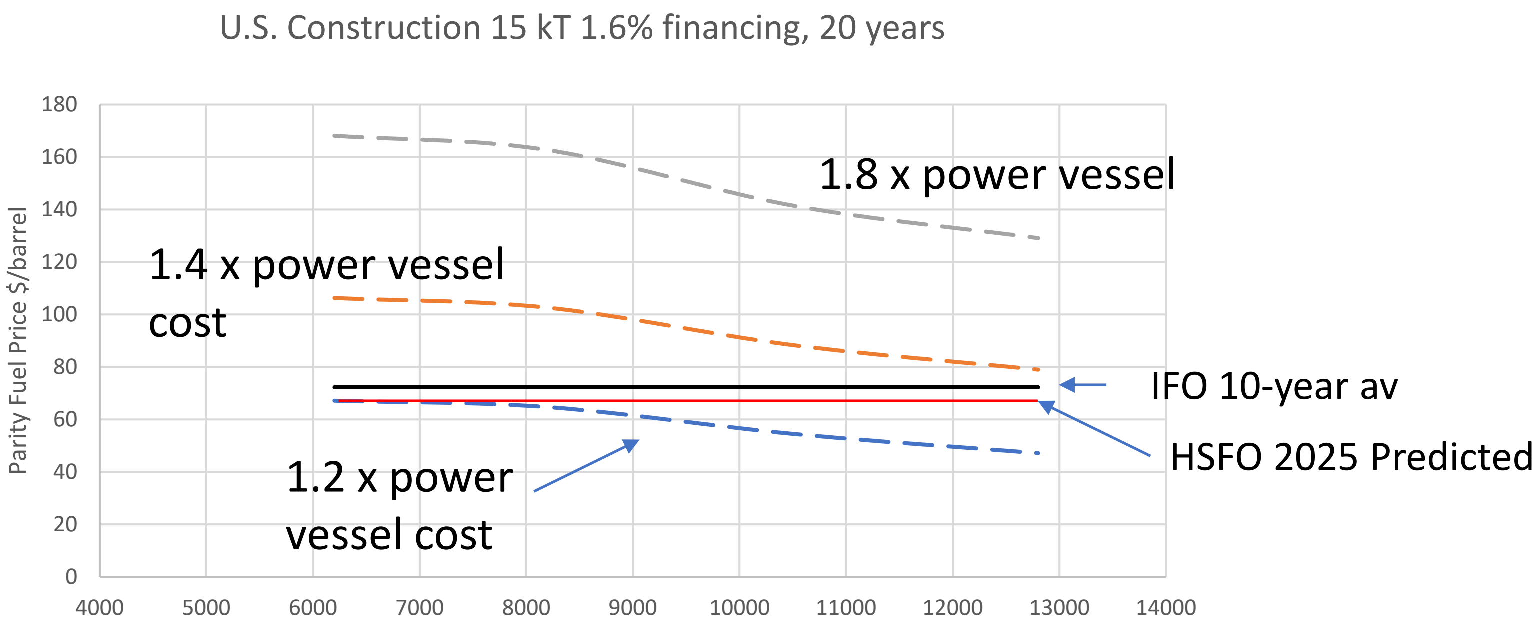
Fuel prices over dashed lines represent sailing vessel advantage



- Maintenance includes sail replacement every two years.

US Construction: 15 kT vessel

Fuel prices over dashed lines represent sailing vessel advantage



With US build, less shield against cost over-runs in sailing vessel build, but still profitable using predicted HSFO prices

Conclusions

- Based on recent-past HSFO fuel costs as well as on predicted prices, it appears that bulk cargo merchant sailing ships between 15,000 and 45,000 CDWT display a significantly lower required freight rate (RFR) than engine-driven vessels.
- The longer the voyage, the greater the advantage for the sailing vessel.
- There is a voyage length below which sailing vessel is no longer profitable.
- Particularly attractive may be the 15,000 CDWT vessel, which has a lower RFR than the 30,000 CDWT engine-driven vessel.
- More complete economic analysis required: round-trip cargo and delay costs considered, as well as port accessibility.
- Folding/collapsing masts or some other alternatives need to be developed to permit access of more ports (due to air draft).

Solutions for the design and operation of wind assisted vessels

Natural propulsion in ship design conference, New York, November 16 2021

About D-ICE

We are a team of 23 PhDs & Engineers aiming to solve real & complex industrial challenges for Maritime & Energy industries.

Main ambitions

Develop & Produce Clean Energy

Reduce Greenhouse emissions

Improve Safety at Sea

Technical & Commercial Partnerships

Multiconsult NUMECA INTERNATIONAL DG Energy

Key figures

- Founded in 2015
- Offices in Nantes & Paris (France)
- Turnover about ~850k€ (2019)
- 15+ clients / 45+ projects
- 100% independent

Hydrodynamics. Robotics. Control Systems. Artificial Intelligence. Software Engineering. Ice Mechanics.

Our Expertise

Wind Assisted Propulsion Engineering & Services
Statistical weather routing
Modelling & Simulation
Control Systems

Dynamic Positioning Services & Engineering
Design, Specifications
Simulations
Commissioning
R&D

Offshore Engineering
Hydrodynamics studies (BEM, CFD)
Modelling & Simulations
Metocean Analysis
Operations Planning & Design

Offshore Wind Engineering
Transport, installation & Maintenance
Modelling & Simulations
Control Systems

Ice Engineering
Design, Modelling & Simulations
Basin Tests & Full Scale Tests
DP & Control Systems

Floating Offshore Wind Engineering
Transport, installation & Maintenance
Modelling & Simulations
Control Systems

Weather Routing Services
Route optimization & planning
Metocean analyzis
Remote support

R&D Engineering & Services
Modelling & Simulations
Applied Mathematics
Big Data
A.I
Computer Vision
Control Systems

Methodologies & Tools for Design

Methodologies & Tools for the Design of WASP

FRyDoM

SATORI

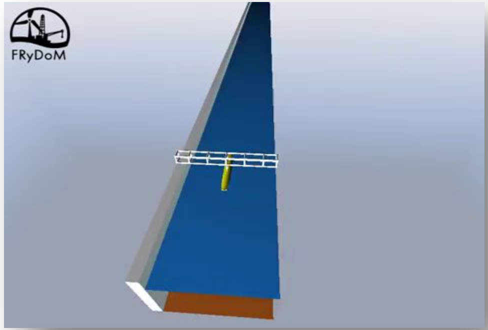
FRyDoM

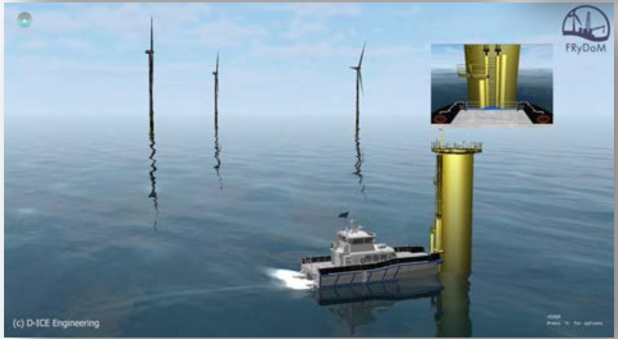
- Project initiated in 2016
- Strong ongoing developments
- Evolutions & Maintenance by D-ICE

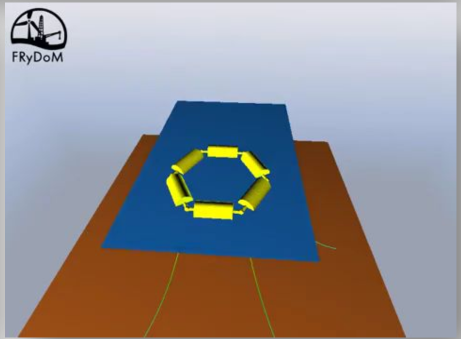
This work was carried out within the framework of the WEAMEC, West Atlantic Marine Energy Community, and with funding from the Pays de la Loire Region

FRyDoM

Physics-based modelling and simulation framework dedicated to complex marine platforms, structures, systems and operations.







Constrained Multibody Dynamics

Advanced Hydrodynamics

Advanced Control Systems

Propulsion & Actuators

Complex Mooring

Embeddable Framework

Python/CMake/C++14

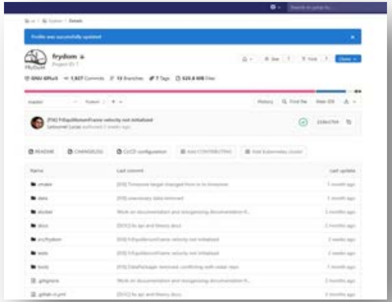
Industrial-Grade Software

Open Source Core & Enterprise Edition

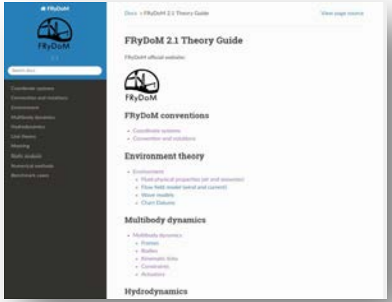
frydom.org
theory.frydom.org
register.frydom.org

FRyDoM

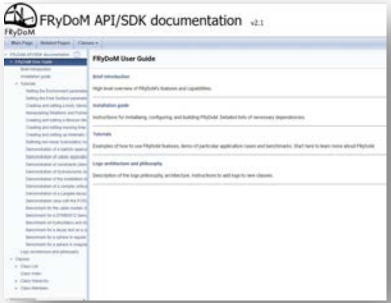
FRyDoM Community Edition (CE)



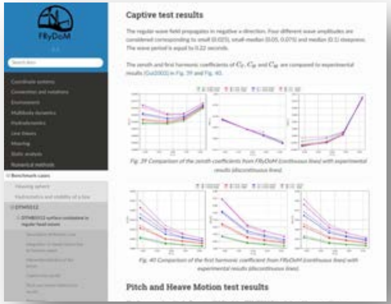
Professional Development Platform (Gitlab)
Frydom-ce.org



Theory Guide
theory.frydom.org



Code documentation (API/SDK)
api.frydom.org

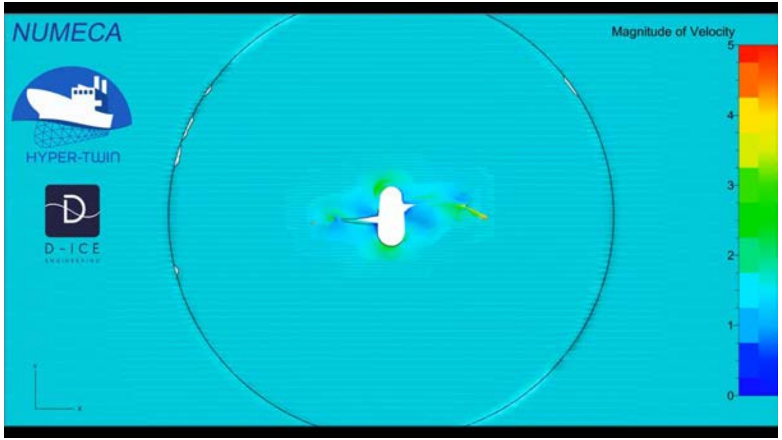


Several automated Benchmarks

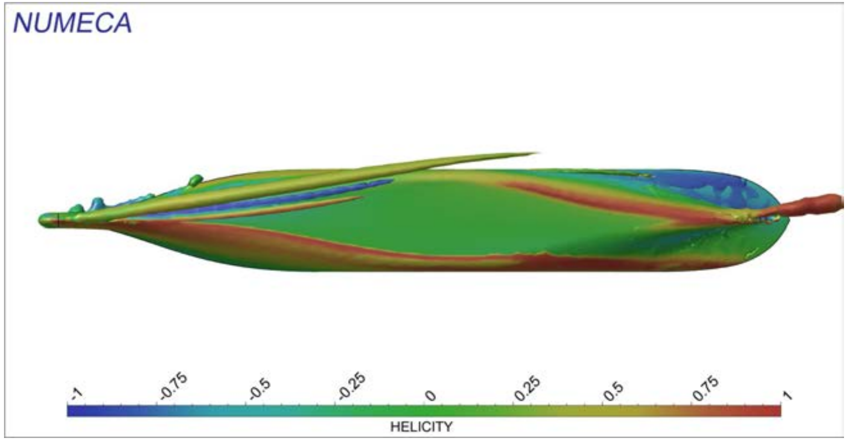
FRyDoM CE
www.frydom.org

FRyDoM

Achieving High-Fidelity - Coupling with CFD (NUMECA Fine^{TM}/MARINE)



Propulsion in strong current conditions



Planar Motion Mechanism (PMM) Simulation

FRyDoM

- Modelling & Simulation of WASP with Rotor Flettners
- Flettner rotors are independent bodies fixed to the ship with constraints and modelling of Magnus Effect
- 3D real-time vizualisation with VIPER

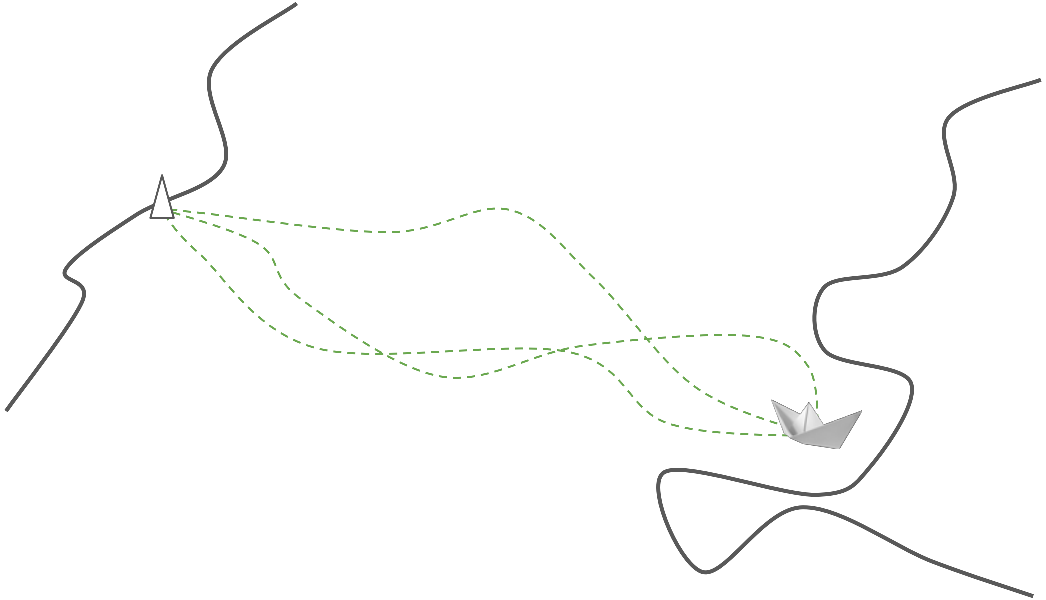
Methodologies & Tools for the Design of WASP

- Better mastering & understanding of the underlying physics is fundamental
- High-Fidelity Modelling approaches are crucial to evaluate
  - General performances of the design
  - Load assessment
  - Ship Stability
  - VPP (Velocity Performances Program)
  - Etc.

But how to assess the concept and maximize the performances (wind assistance, auxiliary power production ...) ?

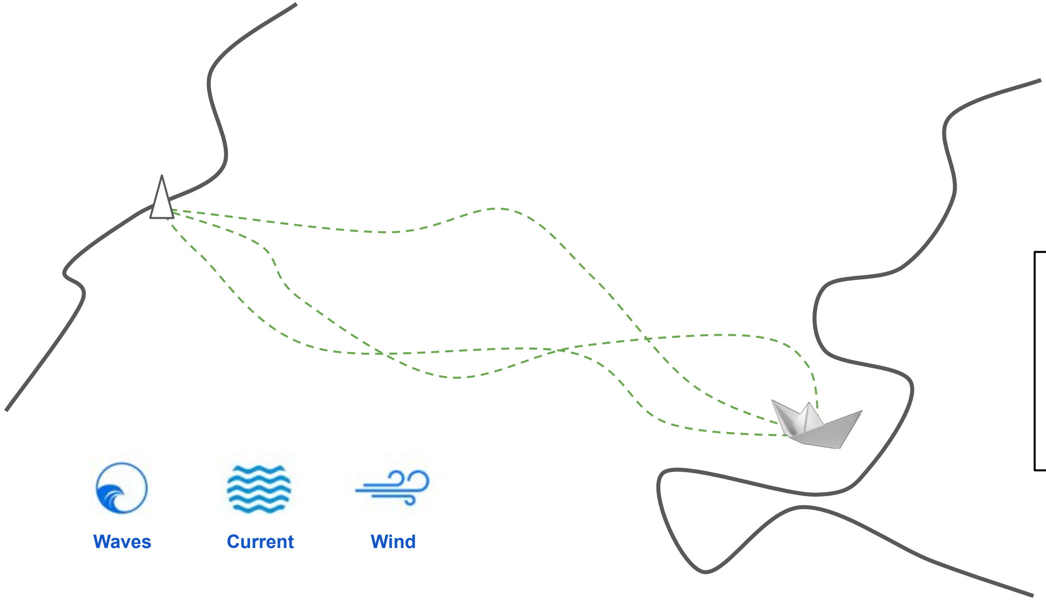
Weather routing - *Generalities*

Problem: Finding the best route or set of routes from a position to another regarding some optimization criterias and constraints



Weather routing - *Generalities*

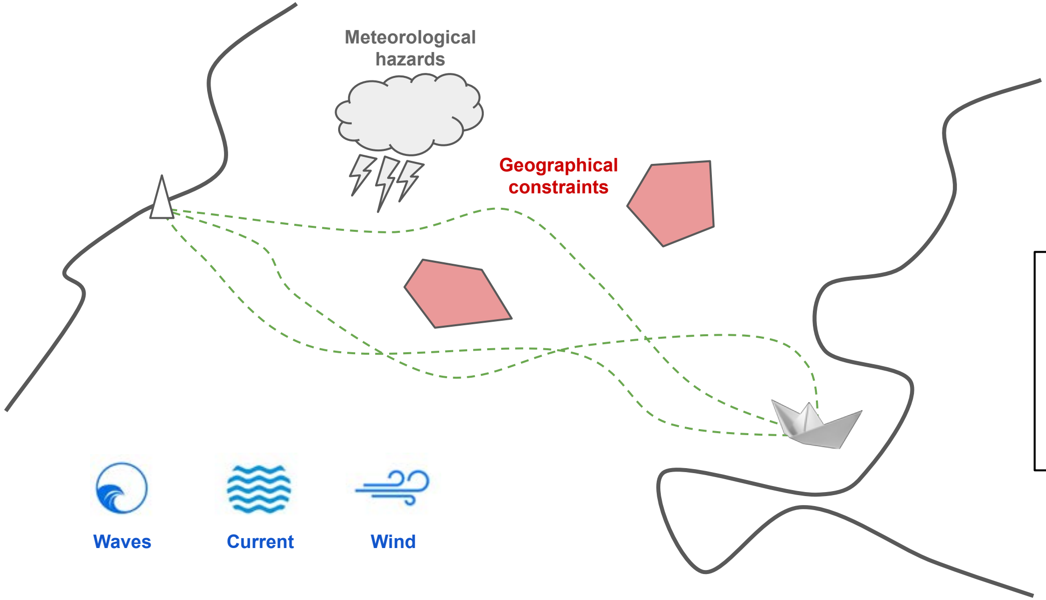
Problem: Finding the best route or set of routes from a position to another regarding some optimization criterias and constraints



- Various environmental fields which strongly impact ship behaviour

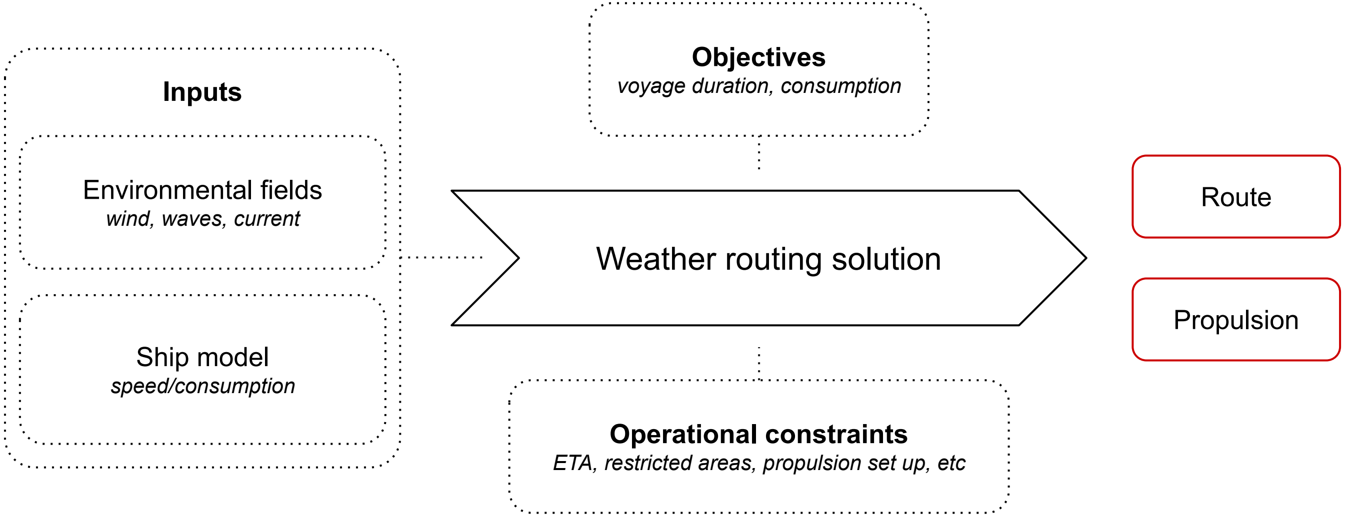
Weather routing - *Generalities*

Problem: Finding the best route or set of routes from a position to another regarding some optimization criterias and constraints



- Various environmental fields which strongly impact ship behaviour
- Many constraints including for safety reasons

Weather routing - *Generalities*



Few observations:

- two different approaches for weather routing of motor ship or sailing ships
- no off-the-shelf solutions for hybrid propelled vessels
- ships becoming more complex needing various constraints and multi-objective optimizations

Weather routing - *Solution*

Approach based on graph theory with last generation algorithms

- mono and multi-objective optimization
- tailorable and flexible
- sailing, motor, and hybrid ships

What led us compute route optimization **with the same solution** for

★ sailing ships

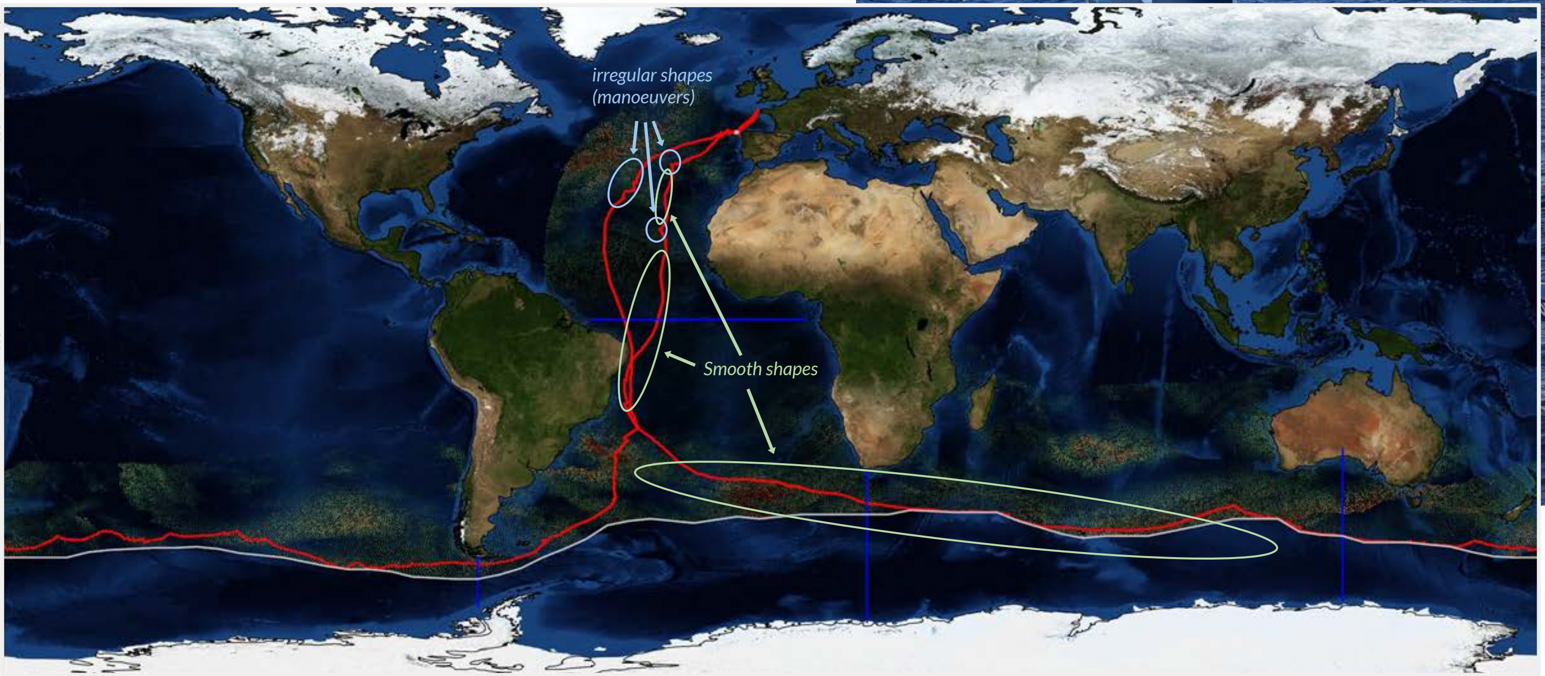
Weather routing - *Solution*

Approach based on graph theory with last generation algorithms

- m
- ta
- sa

What led

★ sa



Weather routing - *Solution*

Approach based on graph theory with last generation algorithms

- mono and multi-objective optimization
- tailorable and flexible
- sailing, motor, and hybrid ships

What led us compute route optimization **with the same solution** for

★ sailing ships
★ conventional ships

Weather routing - *Solution*

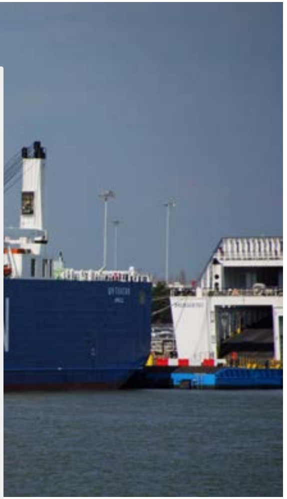
Approach based on graph theory with last generation algorithms

- mono and multi-objective optimization
- tailorable and
- sailing, motor

What led us compute

★ sailing ships

★ conventional



Weather routing - *Solution*

Approach based on graph theory with last generation algorithms

- mono and multi-objective optimization
- tailorable and flexible
- sailing, motor, and hybrid ships

What led us compute route optimization **with the same solution** for

★ sailing ships
★ conventional ships
★ hybrid ships

Weather routing - *Solution*

Approach based on graph theory with last generation algorithms

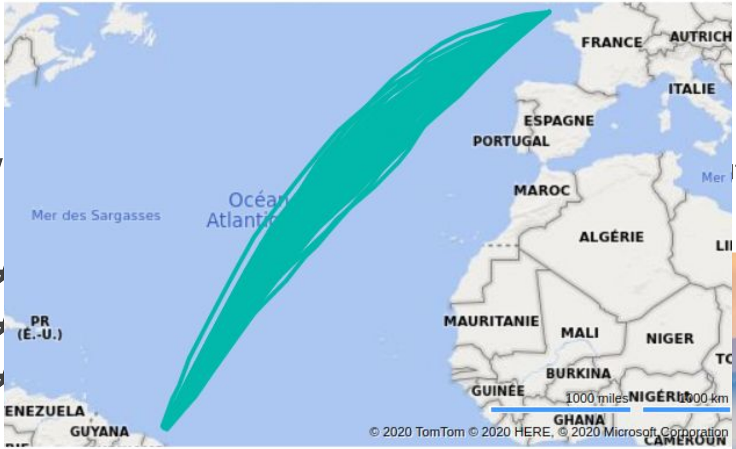
- mono and multi-objective optimization

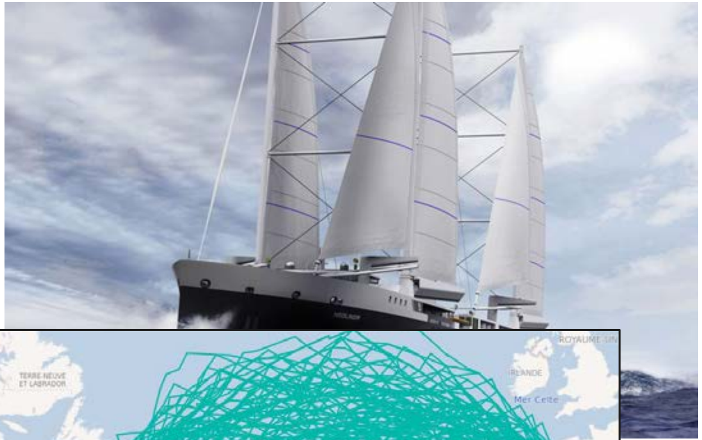
W … tion for

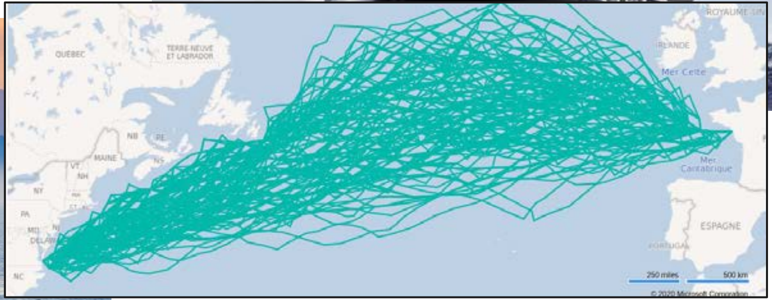
★

★

★







Methodologies & Tools for the Design of WASP

FRyDoM

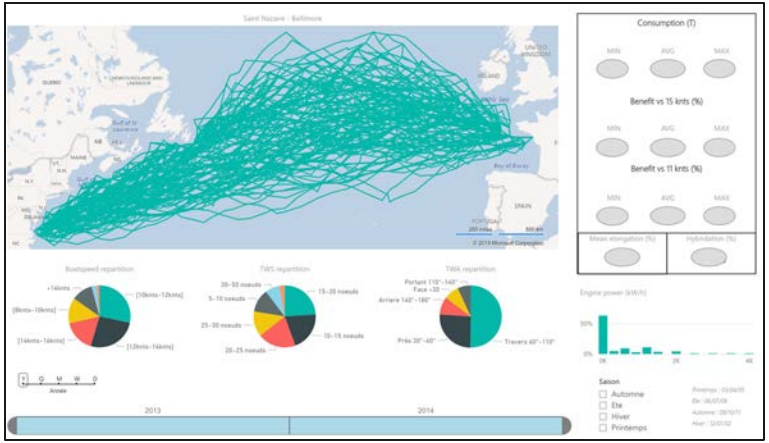
SATORI

SATORI

Propose a solution for **ship owner**, **naval architects**, and **solution developers** to launch statistical weather routing studies by **their own**, online.

From historical weather datas get statistics to:

- Evaluate benefits & payback of a wind assist solution
- Validate your ship performances & associated business model
- Optimize your design

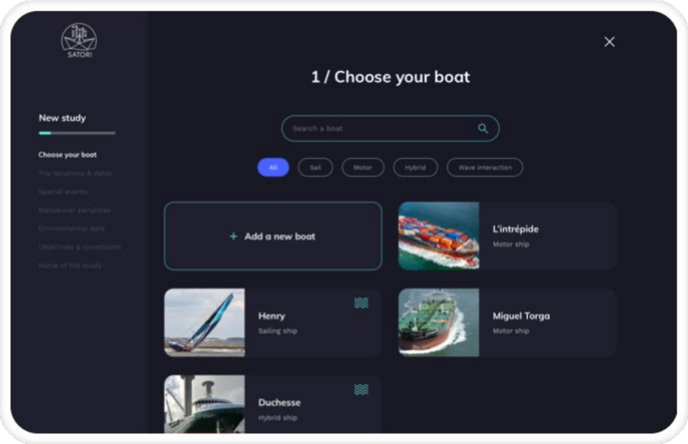


Project duration 18 months
Funded through CMEMS User Uptake Program
Market release: November 2020

SATORI

1. **Define your study** : create an account, upload your ship performance data and submit your calculation

- *mechanical, sailing, or hybrid propulsion*
- *ETA, waypoints, canal*
- *First / Last departure dates and frequency*
- *Manoeuvrer penalties*
- *Polar tables of the ship*
- *Waves speed loss calculation*
- *etc*

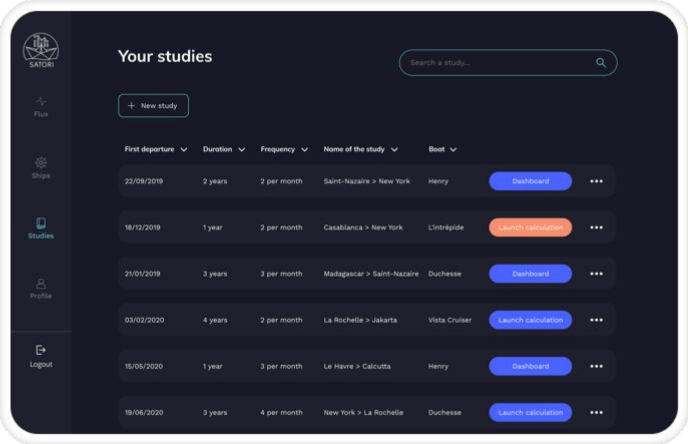


Project duration 18 months
Funded through CMEMS User Uptake Program
Market release: November 2020

SATORI

1. **Define your study** : create an account, upload your ship performance data and submit your calculation
2. **SATORI calculates all optimal routes**

- *Automatic cloud computing and notification at the end*

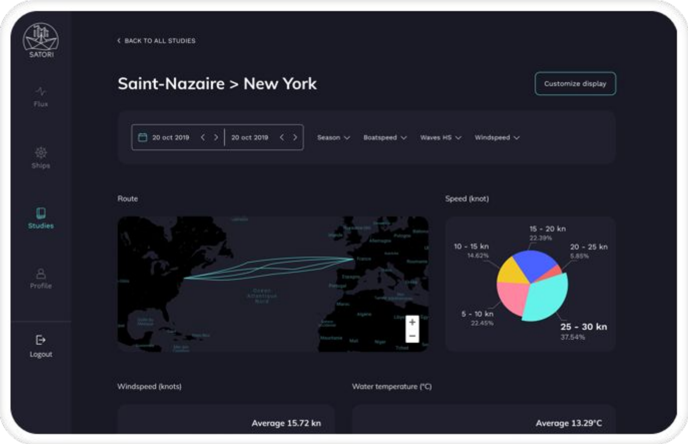


Project duration 18 months
Funded through CMEMS User Uptake Program
Market release: November 2020

SATORI

1. **Define your study** : create an account, upload your ship performance data and submit your calculation
2. **SATORI calculates all optimal routes**
3. **Create your dashboard** : analyze your results through our dynamic visualization

- *Online customization*
- *Various visuals (map, pie chart, bar chart, scatterplots, density map)*
- *Interactive filtering from visuals selection*
- *Share functionality*



Project duration 18 months
Funded through CMEMS User Uptake Program
Market release: November 2020

SATORI

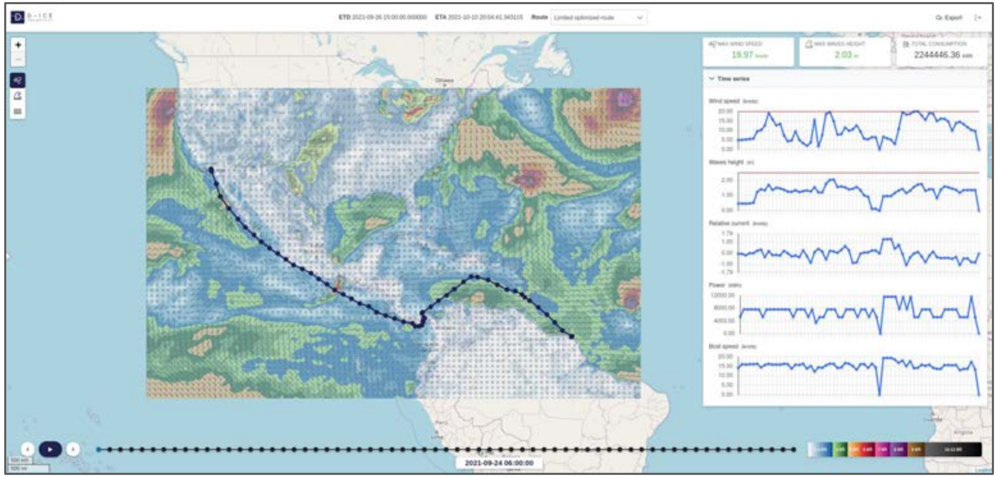
The objective of this service is to make studies cheaper to integrate weather routing during the whole design process

-> Service is operational since november 2020 : **~ 210k computed routes** during last year

Some references on statistical route optimization

Operations

Operational routing

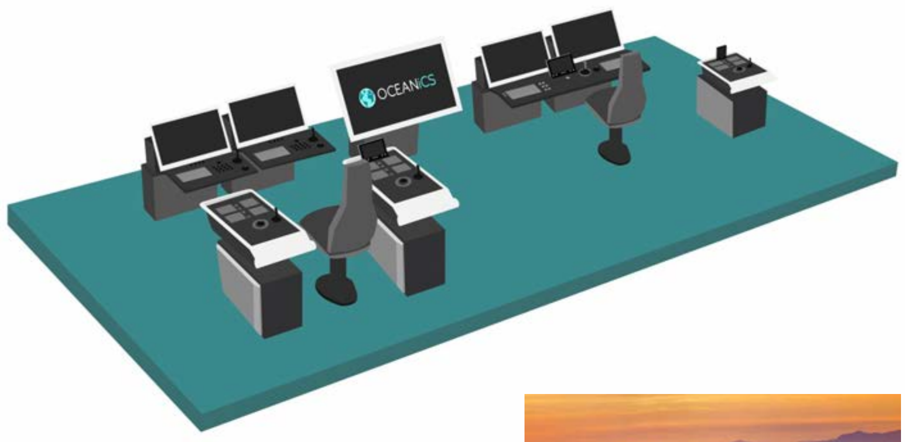


- Optimization of route and engine power
- integration of tailorable constraints (ETA, navigation area, maximum motions, etc)
- Daily tailorable report & dynamic visualization
- 24/7 assistance
- Wind /waves / current environmental fields

About 5 to 10% of fuels savings expected + safety

OCEANiCS

- Cutting-edge Navigation System towards **Autonomy** at Sea
- Full Features
  - ECDIS
  - Conning
  - **Weather Routing**
  - DP & Autopilot & Track Control
  - Sails Management
  - Cameras & Docking Sensors Management
  - Situational Awareness
  - Collision Avoidance
- Tailorable & Evolutive system
- User Centered Design (UI/UX)
- Cost Effective, Sea Proven & Type Approved Hardware
- Cutting-edge algorithms powered by AI, nonlinear control, nonlinear optimization & nonlinear filtering
- Strong ongoing R&D (auto-docking, perception based control, etc.)



Rewarded Innovation

Conclusion

- Improved and cutting-edge tools and methods are crucial for addressing new shipping challenges
- Wind Assistance is a very credible solution in the global picture
- Use of consistant tools, approaches and concept at all stage is mandatory
- Innovative systems will be installed in near future to demonstrate the full performances
- Disruptive concepts (e.g. High Fidelity Digital Twins) are promising for continuous improvements

FRyDoM

SATORI

Real Challenges. True Solutions.

A start up to decarbonize Shipping

November 16. 2021

Wind Support NYC
Webb Institute
SNAME

CONFIDENTIAL

Context

The Company

The Oceanwings system

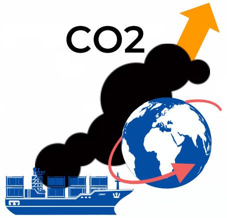
Study and next phases

STRINGENT REGULATIONS TO COPE WITH CO2 ISSUE

SHIPPING AS THE MOST EFFICIENT FREIGHT INDUSTRY, YET POLLUTING

90%
of world trade is carried by the international shipping industry

2050
World trade to **double**



Shipping's CO2 emission to **increase** to
17% (from 11%)
of the world transportation CO2 emission by **2050**

REGULATIONS WILL BE ENFORCED BY IMO

Regulation enforced by IMO INTERNATIONAL MARITIME ORGANIZATION

2020
Sulphur Cap
0.5%
(from 3.5%)
Maritime fuel price to double

2030
-40%
CO2 reduction*

2050
-70%
CO2 reduction*

IMO's shipping CO2 emission regulation adopted by the European Union in Sept-2020

* Requirement per unit compared to 2008 level

WIND PROPULSION NECESSARY PART OF THE ANSWER

AYRO

LEVERS TO REDUCE EMISSIONS

EMISSION SAVING DEVICES

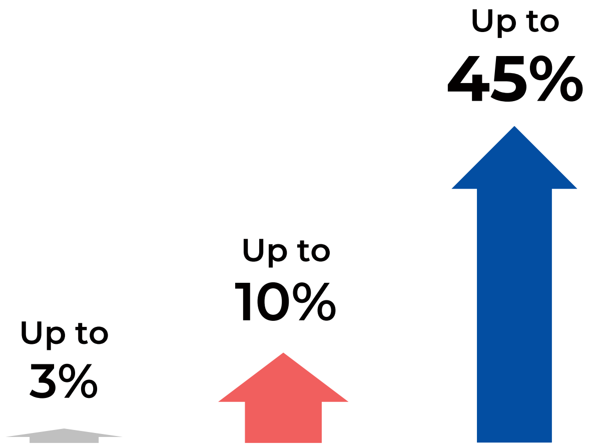
Scrubbers
LNG
Compliant Fuels

FUEL SAVING DEVICES

Energy savings devices

Wind Propulsion System

% OF EMISSION SAVINGS



Source: GLOMEEP (IMO)

“

The use of wind propulsion technology onboard a product tanker vessel could take us to a new playing field.
CTO, Maersk Tankers. MAERSK

Wind Propulsion is part of our Roadmap.
CMACGM CMA CGM

Wind-assist propulsion is one of the few technologies potentially offering double digit fuel savings today.
Lloyd’s Register

WHY IS WIND PROPULSION BACK IN SHIPPING?

SIMULATION TECHNOLOGIES
allow for holistic approach and precise evaluation at design stages

CONTROL TECHNOLOGIES
allow for optimized and safe system behaviour

MANUFACTURING TECHNOLOGIES
allow for realistic design-to-cost approach

Context

The Company

The Oceanwings system

Study and next phases

FROM WINNING THE AMERICA'S CUP TO TRANSPORTING ARIANE 6

2010
America's cup Winner

2016
Prototype

2018-2019
Industrial Demonstrator

2020+
Decarbonation of Maritime Transport

- Wingsail designed for **BMW Oracle Racing**, Winner of the 33rd America's Cup in 2010

- Development in collaboration with **Ademe**
- Extensive testing in 2017

- 2 Oceanwings equip **Energy Observer**, a Zero CO_2 emission ship, sailing successfully for more than 2 years across the seas

- **Canopee**, the 1st modern wind powered ship dedicated to Ariane 6.
- 121m long ship equipped with 4 Oceanwings

AYRO : SPIN-OFF OF VPLP WITH INDUSTRIAL EXPERTISE

BENEFITING FROM VPLP DNA

Single-handed round the world record

The first cargo ship with significant wind assisted propulsion

- Uncompromising on performance
- Design-to-cost know-how
- Customer focus
- Unique talent to innovate in naval architecture

EXPERTISE IN SHIPPING AND INDUSTRY

Expertise in maritime and propulsive innovation

Industrial expertise

- An industrial company gathering talents maritime and competitive industries
- A dedicated structure with appropriate funding
- An agile and visible initiative to catalyze the decarbonation of the maritime transport

AYRO'S MANAGEMENT TEAM

Marc VAN PETEGHEM
Designer and chairman at Ayro
Owner at VPLP Design
World renowned sailing architect and designer
Southampton Institute of Technology

Les Echos
Multicoque
Voiles

Ludovic GÉRARD
CEO
25Y experience in Shipping industry and naval architecture
Ex-Vice President, CMA Ships
ENSTA Paris & Maritime Executive MBA KEDGE Marseille

Giorgio PROVINCIALI
CTO
25Y management in aerodynamics and naval architecture
Head of performance at America's Cup
ENSTA Paris & Politecnico di Milano

Nicolas SDEZ
CSO
6Y management experience with Ayro from scratch
Research experience at Georgia Tech
ENSTA Paris & Politecnico di Milano

Karim EIDO
COO
25Y experience in Strategic development, Performance management & Business development
Ex-Operational Performance Senior Consultant
Ex-Director at Vallourec
Centrale de Nantes & EDHEC Business School

Romain GRANDSART
CBO
14Y experience in Business Development and Finance
Ex Business Developer at ArcelorMittal
Ex-Head of IR and M&A at Aperam
HEC Entrepreneurs Mines de Nancy & ENSTA Bretagne

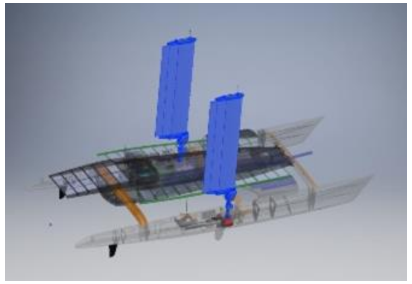
AYRO ACCOMPANIES SHIP OWNERS AND BUILDERS ALONG THE SHIP LIFECYCLE

BENEFITING FROM VPLP DNA

Engineering	Products	Services

Engineering

- Performance and fuel savings simulations
- Integration studies
- New build and retrofit



From design…

Products

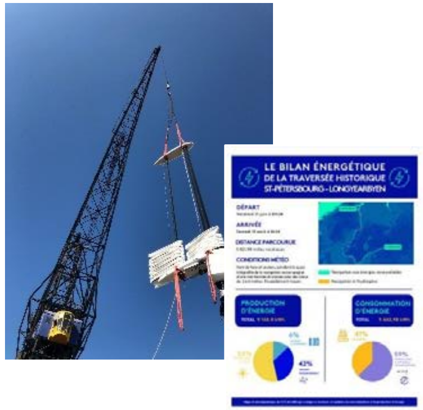
OCEANWINGS

AIUTO

… to solutions…

Services

- Installation & Training
- Maintenance
- Data services



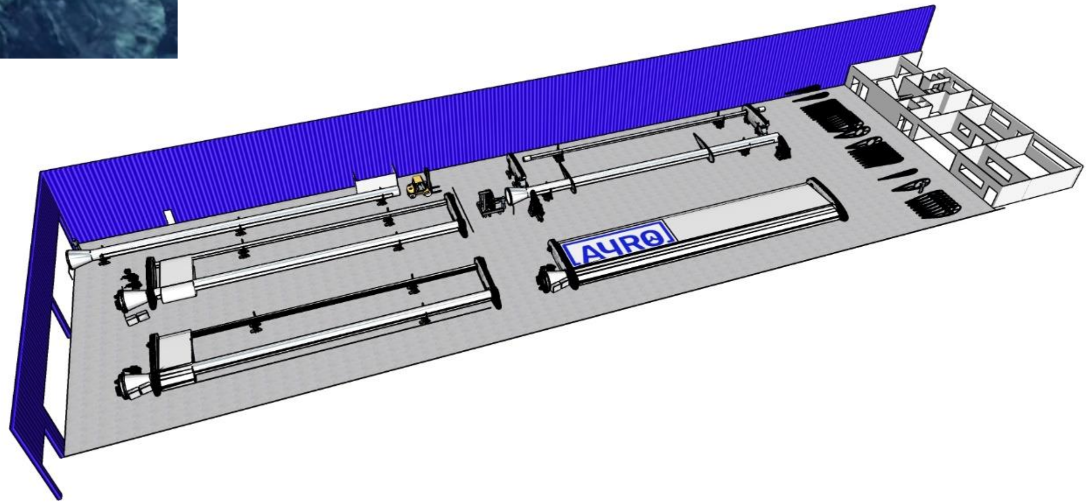
… and operations

OPERATIONS – INDUSTRIALIZATION: FACTORY IN CAEN

Agreement with CCI Caen signed

Date of starting lease : 1st Dec 2021

Start production activity : March 2022



CAPITAL STRUCTURE – SERIES B FUND RELEASE

10.5 M€ FUND RAISING ACHIEVED AND ANNOUNCED SEPT, 13 2021

Investors :

Ocean Zero Lts, USA

BPI , France

Mer Invest , France

Press Release

AYRO (France) raises €10.5 million capital from Ocean Zero (USA), Bpifrance (France) and Mer Invest (France) to boost the development of its innovating wingsail solution to help decarbonize the maritime transport industry.

Paris, New York, September 13th, 2021-10:00 am CET)

AYRO, an industrial start-up that designs and delivers Oceanwings®, a wind propulsion hybrid system for maritime transport, raises €10.5 million capital from Ocean Zero (USA), Bpifrance (France) and Mer Invest (France).

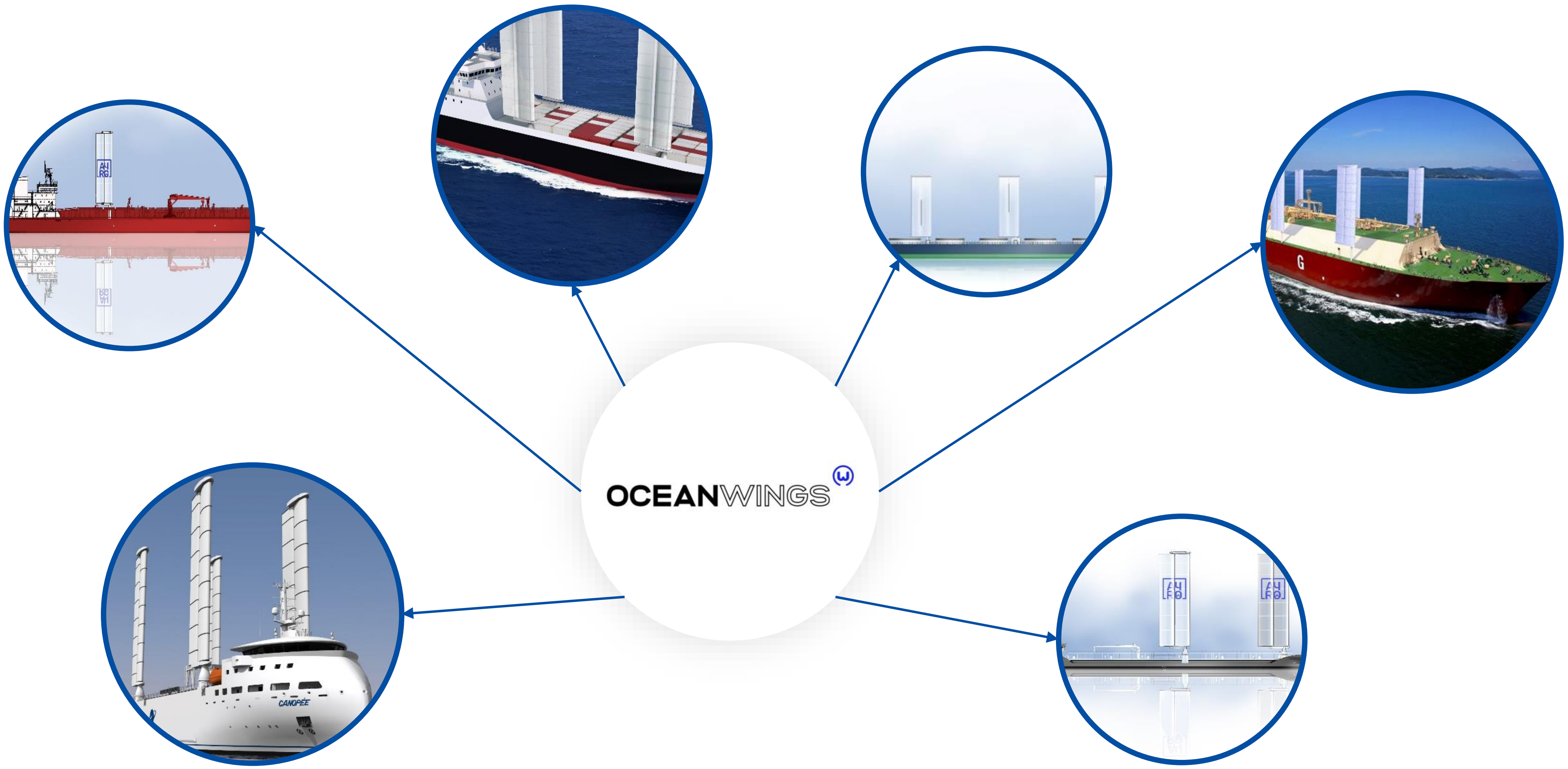
Context

The Company

The Oceanwings system

Study and next phases

OCEANWINGS ABOARD VESSELS



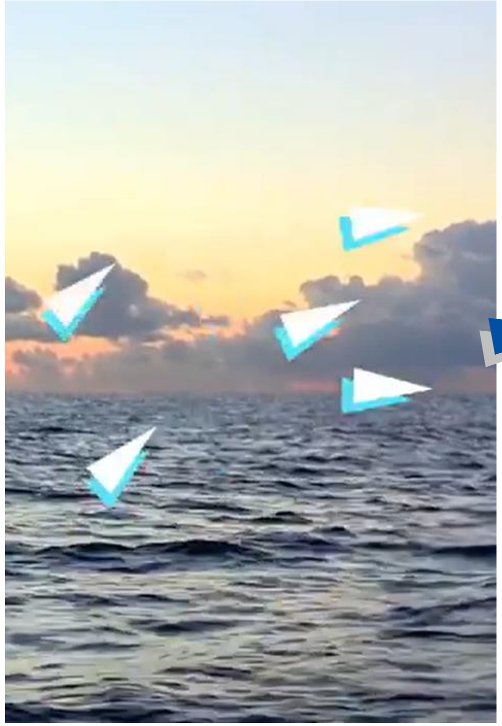
OCEANWINGS OPERATING PRINCIPLES

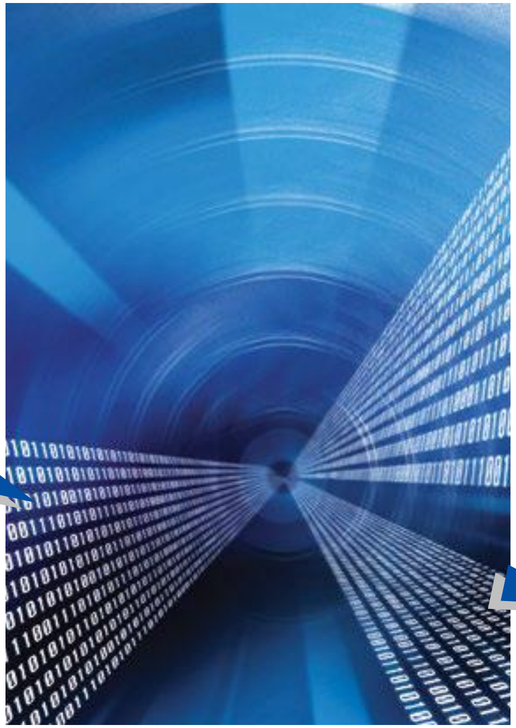
AYRO

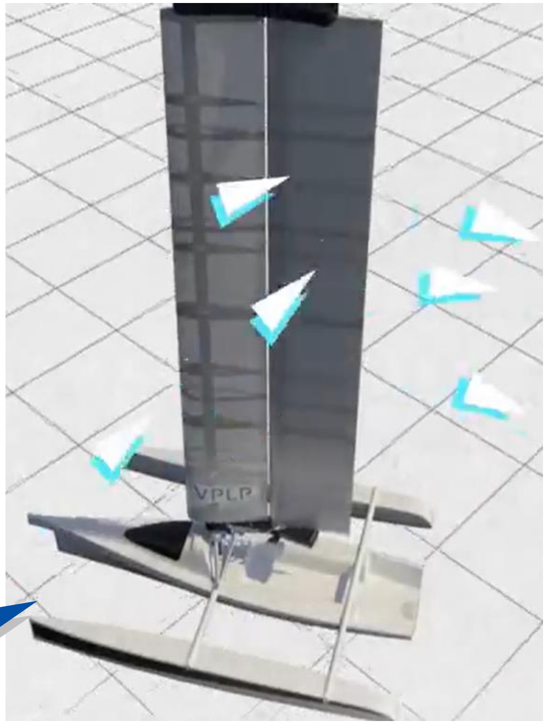
1
SENSORS ON THE WINGSAILS MEASURE THE WIND

2
A COMPUTER ANALYSES THE DATA

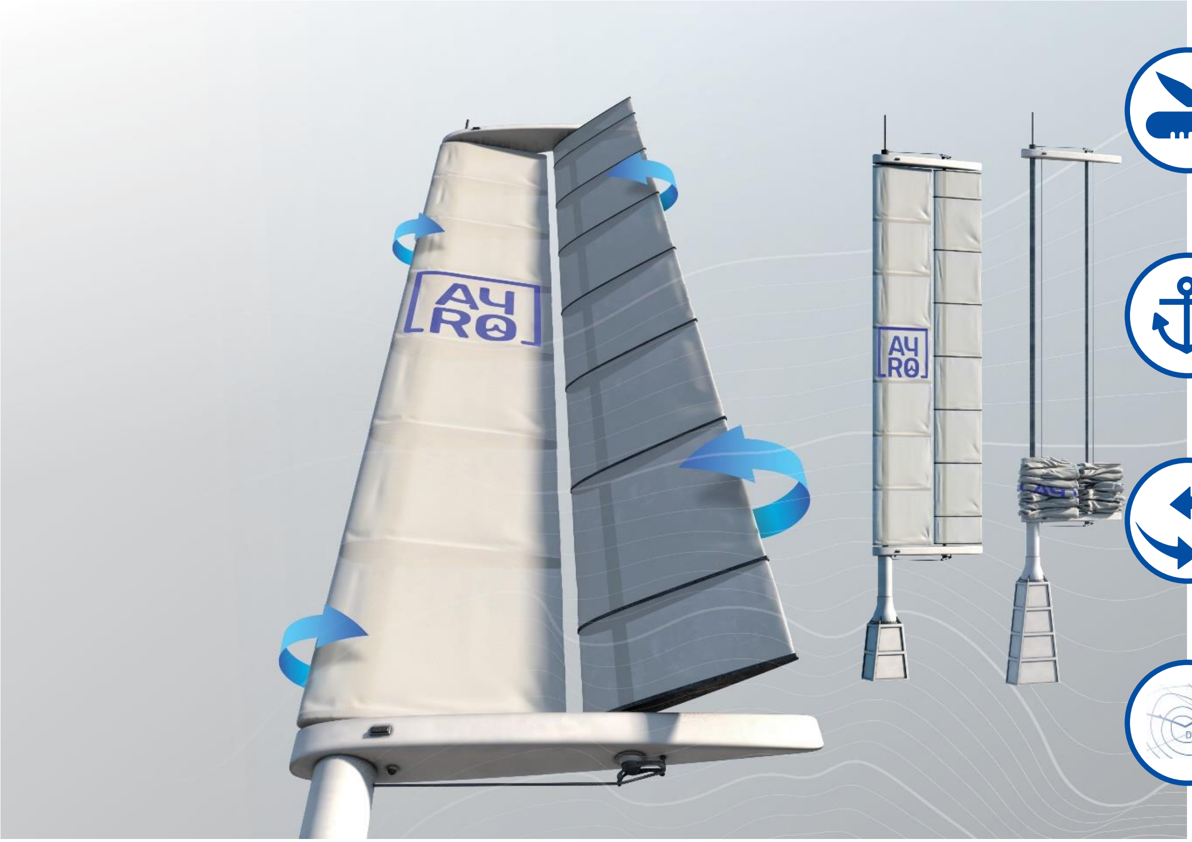
3
MOTORS ADJUST THE WINGSAIL ANGLE OF ATTACK AND CAMBER







OCEANWINGS ADVANTAGES



REEFABLE AND FURLABLE

- Safe at harbour, no impact on ships behaviour within minutes

LIGHT & COMPACT

- Easy Installation - Tilting - Moving / No stability impact
- Limited impact on cargo capacity
- Deck Footprint 2.5m x 2.5m

EXTREME VERSATILITY TO WIND ANGLES AND SPEED

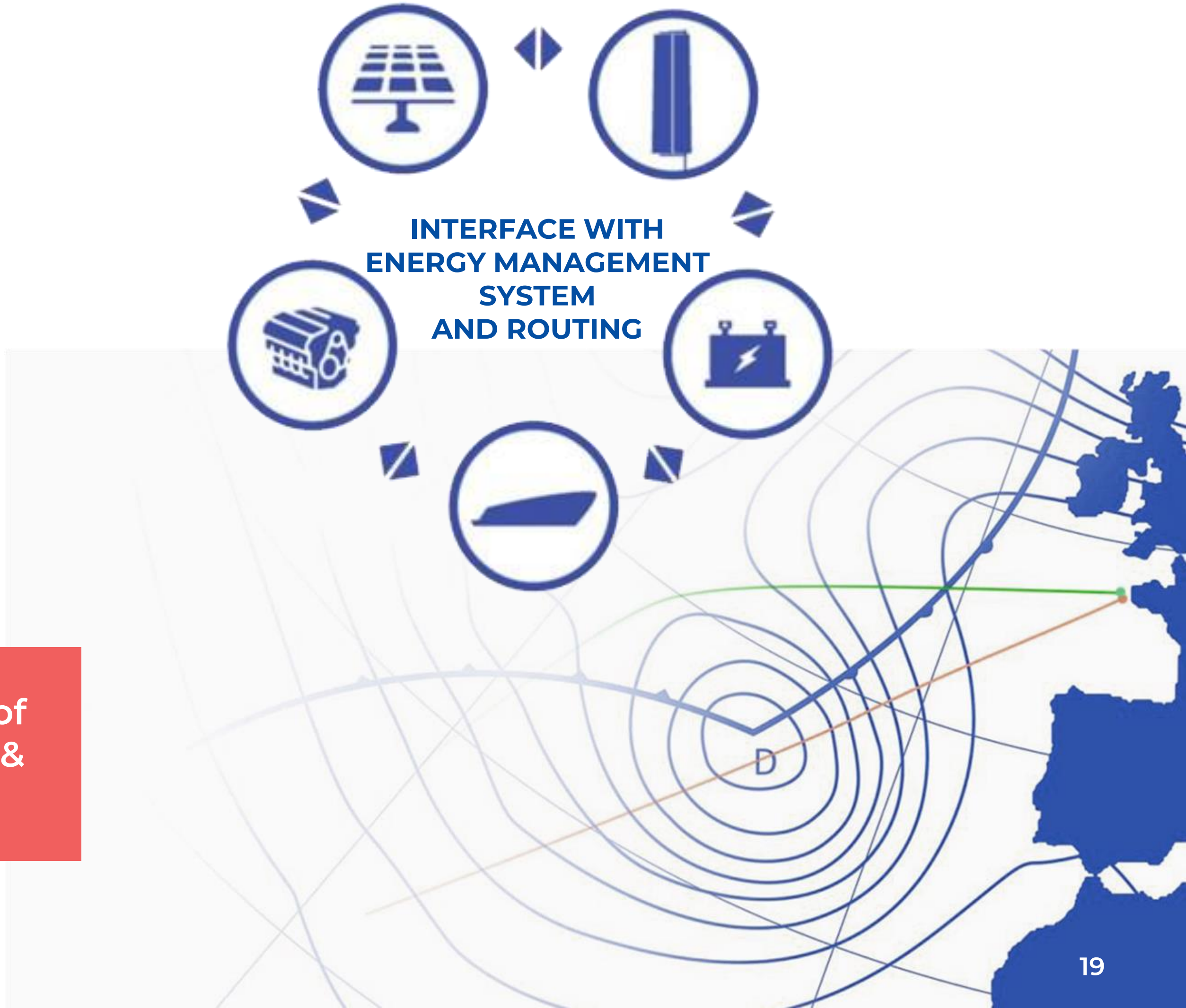
- Propulsive Power from 5° AWA* (~constantly beneficial)

FLEXIBILITY WITH ROUTE RE-SCHEDULING

* AWA means Apparent Wind Angle

AUTOMATION & CONTROL SOFTWARE

Automated control command of system monitoring dashboard & all-level reporting ...



Context

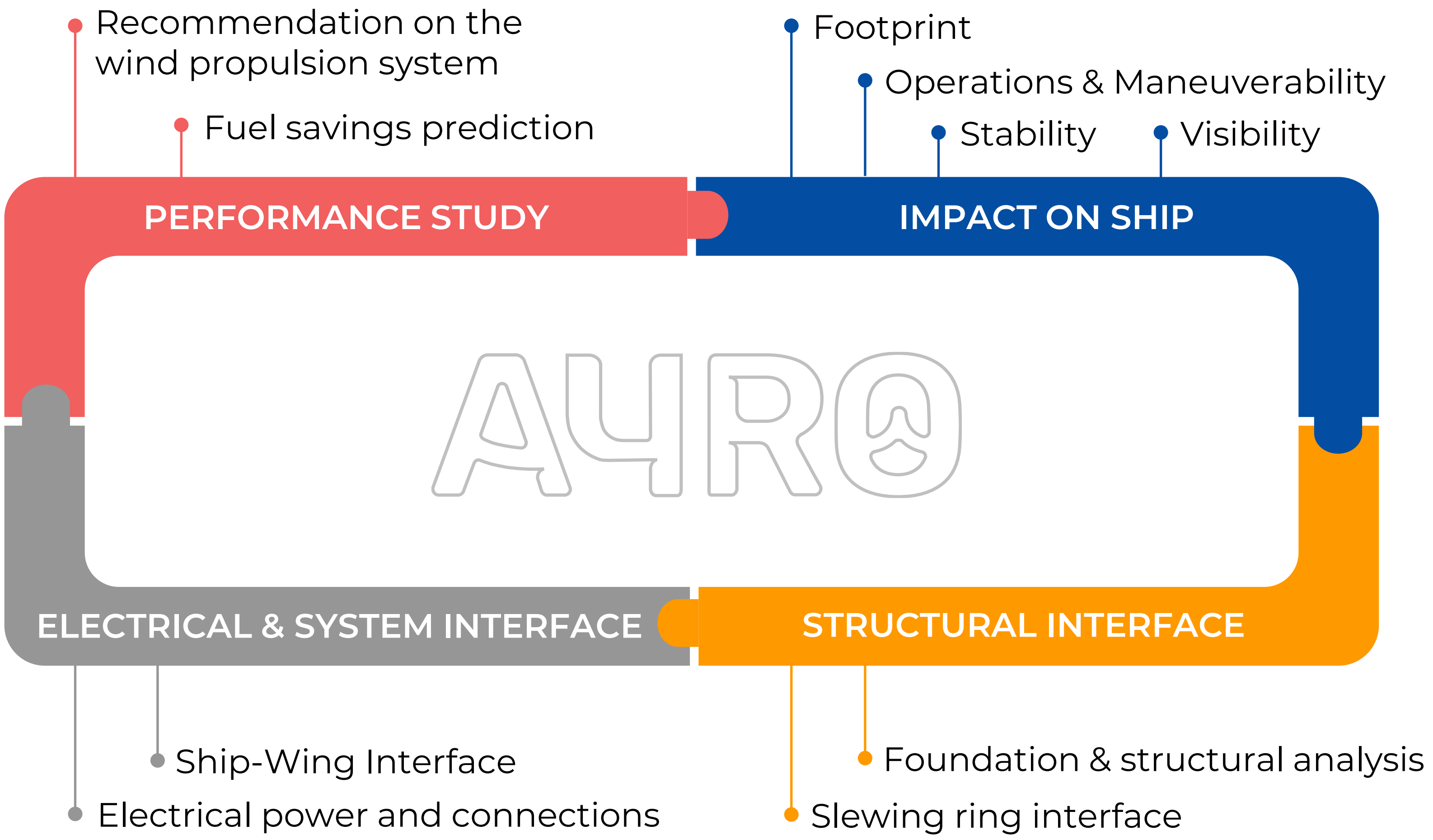
The Company

The Oceanwings system

Case Studies

DESIGNING THE MOST PERFORMANT AND ADAPTED SYSTEM TO YOUR SHIPS AND OPERATIONS

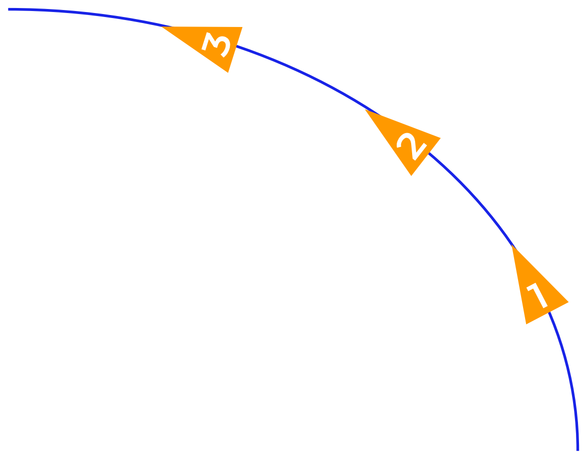
AYRO'S COMPREHENSIVE APPROACH TO DESIGN YOUR WIND PROPULSION SYSTEM



AYRO's intention is to carefully understand the program and the naval architecture of your ships to design **the most suitable wind propulsion system** for your challenges and objectives.

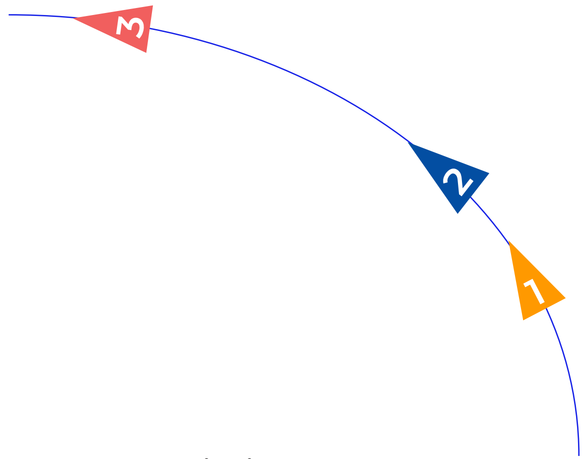
ASSESSMENT METHODOLOGY

STEP 0



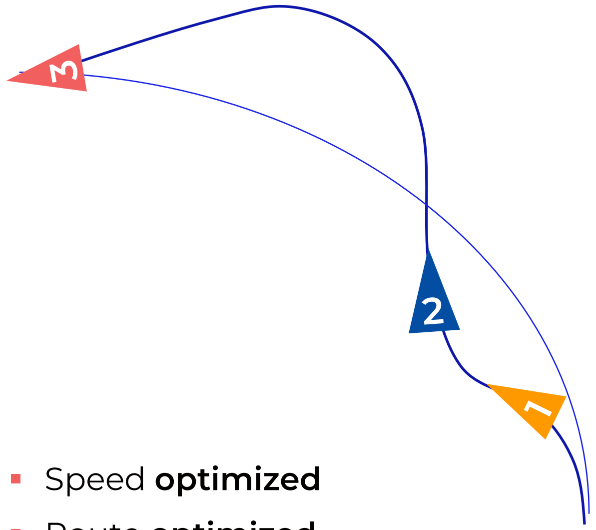
- Speed constant
- Route constant

STEP 1



- Speed **optimized**
- Route constant

STEP 2

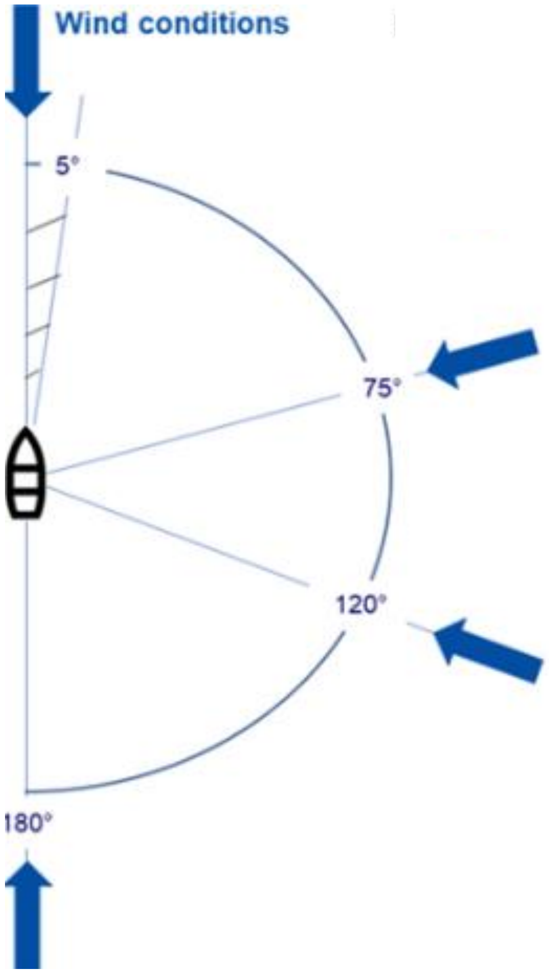


- Speed **optimized**
- Route **optimized**

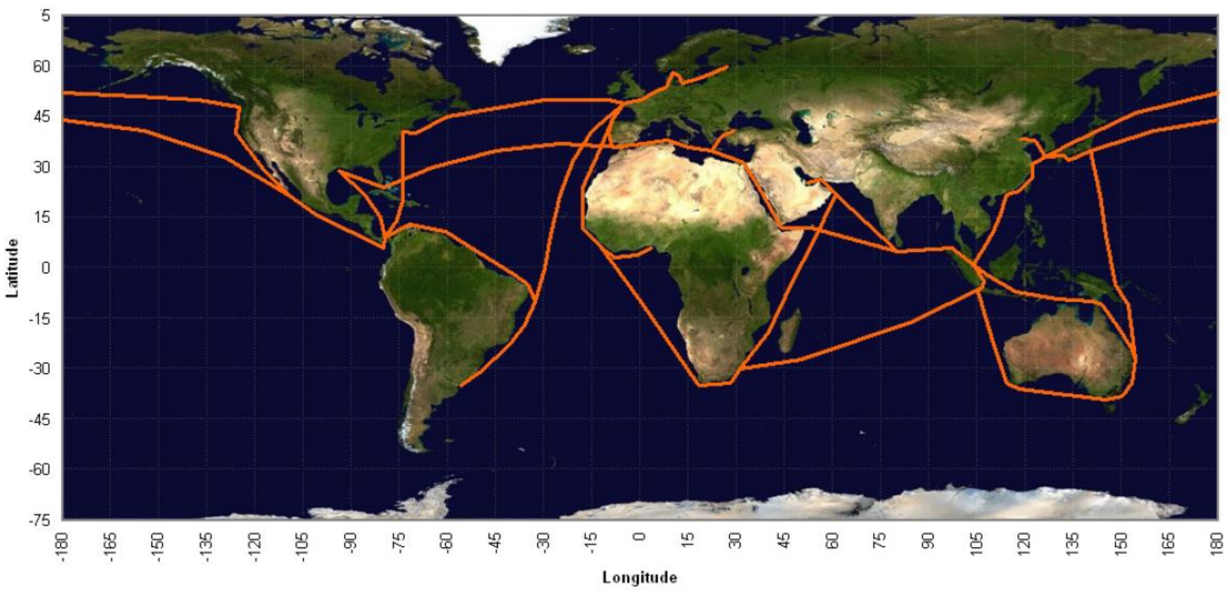
- **Later stages performance analysis requiring additional engineering resources ;**
- **Significant additional fuel savings potential could reach more than 150% of Step 0 performance.**

TAKING INTO ACCOUNT THE WIND CONDITIONS IN SHIP OPERATION, WINGSAIL HAS THE HIGHEST POTENTIAL

OPERATING WINDOWS OF THE KEY WASP TECHNOLOGIES vs. WORLDWIDE OPERATIONS



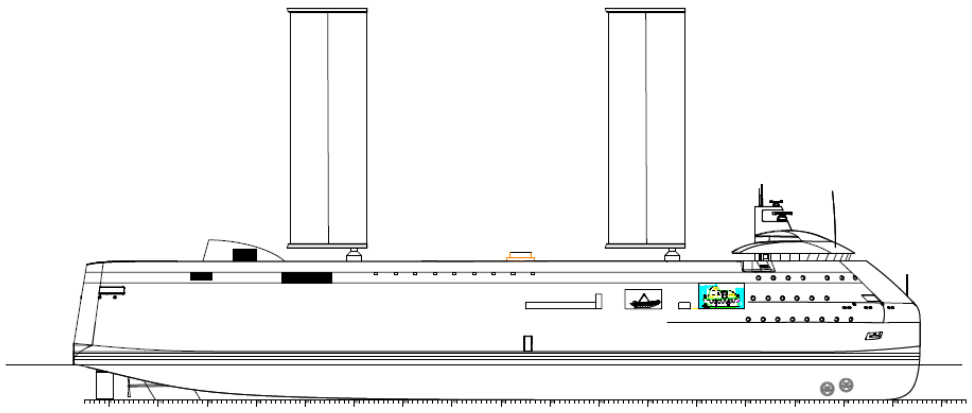
TWA	AWA
43%	87%
20%	9%
37%	3%



➢ AWA probabilities for 16kts ship speed

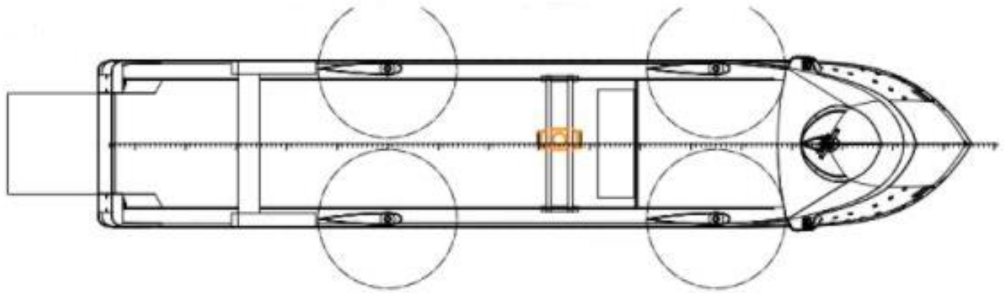
CANOPEE PROJECT

PROFILE VIEW



MAIN CHARACTERISTICS OF THE PROJECT

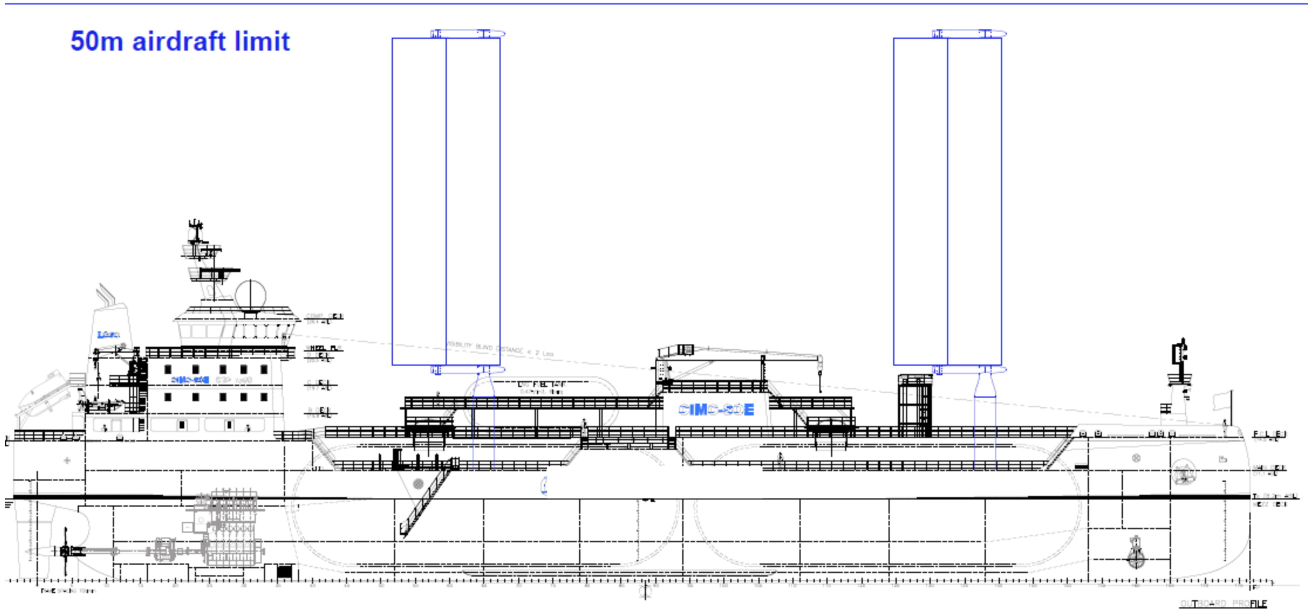
TOP VIEW

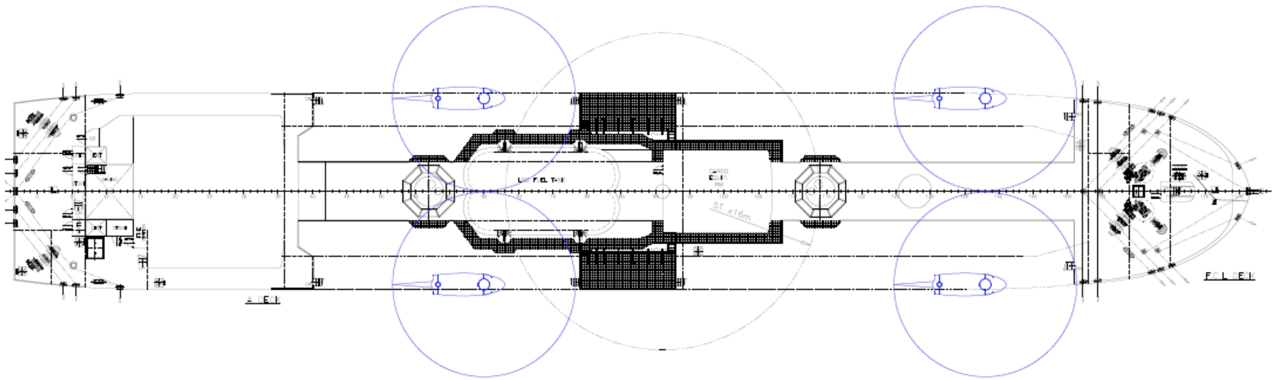


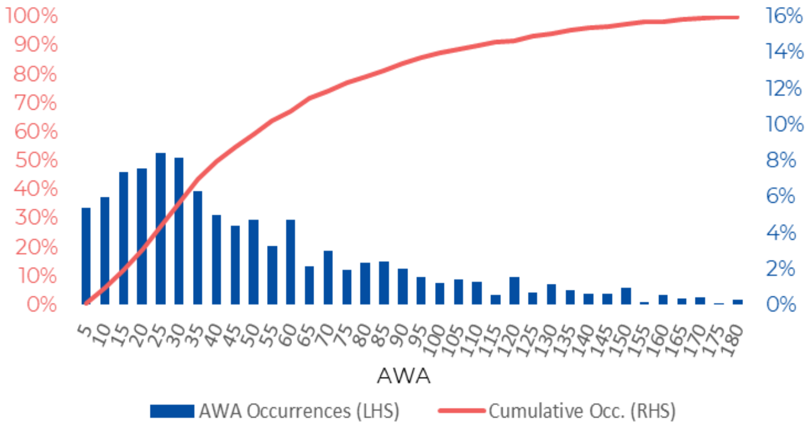
- RoRo 121 meters length
- To be delivered by the end of 2022
- Designed for 16,5 knots
- Fuel savings ranging from 20% to 35%

CASE STUDIES

7 500 CBM LPG CARRIER







- 79% of the wind sailing conditions of the ship will be below 75° of Wind Apparent Angles.

Fuel and Co2 savings for the considered round trip

Speed [kts]	13.5
Brake power [kW]	3780
Duration [h]	85.9
Mechanical Energy [kWh]	324532
Mechanical Fuel Consumption [T] @146g/kWh	47
Engine eq. power 1xOW [kW]	166
Nb of OW	4
Engine eq. power 4xOW363 [kW]	664
Saved Energy [kWh]	57008
Fuel saving [T] @146g/kWh	8.3
Cf, (t CO2)/(t Fuel)	2.75
CO2 saving [T]	22.8
Rel. Fuel Savings	18%

25 000 DWT CHEMICAL TANKER EQUIPPED WITH 6 OW 3.6.3 ®

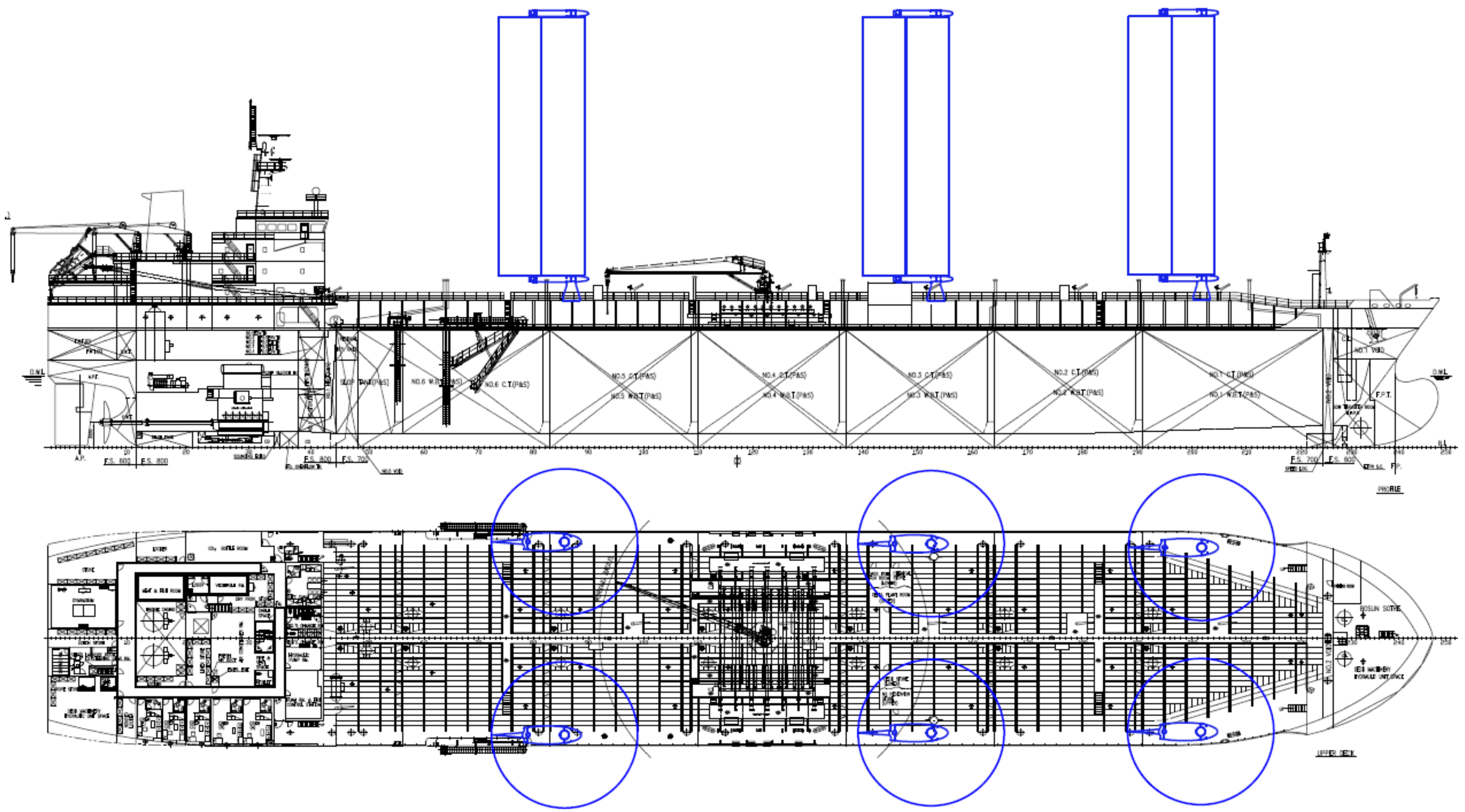
KEY GENERAL CHARACTERISTICS

▪ Ship type	Tanker
▪ LOA/LPP	177,6/168 m
▪ Dwt	25 000 t

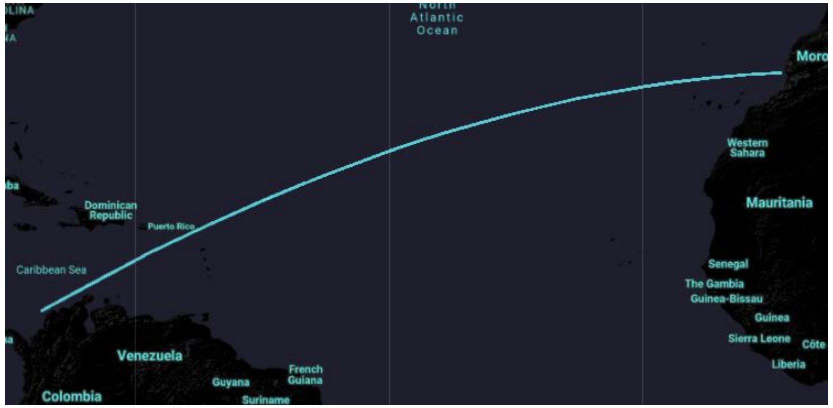
SAILING CONSIDERATIONS

- Sailing speeds considered: 14 kts
- Single trip route considered :
  - MOROCCO > CENTRAL AMERICA

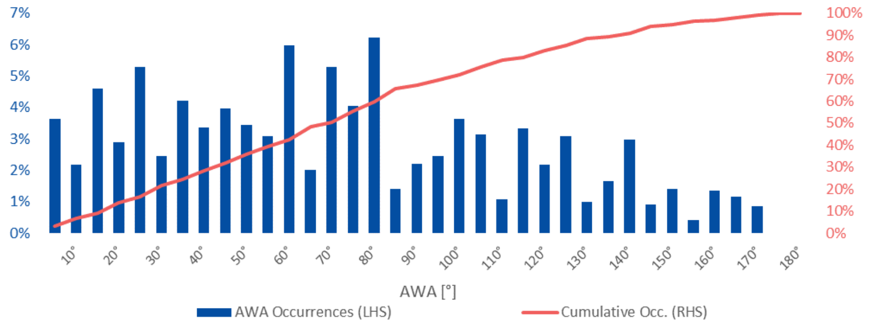
- Loaded condition (design draft)
  - Draft 9,2 m
  - Displacement 34 000 t



COLLECTION OF WIND STATISTICS OVER SINGLE TRIP MOROCCO > CENTRAL AMERICA



Routing calculation using Satori D-Ice



Trip duration (one way)	days	11.4
Route length	nm	3 816
Speed	kts	14.0

Savings over 25 years operating on this route with 85% use rate

Fuel savings over 25y	T	19 841
CO_2 savings over 25y	T	63 612

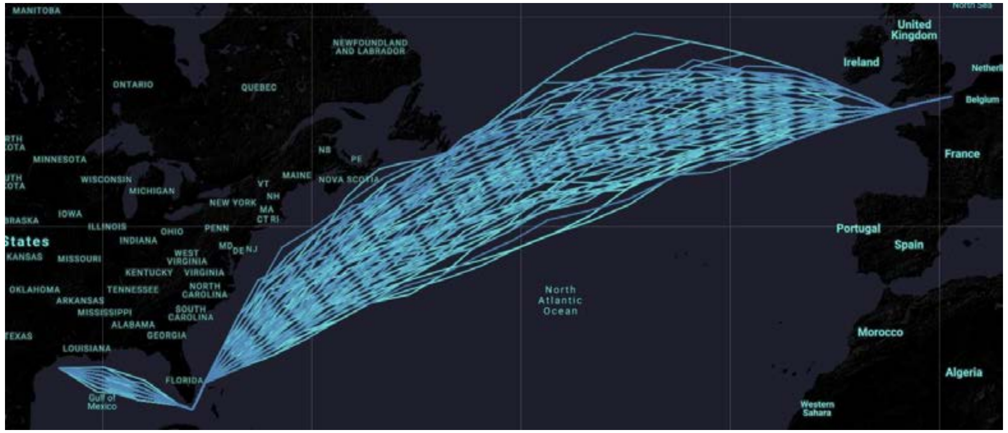
Cost savings over 25 years

Fuel cost	€/T	600 €
CO_2 emissions tax	€/T	50 €
Total cost savings	€	15 085 444 €

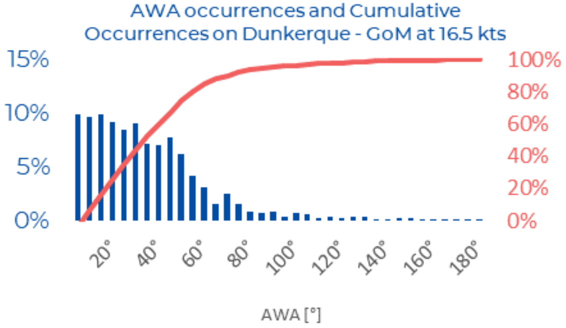
- The 6 Oceanwings system allows 2.6 t of fuel savings per day when operating on this route at 14 kts, and 794 t fuel savings per year considering a use rate of 85%.
- The fuel savings represent 12% of ship consumption.

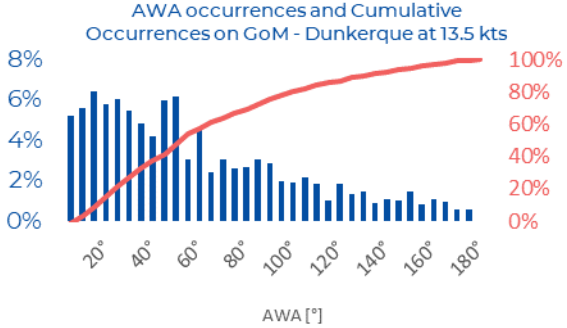
CASE STUDIES

180 000 M3 LNG CARRIER – SAVINGS OVER ROUTE N. EUROPE – GULF OF MEXICO



Routing calculation using Satori D-Ice





- Oceanwing is the most relevant wind propulsion technology as more than 75% (forward trip) and 45% (backward) of the apparent wind angles are below 45°
- The 6 Oceanwings system allows 9.5t and 3.8t of daily fuel savings respectively on forward and backward trip.
- This leads to 1 984 tons of annual fuel savings when operating on this route and considering 85% use rate.

Route Dunkerque - GoM		Forward	Backward
Trip duration (one way)	days	12.1	14.8
Route length	nm	4 800	4 800
Speed	kts	16.5	13.5
Relative Fuel Savings with 6 x OW	%	19.5%	15.2%

Savings over 25 years operating on this route with 85% use rate		
Fuel savings over 25y	T	49 598
CO2 savings over 25y	T	136 394

Cost savings over 25 years		
Fuel cost	€/T	600 €
CO2 emissions tax	€/T	50 €
Total cost savings	€	36 578 277 €

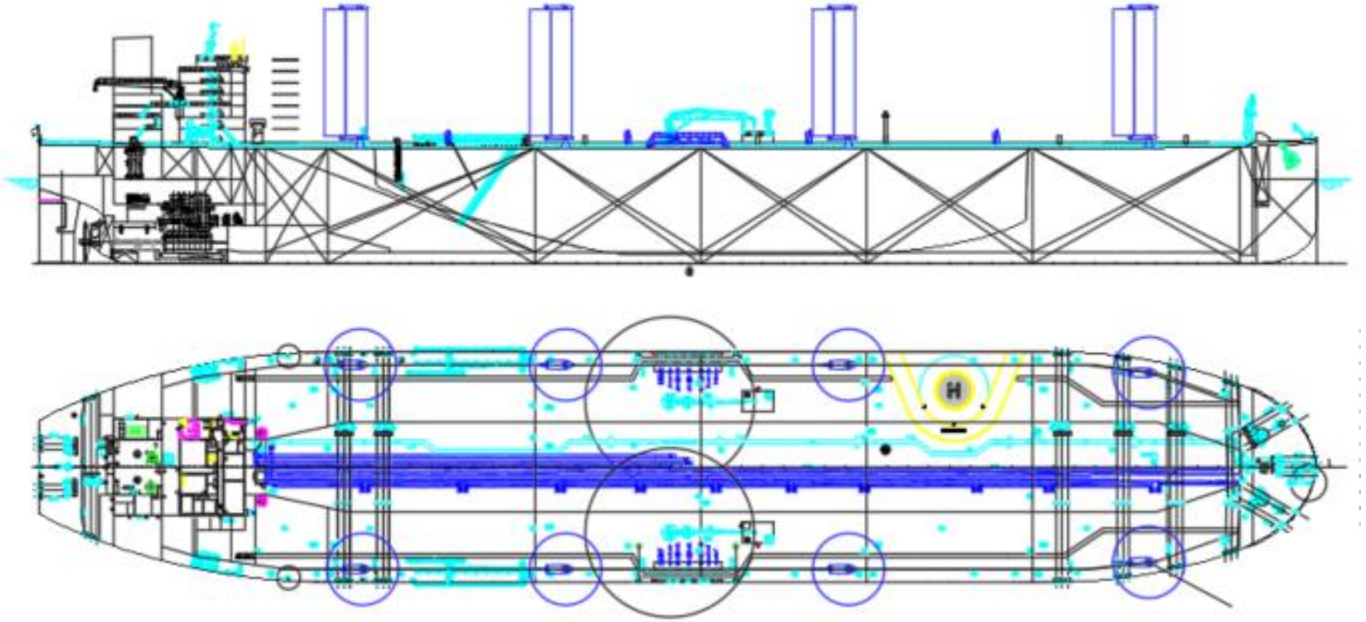
VLCC EQUIPPED WITH 8 OW 3.6.3 ®

KEY GENERAL CHARACTERISTICS

- Ship type VLCC
- LOA 332,9 m
- Dwt ~300 000 t

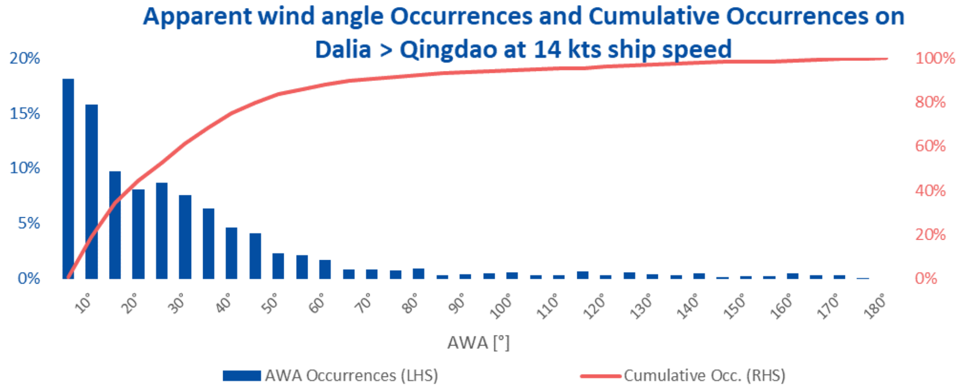
SAILING CONSIDERATIONS

- Sailing speeds considered: 14 kts
- Single trip route considered :
  - Dalia [ANG] > Qingdao [CHI]
  - Gebig [BRA] > Dalian [CHI]
- Loaded condition



PERFORMANCE PREDICTIONS OVER SINGLE TRIP DALIA > QINGDAO (LOADED) - VLCC

Routing calculation using Satori D-Ice



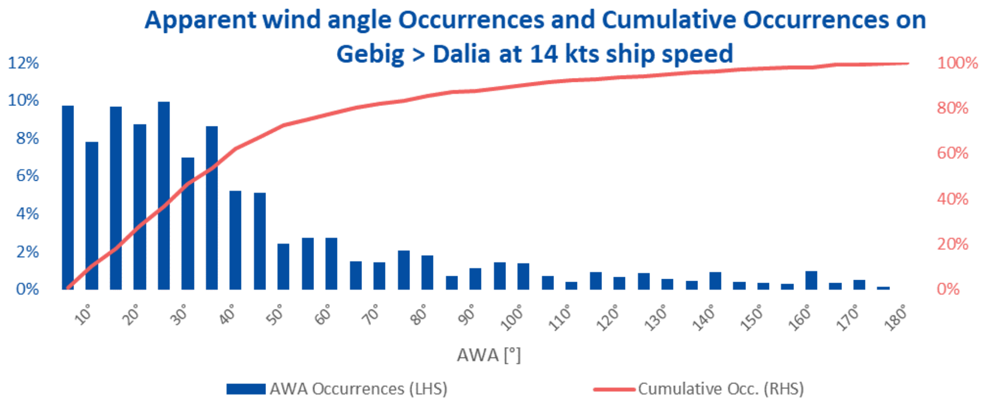
Route : Dalia > Qingdao		
Trip duration (one way)	days	28.4
Route length	nm	9 536
Speed	kts	14.0
Rel. Fuel Savings with 8 x OW	%	9.5%

- Oceanwing is the most relevant wind propulsion technology as more than 80% of the apparent wind angles are below 45°.
- The 4 Oceanwings system allows 1685 tons of annual fuel savings when operating on this route and considering 85% use rate.

PERFORMANCE PREDICTIONS OVER SINGLE TRIP GEBIG > DALIAN (LOADED) - VLCC

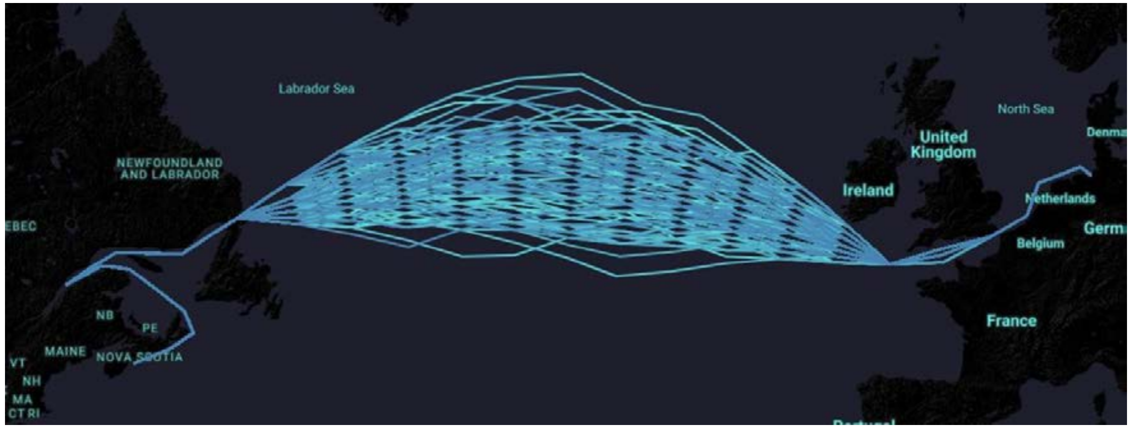
Routing calculation using Satori D-Ice

Route : Gebig > Dalia		
Trip duration (one way)	days	33.6
Route length	nm	11 306
Speed	kts	14.0
Rel. Fuel Savings with 8 x OW	%	11.6%



- Oceanwing is the most relevant wind propulsion technology as more than 67% of the apparent wind angles are below 45°.
- The 4 Oceanwings system allows 2062 tons of annual fuel savings when operating on this route and considering 85% use rate.

PERFORMANCE PREDICTIONS ROUNDTRIP N. EUROPE <> USA - CONTAINER SHIP

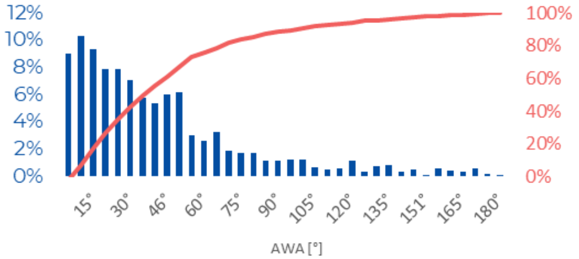


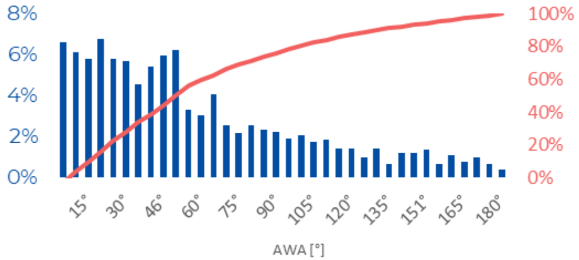
Routing calculation using Satori D-Ice

		Outward	Return
Trip duration (one way)	days	12.1	10.5
Route length	nm	3 783	3 783
Speed	kts	13.0	15.0
Relative Fuel Savings with 6 x OW	%	25.3%	23.5%

Savings over 25 years operating on thisRoute with 85% use rate		
Fuel savings over 25y	T	54 762
CO2 savings over 25y	T	175 566

Cost savings over 25 years		
Fuel cost	€/T	600 €
CO2 emissions tax	€/T	50 €
Total cost savings	€	41 635 343 €

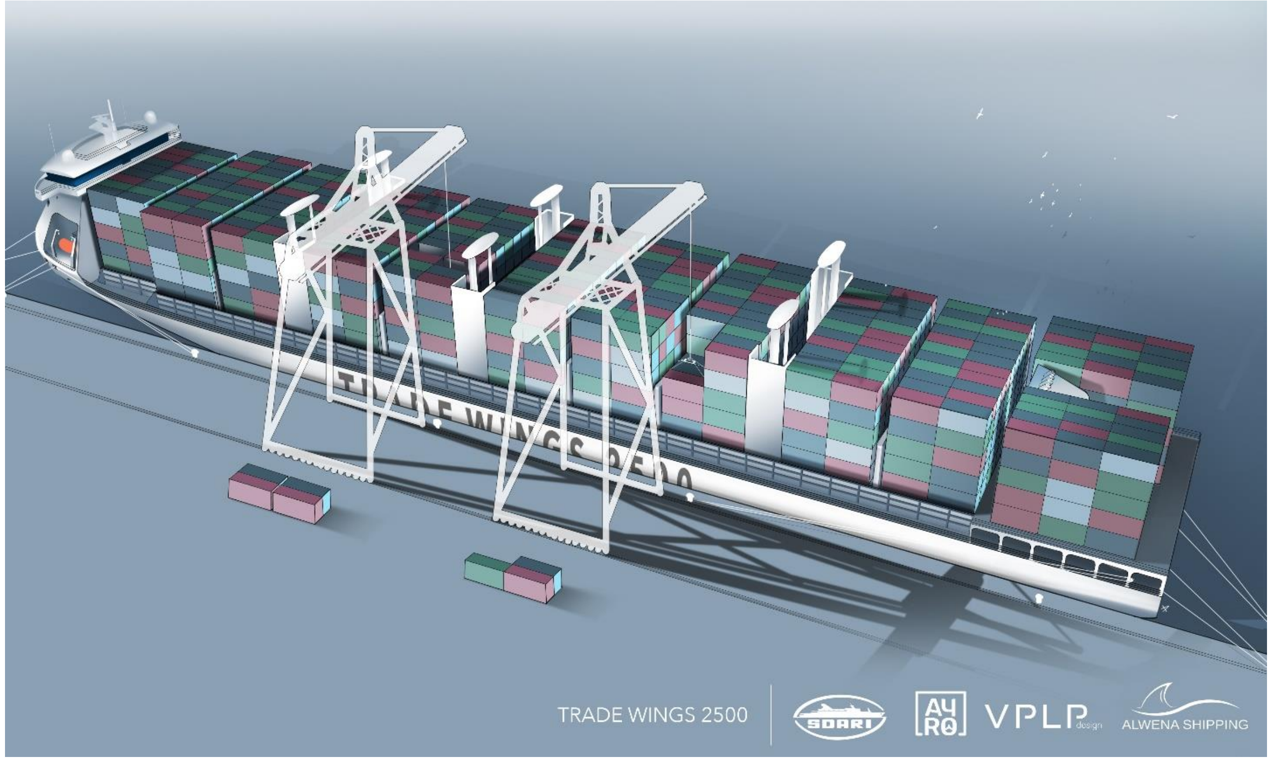




- Oceanwing is the most relevant wind propulsion technology as more than 65% (outward trip) and 50% (return) of the apparent wind angles are below 45°
- The 6 Oceanwings system allows 6.3t and 7.9t of daily fuel savings respectively on outward and return trip.

TRADE WINGS 2500

LOW EMISSION SAIL-ASSISTED 2500 TEU CONTAINER VESSEL WITH APPROVAL IN PRINCIPLE FROM BUREAU VERITAS



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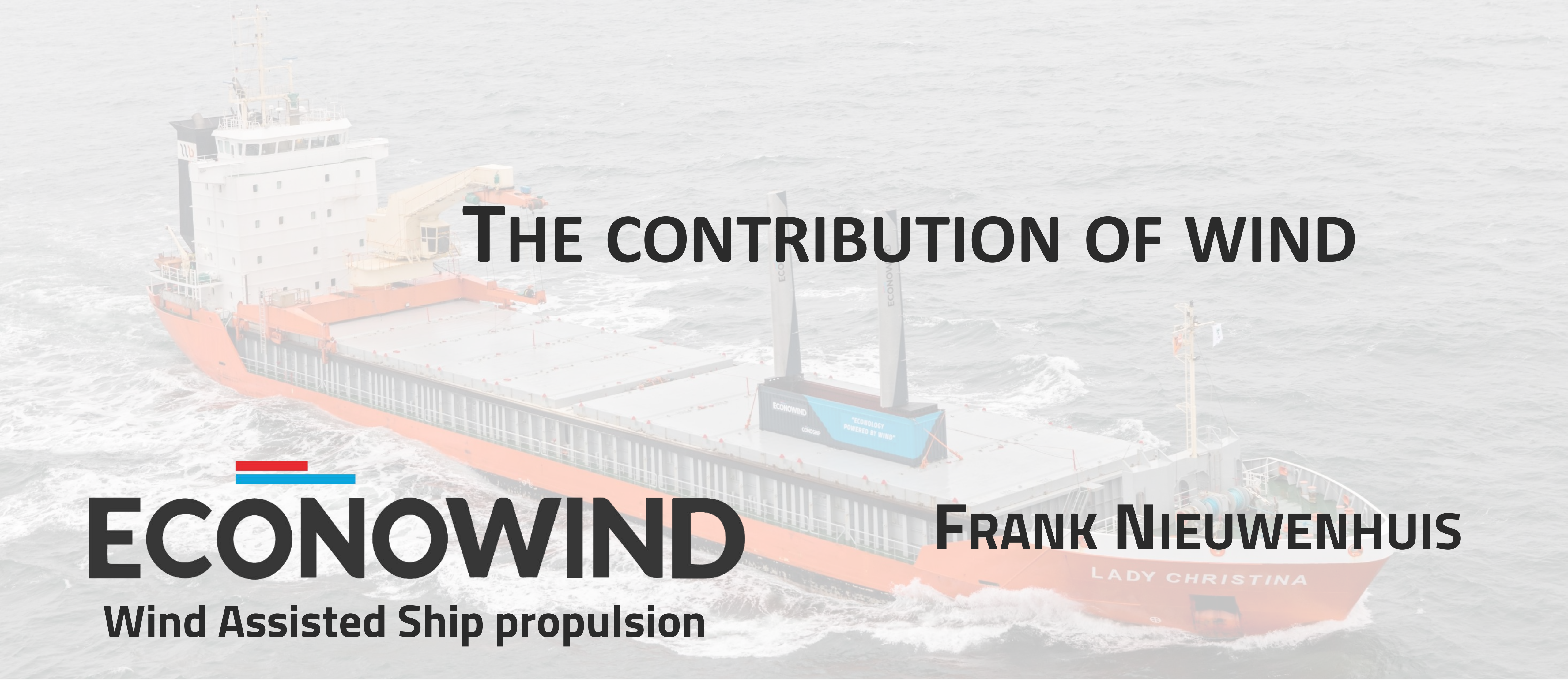
Natural propulsion in ship design

ECONOWIND
Wind Assisted Ship propulsion

Frank Nieuwenhuis



The contribution of wind

ECONOWIND
Wind Assisted Ship propulsion

Frank Nieuwenhuis

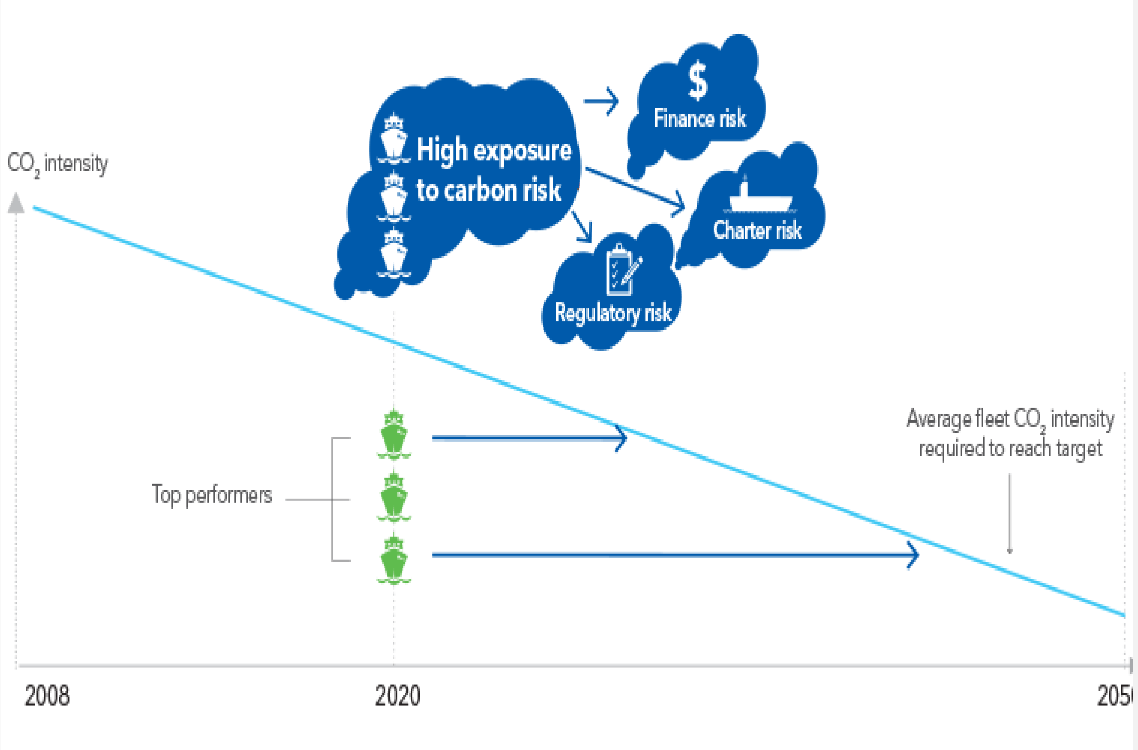
SHIPPING OWNER PAINS

Shipowner’s challenge:

- IMO: from 2023 ships must reduce carbon intensity by 2% annually
- 2023: EU ETS will add costs per ton CO2 to shipping
- IMO: by 2050 target to lower emission intensity by 70%

It is an ongoing proces…..

….. starting today

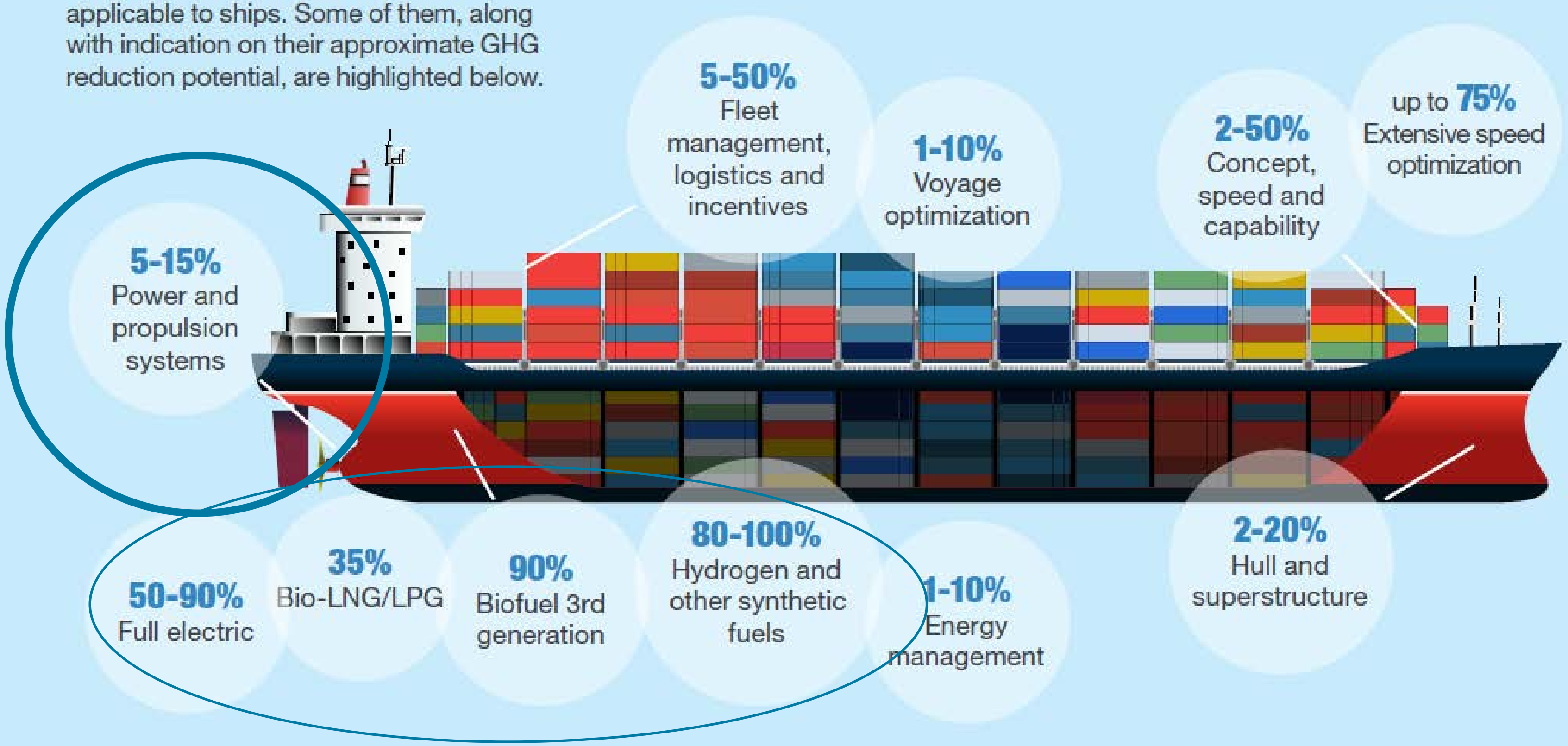


ECONOWIND

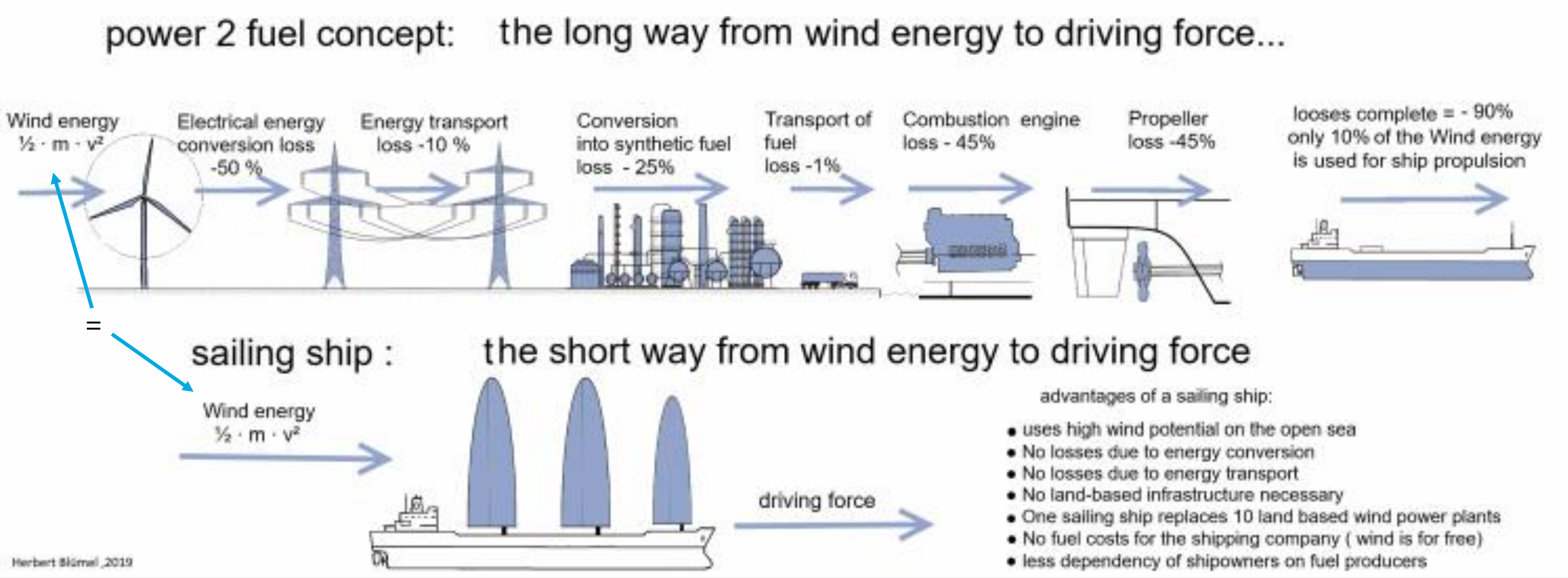
IMO EXPECTATIONS

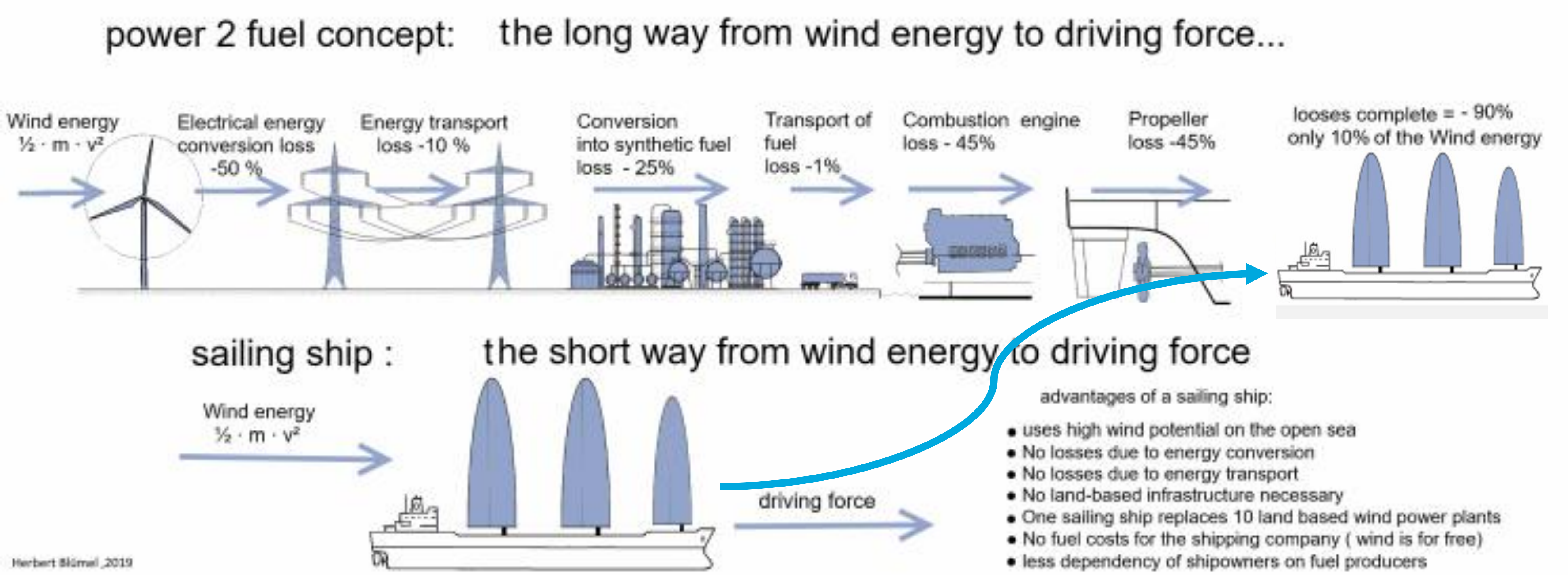
A wide variety of design, operational and economic solutions

Achieving the goals of the Initial IMO GHG Strategy will require a mix of technical, operational and innovative solutions applicable to ships. Some of them, along with indication on their approximate GHG reduction potential, are highlighted below.



WIND?


power 2 fuel concept: the long way from wind energy to driving force...
Wind energy
½ · m · v²
Electrical energy conversion loss -50 %
Energy transport loss -10 %
Conversion into synthetic fuel loss - 25%
Transport of fuel loss -1%
Combustion engine loss - 45%
Propeller loss -45%
looses complete = - 90%
only 10% of the Wind energy is used for ship propulsion
=
sailing ship : the short way from wind energy to driving force
Wind energy
½ · m · v²
driving force
advantages of a sailing ship:
• uses high wind potential on the open sea
• No losses due to energy conversion
• No losses due to energy transport
• No land-based infrastructure necessary
• One sailing ship replaces 10 land based wind power plants
• No fuel costs for the shipping company (wind is for free)
• less dependency of shipowners on fuel producers
Herbert Blümel 2019



NOT ALWAYS GOOD WINDS: HYBRID SYSTEMS

ECONOWIND

MARIN

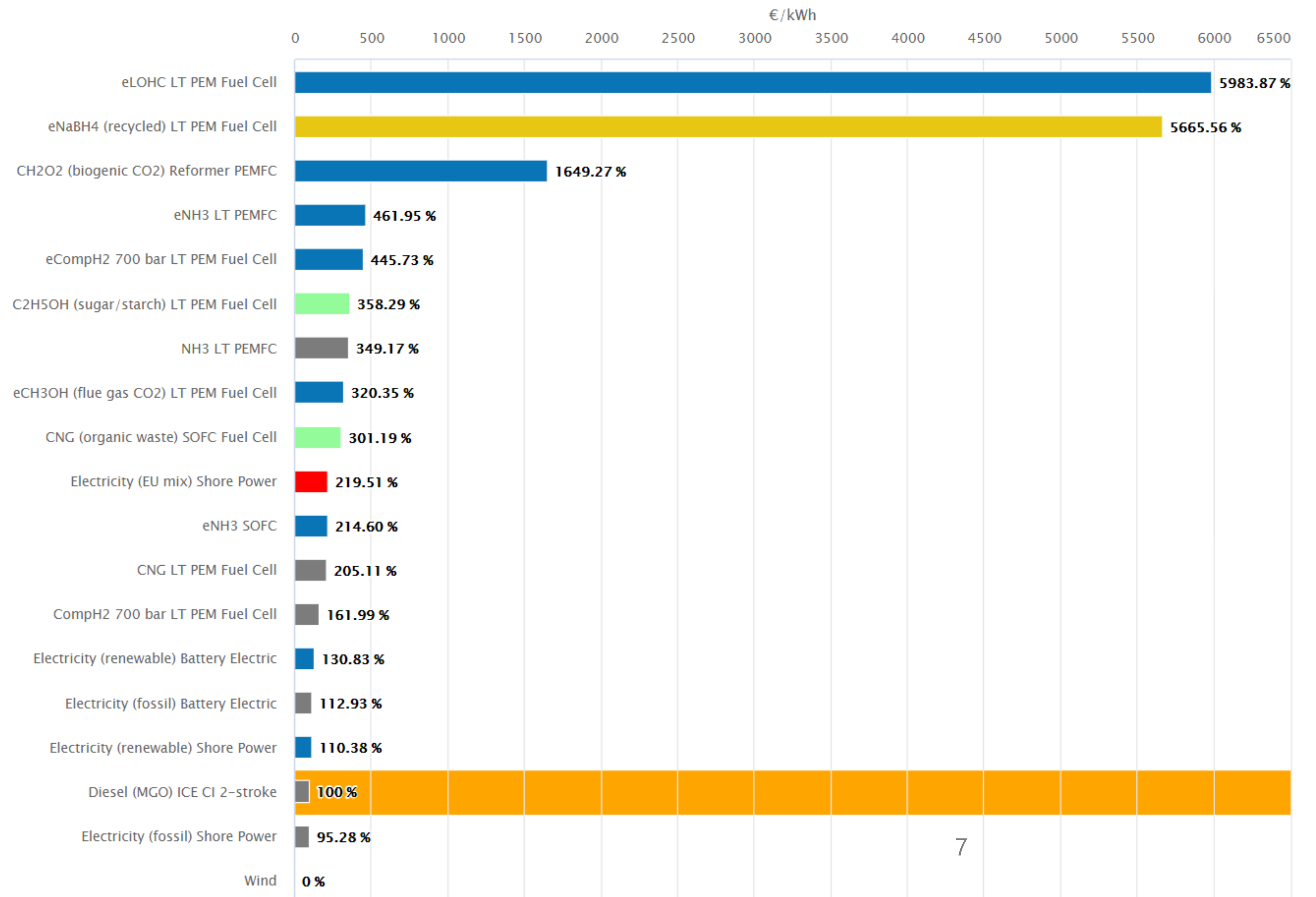
On RENEWABLE ENERGY

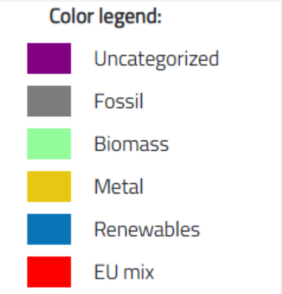
Wind lowest € / kWh

Wind does not need infrastuctre

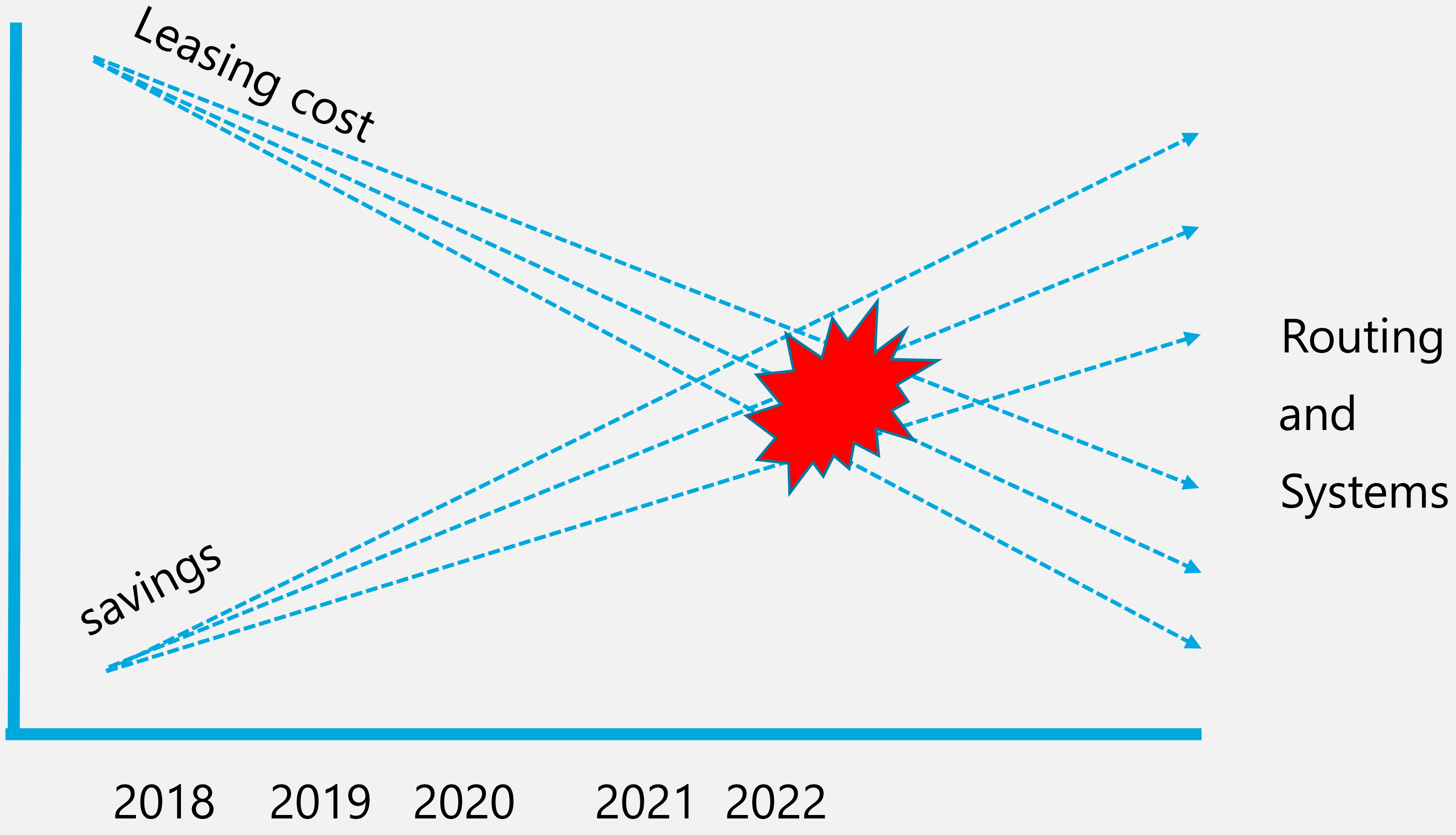
Wind is readily available now

……… Wind varies ……..





The singularity point is here!



2 APPROACHES TO 0-EMMISION

Start 0 emission and scale-up

Start at current ships and increase savings

2 APPROACHES TO 0-EMMISION

Start 0 emission

Scale up

Multiply by 20.000

2 APPROACHES TO 0-EMMISION

Start at current ships

Add Wind Assisted propulsion

Scale up

Multiply by 20.000

ECONOWIND

IWSA
International Windship Association

: Many wind assisted systems available

Study

Collaboration:

2011 - 2015

Wind propulsion studied

Conclusion :

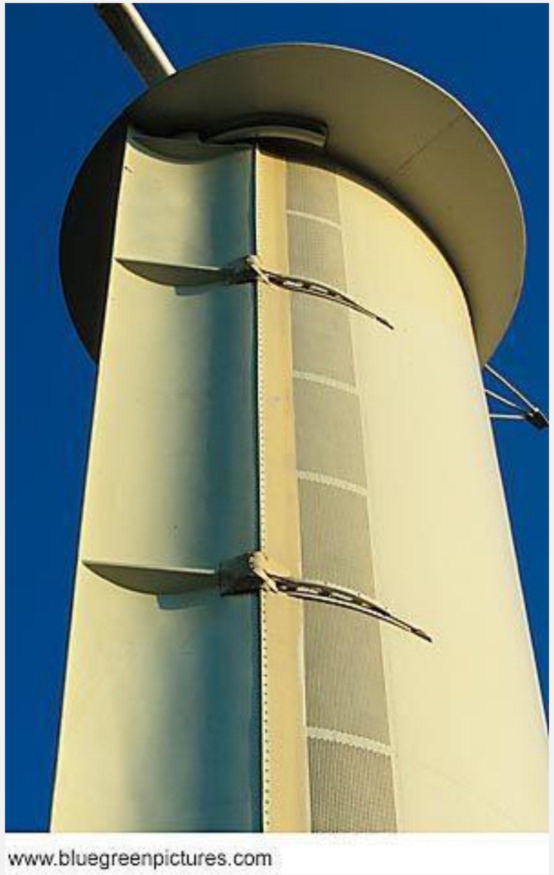
- Wind assisted propulsion is feasable.
- Start with systems up to 25% fuel reduction.

WIND PROPULSION STUDIED

Most promising:

Suction Sail

Jacques Cousteau ~1985



Concept:

- Suction Sail
- Foldable
- Fixed, flatrack or Containerized

Containerized:

ECONOWIND

MAYDEN VOYAGE ON MV LADY CHRISTINA

SNN
SAMENWERKINGSVERBAND NOORD-NEDERLAND
• Stimuleert • Faciliteert • Verbindt

Flatrack

Movable by hatchcrane

ECONOWIND

STEPS TOWARDS 2050

SNN
SAMENWERKINGSVERBAND NOORD-NEDERLAND
• Stimuleert • Faciliteert • Verbindt

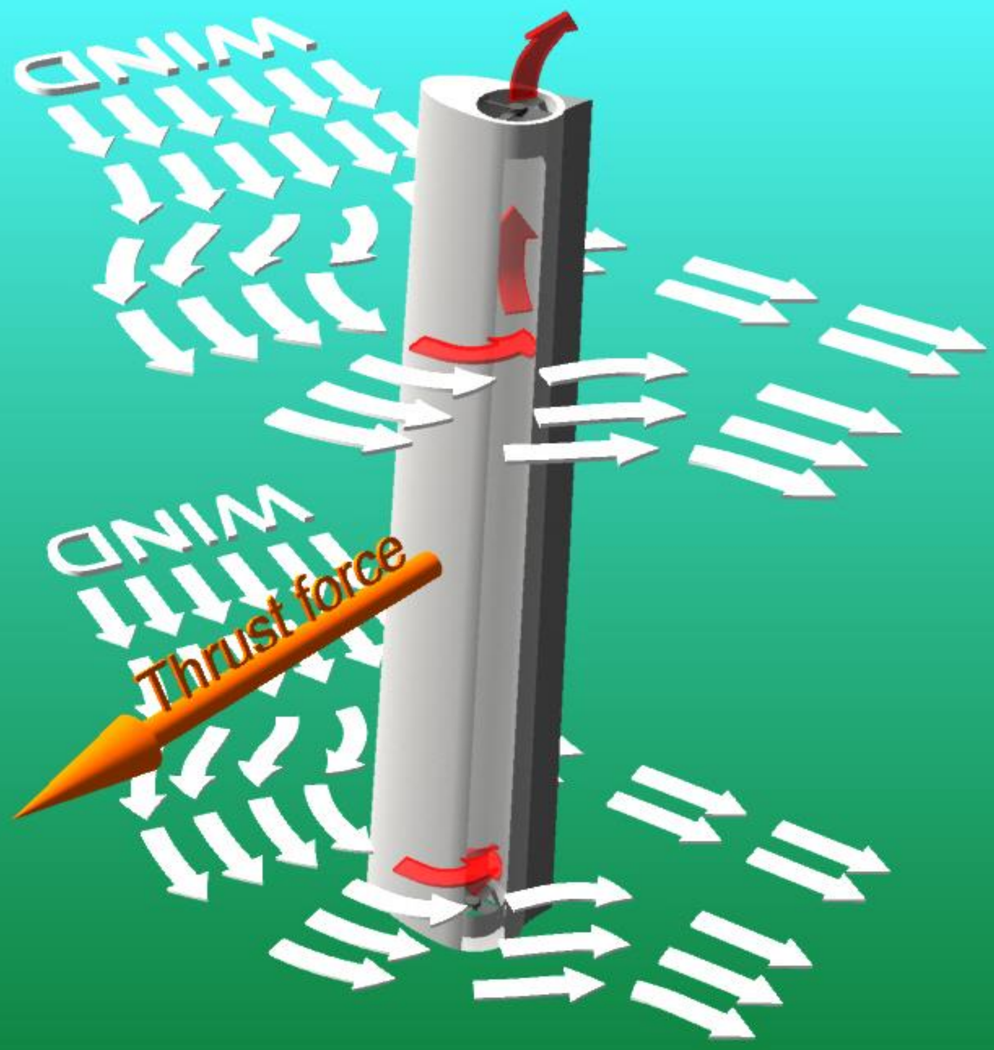
Retrofit:

Why “Suction Sail” ?

Wing with Suction:

Triple force

By optimal aerodynamics

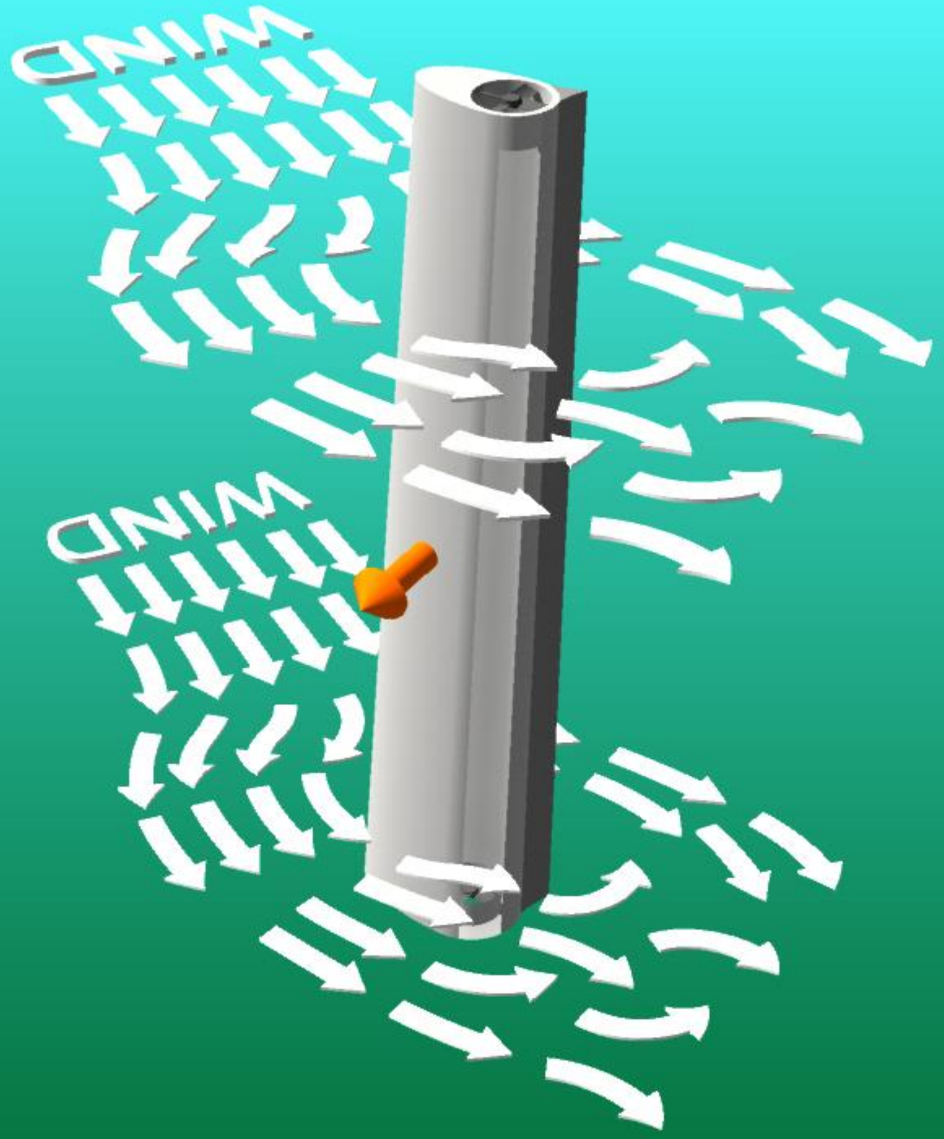


AERO DYNAMICS

Wing without Suction:

Limited force

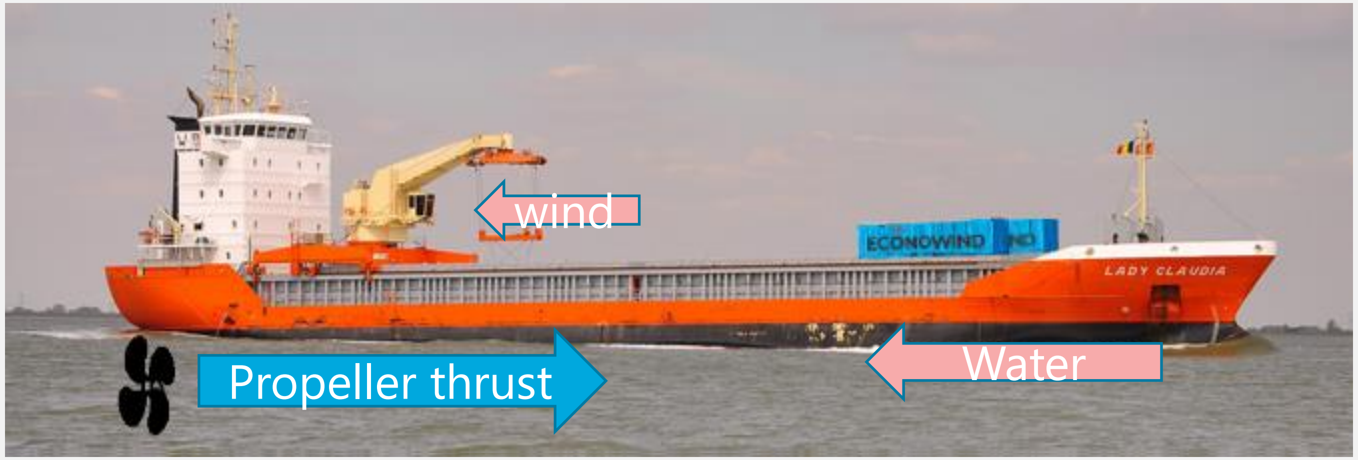
By stalling wing



Aero dynamics

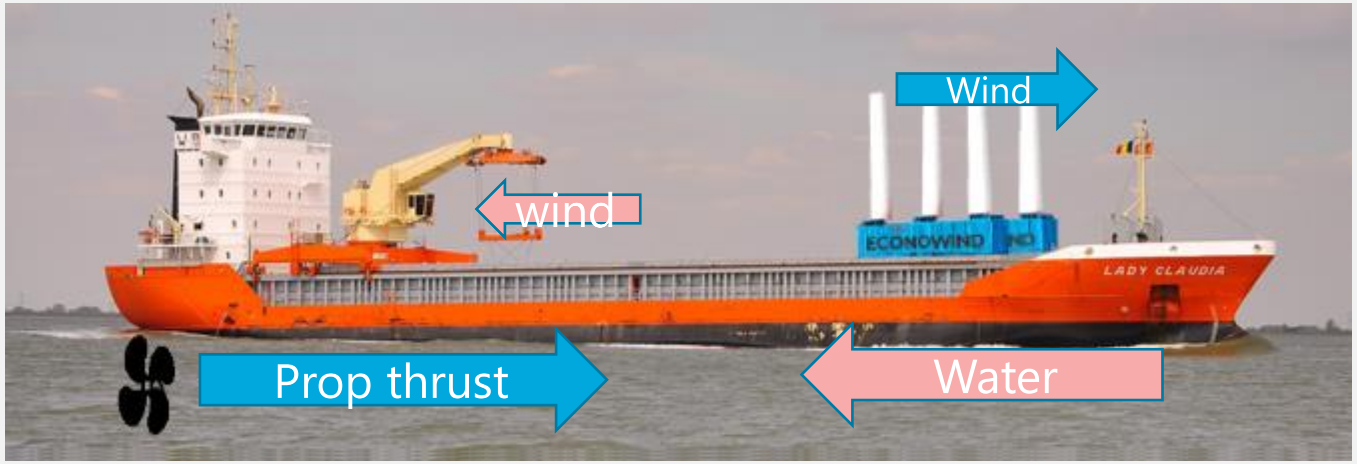
THEORY

Thrust = resistance



Reality

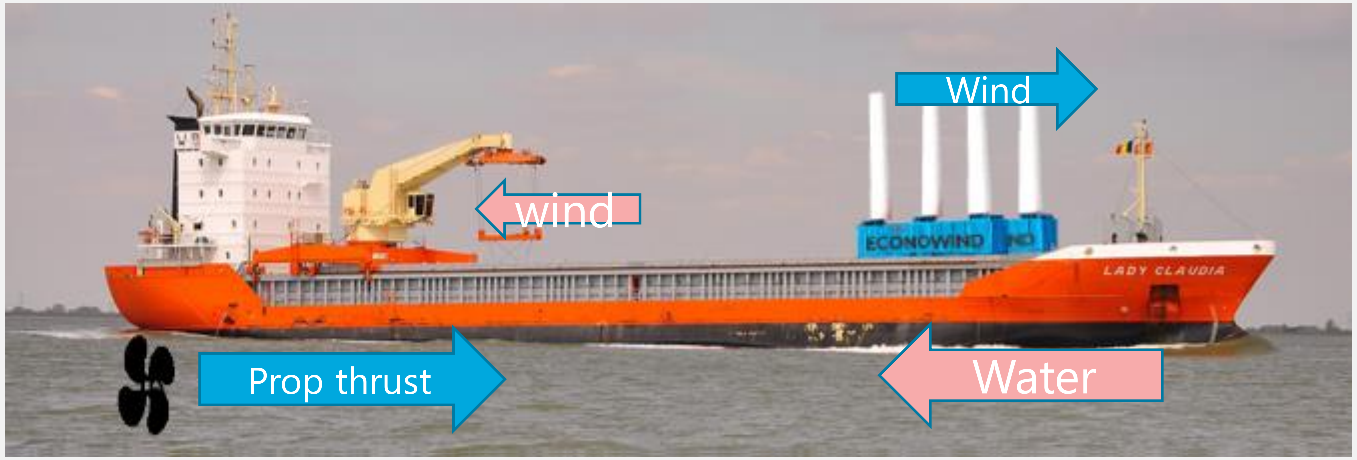
Thrust = resistance



Speed increases

REALITY

Thrust = resistance



Maximal saving at original speed

Conclusion:

We need to evaluate extra speed and fuel consumption

Interreg
North Sea Region
WASP
European Regional Development Fund
EUROPEAN UNION

Testing for Real:

MV Ankie: 10 x 2,1m

ECONOWIND

MV Ankie

MV Ankie: 10 x 2,3m

Interreg
North Sea Region
WASP
European Regional Development Fund
EUROPEAN UNION

ECONOWIND

MV Ankie

Interreg
North Sea Region
WASP
European Regional Development Fund

EUROPEAN UNION

Prediction

	0				0	15							
	ship speed		Distance	time	True wind speed	wind to heading	Apperent wind speed	Angle to heading	Cx Thrust coef	Thrust Force	Total Resistance ship	Motor force	Force reduction %
	knots	m/s	miles	hours	m/s	degrees	m/s	degree		Fwd kN	kN	kN	
stretch 1	9	4,63	1000	111	10	0	14,6	0,0	-1,3	0,0	50	50	0,0%
stretch 2	9	4,63	1000	111	10	15	14,5	10,3	-0,3	0,0	50	50	0,0%
stretch 3	9	4,63	1000	111	10	30	14,2	20,6	0,6	3,1	50	47	6,2%
stretch 4	9	4,63	1000	111	10	45	13,7	31,1	1,6	7,1	50	43	14,2%
stretch 5	9	4,63	1000	111	10	60	13,0	42,0	2,5	10,2	50	40	20,1%
stretch 6	9	4,63	1000	111	10	75	12,1	53,2	3,4	12,0	50	39	23,7%
stretch 7	9	4,63	1000	111	10	90	11,0	65,2	4,2	12,5	50	38	24,8%
stretch 8	9	4,63	1000	111	10	105	9,9	78,1	5,0	12,0	50	39	23,7%
stretch 9	9	4,63	1000	111	10	120	8,7	92,4	5,7	10,6	50	40	20,9%
stretch 10	9	4,63	1000	111	10	135	7,5	109,0	6,3	8,7	50	42	17,1%
stretch 11	9	4,63	1000	111	10	150	6,4	128,9	6,6	6,6	50	44	13,1%
stretch 12	9	4,63	1000	111	10	165	5,7	152,8	6,1	4,8	50	46	9,5%
stretch 13	9	4,63	1000	111	10	180	5,4	180,0	4,4	3,1	50	47	6,1%
				1444									

ECONOWIND

MV Ankie

Prediction

9 knots, 10 m/sec: 20 – 25%

	0				0	15							
	ship speed		Distance	time	True wind speed	wind to heading	Apperent wind speed	Angle to heading	Cx Thrust coef	Thrust Force	Total Resistance ship	Motor force	Force reduction %
	knots	m/s	miles	hours	m/s	degrees	m/s	degree		Fwd kN	kN	kN	
stretch 1	9	4,63	1000	111	10	0	14,6	0,0	-1,3	0,0	50	50	0,0%
stretch 2	9	4,63	1000	111	10	15	14,5	10,3	-0,3	0,0	50	50	0,0%
stretch 3	9	4,63	1000	111	10	30	14,2	20,6	0,6	3,1	50	47	6,2%
stretch 4	9	4,63	1000	111	10	45	13,7	31,1	1,6	7,1	50	43	14,2%
stretch 5	9	4,63	1000	111	10	60	13,0	42,0	2,5	10,2	50	40	20,1%
stretch 6	9	4,63	1000	111	10	75	12,1	53,2	3,4	12,0	50	39	23,7%
stretch 7	9	4,63	1000	111	10	90	11,0	65,2	4,2	12,5	50	38	24,8%
stretch 8	9	4,63	1000	111	10	105	9,9	78,1	5,0	12,0	50	39	23,7%
stretch 9	9	4,63	1000	111	10	120	8,7	92,4	5,7	10,6	50	40	20,9%
stretch 10	9	4,63	1000	111	10	135	7,5	109,0	6,3	8,7	50	42	17,1%
stretch 11	9	4,63	1000	111	10	150	6,4	128,9	6,6	6,6	50	44	13,1%
stretch 12	9	4,63	1000	111	10	165	5,7	152,8	6,1	4,8	50	46	9,5%
stretch 13	9	4,63	1000	111	10	180	5,4	180,0	4,4	3,1	50	47	6,1%
				1444									

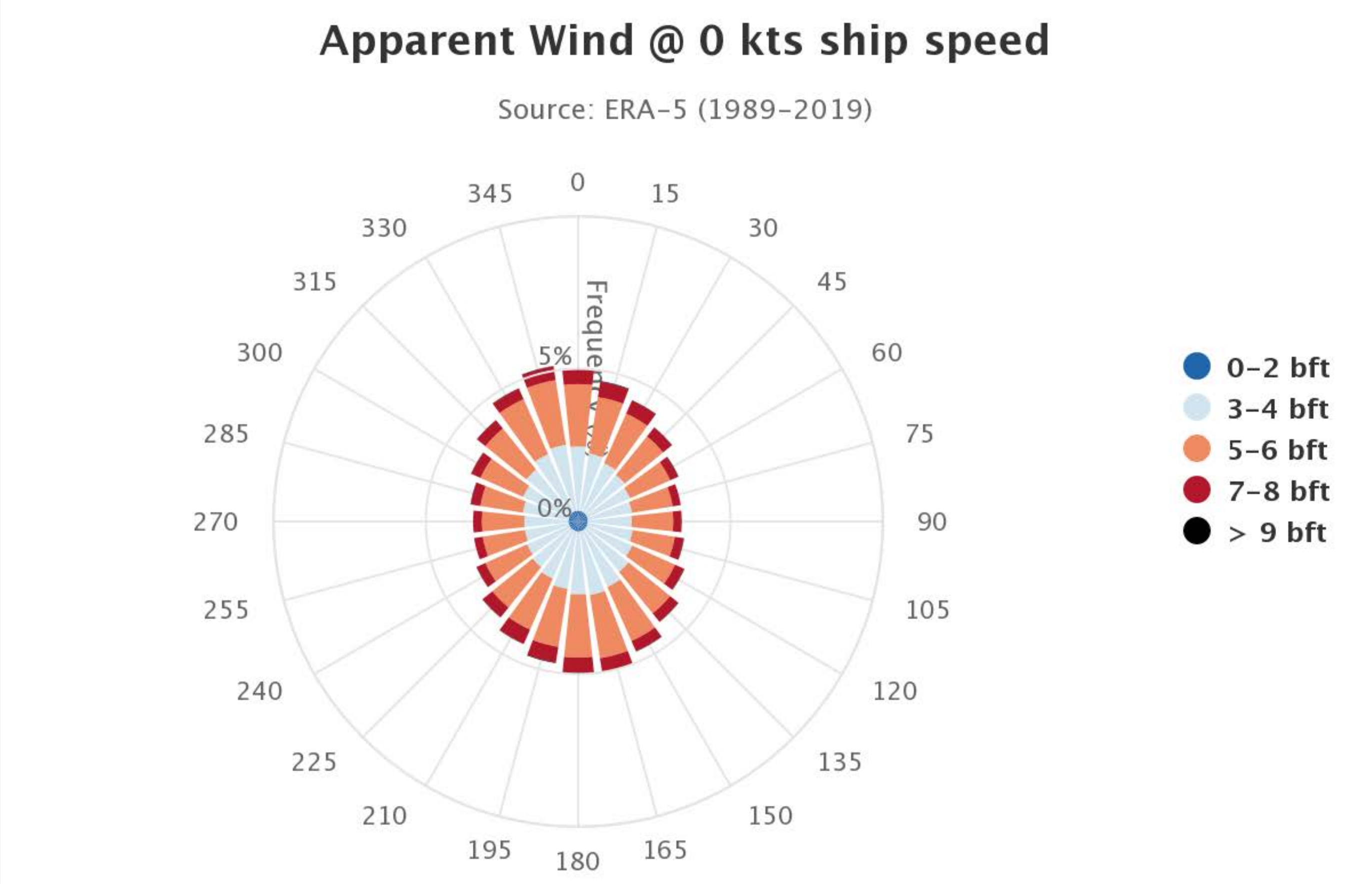
ECONOWIND

MV ANKIE

Sailing:

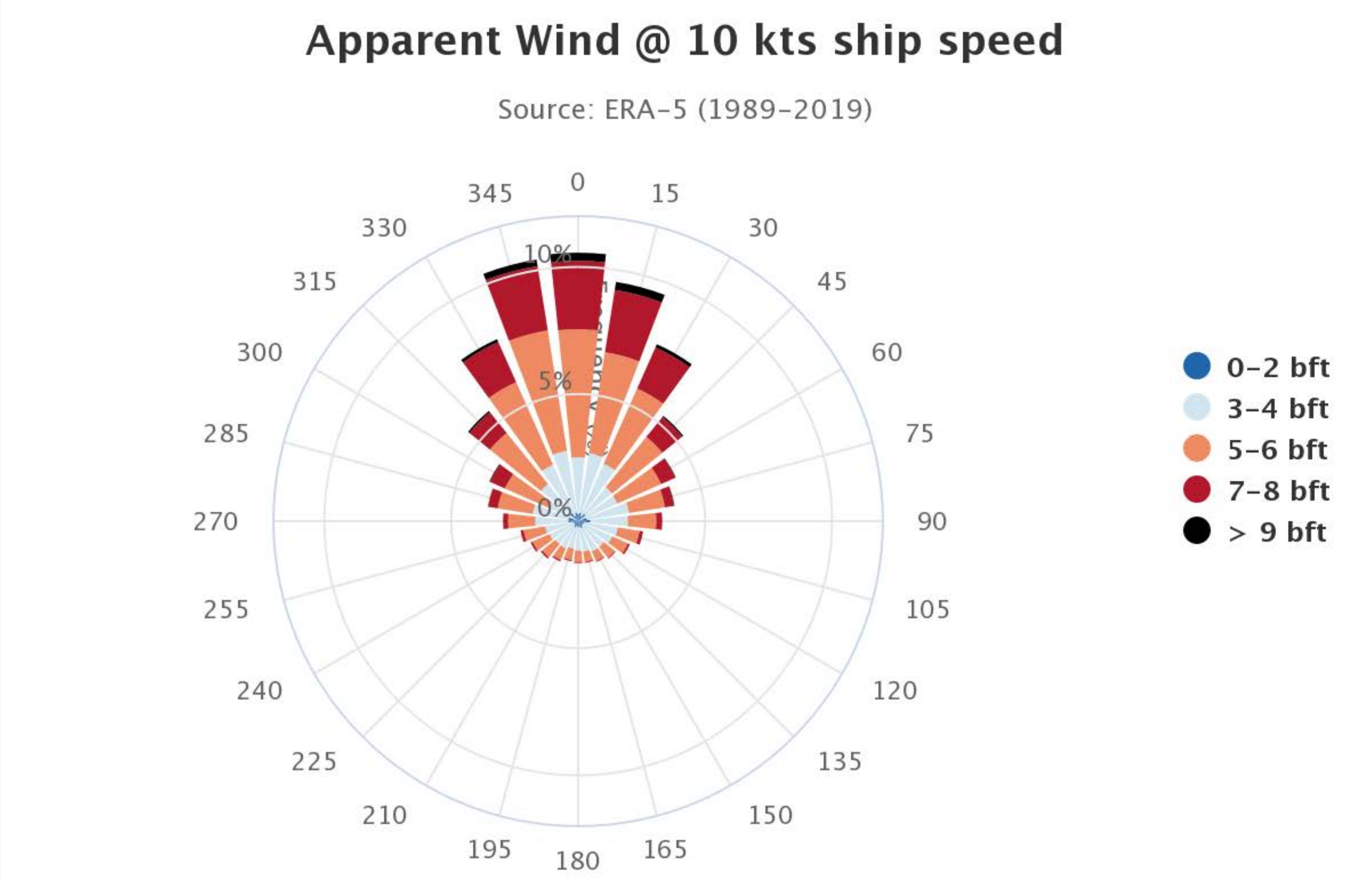
Influence of shipspeed

SOG = 0 [kts]



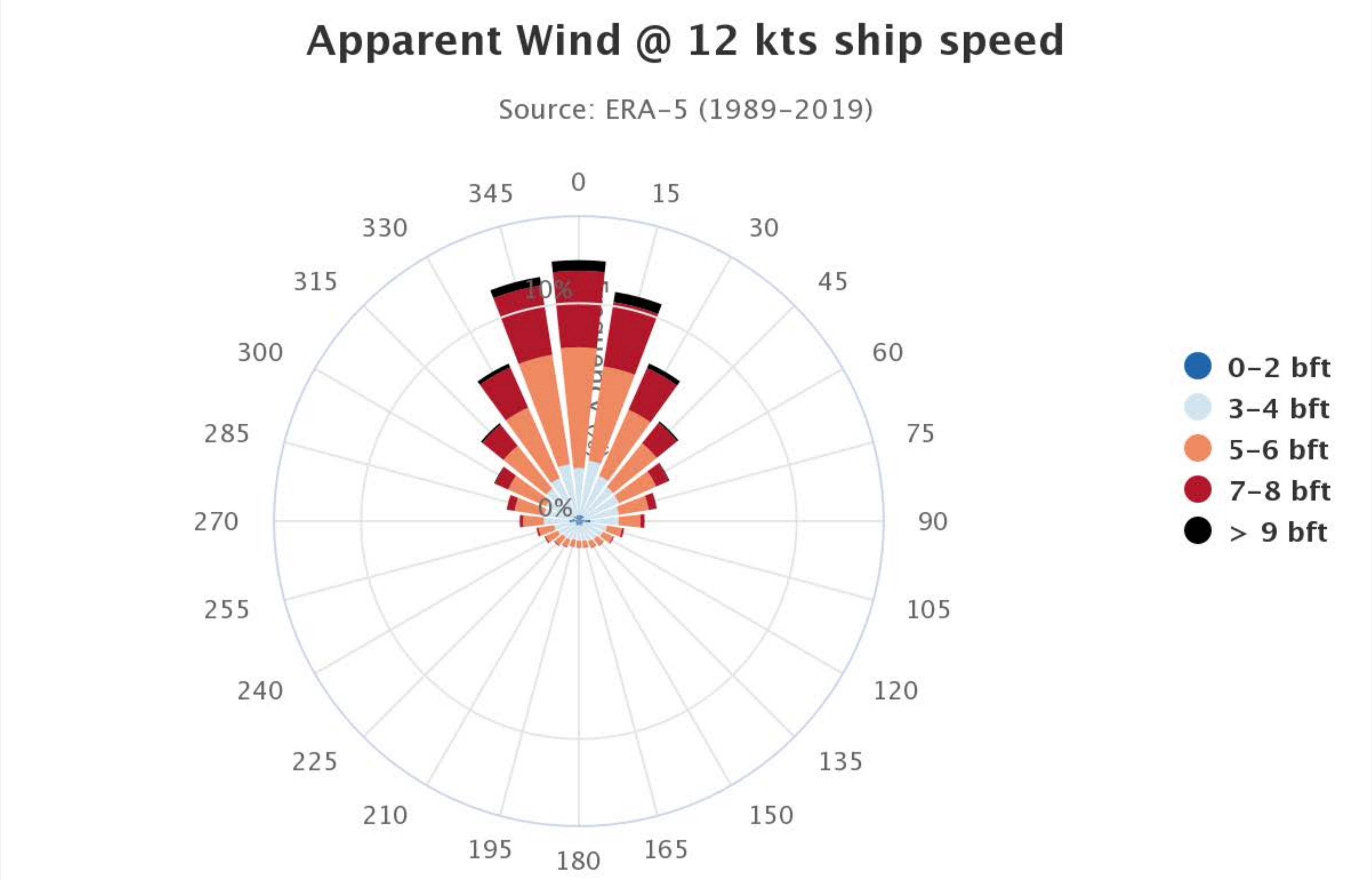
ECONOWIND

SOG = 10 [kts]



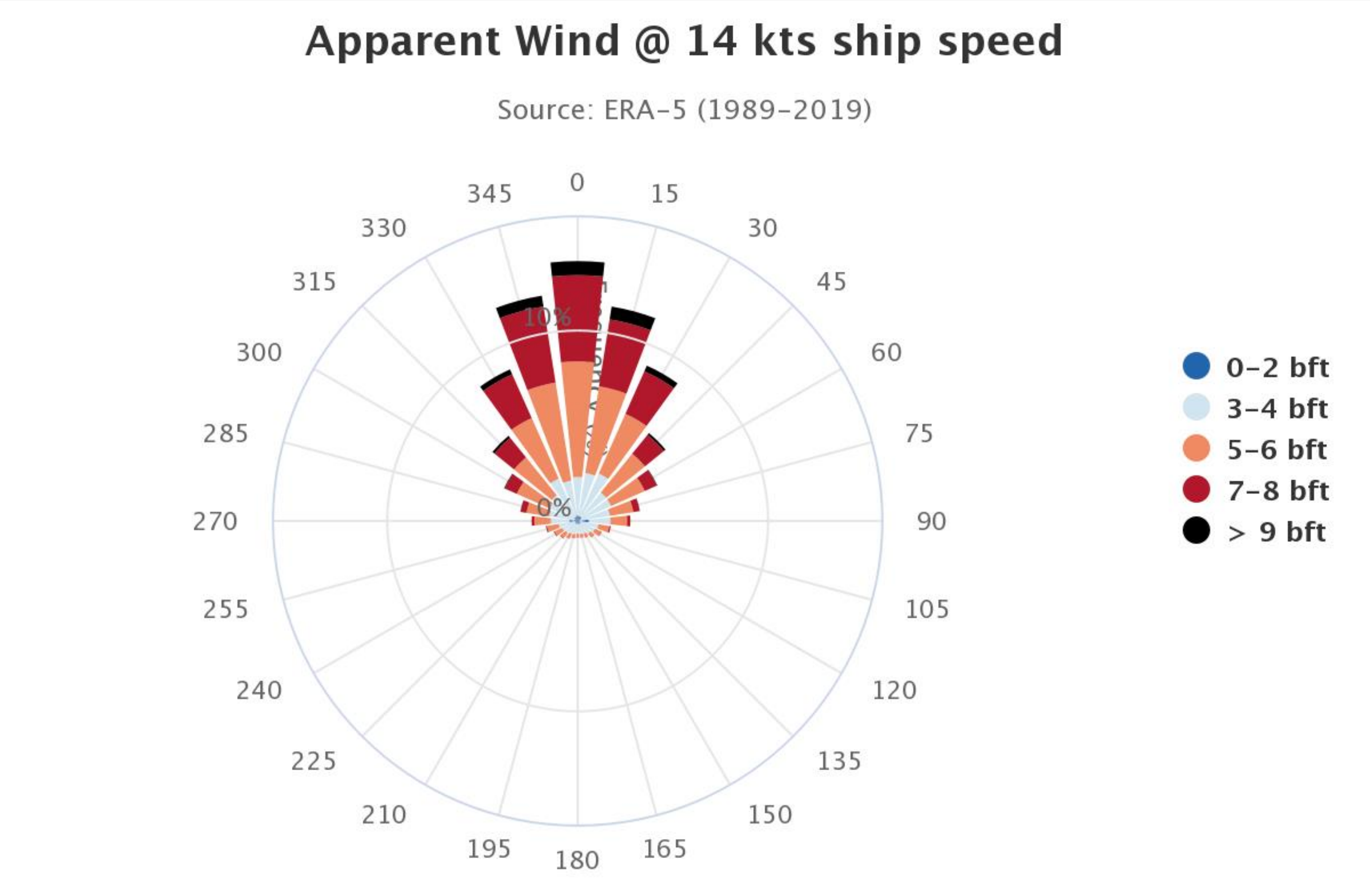
ECONOWIND

SOG = 12 [kts]



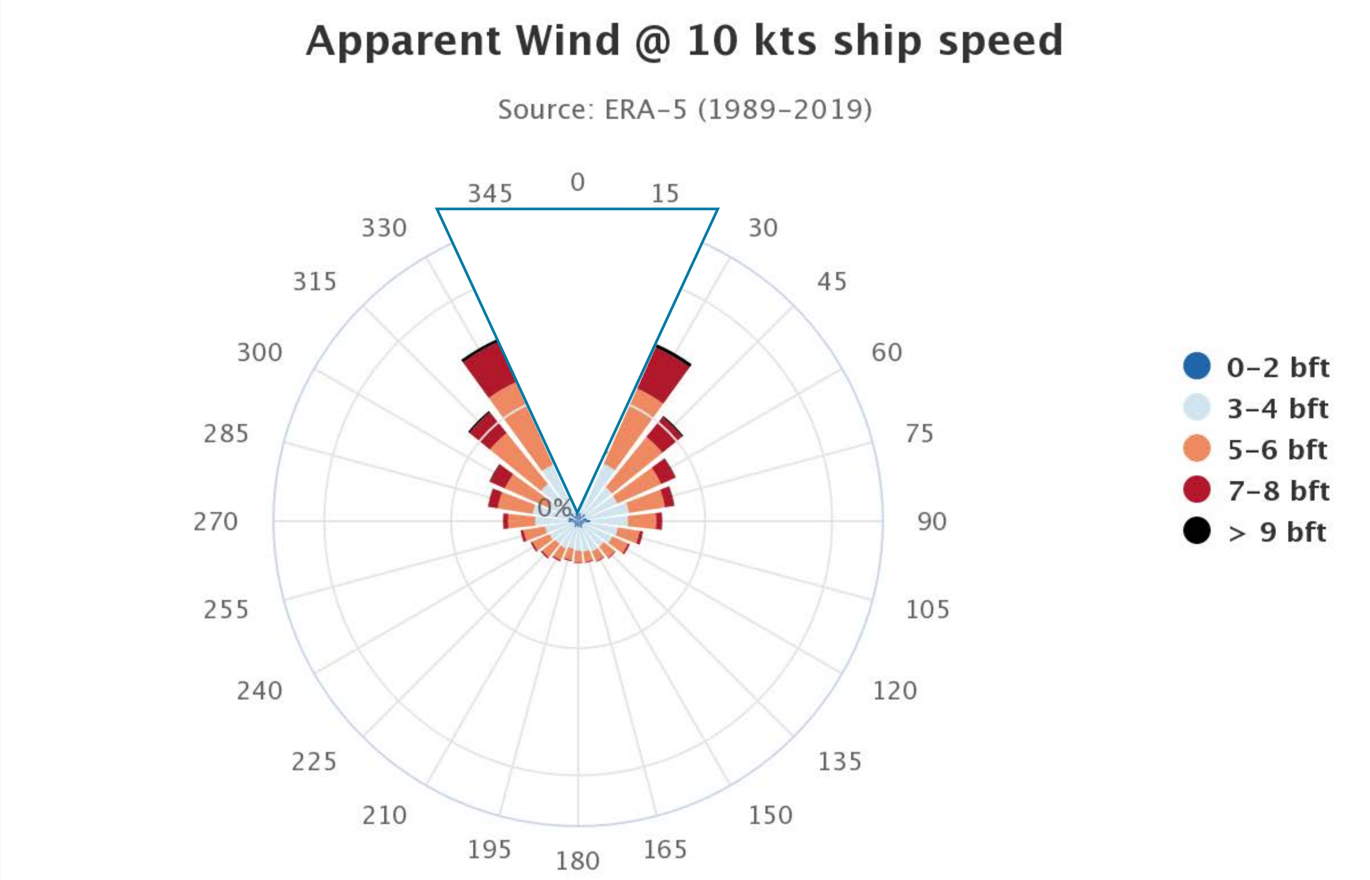
ECONOWIND

SOG = 14 [kts]



ECONOWIND

SOG = 10 [kts]

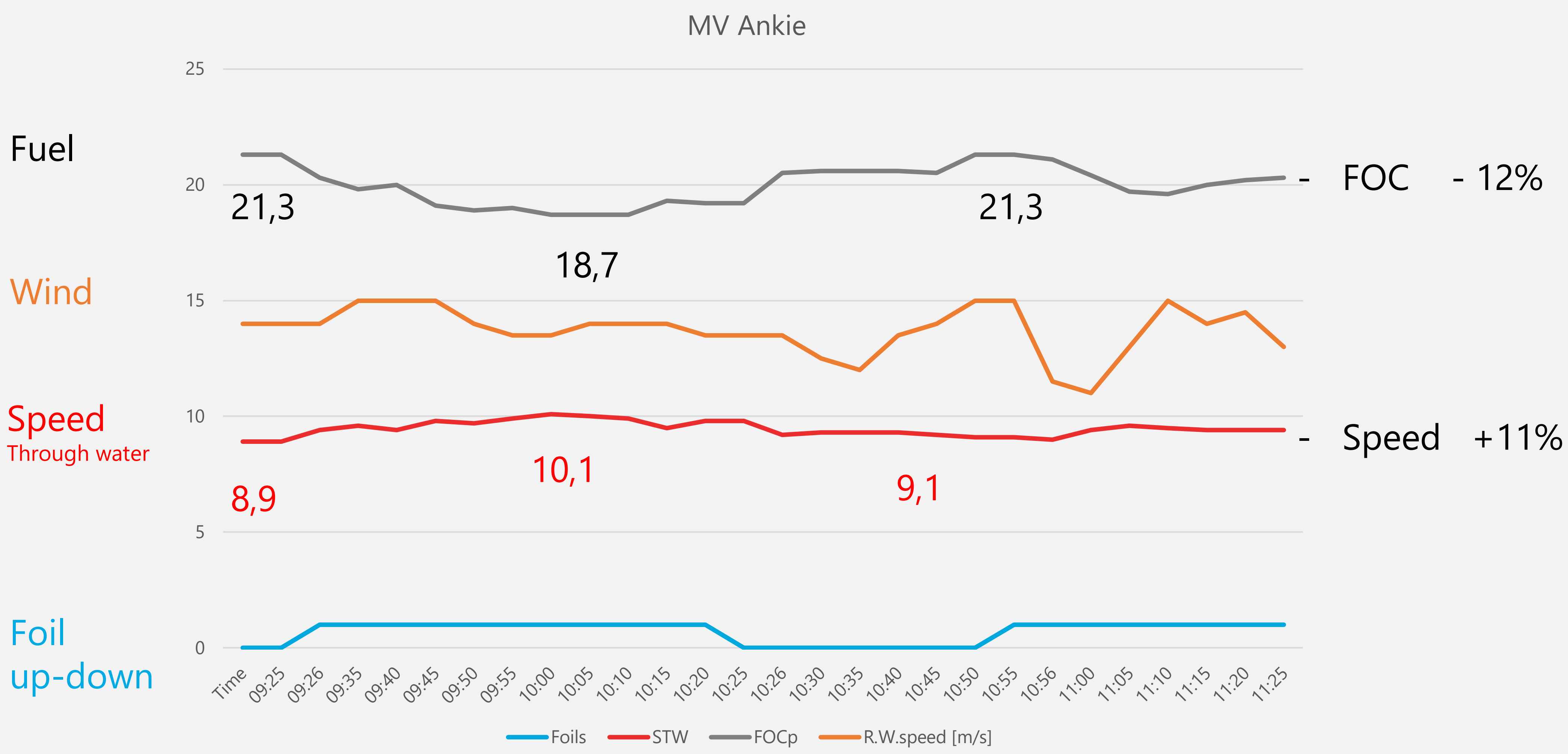


ECONOWIND


SWL 300 KG

Results:

MV ANKIE



ECONOWIND

MV Ankie

Results:

In reality over whole year / all routes?

MV Ankie

MEASURING IN ACTION

Measurements over 2 years period

Interreg
North Sea Region
WASP

European Regional Development Fund

EUROPEAN UNION

STEPS TOWARDS 2050

TAKE AWAY MESSAGE:

- **Wind assist is available TODAY**
- **Savings can equal leasing costs**
- **Changing to new fuels is easier with WASP**

Thank you for watching

Questions?

nieuwenhuis@econowind.nl

NEOLINE
Wind powered Shipping

NATURAL PROPULSION IN SHIP DESIGN CONFERENCE

Nov. 16th 2021

NEOLINE
Wind powered Shipping

WHO IS NEOLINE ?

A pioneer shipowner centered around sustainability

- A French company created in 2015
- Inspired by **Michel Péry**
- 9 founders from shipping industry
- An operational team led by **Jean Zanuttini**
- A new shareholder since June 2020

SOGESTRAN
GROUP

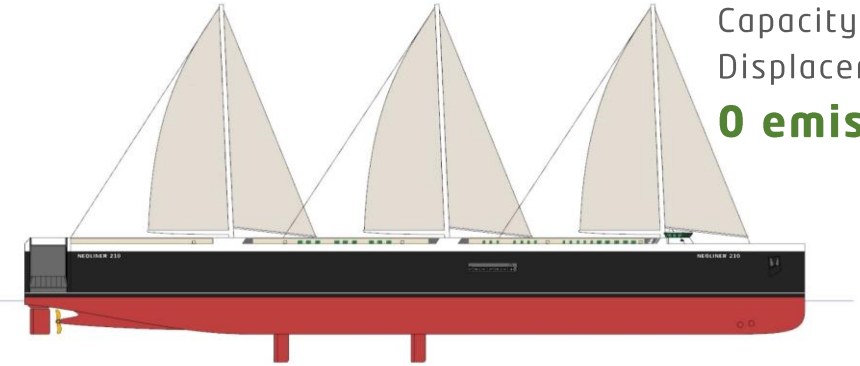
OUR 2030 VISION

Industrial **Competitive** **0 emissions**

Neoliner 136m

Capacity of 1500 lm or 540 cars
Displacement : 11 000t

80% to 90% of consumption reduction



Neoliner 210m

Capacity of 9000 lm or 4200 cars
Displacement : 35 000t

0 emission

First « shipper partner » : GROUPE RENAULT

Illustration Pierre Zanuttini

NEOLINE
Wind powered Shipping

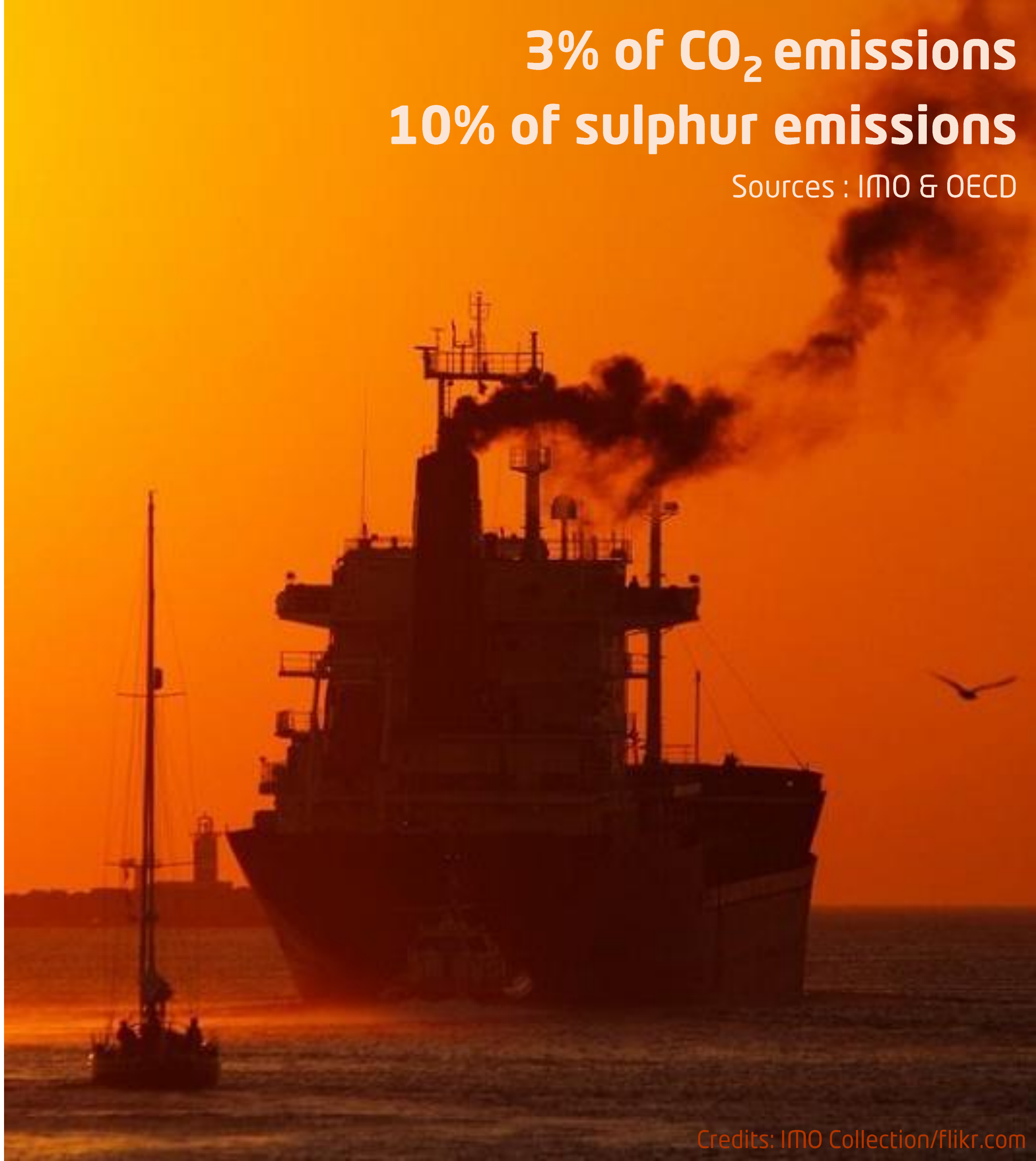
MACRO-ECONOMIC CONTEXT

A sector in question

IMO

European Green Deal

- Societal and regulatory constraints
- Transport costs incertainties
- Maritime transport concentration

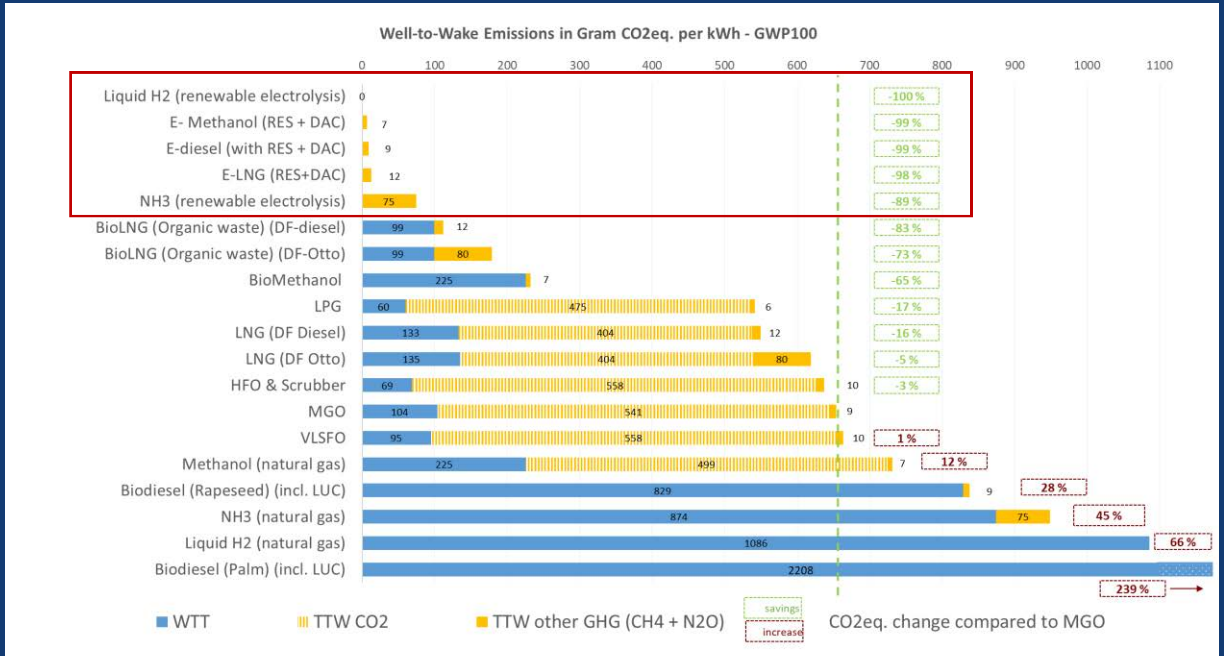


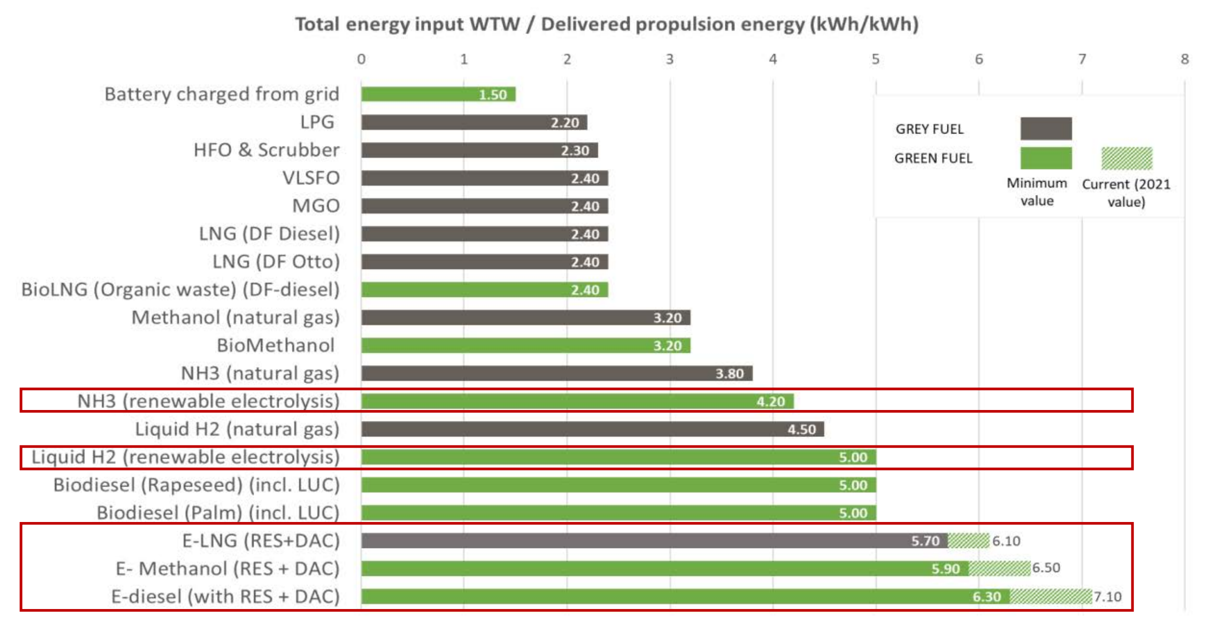
A difficult equation toward 0 emission

- Only e-fuels can really reduce GHG emission
- However, they need 2 to 3 times more energy
- Availability will be insufficient

→ **Need to drastically reduce energy consumption**

→ **Need to use a more direct renewable energy**





Source: SINTEF Ocean AS Dr. Elizabeth Lindstad

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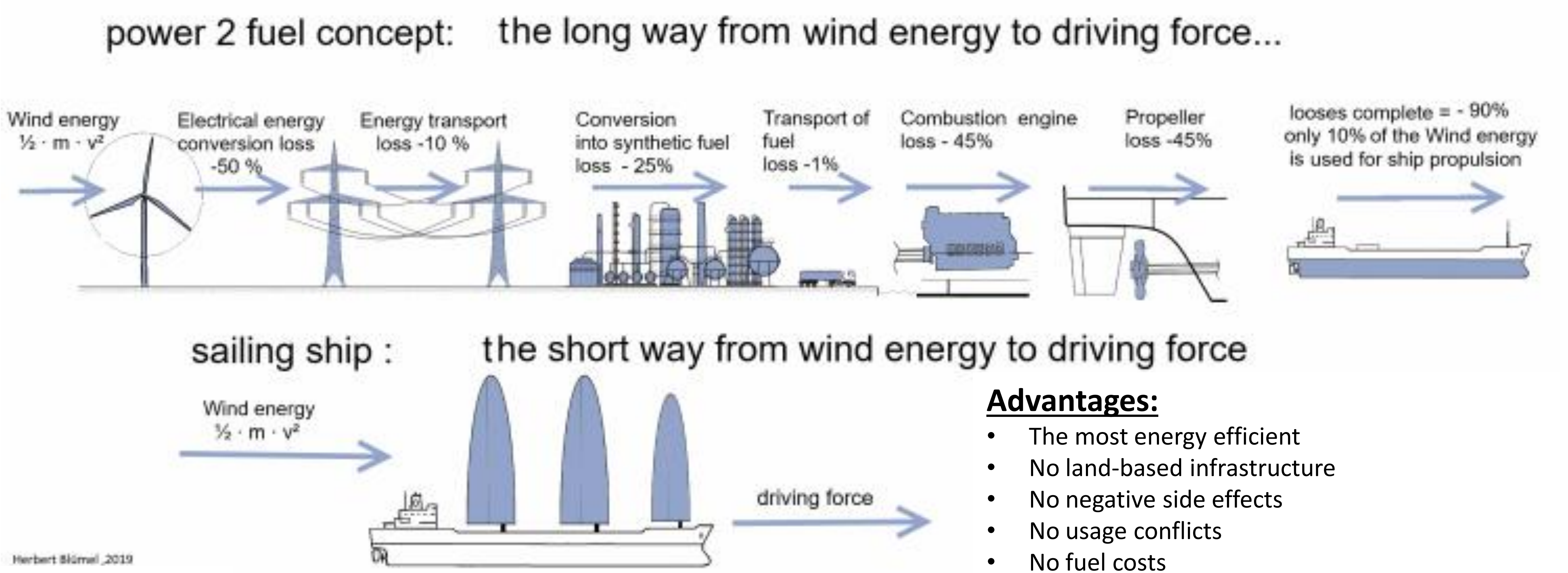
WHY USING WIND ?

Available everywhere

Efficient



Herbert Blümel - 2019

Advantages:

- The most energy efficient
- No land-based infrastructure
- No negative side effects
- No usage conflicts
- No fuel costs
- Less dependency on fuel producers

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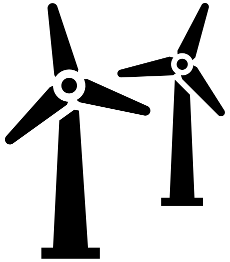
Wind powered Shipping

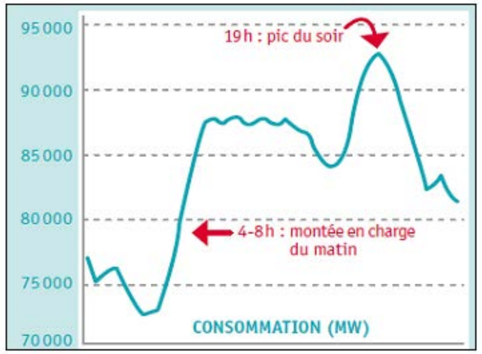
WHY USING WIND ?

Uncontrolled intermittency vs



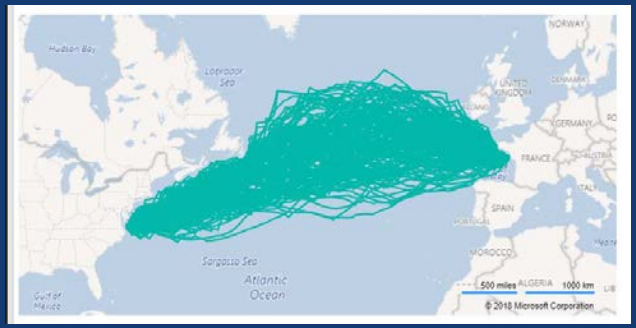
Fixed

« non-negociable » consumption



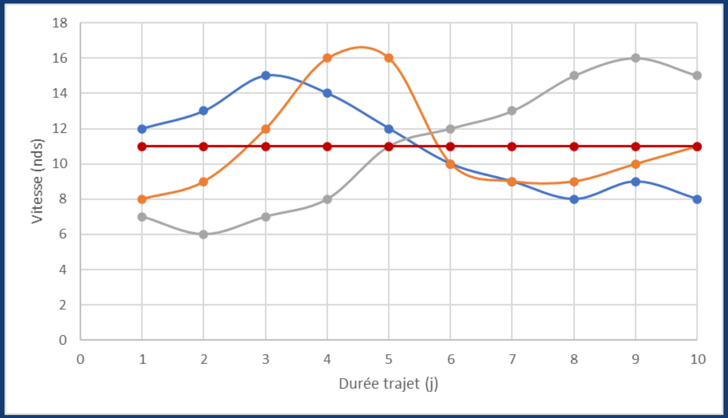
Need to provide controlable energy most of time

Managed intermittency



Optimized routing

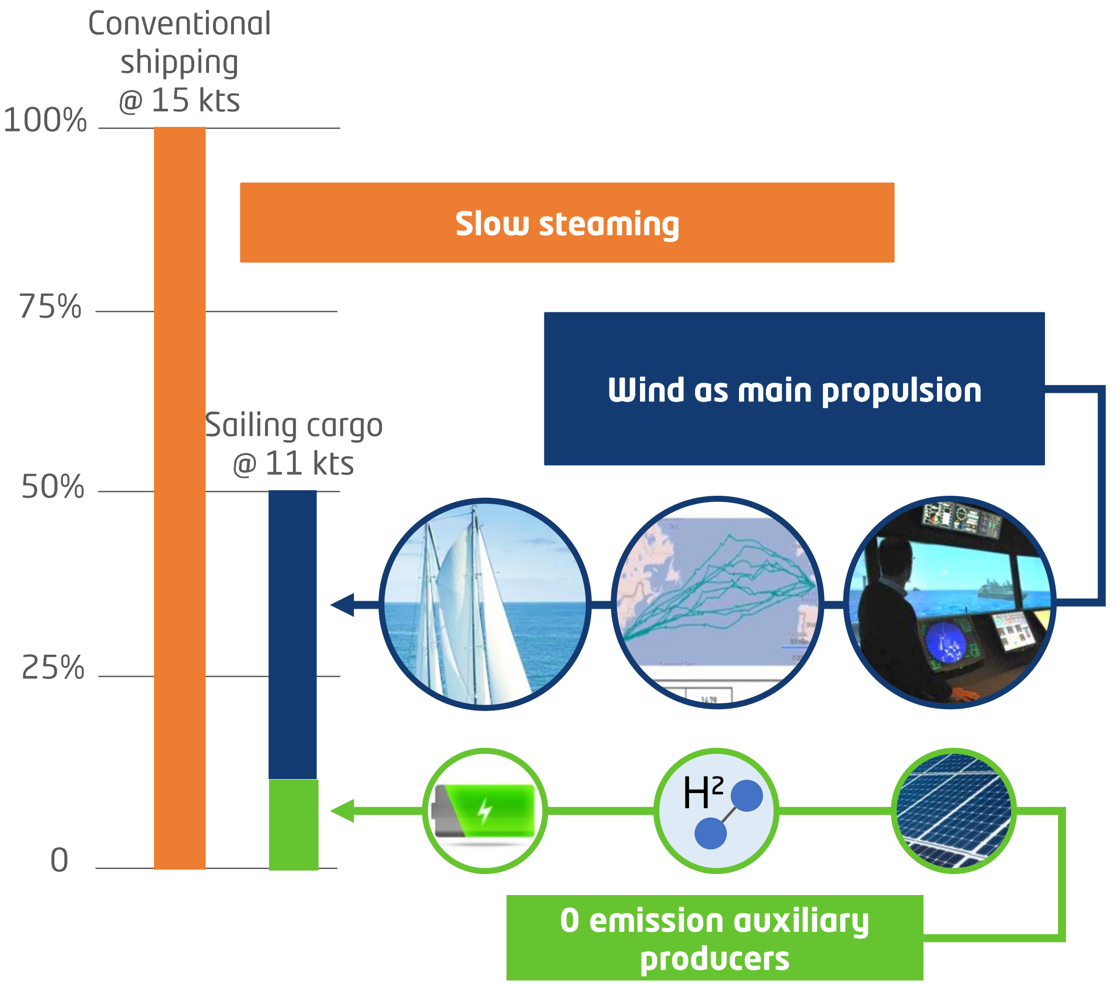
Adjustable consumption profile



Controlable energy rarelly needed

NEOLINE Wind powered Shipping

Reaching 0 emission with wind:



NEOLINE
Wind powered Shipping

NEOLINER 136

A clean, safe and efficient transport tool

- Main features

  - **Dimensions……………………...........136 m x 24,2 m (446ft x 78,64ft)**
  - **Sails surface……………………………....4200 sqm**
  - Auxiliary propulsion………………..diesel-électric 4000 kw
  - Air Draft ………………………………......reductible to 41,5 m (134,51’)
  - Draught………………..………………….....reductible to 5,5 m (16,40’)
  - Crew…………………………………….........14 (+12 passengers)

- Specialized for oversized and heavy frets

  - Height (max)…………………………………………………..9,80 m (29,52 ft)
  - Roro capacity…………………………………………..…….1700 lm
  - Breakbulk…………………………………………………………..5 300 T
  - Cars capacity…………………………………………………...540 cars
  - Container capacity…………………………………………..273 TEU’s

Credits: Neoline / Mauric

Economic model

Cost structure

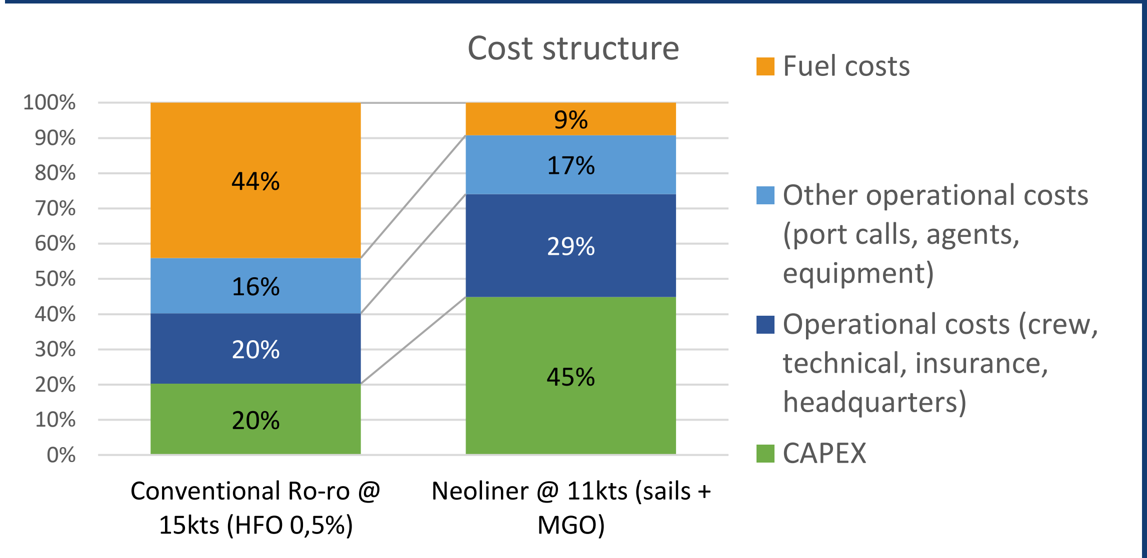
- Less OPEX, more CAPEX
- Equivalent costs when fuel price is about $60

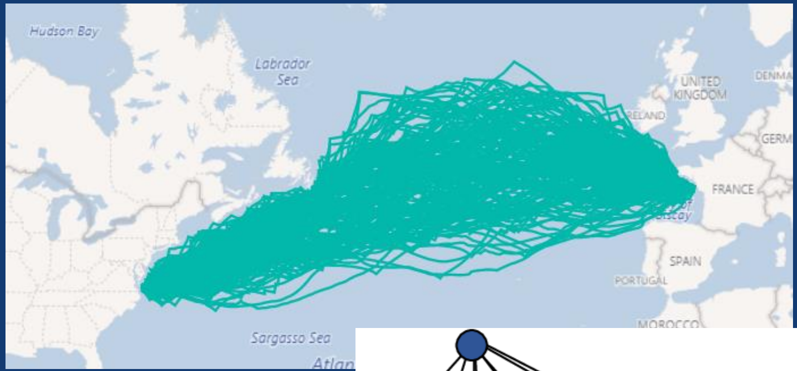
Advantages for shippers

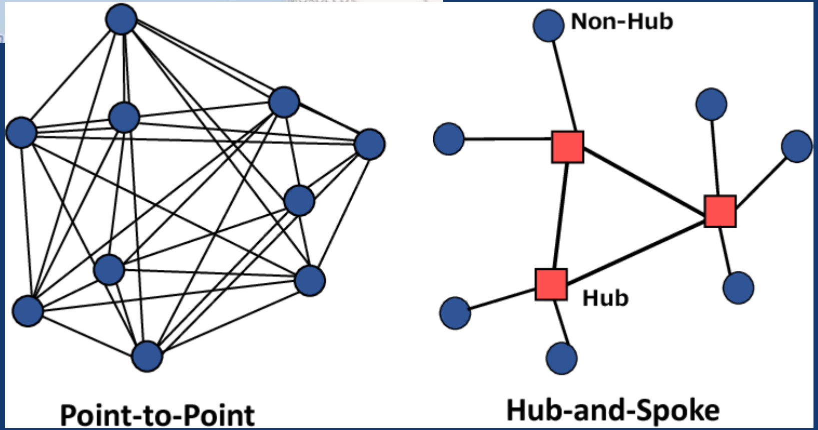
- Highest standard for shipper's CSR policy
- Independant from fuel prices (no BAF)
- Image and marketing advantage
- High quality transport, comply with standard logistics procedures

Drawbacks can be overcome

- Wind intermittency => weather routing and auxiliary propulsion
- Lower speed => « point to point » secondary routes (vs hub logic)
- Smaller vessels => savings on pre-haulage and higher filling rate







A new regular transatlantic route France <-> North America

- Original secondary route
- Ideal from wind perspective
- New hinterlands proximities

Shippers allready involved:

- Transport contracts:
  - Groupe Renault
  - Groupe Bénéteau
  - Manitou Group
  - Michelin
  - HENNESSY
  - Clarins
  - Longchamp

NEOLINE Wind powered Shipping

THE PILOT LINE

Routing studies

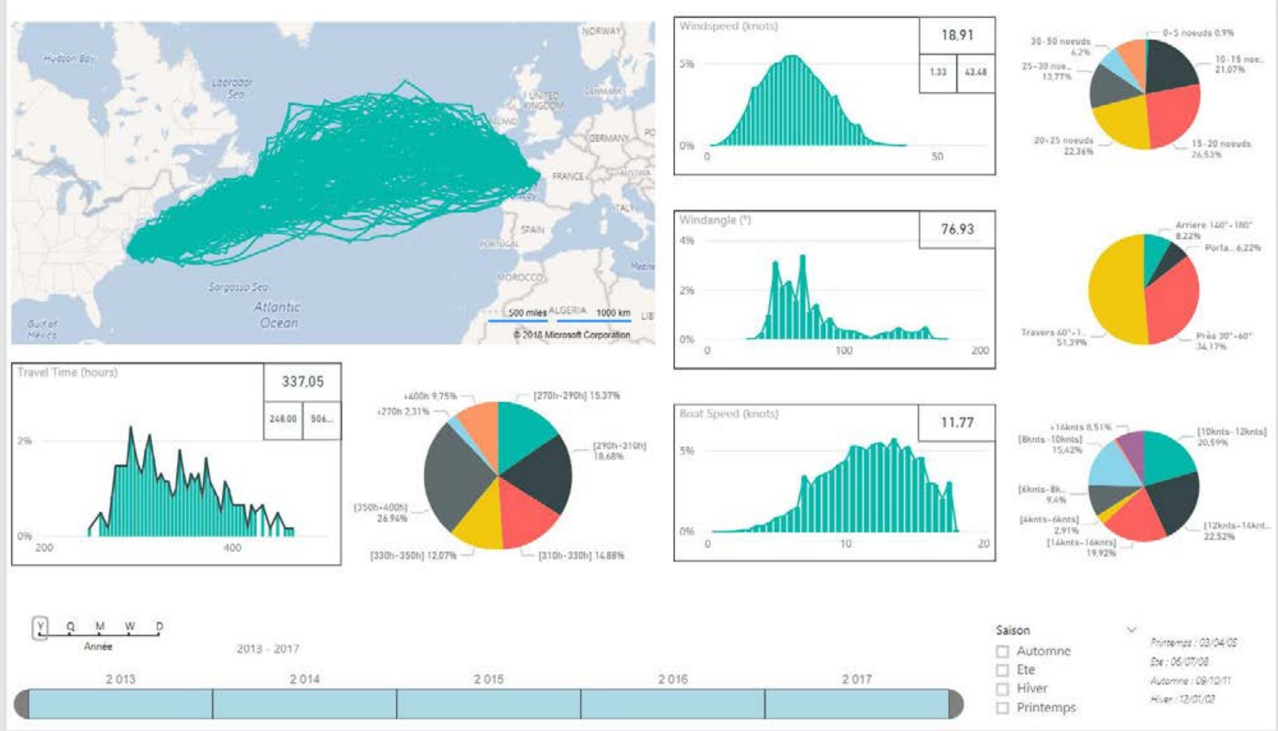
- ✓ **50% of time at 12kts under sails only**
- ✓ **24% westbound route lengthening**
- ✓ **16% eastbound route lengthening**

- ✓ For a trip at 11kts of commercial mean speed:
  - ➢ Mean fuel consumption: **34t**
  - ➢ Fuel consumption of Classical vessel at 11kts : **119t**

    71% of reduction
  - ➢ Fuel consumption of classical vessel at 15kts : **216t**

    84% of reduction (93% winter)

- ✓ **50% of fuel consumption for onboard electricity**



D-ICE ENGINEERING

NEOLINE

Wind powered Shipping

www.neoline.eu

Région PAYS DE LA LOIRE

Armateurs de France

French Maritime Cluster
Bound for Blue Growth

NANTES SAINT-NAZAIRE PORT

bpifrance

PÔLE MER BRETAGNE ATLANTIQUE

EMC2

ATLANPOLE
Land of innovation


La Hermosura del Gulfo de Nicoya - Costa Rica, Centroamérica
inversiones marítimas ceiba sociedad anonima
SAILCARGO INC.
clean ocean cargo

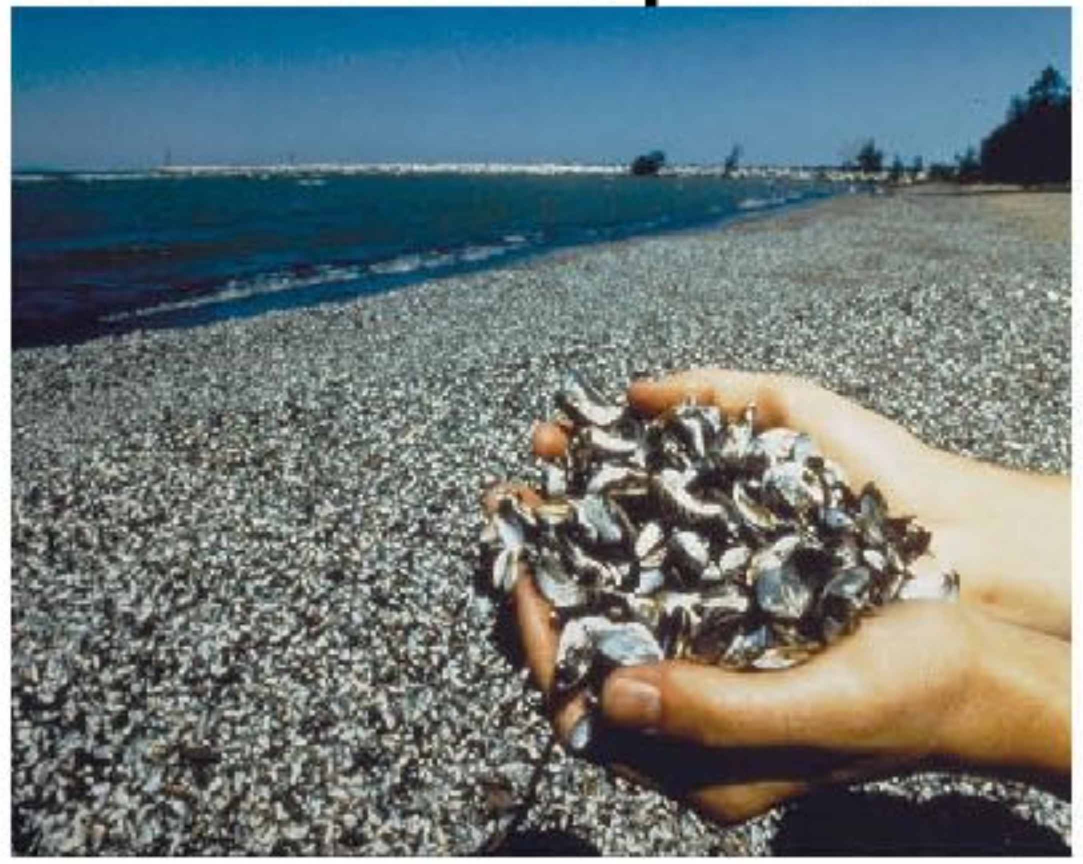
THE PROBLEM WITH THE SHIPPING INDUSTRY

Iron Ore Mining

Air Pollution

Sewage Discharge

Invasive Species



Acoustic Pollution

Shipbreaking

Oil Spills

Accidents at Sea

TARGET PRODUCTS

INVERSIONES MARITIMAS PITAYA SOCIEDAD ANONIMA

REGISTERED IN COSTA RICA, JUNE 2021

DESCRIPTION Due an increasing demand for clean shipping services, the construction of PITAYA has been announced. The ship will have an auxiliary electric engine, and may use hydrogen fuel cells. Request the business plan to learn more.

PROJECT TITLE	PITAYA
TITLE TRANSLATION	DRAGON FRUIT
DURATION BUILD	36 - 42 MONTHS
BUILD LOCATION	ASTILLEROVERDE SHIPYARD, PUNTA MORALES
OPPORTUNITY	INVESTMENT
ESTIMATED COST	$4.4M
MINIMUM INVESTMENT	$20,000.^00USD^ UNTIL AUTUMN 2021
ESTIMATED R.O.I.	6 - 8% ANNUALLY
CARGO CAPACITY	9 TEU, 250 TONS, 350 CUBIC METRES
TRADE ROUTE	SOUTH AMERICA - EASTERN SEABOARD, U.S.A. SANTA MARTA, COLOMBIA - ATLANTIC CITY, NEW JERSEY
ROUND TRIPS	7 ANNUALLY REDUCED TO 6 TRIPS ONCE EVERY 5 YEARS, FOR MAINTENANCE
CLIENT STATUS	ALL NORTHBOUND CARGO SECURED
PROJECT STATUS	**BEGUN; ENGAGED** NOW SECURING LETTERS OF INTENT TO INVEST INVEST@SAILCARGO.INC, L.O.I. AVAILABLE BY REQUEST

COSTA RICA + CANADA JOINTLY PRESENT GOLD MEDAL AWARD

OUR MISSION
IS TO PROVE THE VALUE OF CLEAN SHIPPING

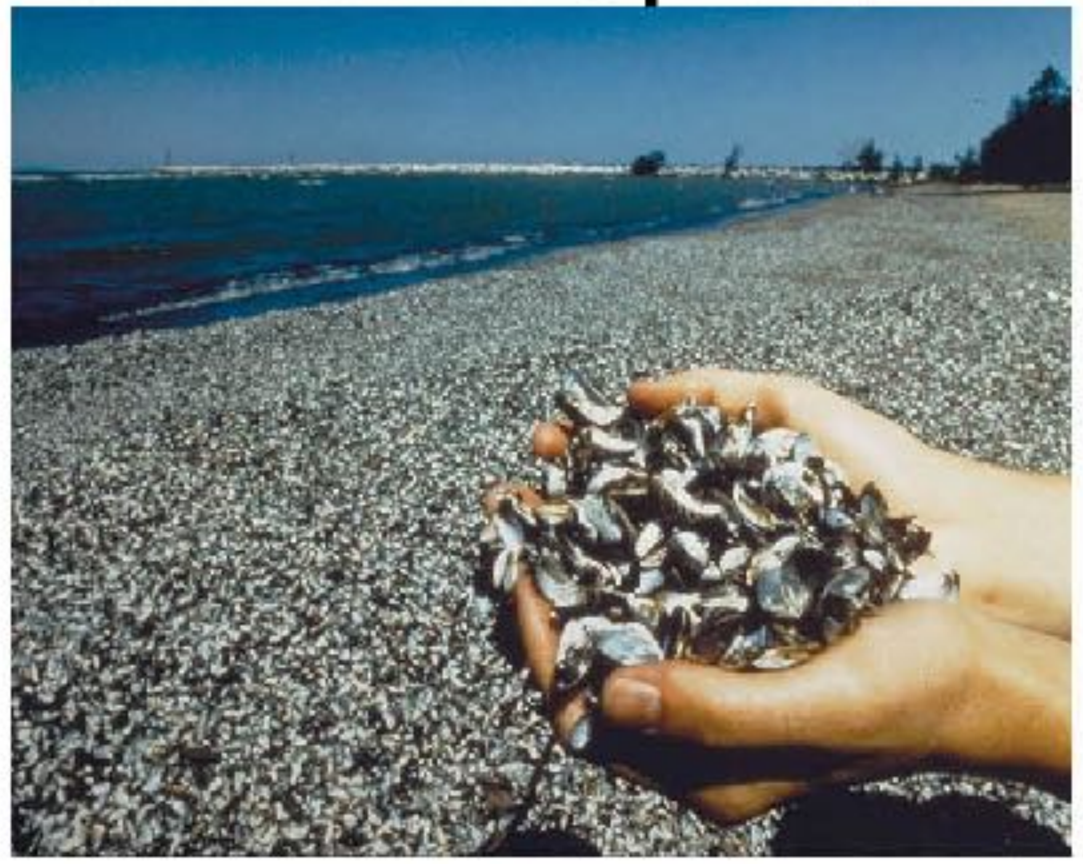
THE PROBLEM WITH THE SHIPPING INDUSTRY

Iron Ore Mining

Air Pollution

Sewage Discharge

Invasive Species



Acoustic Pollution

Shipbreaking

Oil Spills

Accidents at Sea

The problem isn’t really that we have a problem,

It’s that we don’t have a solution…

SAILCARGO INC.

CAFÉ
WILLIAM
SPARTIVENTO

HUNDESTED PROPELLER A/S

VerdEnergia
PACIFICA

Rocket Company ™
A
ASTRA

AstilleroVerde

DYKSTRA
NAVAL ARCHITECTS

IWSA
International Windship Association

ZESTAs.

BALLARD®

BLUE
ACTION
LAB

SAILCARGO INC.

CAFÉ WILLIAM SPARTIVENTO

HUNDESTED PROPELLER A/S

VerdEnergia PACIFICA

Rocket Company™ ASTRA

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AD ASTRA

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ACTION
LAB

SAILCARGO INC.


veer


veer

CAFÉ
WILLIAM
SPARTIVENTO

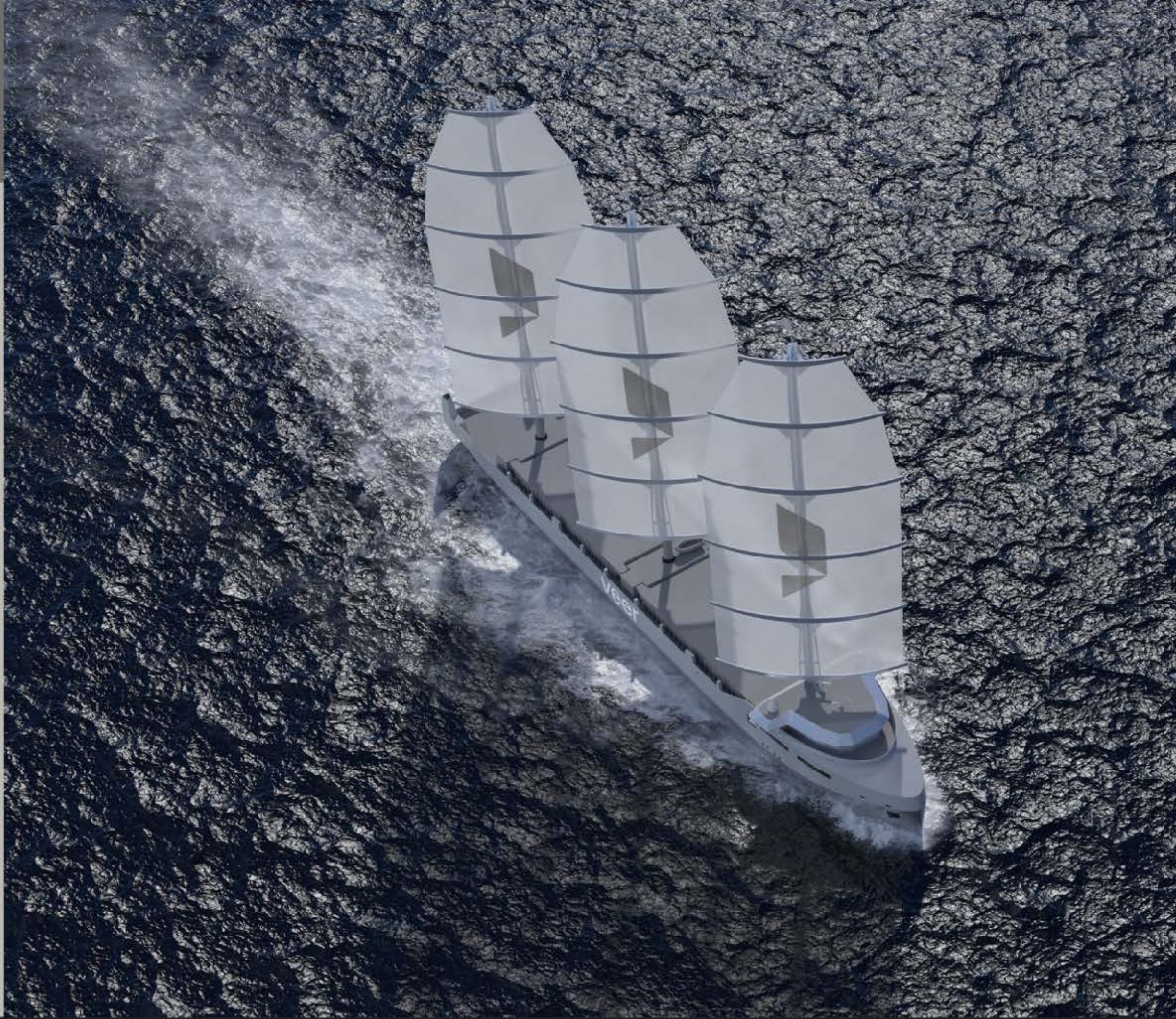
Cafe William Major Client

"Coffee has the biggest footprint of any beverage on the planet. As a company we have been trying to improve on that through different means – the means that we are able to control.

But regardless of what we do, the biggest problem is that it boards the dirtiest form of transportation.

The answer that we found was VEER. We believe that, through partnership, we can use our leverage as a company to assist – that is, **importing hundreds and hundreds of containers from all over the world.**"

Serge Picard
Founder
Cafe William




veer


veer

Specifications

Designed to be the **fastest** emission-free cargo ship in the world. Powered by the wind and clean hydrogen fuel cells. **Capable of ocean-crossings, completely energy independent.**

Both container ship and tanker designs are being designed currently by VEER x Dykstra Naval Architects.

Project Particulars

Build Duration	24 Months.
Build Location	To Be Determined.
Opportunity	Investment into Topholding Company.
Estimated Cost per Ship	Preliminary Estimate: +$25M USD
Return on Investment	Preliminary Estimate: 6% Annually.
Technology	DynaRig Existing & Proven. Hydrogen Ready.
Project Status	Design Phase. Significant Interest from Clients. Now securing Letters of Intent to Invest, to Ship.

Container Ship Design

Project Title	MAMBA
Speed Under Engine	12 kts
Speed Potential Under Sail	20 kts
Length Over All	100 m
Beam Max.	15.6 m
Draft Max.	7.0 m
Air Draft Max.	62.5m (Panamax)
Cargo Capacity	100 TEU Inside Holds, 62 TEU On Weather Deck. Inside of holds containerized. On weather deck not containerized.

Tanker Design

Length Over All	120 m
Cargo Capacity	Initial Investigation Suggests 4.1M Litres Capacity. Details differ from above for tanker scenario.


veer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www.veer.voyage

veer.voyages

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