Proceedings of the 4th

Sustainability *in* Ship Design *and* Operations

Conference

October 28-29, 2024

Volume 2 Part 2: Presentations

Conference Information

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

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

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GRAIN DE SAIL

28/10/2024

LE GOÛT DE L'AVENTURE !

A UNIQUE & INTEGRATED BUSINESS MODEL

SOURCING

MARITIME SHIPPING IMPORT/EXPORT

PRODUCTION

DISTRIBUTION

GRAIN DE SAIL BY THE NUMBERS (2023)

+ 380 TONNES organic chocolate

- 3,8 M tablets sold
- Forecast 2024 : 4,5 M tablets

+ 85 TONNES of organic coffee

- Forecast 2024 : 135 tonnes

2023

9,6 M€ Revenue

Growth +19%

Forecast 2024
- 11,9M €
- +24%

GRAIN DE SAIL

OUR VALUES

2. OUR VALUES

QUALITY

Products
Services

ADVENTURE !

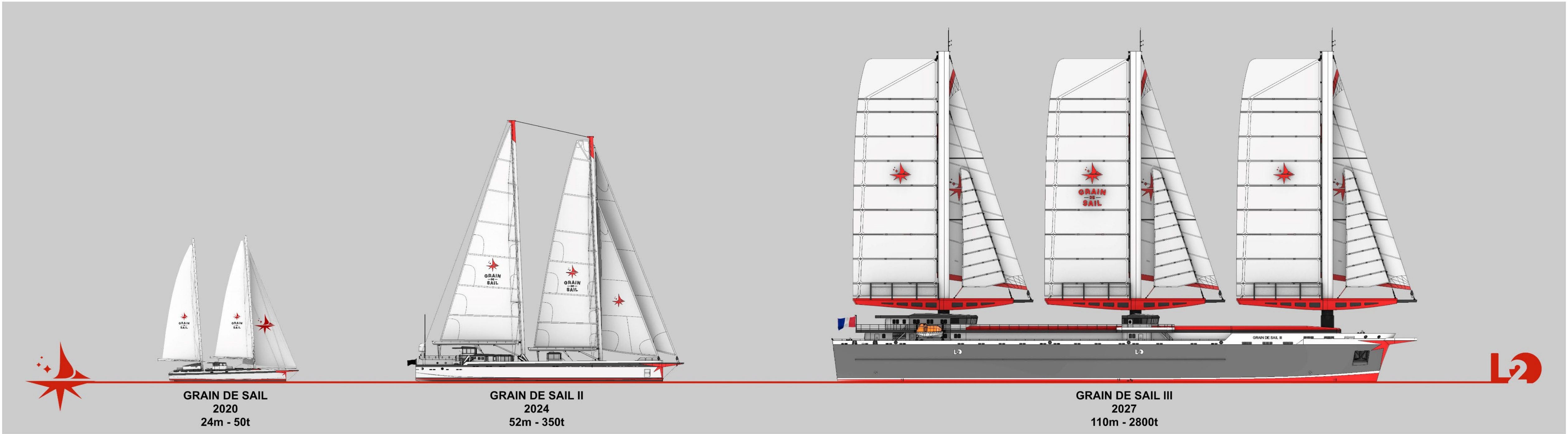
Human adventure
Maritime adventure

SUSTAINABLE DEVELOPMENT

Environment
Social
Economic

OUR CARGO SAILBOATS

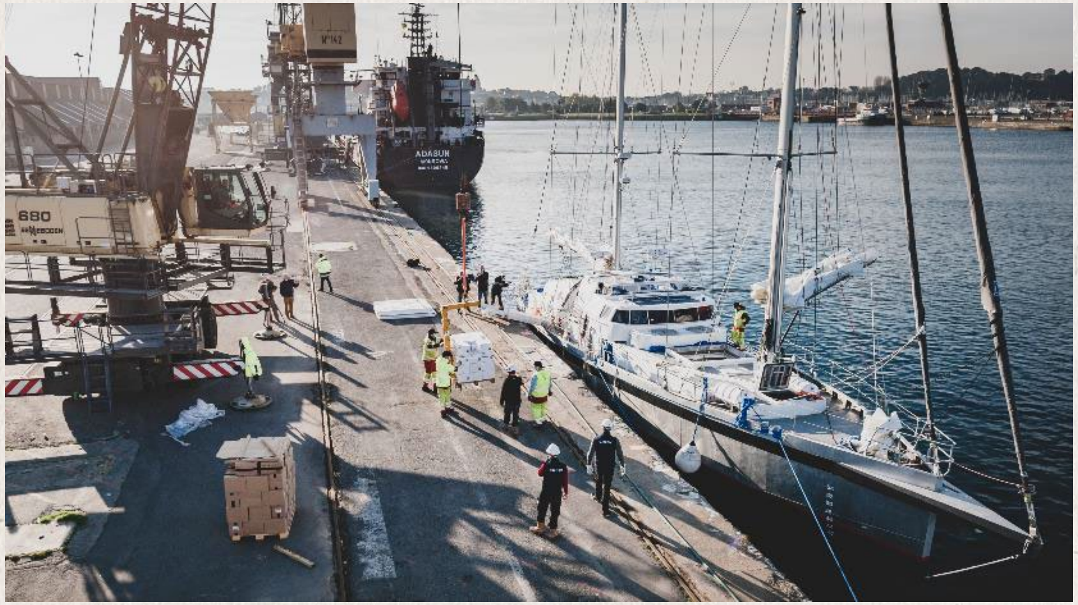
FLEET OF MODERN CARGO SAILBOATS



Pure sailing vessels :

90% carbon emission reduction (1-2 g CO2/ton/km)

6. MODERN CARGO SAILBOATS



Grain de Sail – 1st commercialy-certified cargo sailboat : **24 m** and **50 T** payload capacity

Grain de Sail 2 – operational since March 2024 : **52 m** and **350 T** payload capacity

GRAIN DE SAIL

6. MODERN CARGO SAILBOATS

Grain de Sail III – 2027 :
110m and **2800 T** payload capacity (~200 TEUs)

EFFICIENT CARGO SAILING

3 key points for efficient cargo sailboat design:

1. Hull optimized for wind propulsion,
2. Favorable ratio between wind propulsion capacity and loaded ship weight,
3. Renewable energy production for onboard operations.

KEY LEARNINGS

- The wind-powered maritime transport market is emerging, but volumes remain relatively low for now.
- Reducing the cost of wind-powered transport is essential to attract more shippers and increase volumes.
- Scaling wind-powered transport means expanding the fleet of cargo sailing ships and increasing the loading capacities of these ships.
- The lack of standards and controls for decarbonization performance creates confusion for shippers (not all wind propulsion solutions or wind-propelled ships are equal).
- Routing and operations management are crucial for successful decarbonization.
- Wind-powered transport must adapt to the shippers' operating modes and existing infrastructures.
- Goods must be perfectly secured both on the docks and onboard.
- Departure frequency, more than transit times, is key to meeting the logistics needs of shipper clients.
- Technical solutions provided by equipment manufacturers allow for larger ships while continuing to drastically reduce carbon emissions (reefable sails with large surface areas capable of sailing in all wind directions and strengths).
- The social framework for sailors (types of contracts, pay, working conditions, etc.) is inseparable from the projects for decarbonizing maritime transport.

6. DECARBONIZED MARITIME TRANSPORT

TRANSATLANTIC ROUTES

GRAIN DE SAIL 1

Grain de Sail 2 – 52m et 350 T de capacité d'emport

GRAIN DE SAIL

www.graindesail.com

Grain de Sail SAS
4, route du bas de la rivière 29600 MORLAIX
Tel : 02 98 62 40 91
Mail : contact@graindesail.com

SATCHEL DOUGLAS, ABB

Electric Propulsion Integration Lessons Learned

SISDO 2024

Agenda

- Route Profiles
- Equipment Ratings
- Space Allocation
- Shore Charging Considerations

What are the major design risks in any ship design?

Design Risks

- Weight growth
- Lack of space
- Stability limits
- Speed/power

Route Profiles

Route Profiles

Traditional Diesel

- Design Speed
- Endurance/range

Hybrid - Electric

- Cycle Energy
- Trips/year
- Years of operation before battery replacement

Route Profiles

Traditional Diesel

- 13 kts
- 1500 nm range

Hybrid - Electric

- 2.8 nm crossing
- Charge on one end

250x increase in precision required in speed/power calculations

Route Profiles

- 2.8 nm crossing: 11 minutes @ 12 knots
- 3 minutes maneuvering, 16 minutes unloading/loading in berth
- 9 daily round trips

Route Profiles

Cycle Energy

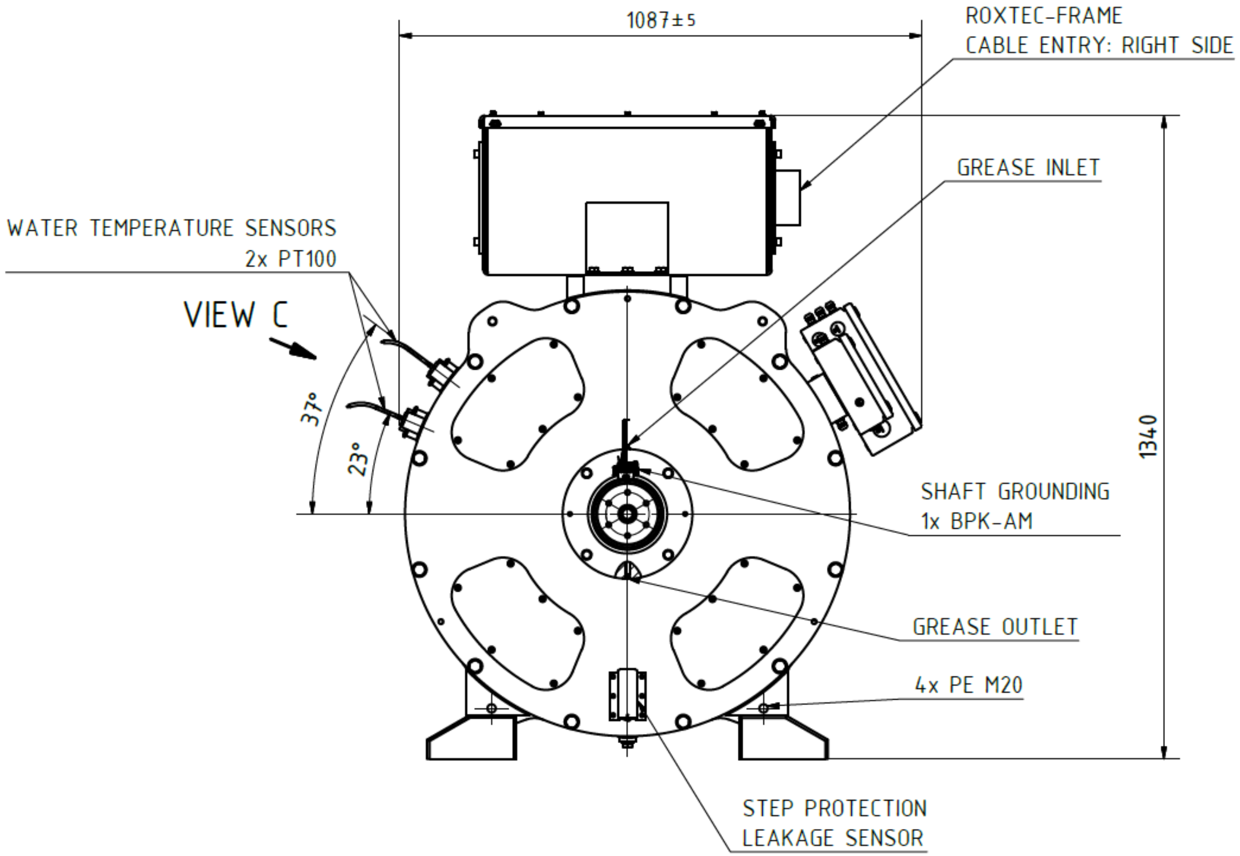
- Speed and power
- Current
- Weather
- Trip duration
- Loading conditions
- Hotel Loads

13-Knot Transit Profile Summary

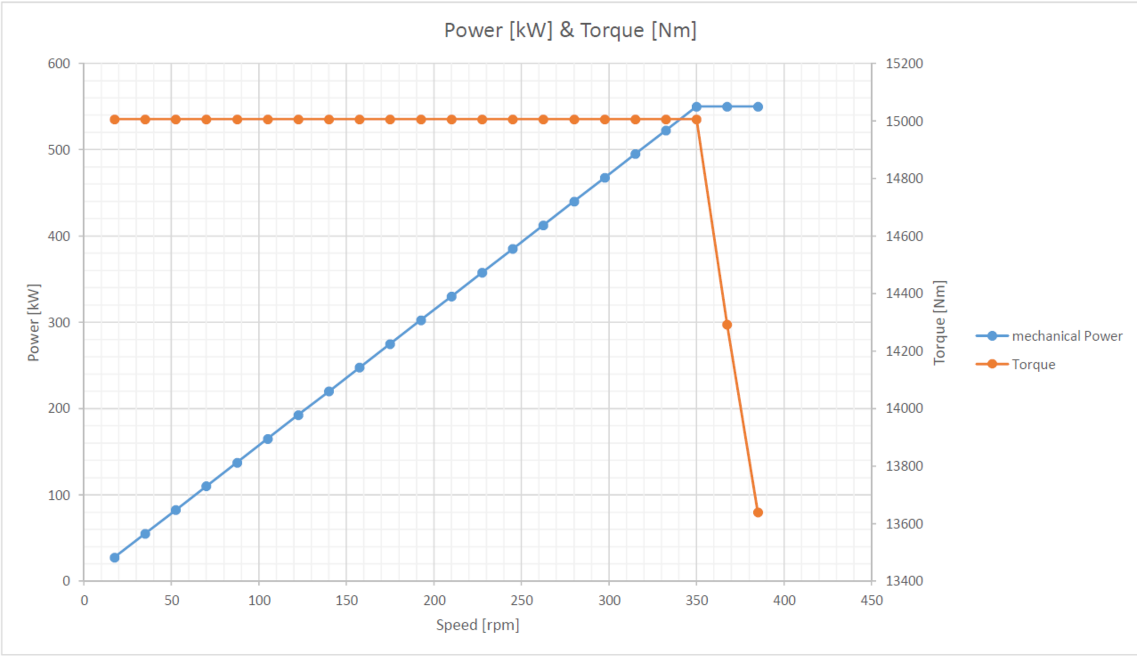
Voyage Segment	Duration (Min)	Fwd Propulsion Power (bkW)	Aft Propulsion Power (bkW)
Disconnection (N/A)	0	0.0	0.0
Maneuvering (Departing)	0.6	165.1	385.1
Accelerating	1.1	220.1	935.3
Transit	11.0	260.2	1040.9
Decelerating	0.7	54.6	218.6
Approach / Coast	0.9	0.0	275.1
Maneuvering (Arriving)	0.7	110.0	220.1
Connecting - Loading/Unloading	0.7	55.0	220.1
Charging - Loading/Unloading	14.1	55.0	220.1
Disconnecting - Loading/Unloading	0.2	55.0	220.1
Maneuvering (Departing)	0.6	165.1	385.1
Accelerating	1.1	220.1	935.3
Transit	11.0	260.2	1040.9
Decelerating	0.7	54.6	218.6
Approach / Coast	0.9	0.0	275.1
Maneuvering (Arriving)	0.7	110.0	220.1
Loading/Unloading	15	55.0	220.1

Equipment Ratings

Equipment Ratings and Margin
Electric Motors



- Electric motors are torque limited by frame size
- Possible to increase RPM to increase power, without changing the frame



Equipment Ratings and Margin

Batteries

- Max C rate
- Need to calculate battery charge/discharge from route profile
- Share with battery vendors or ABB to select size

Eventually, as design progresses, fix the battery size

Equipment Ratings and Margin
Hotel Loads

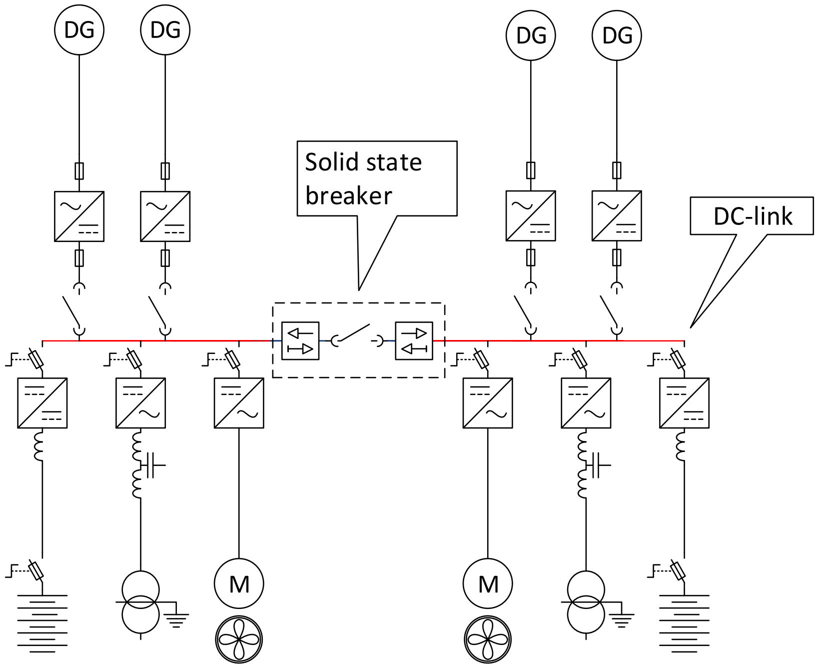
Electrical equipment runs on cooling

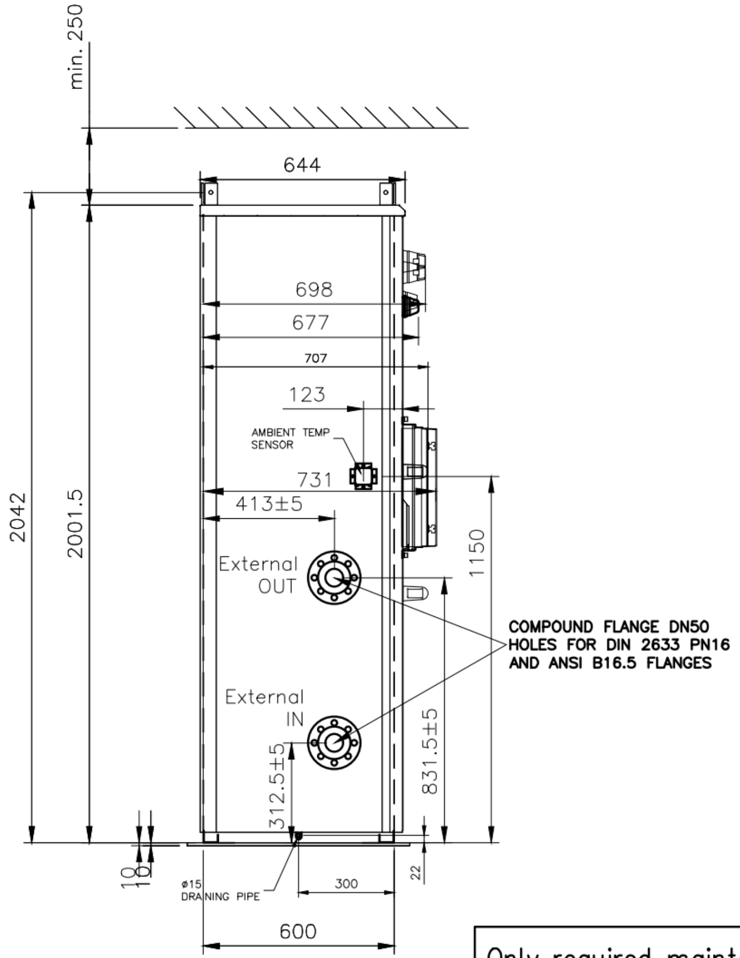
- Be careful with diesel parent vessel ELAs, similar size hybrid vessel will be higher
- Cooling pumps
- Cooling fans
- Anti condensation heaters
- UPSs
- HVAC for multi-drive and battery rooms
  - Avoiding condensation

Space Allocation

Space Allocation

Multi Drive Lineups (Onboard DC Grid™)





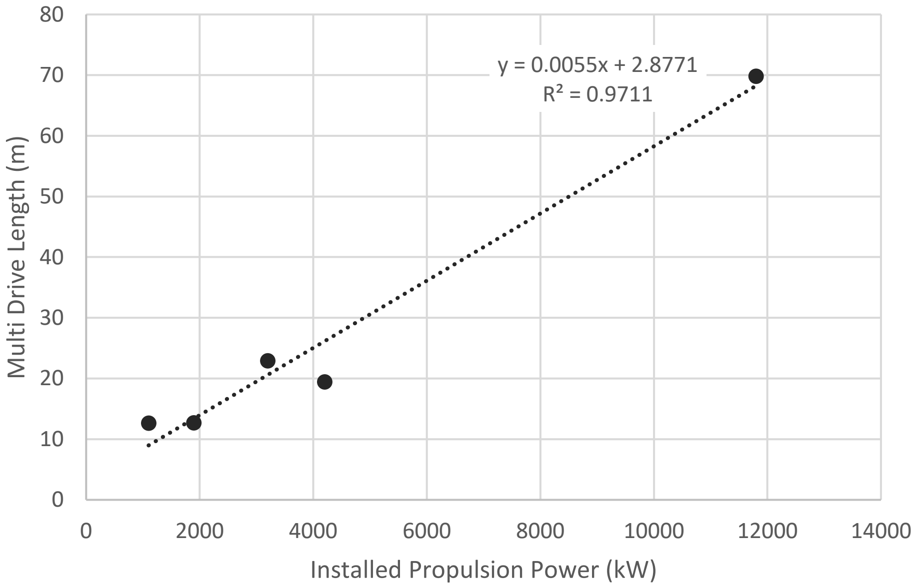
Multi drive (ODCG) Section View

Only required maintenance envelopes are on the front, based on door swing dimensions 800mm

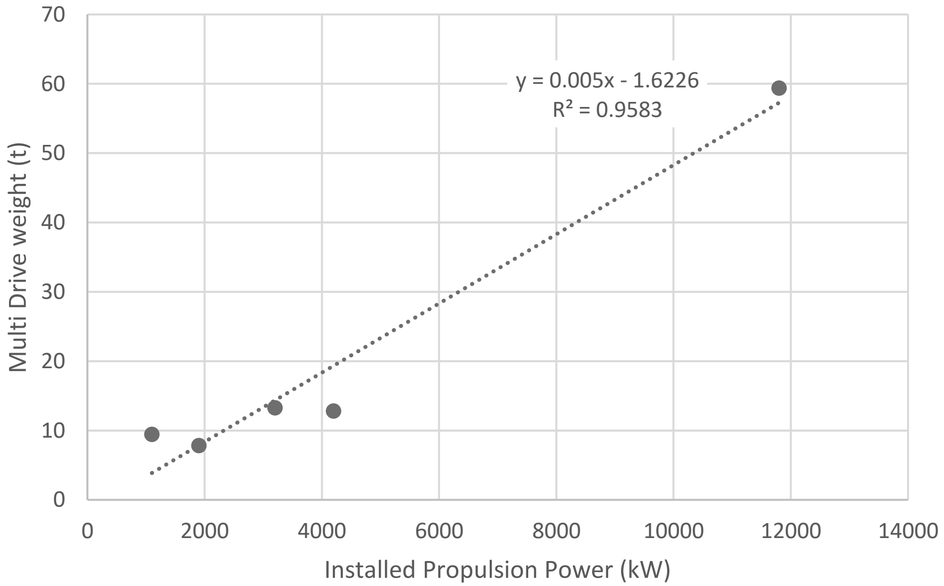
Space Allocation

Multi Drive Lineups

Lineup Length



Lineup Weight

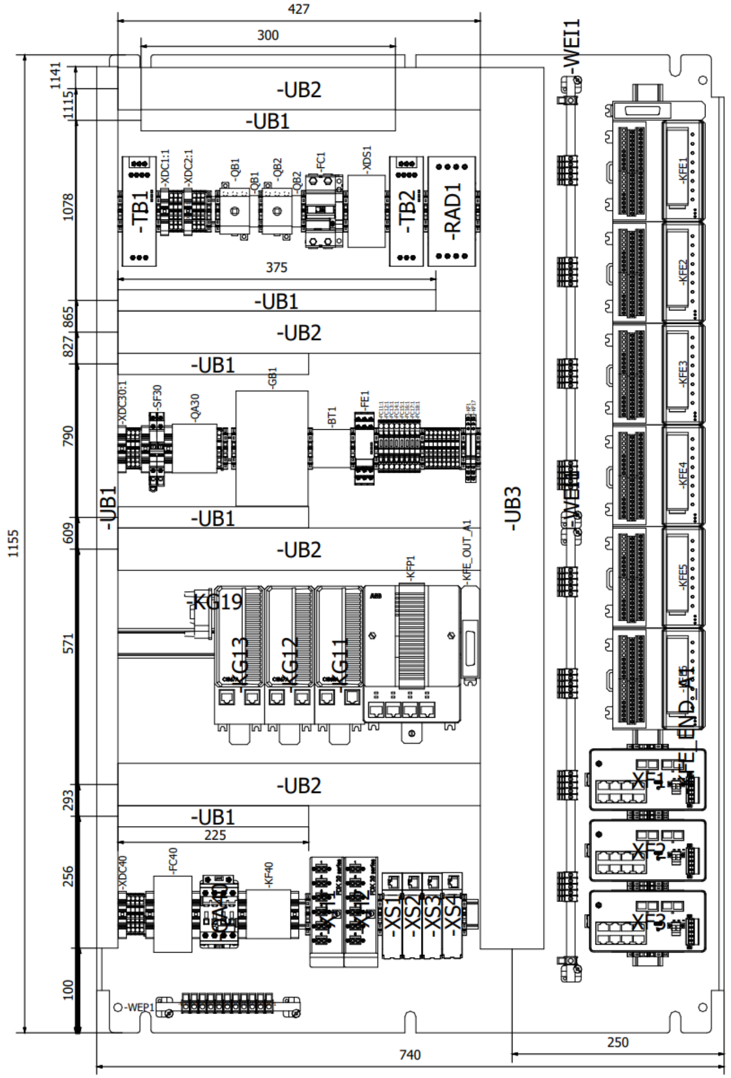


Space Allocation

Control Cabinets

- 1200 mm x 800 mm x 400 mm
- Wall mounted
- 100 kg

- 1x per motor
- 1x per engine
- 2x per Alarm and Monitoring (min)
- 2x control network
- 1x Remote Diagnostics/Data Logger System

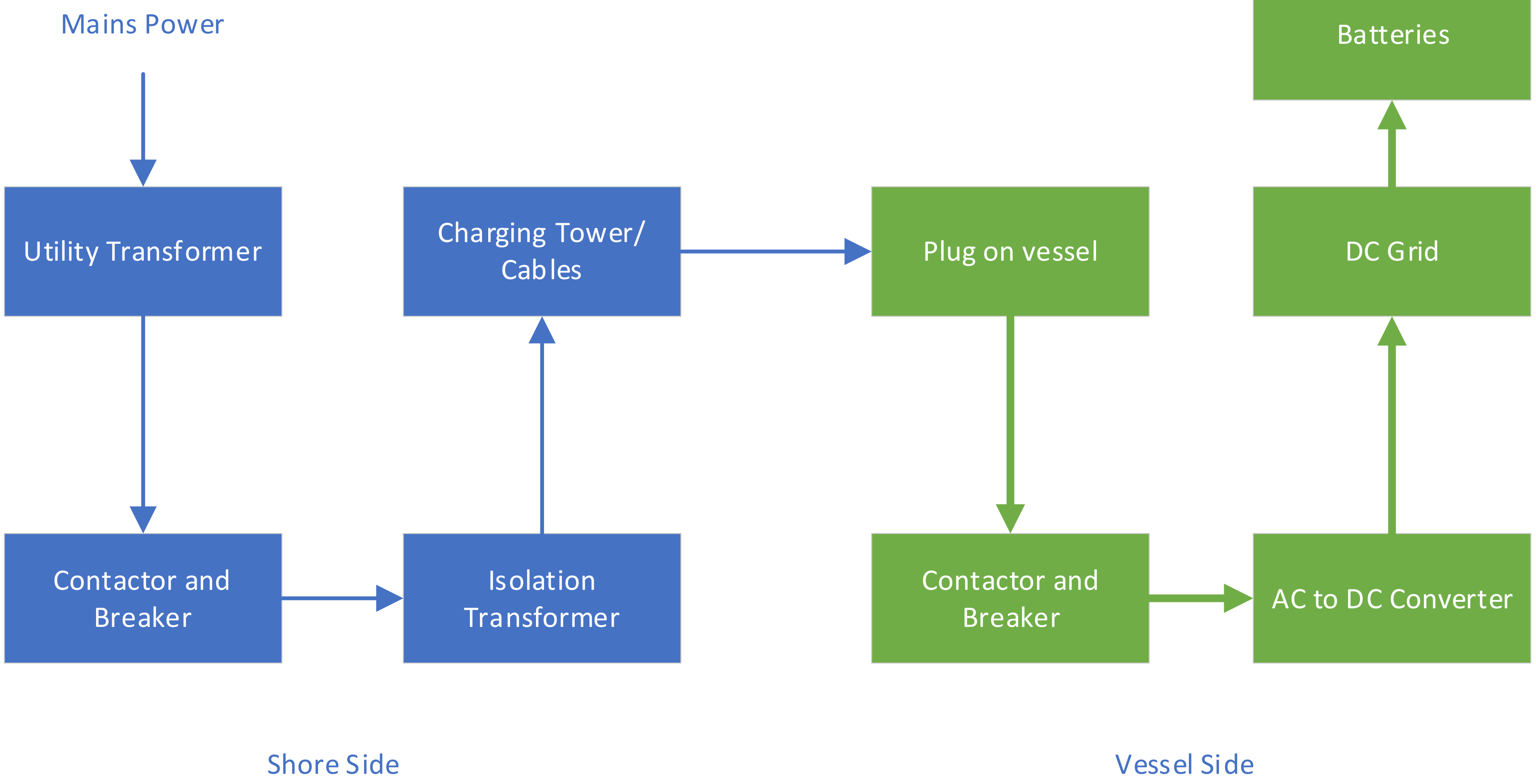


You can never have too many!

Shore Charging

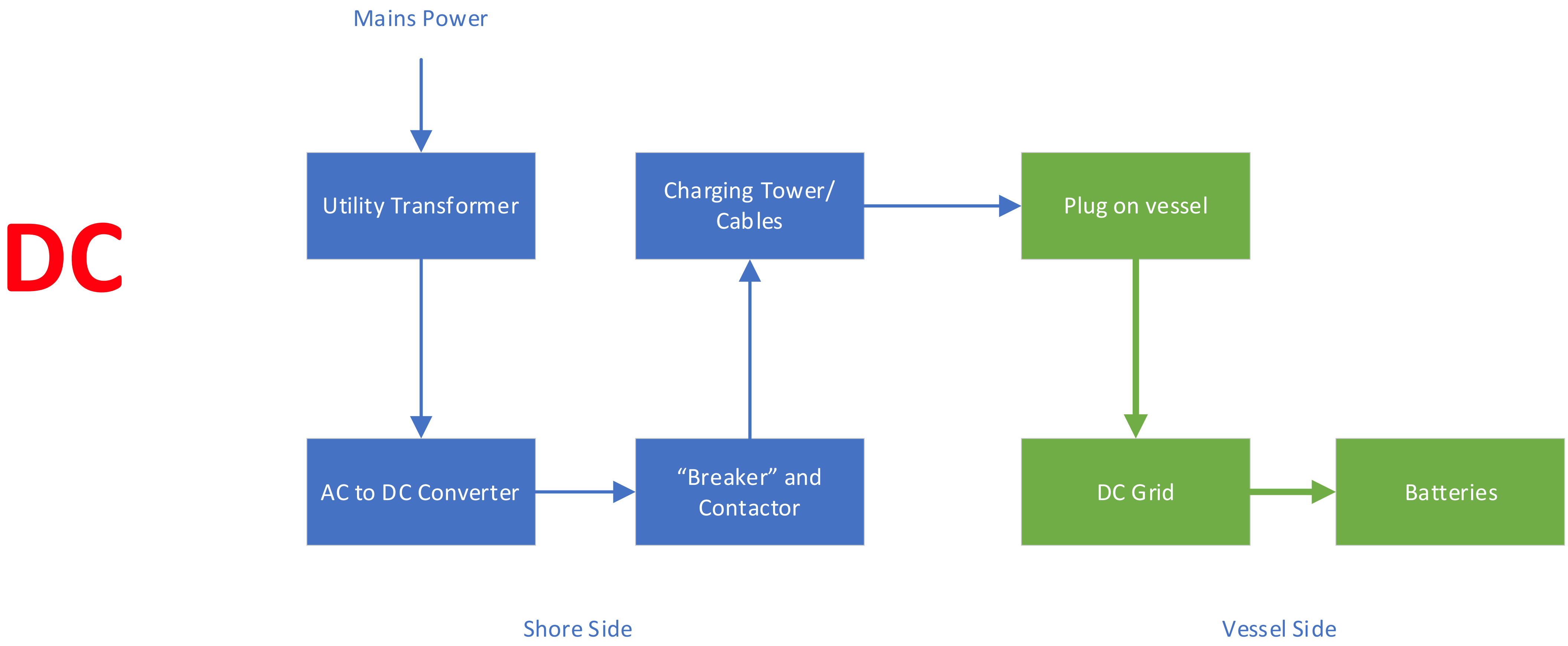
Shore Charging

AC



AC Shore Connection

Shore Charging



DC Shore Connection

Shore Charging

AC

- Less land side equipment
- Medium Voltage can provide higher (>15MW) power

DC

- Less equipment on the vessel
- Less long lead time transformers
- Feasible up to ~6MW charging power
- Supports land side batteries

Shore Charging
Who is responsible?

- AC – Transformer Secondary grounding
  - REALLY need high resistance grounding

YOU are responsible for the interface!

Shore Charging
Who is responsible?

- AC – Make line dead prior to connection/disconnection
  - Shore electrical engineers unclear not used to PLC control/remote switching

YOU are responsible for the interface!

Shore Charging

Who is responsible?

- DC – Short Circuit contribution from the shore to the vessel
  - Need an IGBT based static switch and control system on shore to protect cables and bus bar

YOU are responsible for the interface!

PS.

Just use metric…

Satchel.douglas@us.abb.com

A Novel High Thrust Efficiency Stationary Wind Sail Enabled by CoFlow Jet

CoFlow Jet Lift

Yan Ren, Ph.D., CTO
Gecheng Zha, Ph.D., CEO
CoFlow Jet Lift, Inc
Professor, U. of Miami, FL
gzha@coflowjetlift.com
WWW.COFLOWJETLIFT.COM

DECARBONIZATION OF MARINE TRANSPORTATION:
A NECESSITY FOR GLOBAL ECONOMY AND OUR LIFE

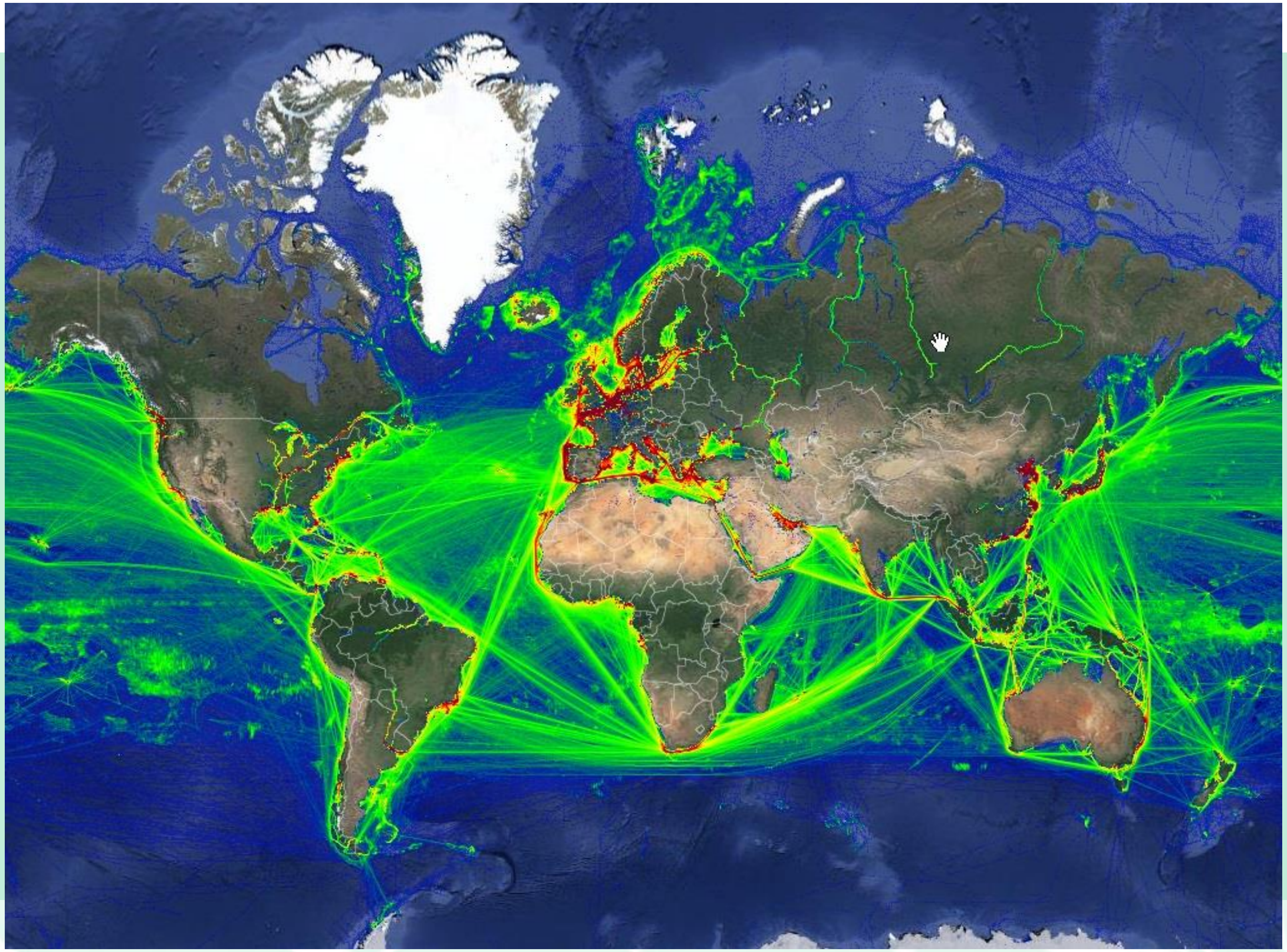
- 90% of global goods are transported by ships

- 2019*:
  Cargo Ships: 100,000
  Goods Shipped: 11 Billion Tons
  CO_2 Emission: 1.076 Billion Tons
  Fuel Burned: 230 Million Tons
  Fuel Cost: $165 Bn ($700/ton)

- EMISSION
  1 of the largest ships:

= 50 million cars#

Marine Ship Traffic | Tracked by Google Maps



* White paper: Wind Propulsion for Ships, Wind Ship Association, France, Sept. 2022

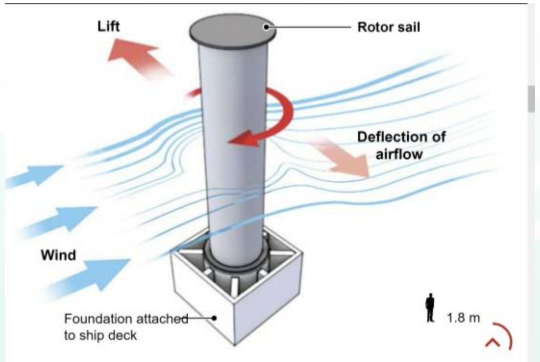
E. Stratiotis, "Fuel Cost in Ocean Shipping", 1/22/2018

THE OCEAN IS RICH IN WIND POWER:
CLEAN, SUSTAINABLE, AND PREDICTABLE

- Conventional flexible wind sails: large, ineffective, inefficient, difficult to control.
- Too weak to power modern cargo ships.

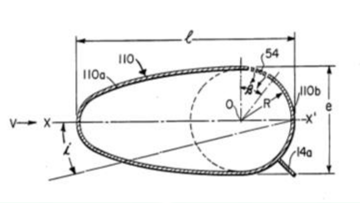
PROBLEMS OF CURRENT RIGID WIND SAILS: LOW THRUST, COMPLEX, HIGH COST, LONG ROI

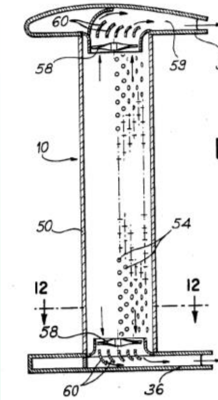
FLETTNER ROTORS: Spinning Cylinders



Credit: Katherine Kornei, 2017

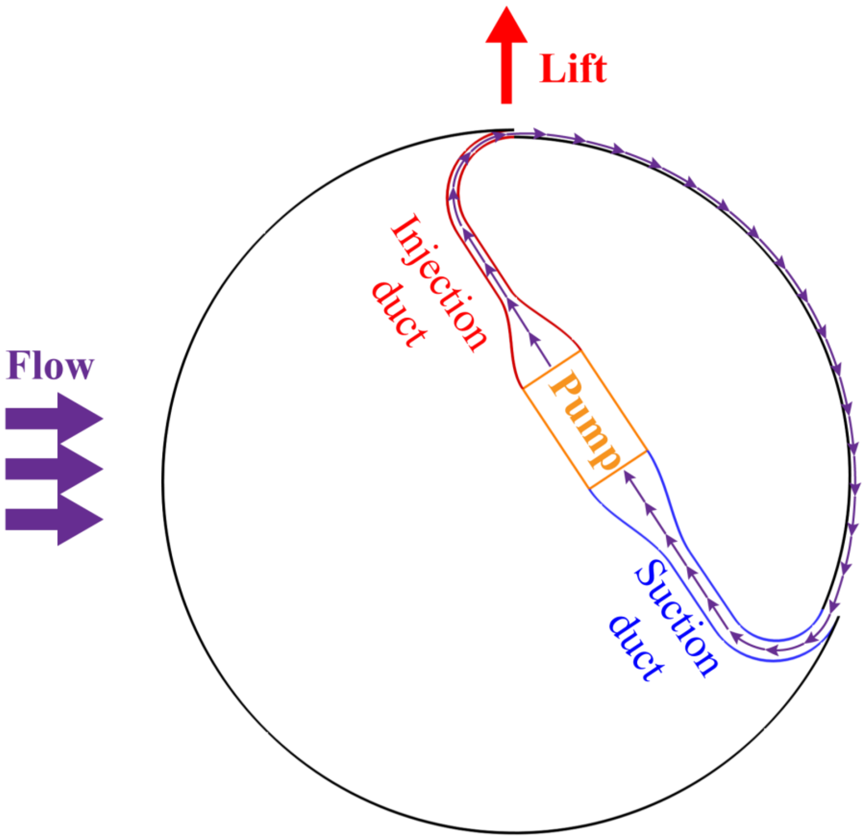
TURBOSAILS





RIGID, THICK WINGS:

OUR SOLUTION – COFLOW JET (CFJ) STATIONARY CYLINDER: ULTRA-HIGH NET LIFT AND POWER



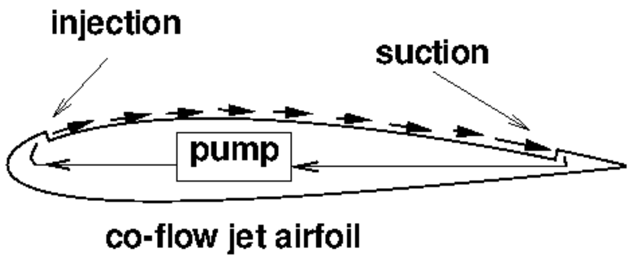
COFLOW JET STATIONARY CYLINDER WIND SAILS:

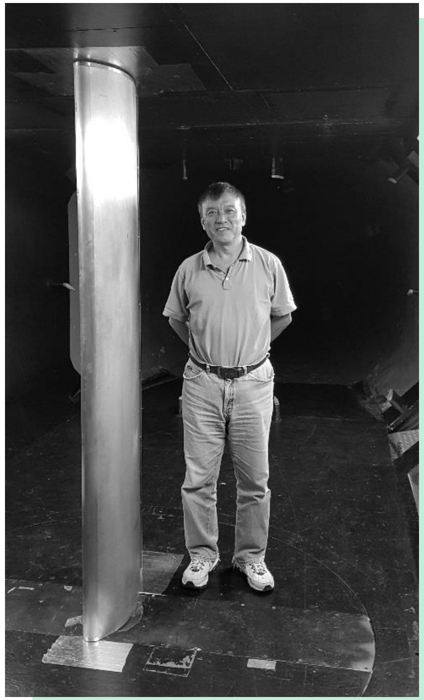
- No rotation, simple system
- Low pressure fans embedded inside the cylinder
- Sucks a small amount of air flow at the 4 o'clock position, pressurized by the fans, and ejects the air mass tangent to the surface at the 12 o'clock position
- Ultra-high lift coefficient (CL>20) from wind
- Very low power required
- Ultra-high net propulsive power from wind
- Originated from Aeronautics Research
- Verified numerically and experimentally in U.S. National Laboratories

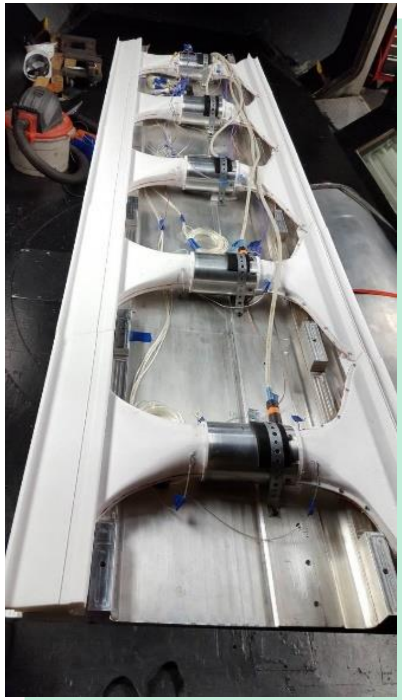
OUR SOLUTION – COFLOW JET (CFJ) STATIONARY CYLINDER: UNIQUE AND SUPERIOR

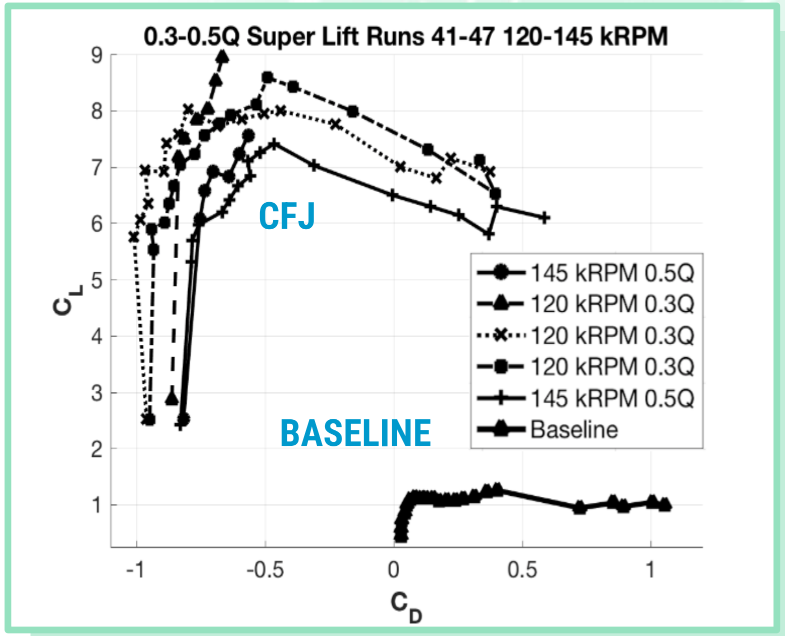
WIND TUNNEL TESTING UNDER DARPA FUNDING

- 18 Patents issued
- 20 Years research
- Grants received: $2.5 Mn (DARPA, NASA, NSF, AFRL, ARO, CIRA, EBPT, …)

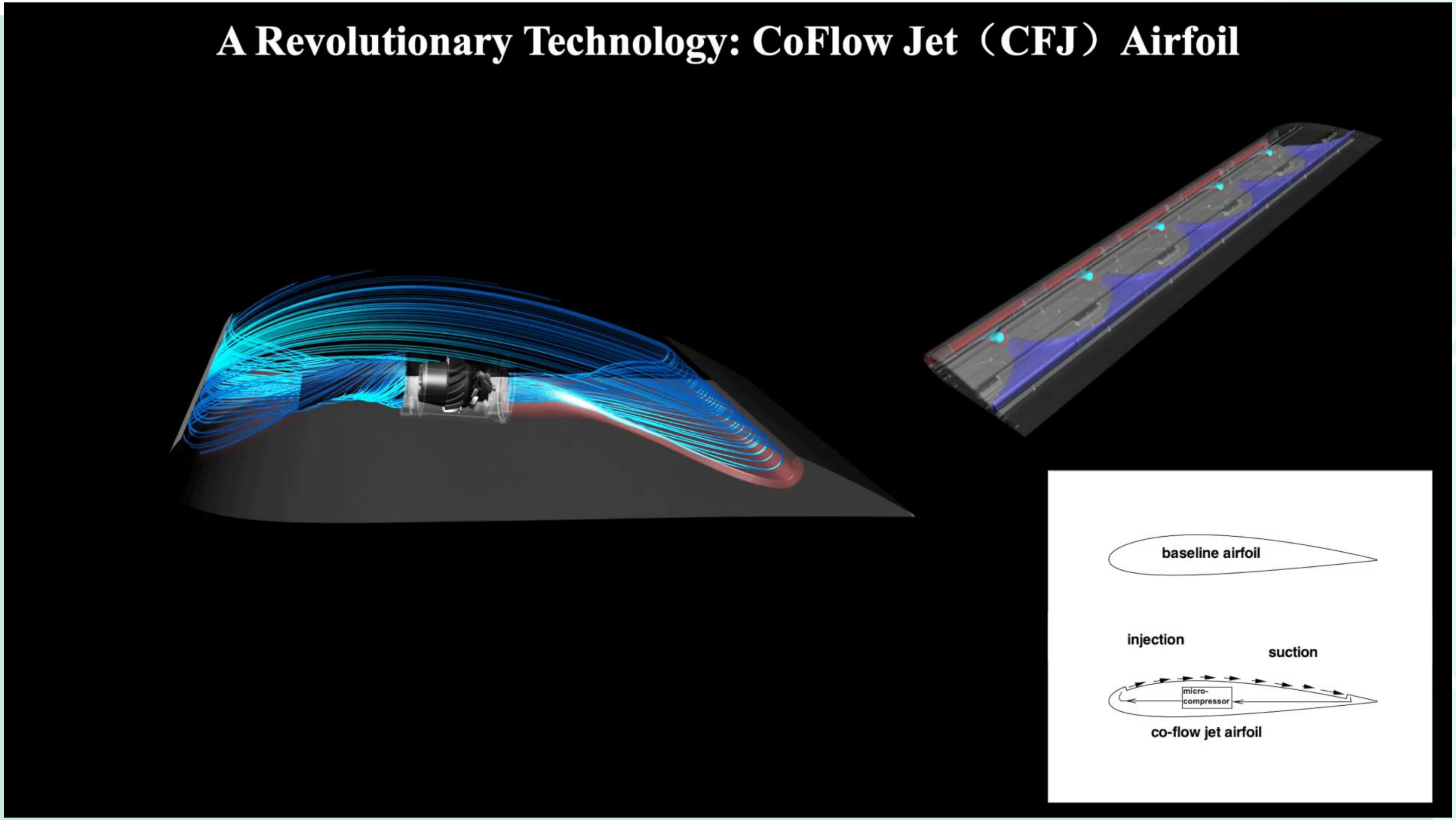






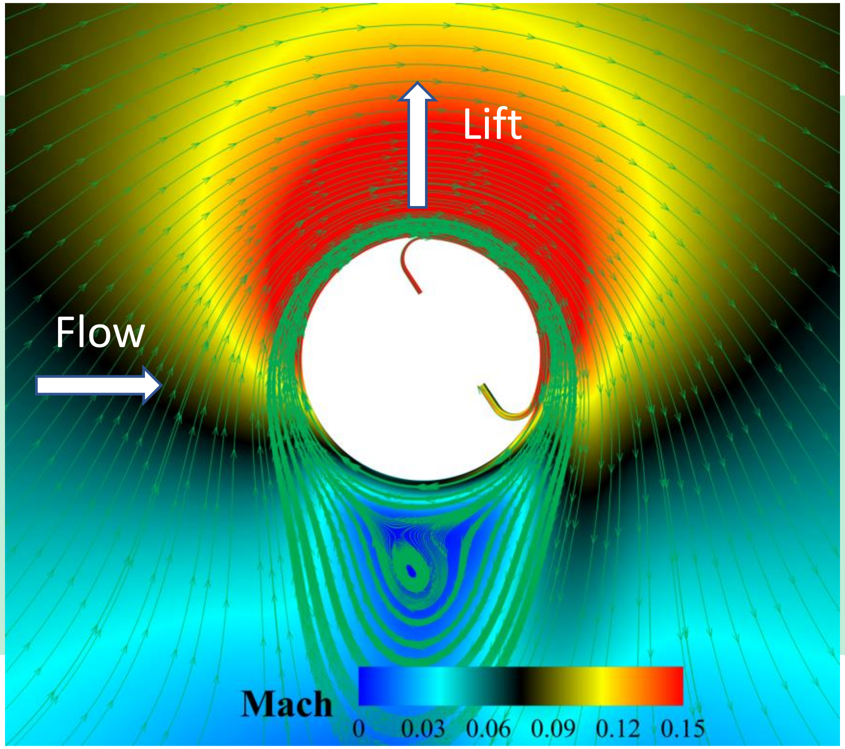


COFLOW JET CONCEPT EXPERIMENT ANIMATION



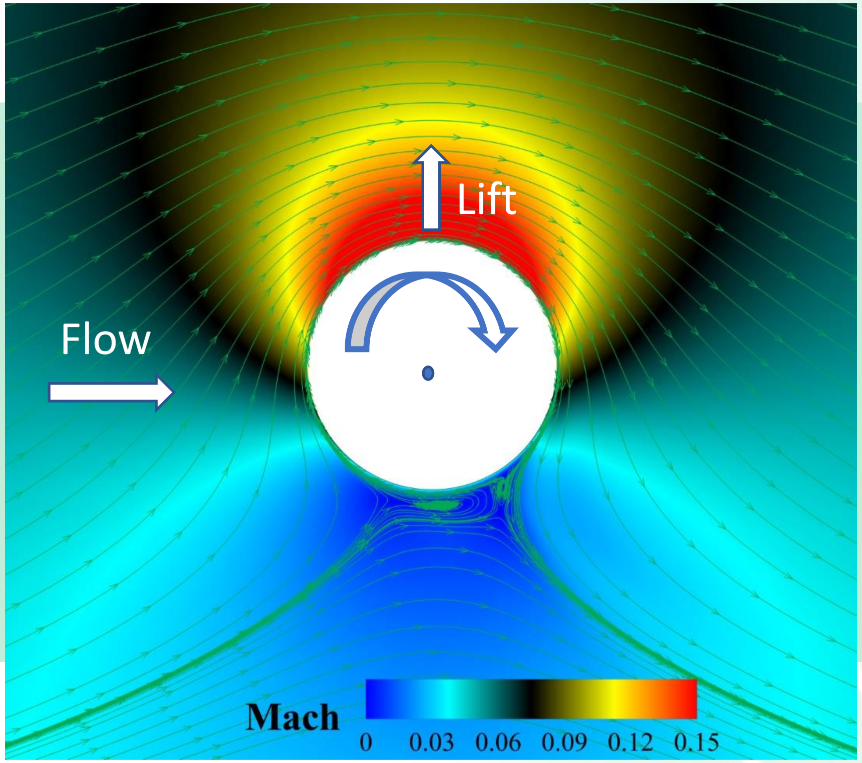
COMPARISON OF COFLOW JET CYLINDER WITH FLETTNER ROTOR BY CFD

CoFlow Jet Cylinder



CL=15, Pc=3.3
High Lift

Flettner Rotor



CL=5, Pc=0.7
(weight=0, V_{rotate}/V_{∞} =3)

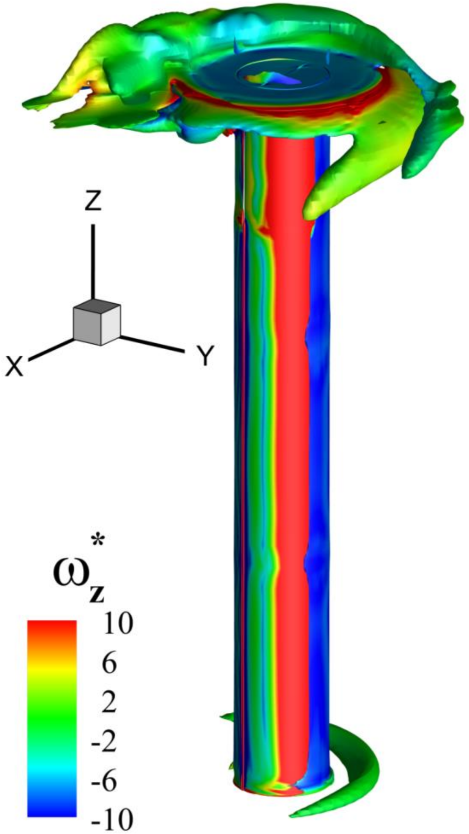
Summary: Reducing CL decreases CFJ power exponentially; Two cases studied: CL=15.3, CL=7.6

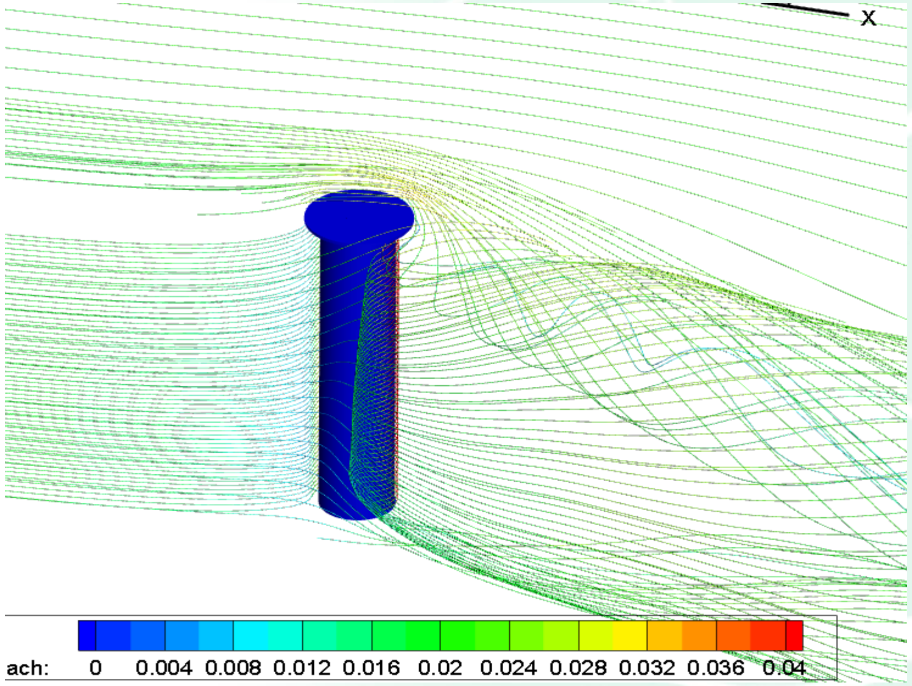
Case 1: CFJ Performance (CFJP): CL=15.3, Pc=3.3, AR=8

Case 2: CFJ Efficiency (CFJE): CL=9.93, Pc=0.77, AR=5

Table 1 CFJ sail compared with a Fletter rotor

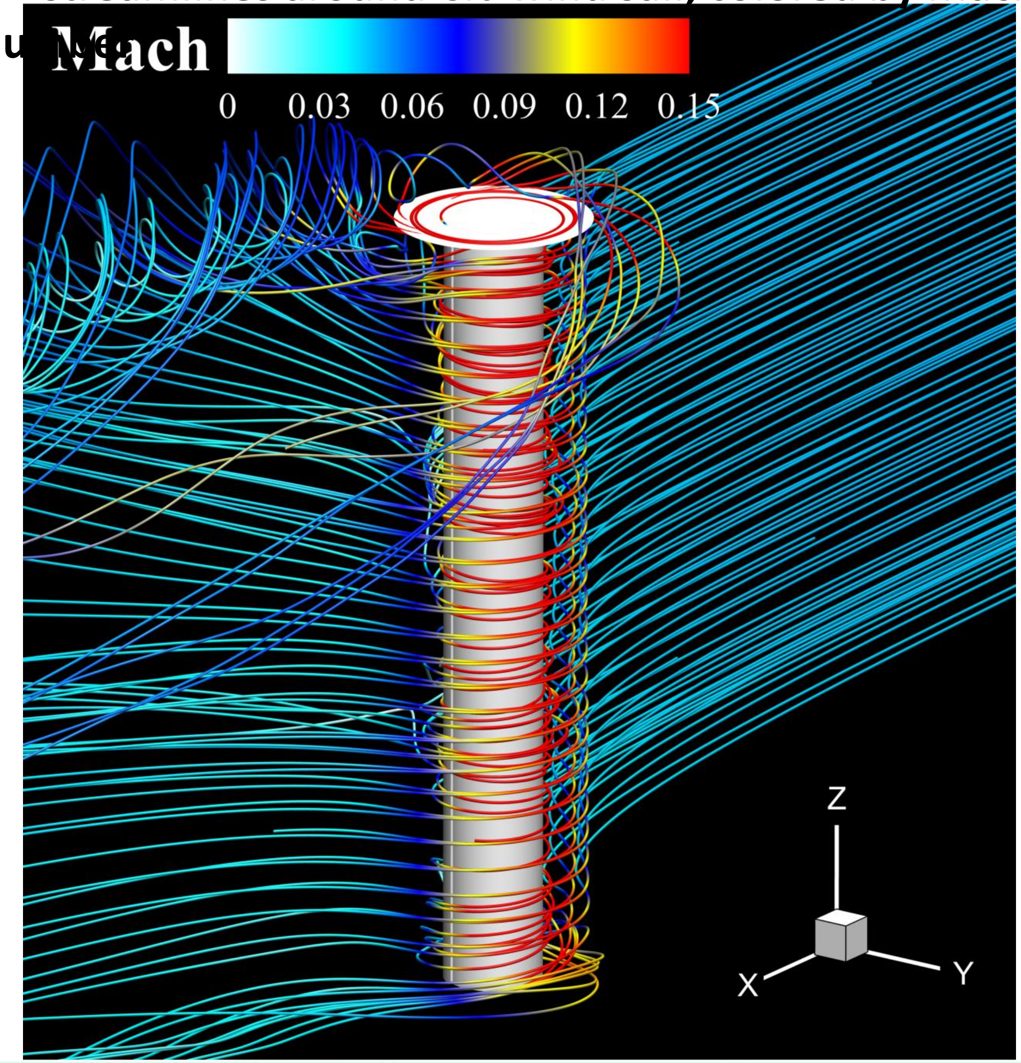
Cases	CL	CD	PC	CL/CD	CL/PC	AR	Cmu
Flettner rotor (FR)	5.000	1.90	0.70	2.632	7.143	2D test	Vrot/ V_∞ =3
CFJP	15.30	4.20	3.30	3.643	4.636	8	1.0
CFJE	9.930	3.37	0.77	2.947	12.90	5	0.5
CFJE2	7.6	2.15	0.35	3.53	21.71	5	0.3



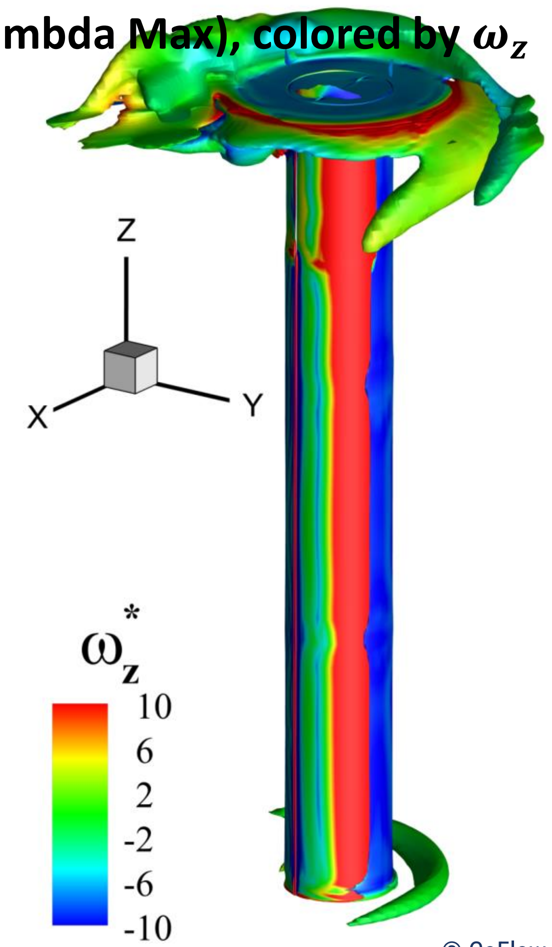


3D flow structures for CFJP

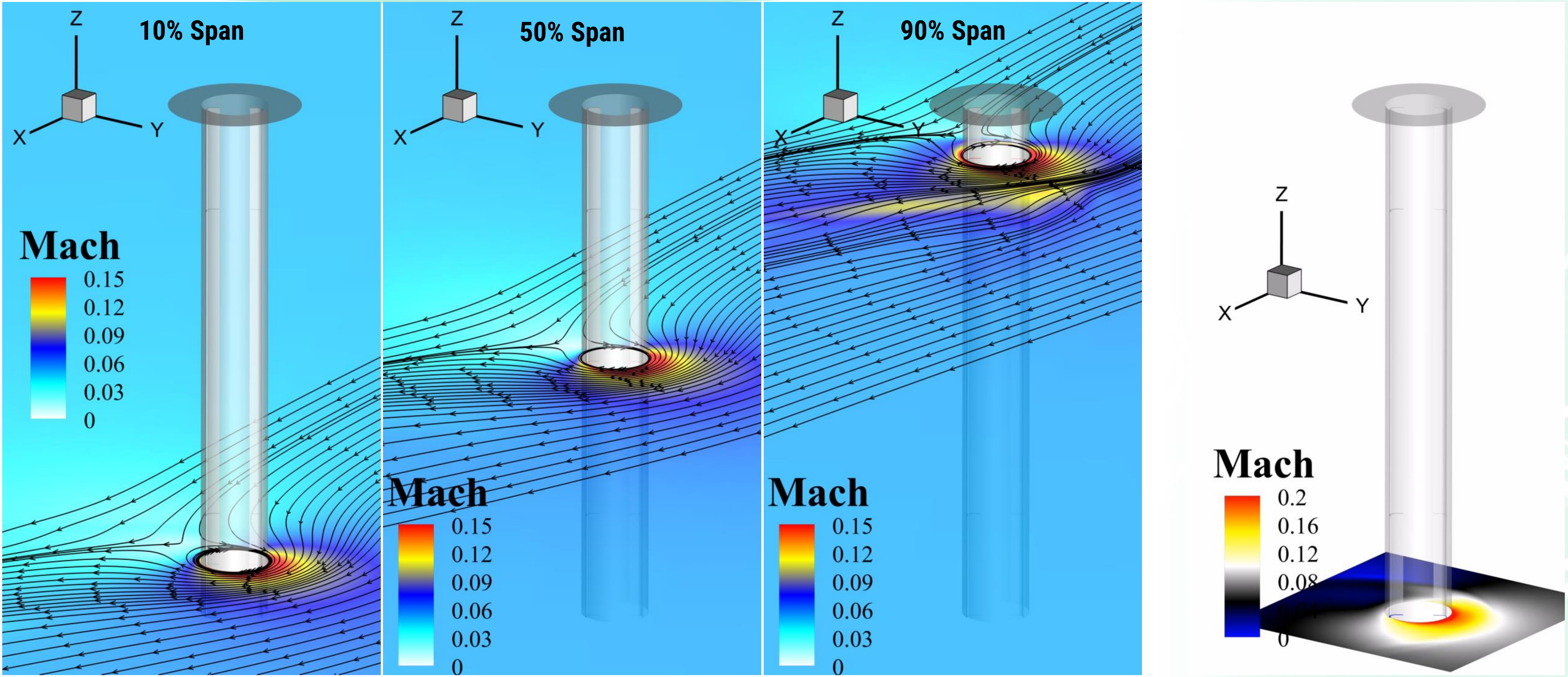
- **3D streamlines around CFJ wind sail, colored by Mach number**



- **Vorticity structures (iso-surface of Lambda Max), colored by ω_z**



3D flow structures for CFJP



CFJ sail net power across the full AWA range

$$P_{net} = 0.5\rho V^3_{AWS}\, S[V_{ratio}*(CL*\sin(AWA)-CD*\cos(AWA)) - Pc]$$

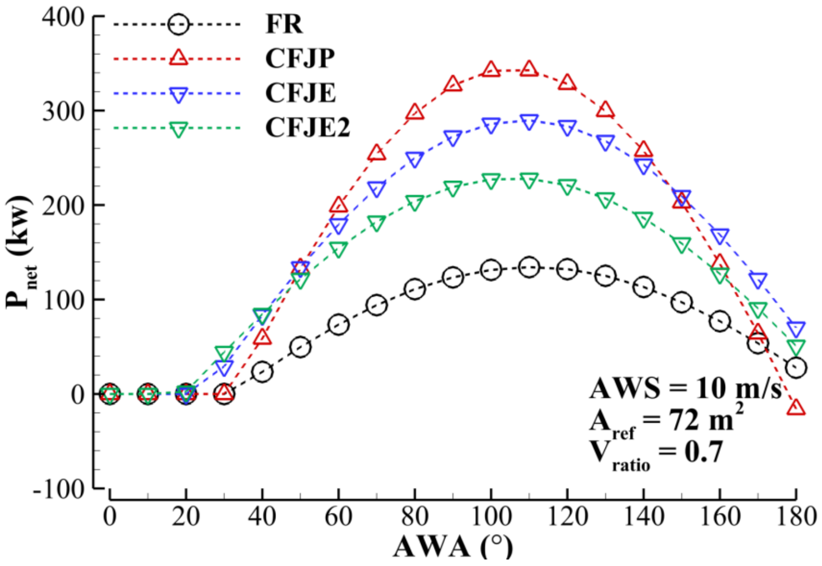
Example Sail:

- Diameter: 3m
- Height: 24m
- AWS(apparent wind speed): 10m/s
- AWA: apparent wind angle
- $V_{ratio} = V_{ship}/V_{AWS}$
- $P_{net} = P_{tot} - P_{FR/CFJ}$

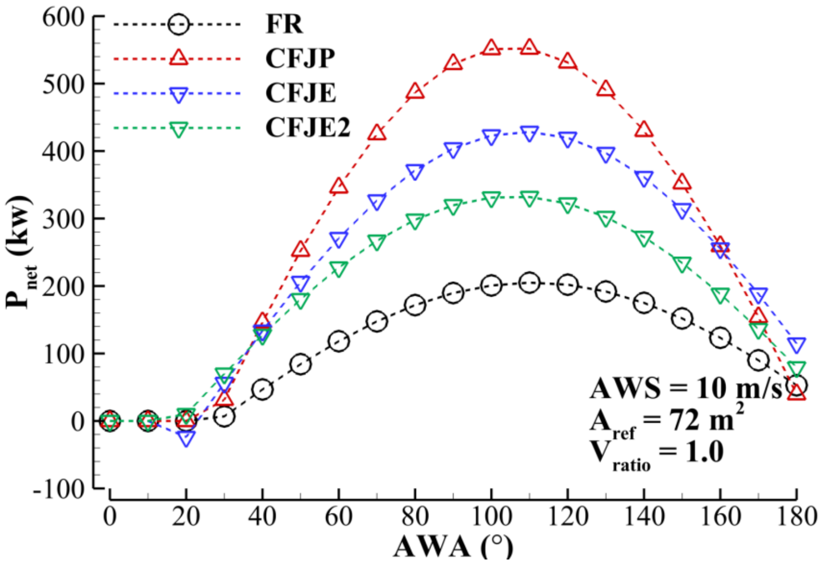
An efficient strategy is to use CFJE and CFJP mode at different AWA:

1) CFJE for headwind or tailwind with AWA <40-60deg, AWA>140deg
2) CFJP mode between 40deg and 140deg.

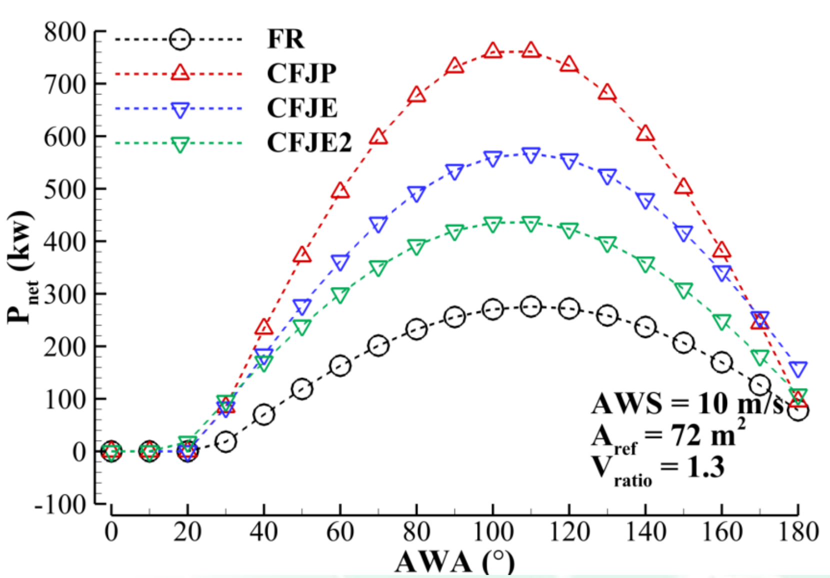
Net Power Production Comparison at Different Velocity Ratios



$V_{ratio} = 0.7$



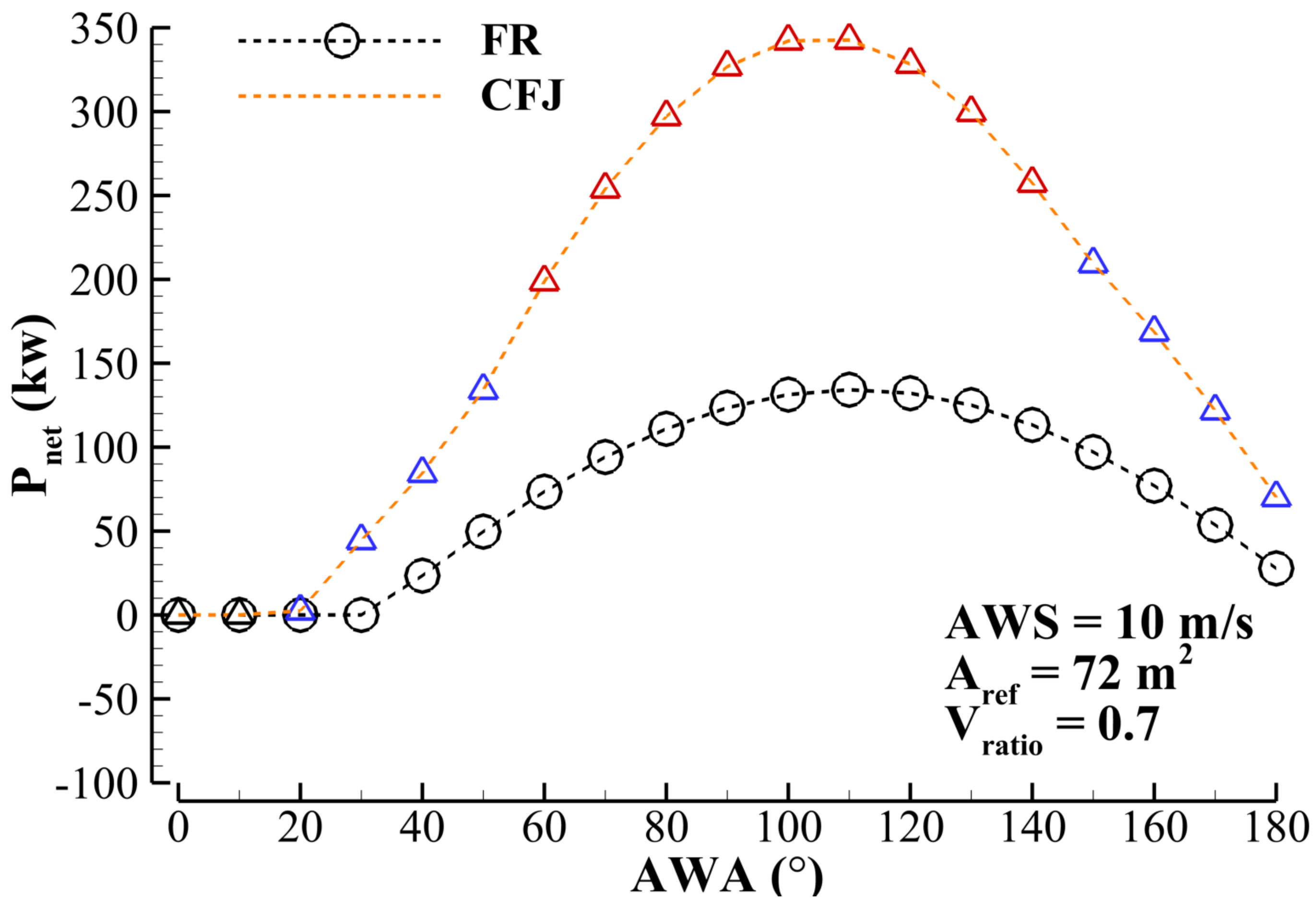
$V_{ratio} = 1.0$



$V_{ratio} = 1.3$

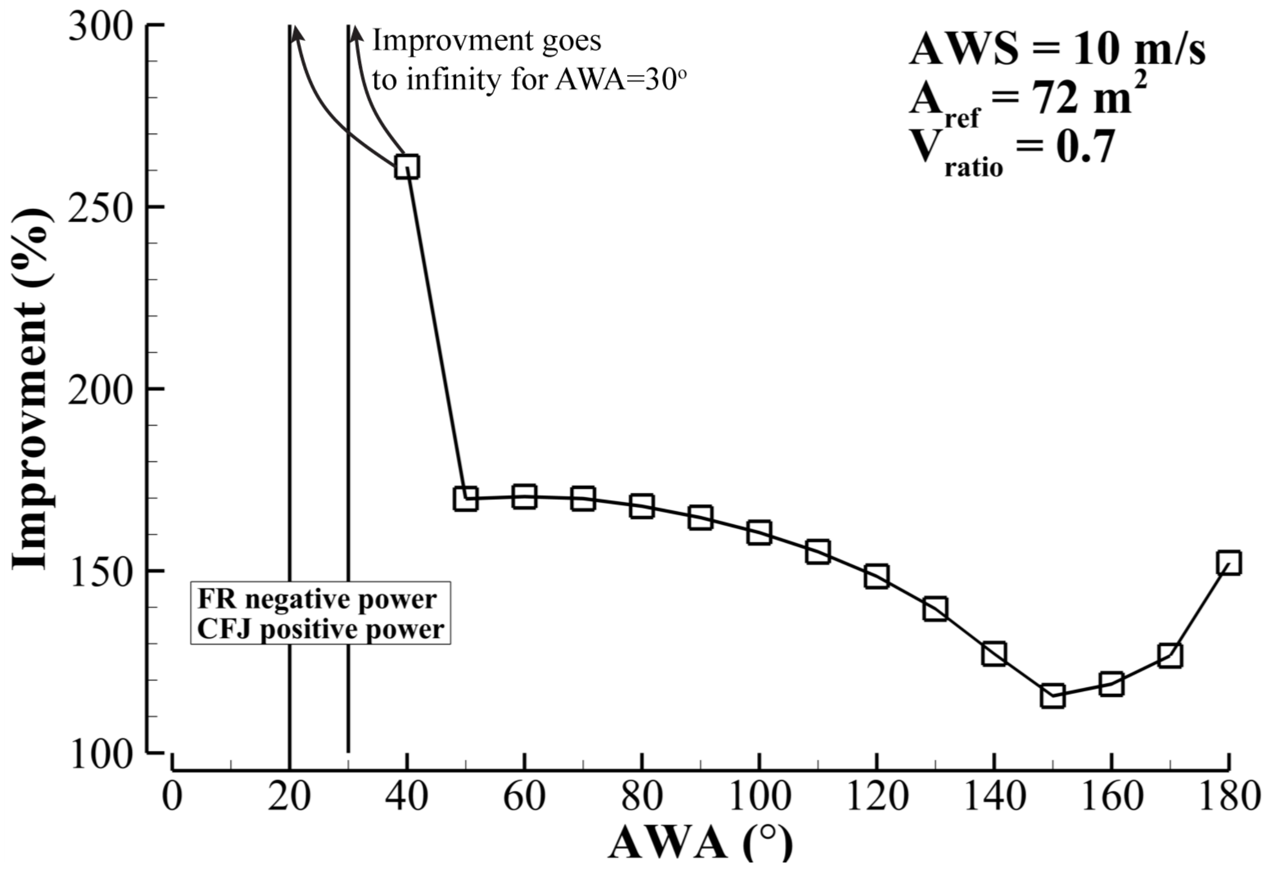
- At low ship speed Vratio ≤1, CFJE and CFJE2 are more efficient at near headwind and tailwind conditions.
- At high ship Vratio >1, CFJP could be efficient for the whole AWA range.
- CFJ wind sails generate significantly more net power than Flettner Rotor across the whole range of AWA.

Net Power Comparison with Combined CFJ Modes: Velocity Ratio = 0.7



- Blue symbol indicates CFJE or CFJE2 and red symbol indicates CFJP
- CFJE modes to be used near head wind or tail wind conditions.
- CFJP mode to be used in side wind conditions.
- CFJ wind sails generate significantly more net power than Flettner Rotor across the whole range of AWA.

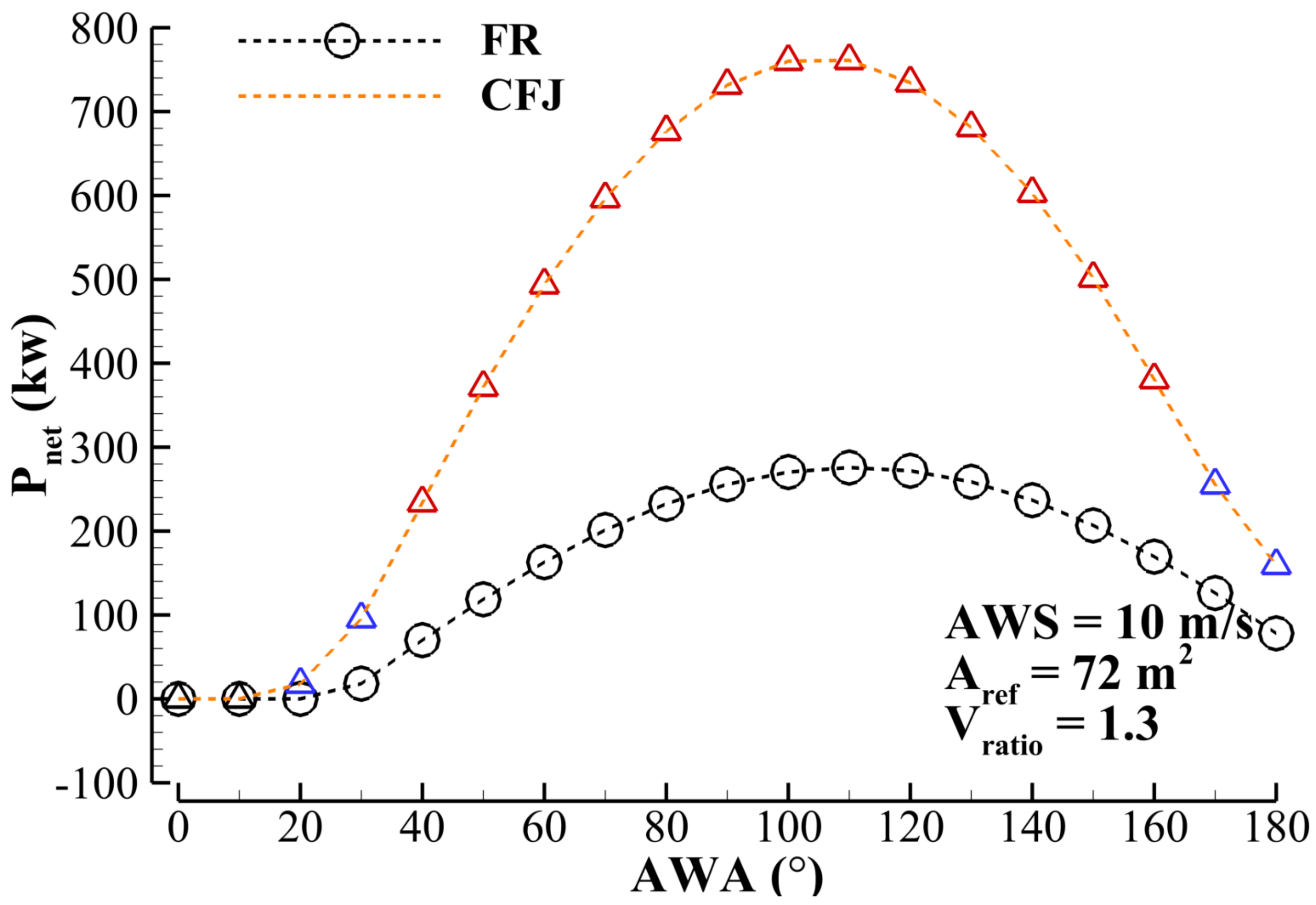
CFJ Wind Sail Net Power Improvement over Flettner Rotor: Velocity Ratio = 0.7



AWA (deg.)	FR net power (kw)	CFJ WS net power (kw)	Improve (%)
0.000	-89.523	-81.806	0.000
10.000	-61.829	-18.822	0.000
20.000	-33.195	2.439	∞
30.000	-4.490	44.392	∞
40.000	23.413	84.528	261.023
50.000	49.668	133.995	169.784
60.000	73.475	198.676	170.402
70.000	94.111	253.953	169.844
80.000	110.950	297.091	167.770
90.000	123.480	326.781	164.643
100.000	131.320	342.120	160.524
110.000	134.232	342.641	155.261
120.000	132.128	328.330	148.495
130.000	125.070	299.621	139.562
140.000	113.275	257.386	127.222
150.000	97.100	209.407	115.661
160.000	77.037	168.644	118.914
170.000	53.695	121.724	126.698
180.000	27.783	70.075	152.222

- CFJ wind sails have wider AWA range and generate significantly more net power than Flettner Rotor, > 115% across the full AWA range.

Net Power Comparison with Combined CFJ Modes: Velocity Ratio = 1.3



- Blue symbol indicates CFJE or CFJE2 and red symbol indicates CFJP
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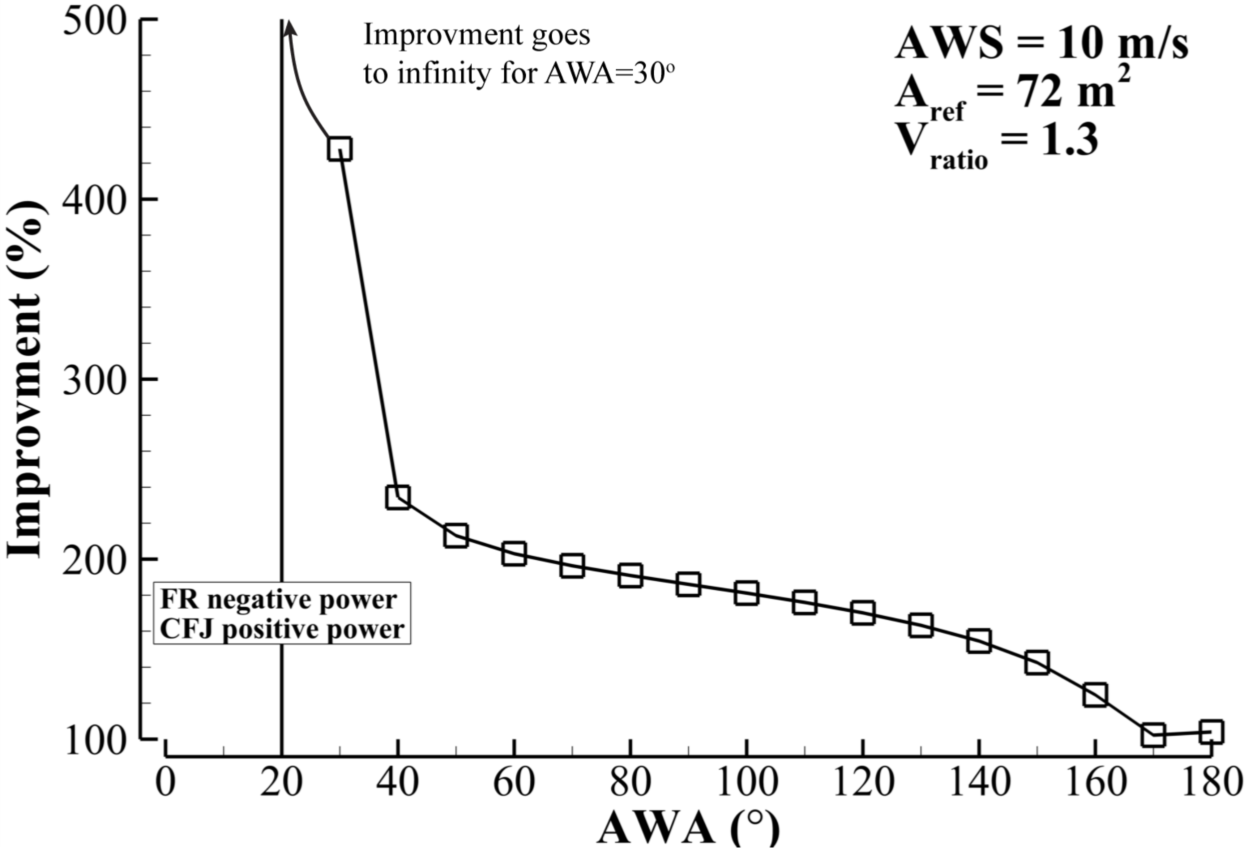
- CFJP mode to be used in side wind conditions.
- CFJ wind sails generate significantly more net power than Flettner Rotor across the whole range of AWA.

CFJ Wind Sail Net Power Improvement over Flettner Rotor: Velocity Ratio = 1.3

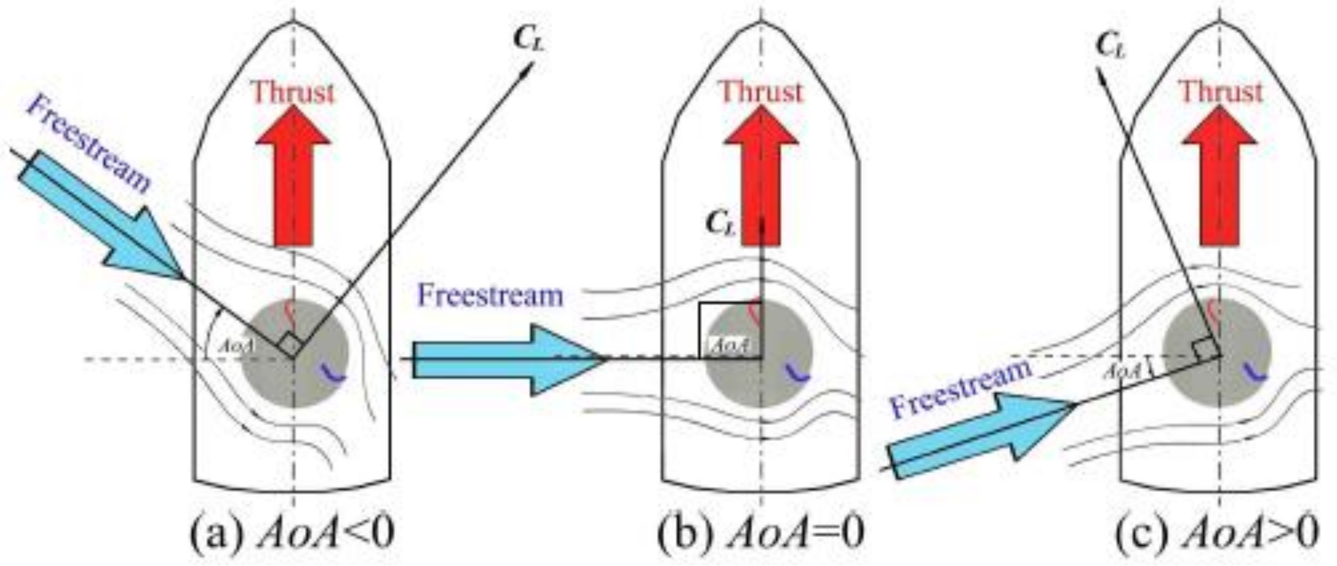


AWA (deg.)	FR net power (kw)	CFJ WS net power (kw)	Improve (%)
0.000	-139.797	-138.695	0.000
10.000	-88.366	-21.725	0.000
20.000	-35.188	17.760	∞
30.000	18.121	95.673	427.955
40.000	69.942	233.838	234.330
50.000	118.700	371.631	213.085
60.000	162.913	493.710	203.052
70.000	201.238	596.367	196.349
80.000	232.510	676.481	190.947
90.000	255.780	731.619	186.034
100.000	270.340	760.105	181.166
110.000	275.748	761.074	176.003
120.000	271.840	734.496	170.195
130.000	258.734	681.179	163.274
140.000	236.828	602.743	154.507
150.000	206.789	501.571	142.553
160.000	169.528	380.737	124.587
170.000	126.178	255.166	102.226
180.000	78.057	159.245	104.011

- CFJ wind sails generate significantly more net power than Flettner Rotor, > 100% across the full AWA range, much more at low AWA.

Angle of Attack Variation Tolerance (2D)

➢Definition of Thrust Coefficient:

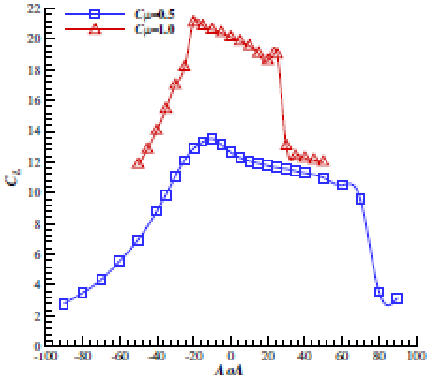


$$C_{Thrust} = C_L \cdot \cos AoA + C_D \cdot \sin AoA$$

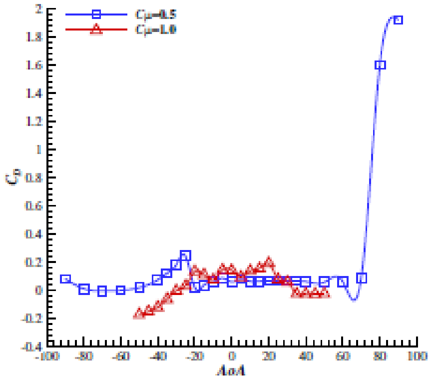
Angle of Attack Effect

➢Time-Averaged C_L, C_D, P_C and C_{Thrust} VS *AoA*:

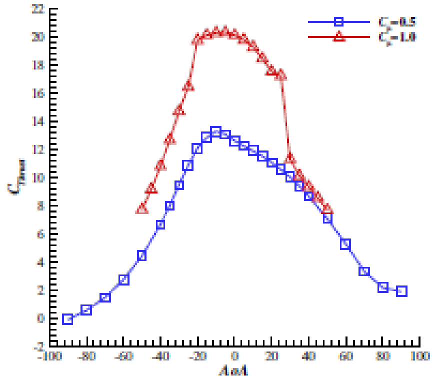
CFJ wind sails can tolerate wind direction variation range of -40deg to 20deg without substantial lift drop.



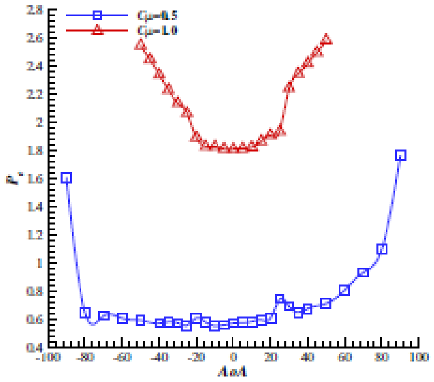
(a) Lift Coefficient.



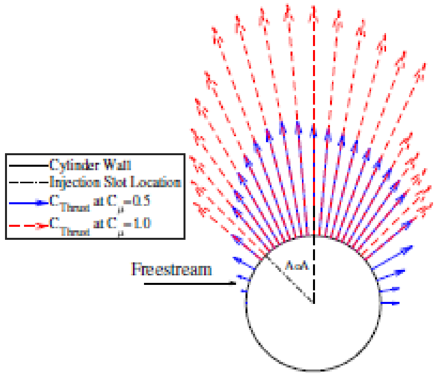
(b) Drag Coefficient.



(c) Thrust Coefficient.



(d) Power Coefficient.

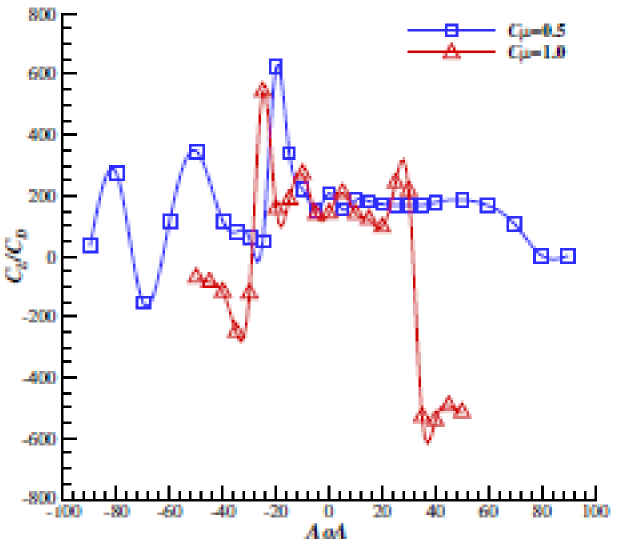


(e) Sketch of C_{Thrust} magnitude.

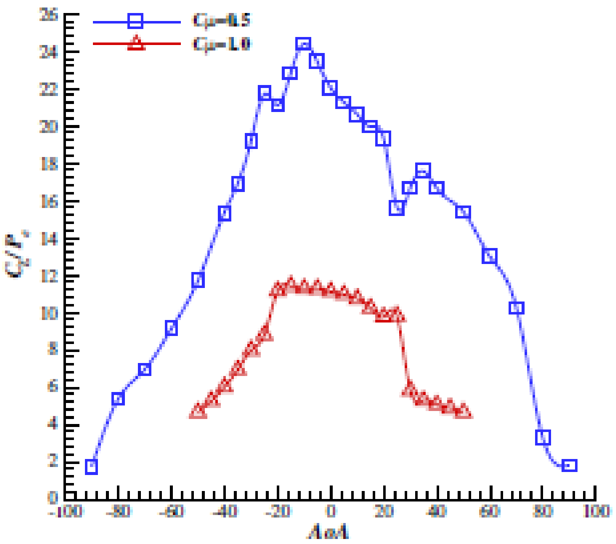
Sketch of C_{Thrust} magnitude

Angle of Attack Effect

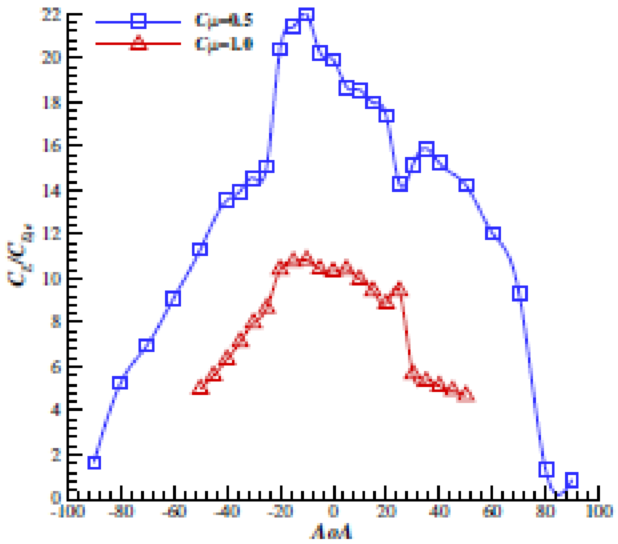
➢ Time-Averaged C_L/C_D, C_L/P_c and $C_L/C_{D,c}$ vs *AoA*



Lift-Drag Ratio



C_L/P_c



Corrected C_L/C_D

BENEFITS OF CFJ STATIONARY CYLINDERS: HIGH THRUST, SIMPLE AND LOW COST

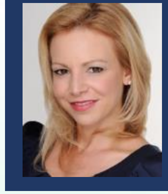
- 20%-50% fuel reduction for large cargo ships
- Propulsive power increase > 100%
- Ultra-high thrust (>2X), CL ≥ 15
- 60-95% wind power for mid/small size cargo ships
- Simple system with no rotating structures
- Compact for all ship sizes
- Very low power required
- Low cost of manufacturing/maintenance
- Retrofitting
- Ideal for fully electric ships

LEADERSHIP TEAM

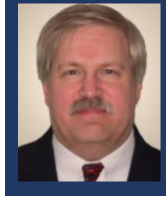
Dr. Gecheng Zha | President, Professor, World Top 2% Scientist, NASA NIAC Fellow

Dr. Yan Ren | Chief Technology Officer

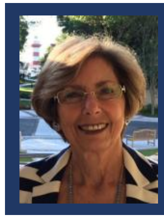
Hagen Ruff | Vice President



Renee Lopez-Cantera | Advisor in PR

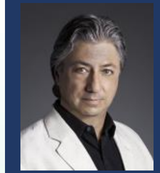


Donald Bingaman | Advisor in Aero Tech

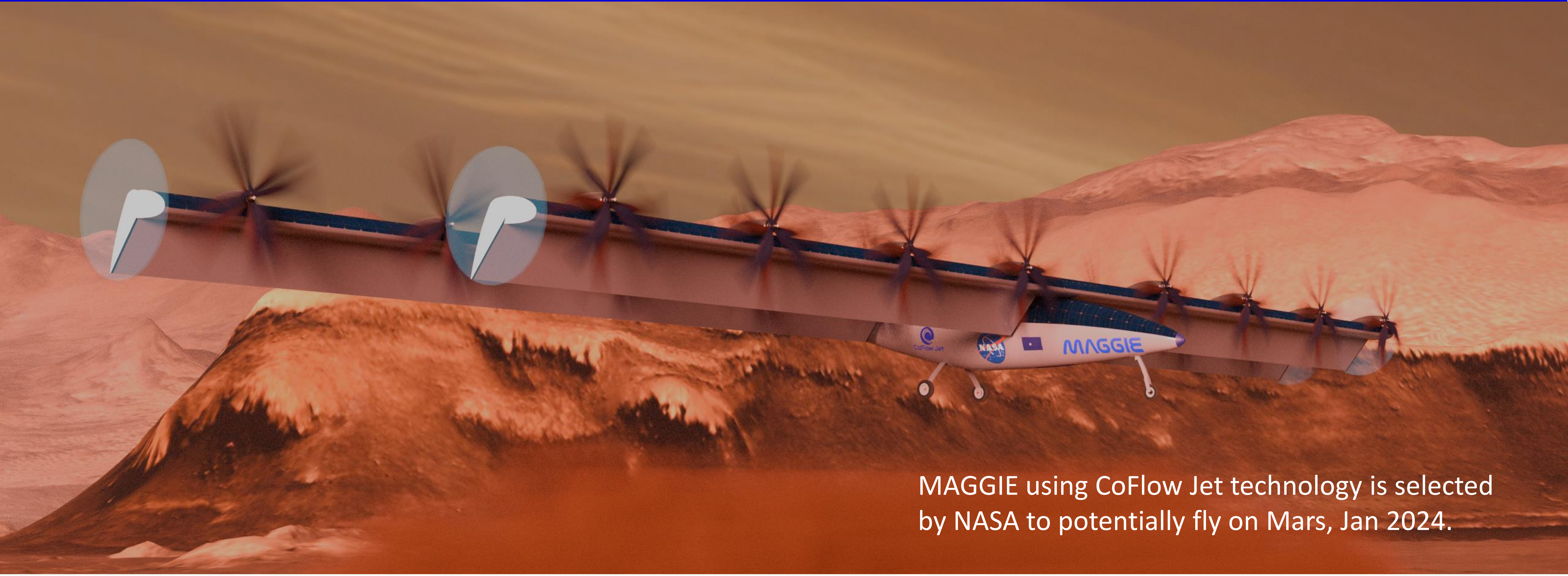


Nancy Bailey | Advisor in Brand Licensing

Syed Biabani | Advisor, Business Development



Chris Piedmonte | Advisor, Business Strategies



MAGGIE using CoFlow Jet technology is selected by NASA to potentially fly on Mars, Jan 2024.

DARPA NASA NSF AFRL EBPT CIRA RICE ALLIANCE CLEAN ENERGY ACCELERATOR

THIRD DERIVATIVE RMI NEW ENERGY NEXUS PAN AMERICAN FINANCE

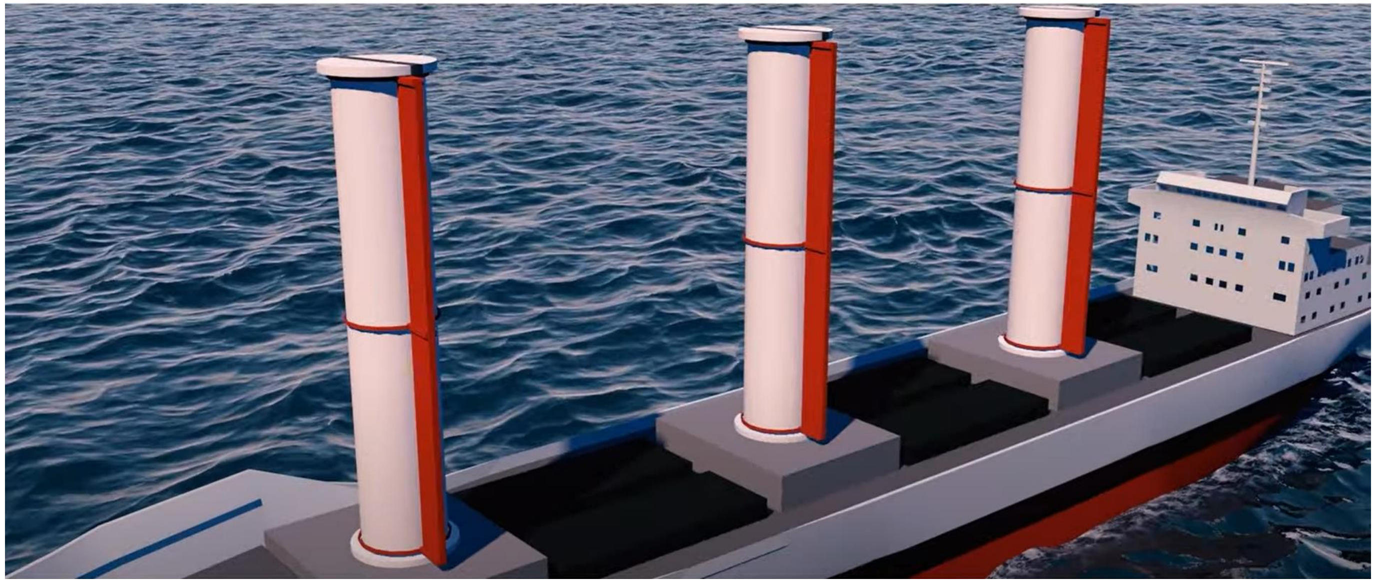
Blue WASP

Wind Assist Specialists

WWW.BLUEWASPMARINE.COM

Performance evaluation of a Flettner rotor with flap

Dr. G. Bordogna, Blue Wasp Marine BV

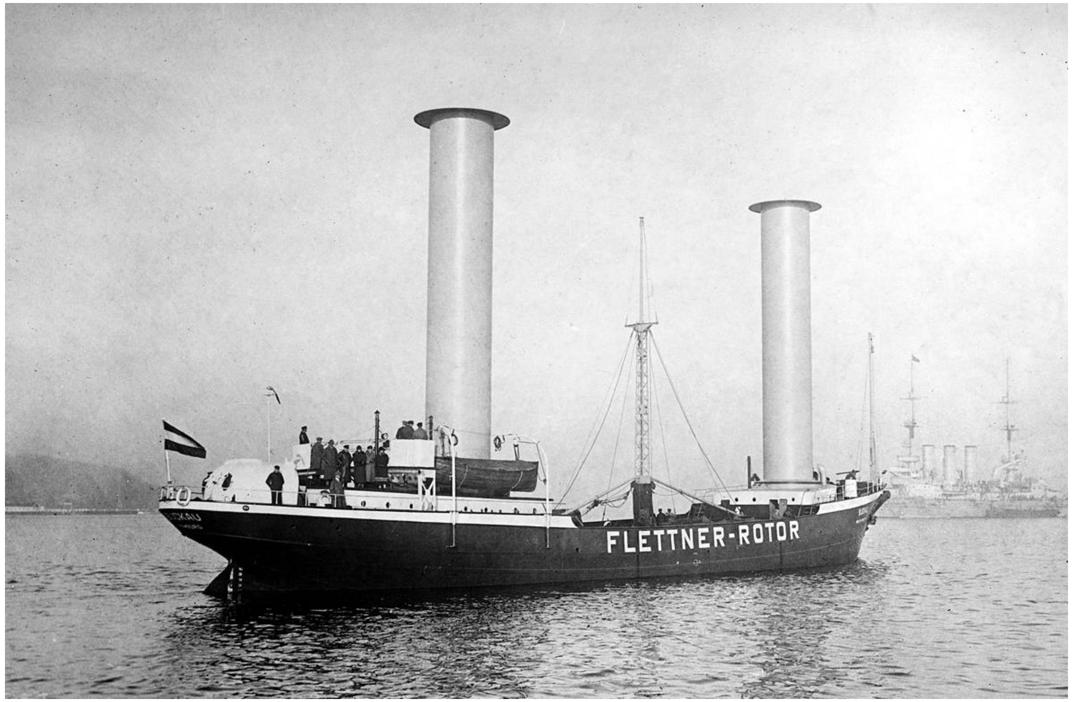


Presentation background & preface

- Results obtained during Wind Assist PhD research (2013-2020) at TU Delft
- Credit to co-authors Albert Rijkens and Nico van der Kolk
- In 2023 TUDelft started a new large research program on Wind Assisted Propulsion
- Blue Wasp Marine is an independent consultancy working with all wind assist technologies

Flettner rotor & flap concept

- Flettner rotor is a spinning cylinder that, thanks to the Magnus effect generates an aerodynamic lift
- It's an active high-lift device, it requires a power input to function
- Today, several ships are fitted with this device
- **Flap addition**: the goal was to fix the separation point, increase CL/CD ratio and improve upwind performance

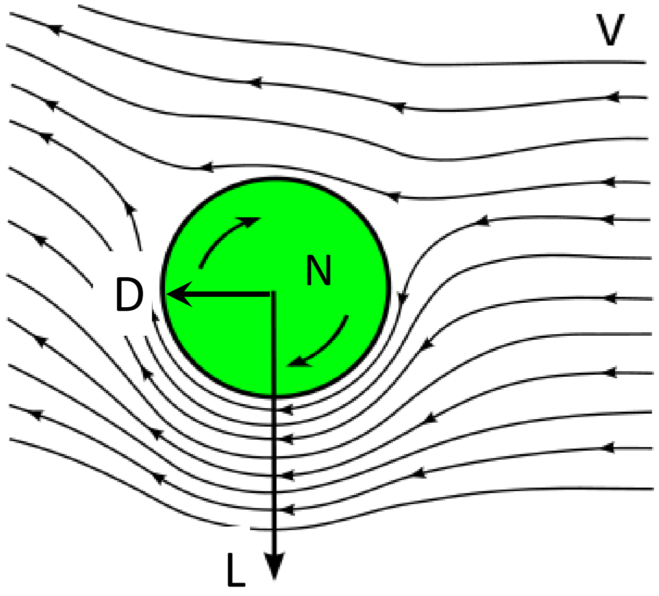


Backau ship equipped with 2 Flettner rotors (1924)

Magnus effect

Relations between forward speed and rotational velocity of the rotor are expressed with the velocity ratio or "k-factor":

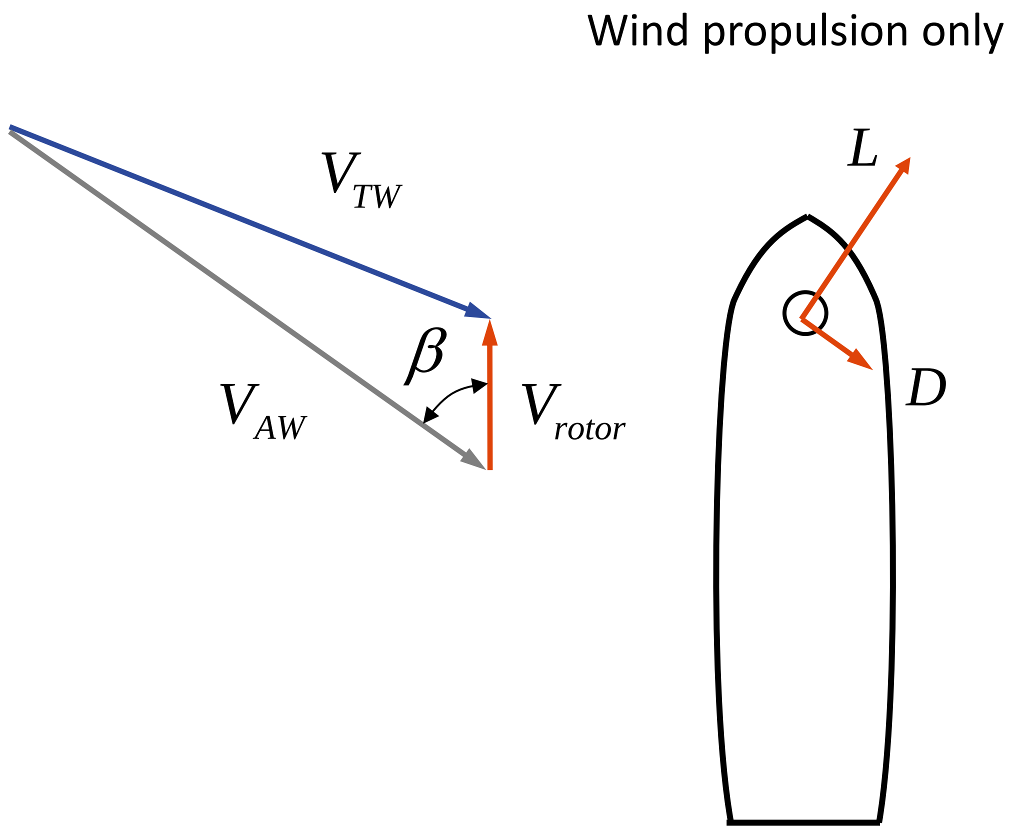
$$k = \frac{N\pi D}{V}$$



N = Rotational speed rotor
D = Diameter of the rotor
V = Wind speed

Importance of Lift-to-Drag ratio

Due to "motorsailing", WASP ships spend large amount of time sailing upwind

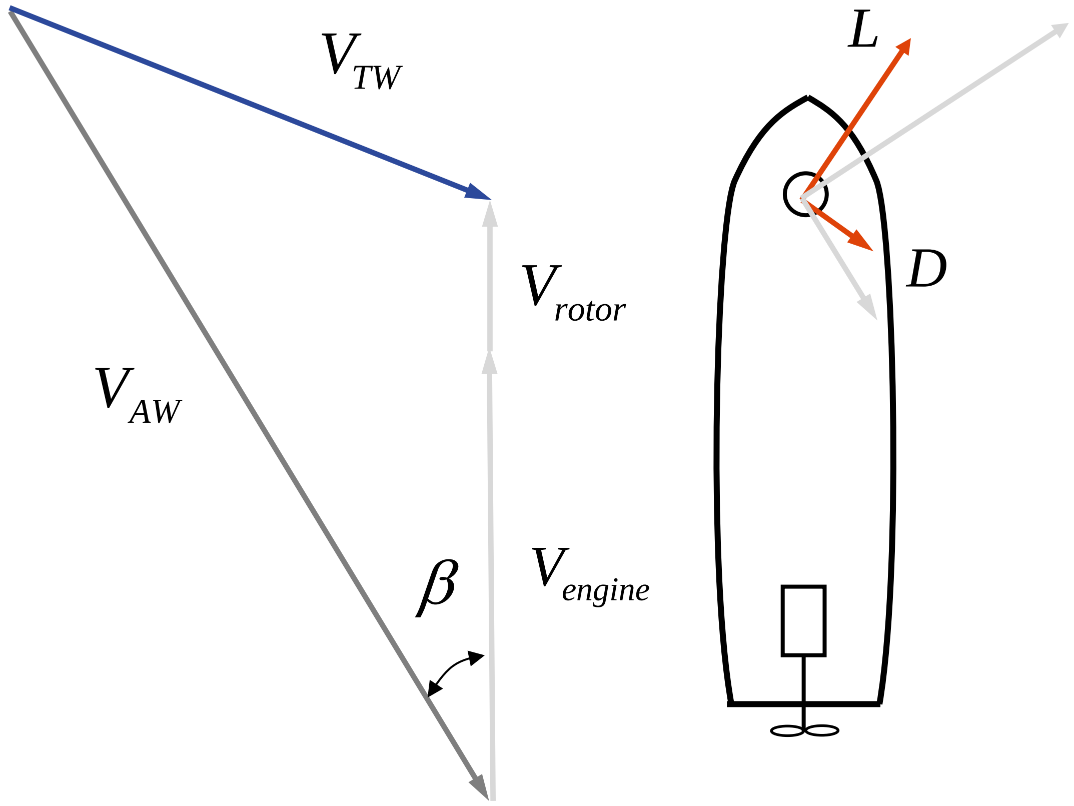


Importance of Lift-to-Drag ratio

Due to “motorsailing”, WASP ships spend large amount of time sailing upwind

Improving the lift/drag ratio would lead to great benefits to WASP ships

Wind assisted propulsion (wind + engine)



Wind tunnel experiments

Model experiments at the Politecnico di Milano wind tunnel

Features

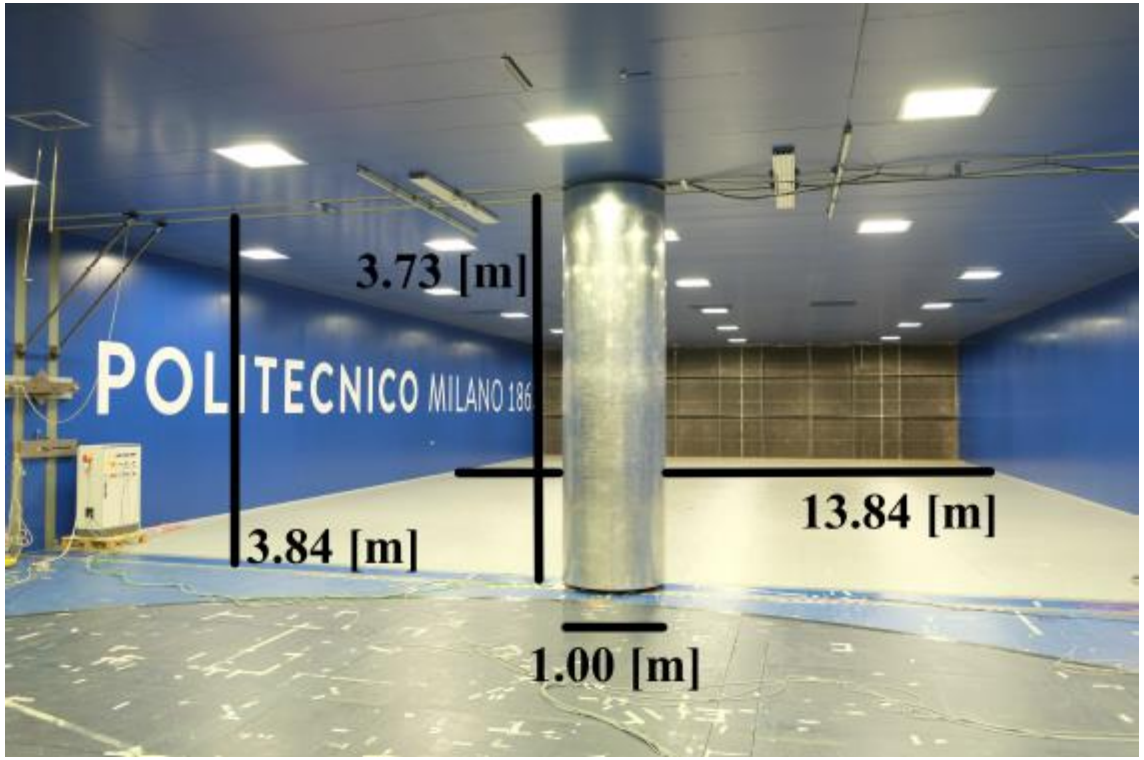
Length = 36 m

With = 13.8 m

Height = 3.8 m

Max wind speed = 15 m/s

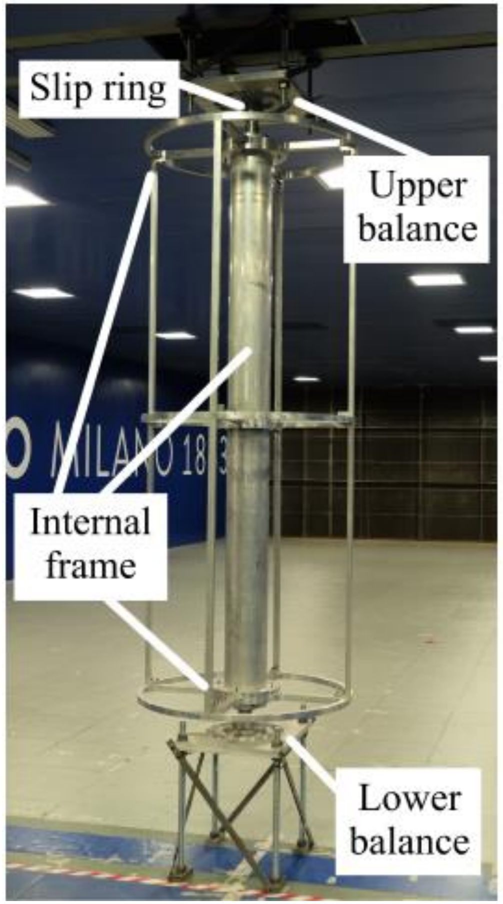
Benchmark tests with the “Delft Rotor”

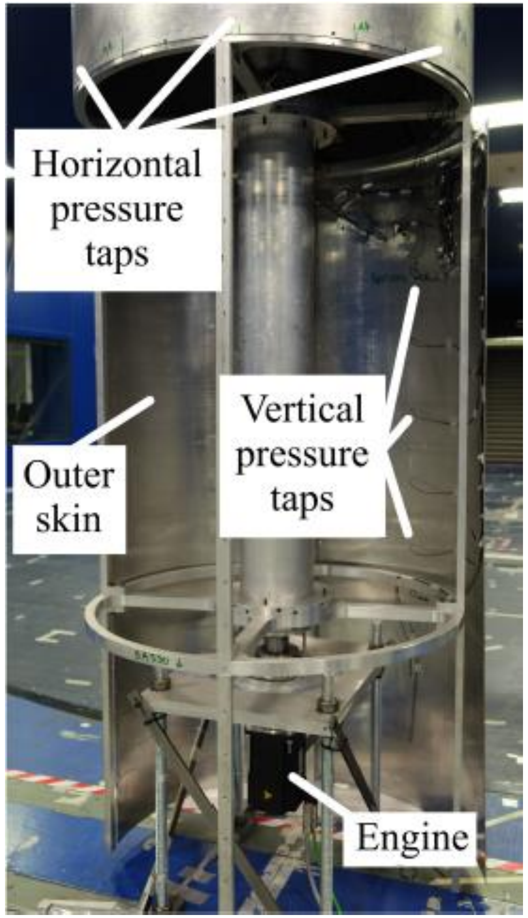


Wind tunnel experiments

Construction of the "Delft Rotor"

- Large scale Flettner rotor (D=1m and H=3.7m)
- No tip effects
- Very high Reynolds numbers
- Equipped with 2 force balances and 2 different pressure measurement systems





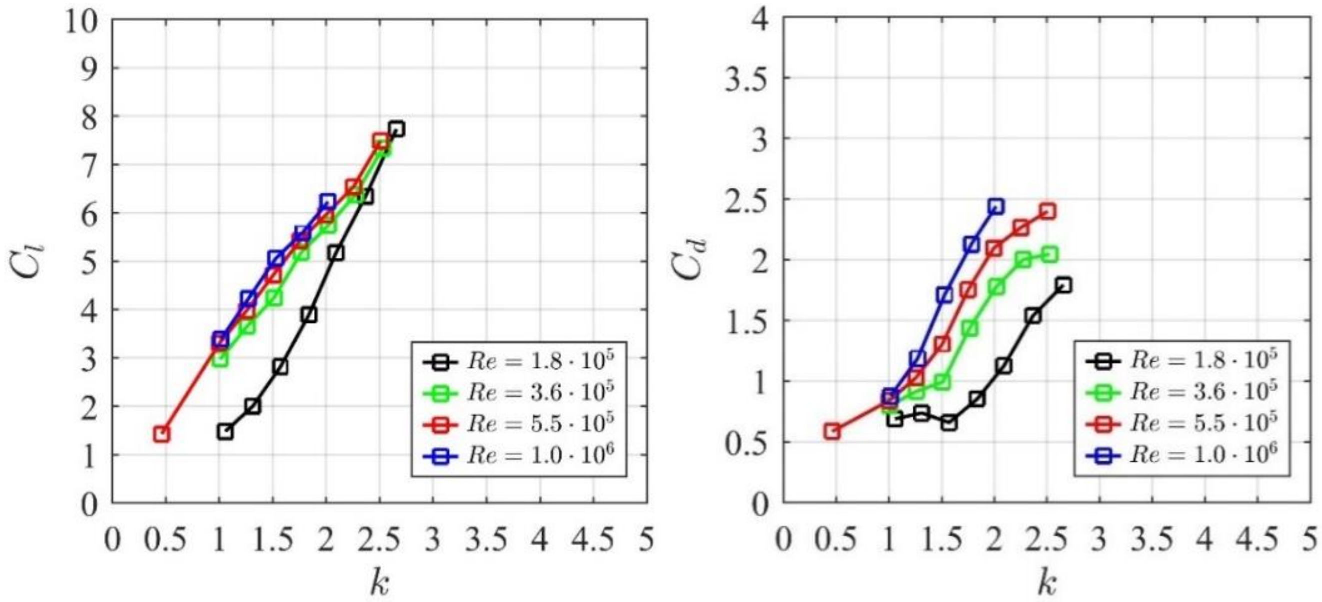
Results Delft Rotor

- Lift coefficients is not affected by the Reynolds number for $Re \geq 3.6 \cdot 10^5$

- Drag coefficients are still influenced by scale effects even for the highest Re tested

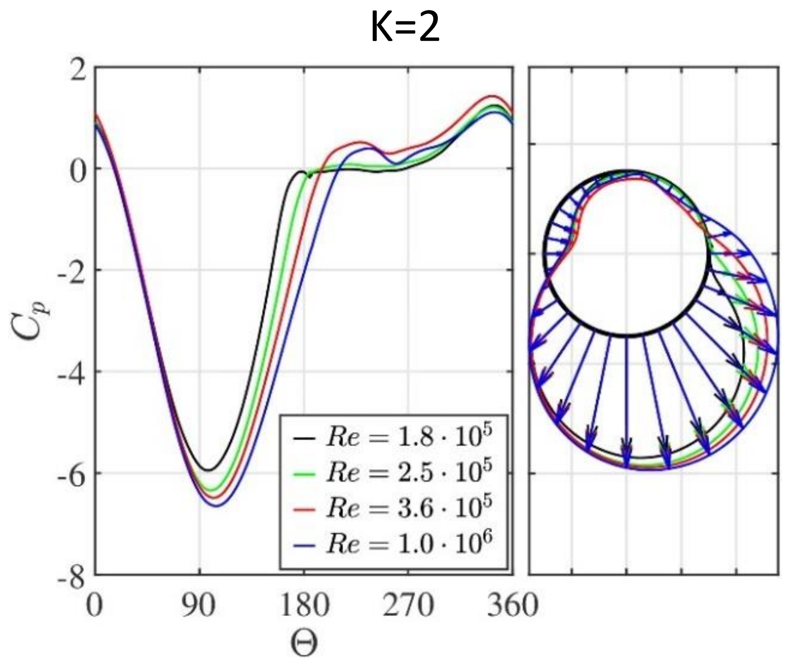
- Tests with flap are conducted at $Re = 3.6 \cdot 10^5$ to achieve a velocity ratio of up to $k = 5$

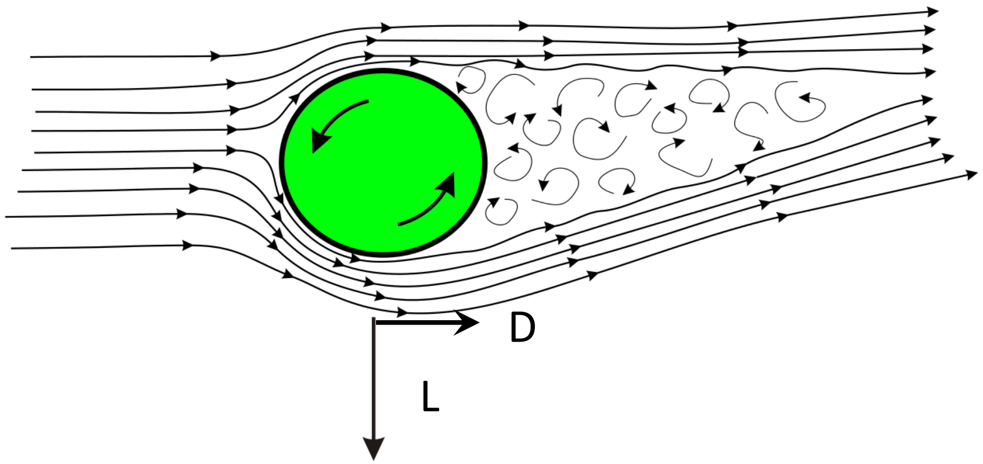
$$Re = \frac{VD}{\nu}$$



Results Delft Rotor

- Pressure distributions at Delft Rotor mid-span
- Effect of Re number on the pressure distribution especially at the rear of the cylinder



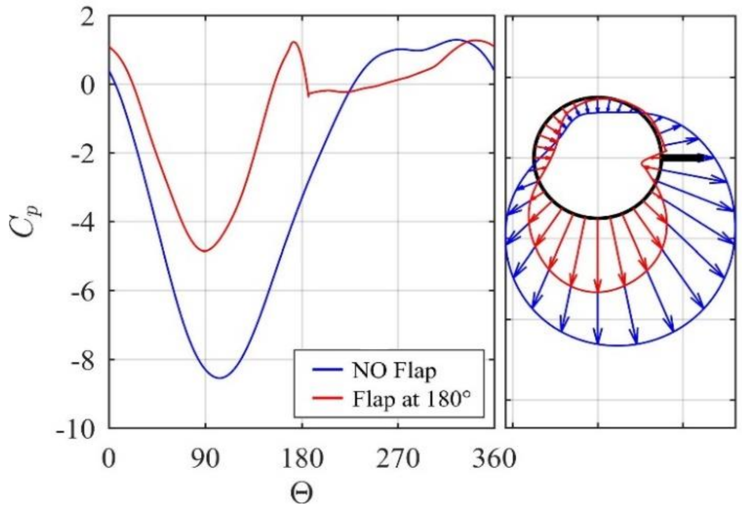


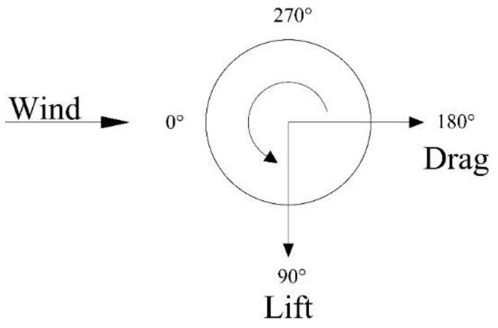
Delft Rotor with flap

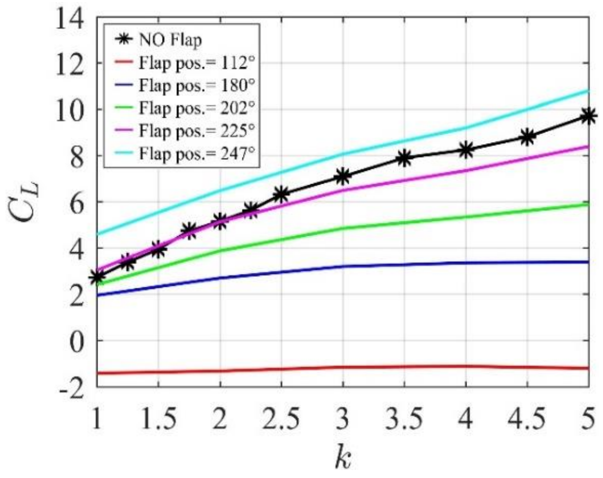
Results Delft Rotor with flap

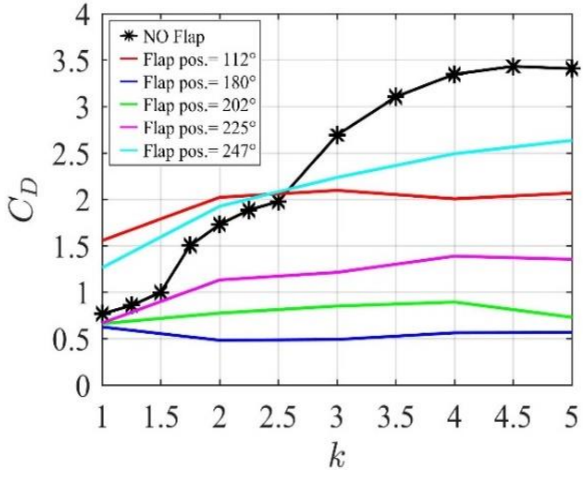
- Flap influences the separation point of the flow
- Drag is reduced
- Lift is reduced to a smaller extent
- Lift-to-drag ratio roughly doubles for the flap at 180 deg position

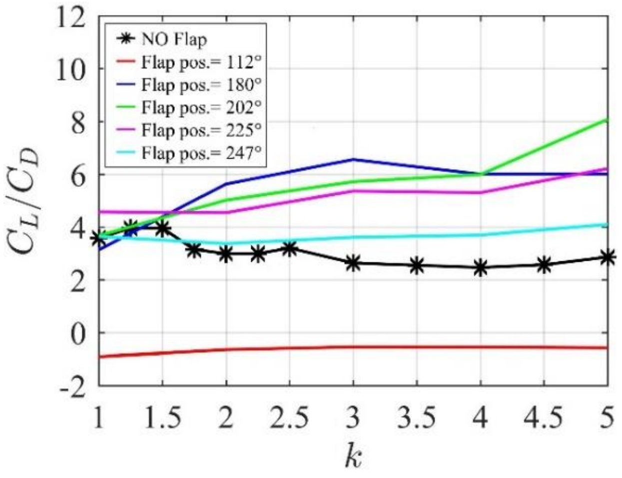
K=3





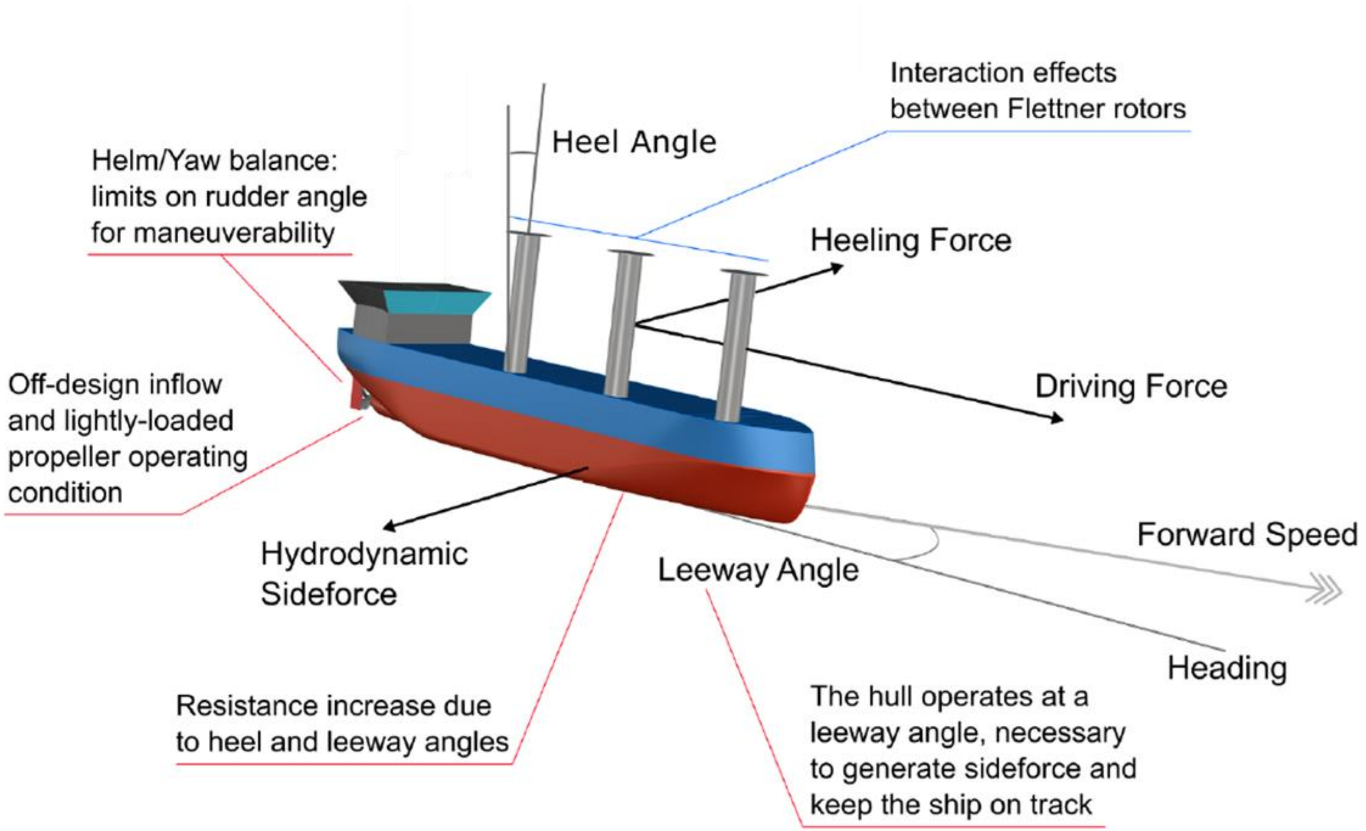






Performance prediction analysis

- Performance Prediction Programme for WASP ships
- Balances aerodynamic, hydrodynamic and main propulsor forces
- Aerodynamic properties of the rotors are based on the wind tunnel experiments
- Hydrodynamic coefficients are based on the Delft Wind-assist Series

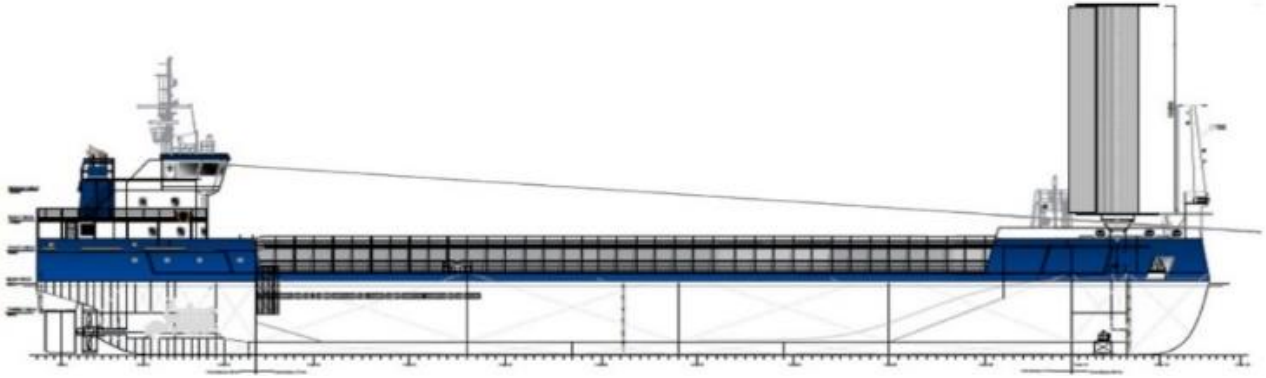


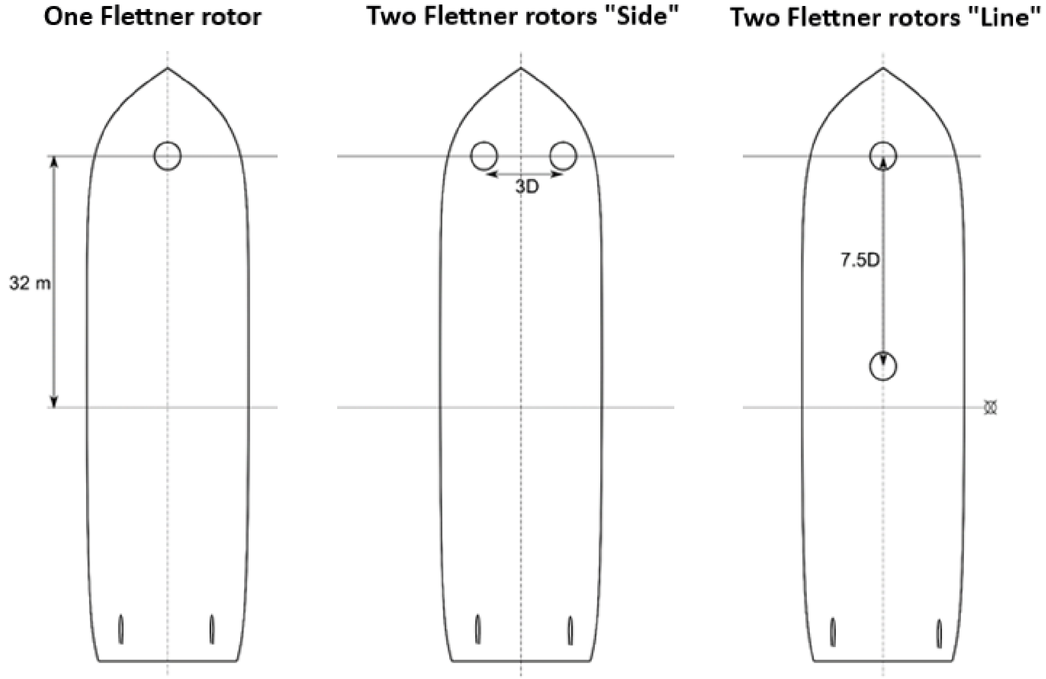
Case study

BW

Configuration

- Comparison of the standard FR and the FR with flap
- Damen Combi Freighter 5000 with an overall length of 86 m
- Rotor dimensions D = 3m and H = 18m
- Different rotor numbers and positions



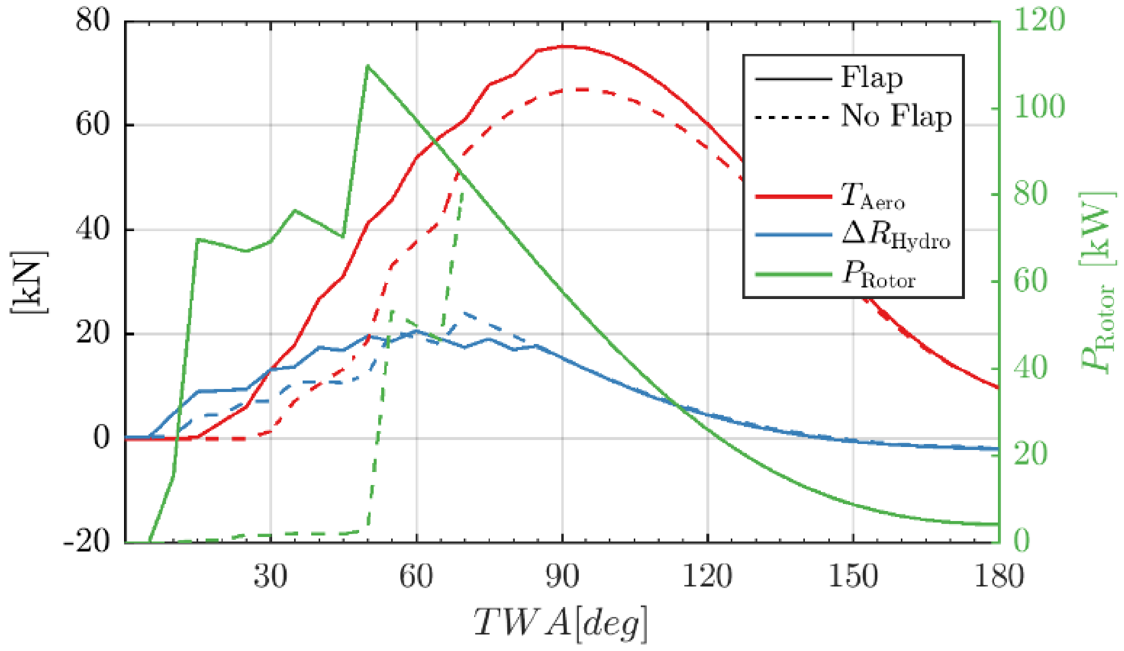


Tacking angle comparison

Results for two Flettner Rotors "Line"

- Aerodynamic thrust of the FR with Flap is greater or equal compared to the Standard FR
- FR with Flap has a considerably smaller tacking angle
- Tacking angle of Standard FR is 42 deg
- Tacking angle of FR with Flap is 30 deg

TWS = 20 kts and Vs = 11 kts



Fuel savings polar comparison

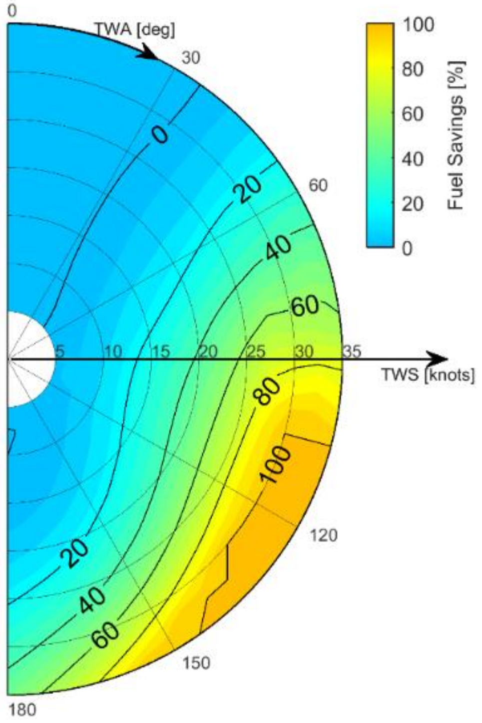
- Polar diagrams show the percentage fuel savings of the ship with rotors compared to the same vessel, operating in the same conditions, but without wind assistance

- FR with flap gives higher fuel savings particularly for $TWA < 90°$

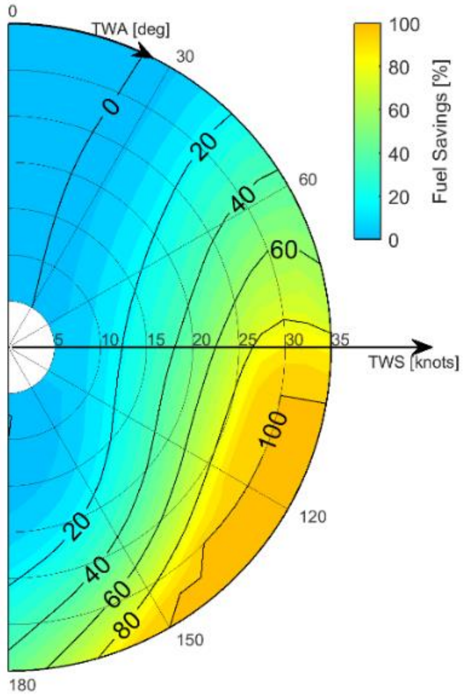
- Ship is able to operate at smaller wind angles

Results for two Flettner rotors “Line”: Vs=11 kts

Standard Flettner rotor



Flettner rotor + flap

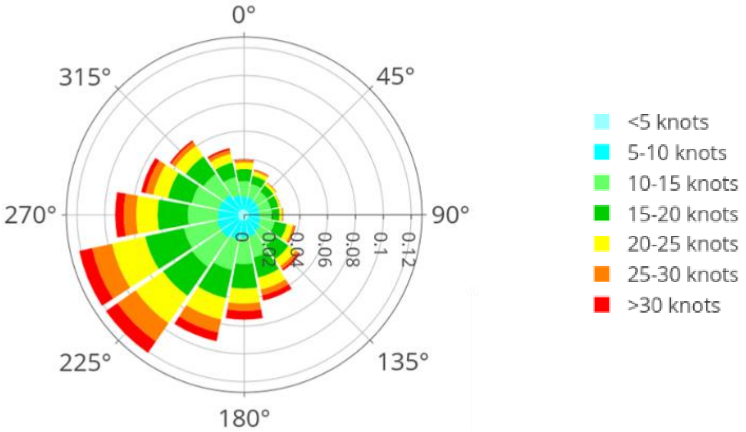


Evaluation on shipping route

- Wind conditions of the North Sea region

- Fuel consumption polar diagrams are multiplied with the wind scatter diagrams for an S-N and N-S route

Wind rose: Rotterdam – Trondheim route



Percentage fuel savings at a ship speed of 11 knots

Route	Two FR without flap	Two FR with flap	Increase
North Sea S-N	15.3%	18.1%	**18.3%**
North Sea N-S	11.4%	15.1%	**32.5%**

Conclusions

Aerodynamic characteristics

- Adding a flap to a FR can increase the lift-to-drag ratio up to a factor of 2

Performance improvements on a ship

- The higher lift-to-drag ratio of the FR with flap assures that it can attain a larger aerodynamic thrust than a Standard FR for upwind sailing conditions
- The improved lift-to-drag ratio of the FR with flap results in a smaller tacking angle which increases the operational profile

Fuel savings

- For the reference ship operating on the North Sea a performance increase of up to 32.5% is reported due to the additional flap on the Flettner Rotors

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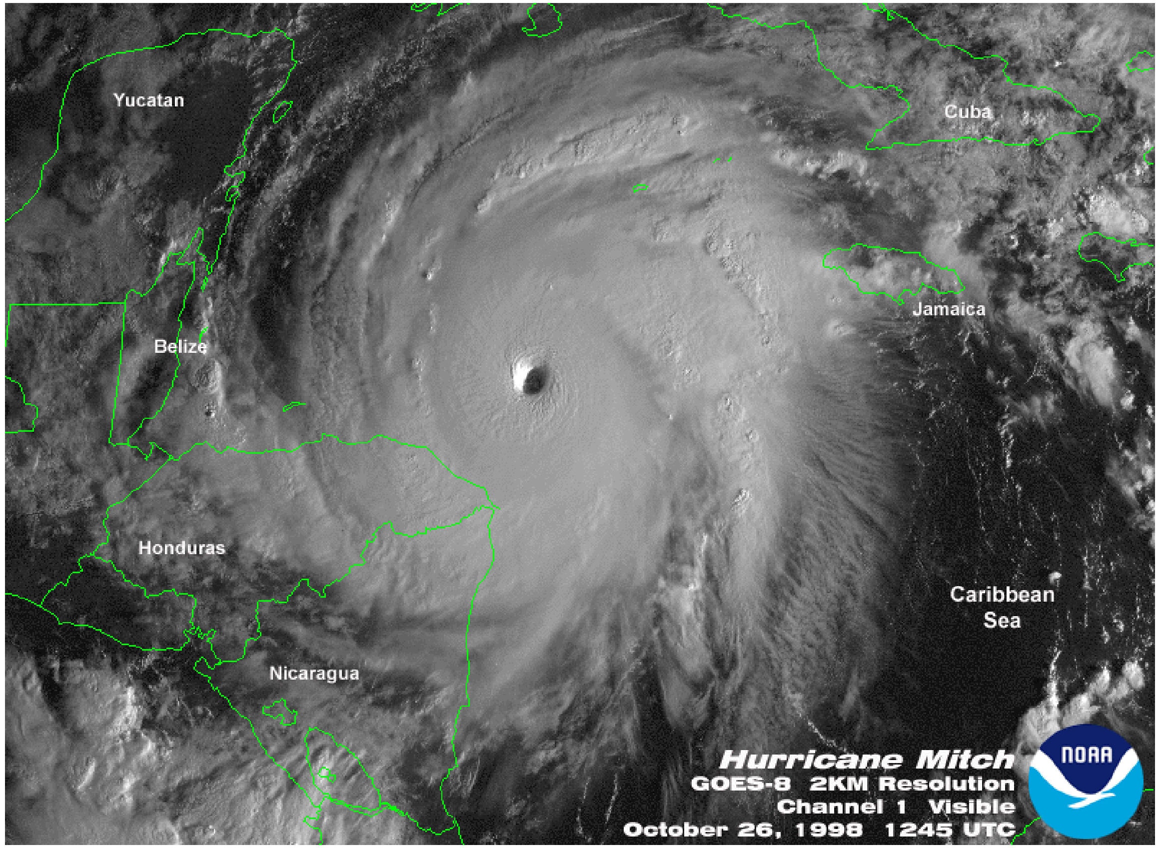
Lessons from sailing vessel disasters

"To the men of the Fantome- there but for the grace of God go I", *The Ship and the Storm – Hurricane Mitch and the Loss of the Fantome*, by Jim Carrier

Sergio Perez, Ph.D.
Department of Marine Engineering, US Merchant Marine Academy

Fantome, 286 foot sailing cruise ship, sank in Oct 1998 in Hurricane Mitch, in waters off Honduras



Mitch was a Category 5 hurricane with 180 mph winds that also decimated Honduras, killing 7,000 people with flood waters, and destroying a large portion of Honduran infrastructure.

On October 26, passengers arrived at ship location in Omoa, Honduras. The Captain decided to cancel the cruise because of Hurricane Mitch, but sailed for Belize with the passengers at midnight. This was done for the comfort of the passengers, as travel to the airport was easier for passengers from Belize. A day was wasted in which a sheltering place for the ship could have been found.

According to 1-2-3 Hurricane Avoidance Rule recommended at that time, the ship should not have sailed. Basically, a circle of about 200 mile radius would be drawn around the hurricane's 24 hours forecast position, and a ship should stay out of that circle. Fantome was on the outer edge. We note that Fantome's escape was blocked on the south by Honduras and west by Belize.

Andy Chase of Maine Maritime (author of *Auxiliary Sail Operations*): "it is clear that he (the Captain) is already hopelessly trapped in a situation with no safe way out..his only option at that time was to find the best harbor".

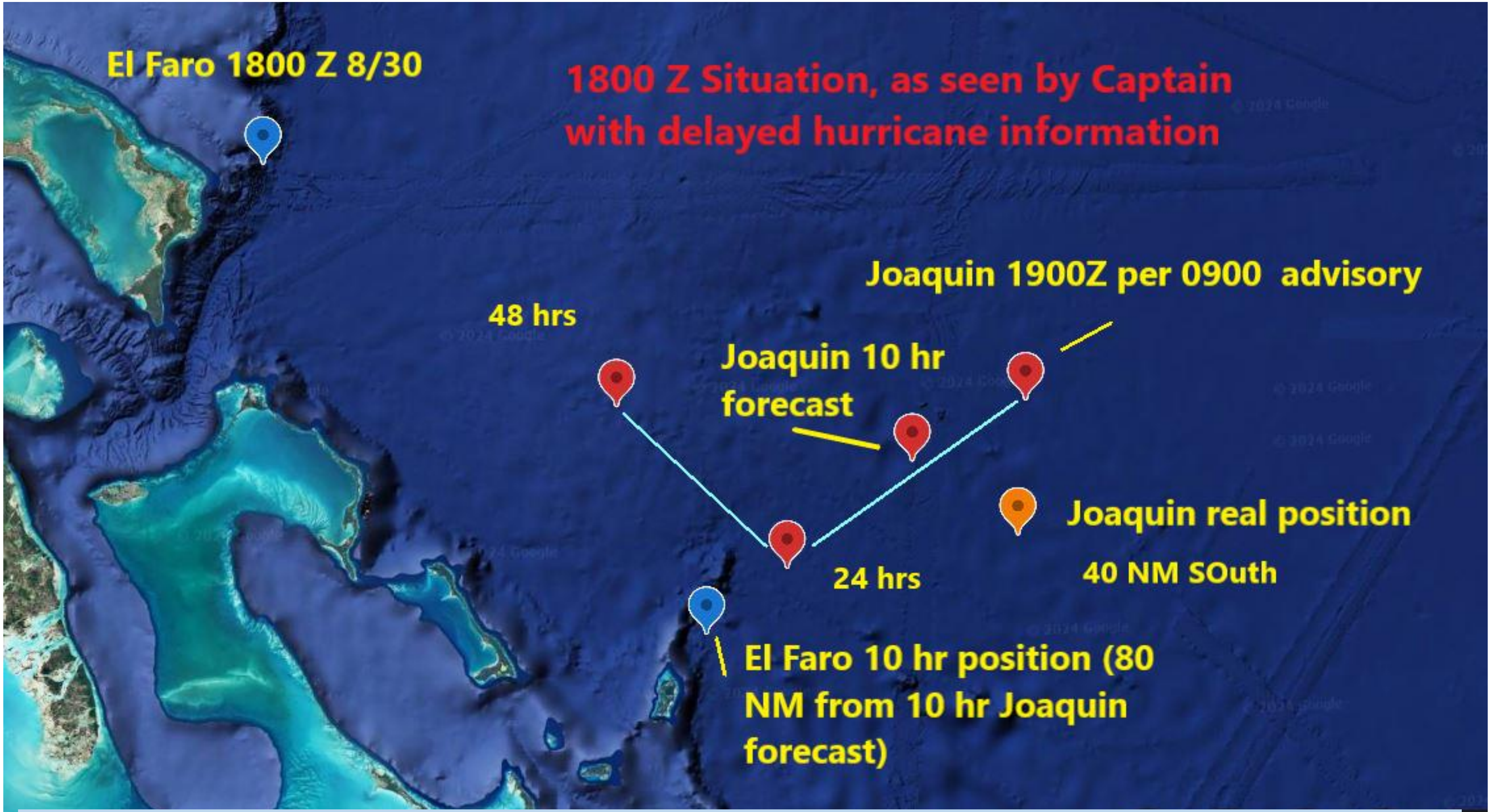
But the Captain sailed to Belize City….

Captain Andy Chase: "I believe the fundamental mistake made by the Captain of the Fantome was to underestimate the unpredictability of a hurricane "

El Faro. Sank off the Bahamas in Hurricane Joaquin enroute from Jacksonville Florida to Puerto Rico, October, 2015 with 38 lives lost.

Figure 3. *El Faro* at sea loaded with containers, viewed from stern. (Photo taken March 12, 2012, at Port Everglades, Florida, by Captain William Hoey)

Captain used commercial hurricane position plotting software with weather information that was 5 hours older than NHC forecast, making the hurricane seem further away than it really was. But even if the forecast had been correct, the Captain was still too close to the storm, as the Captain ascribed a precision to the hurricane forecast position that was unjustified.



"Like a race car driver, he (the Captain) cornered tight along Joaquin's presumed course in order to shave off seconds from his time", Rachel Slade, author of *Into the Raging Sea*

From the NTSB report on the El Faro sinking:

"The NTSB determines that the probable cause of the sinking of El Faro … was the captain's insufficient action to avoid Hurricane Joaquin, his failure to use the most current weather information, and his late decision to muster the crew….."

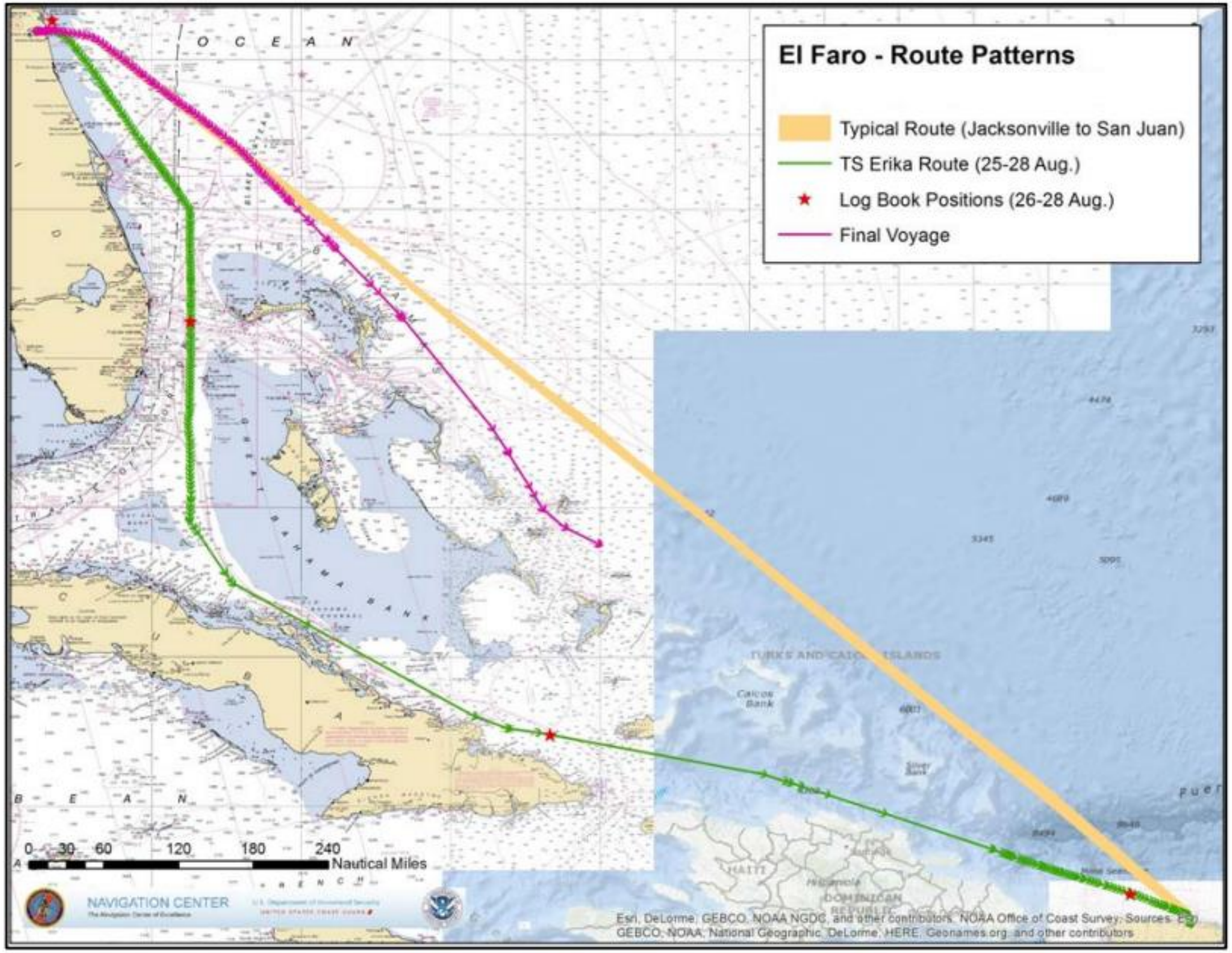
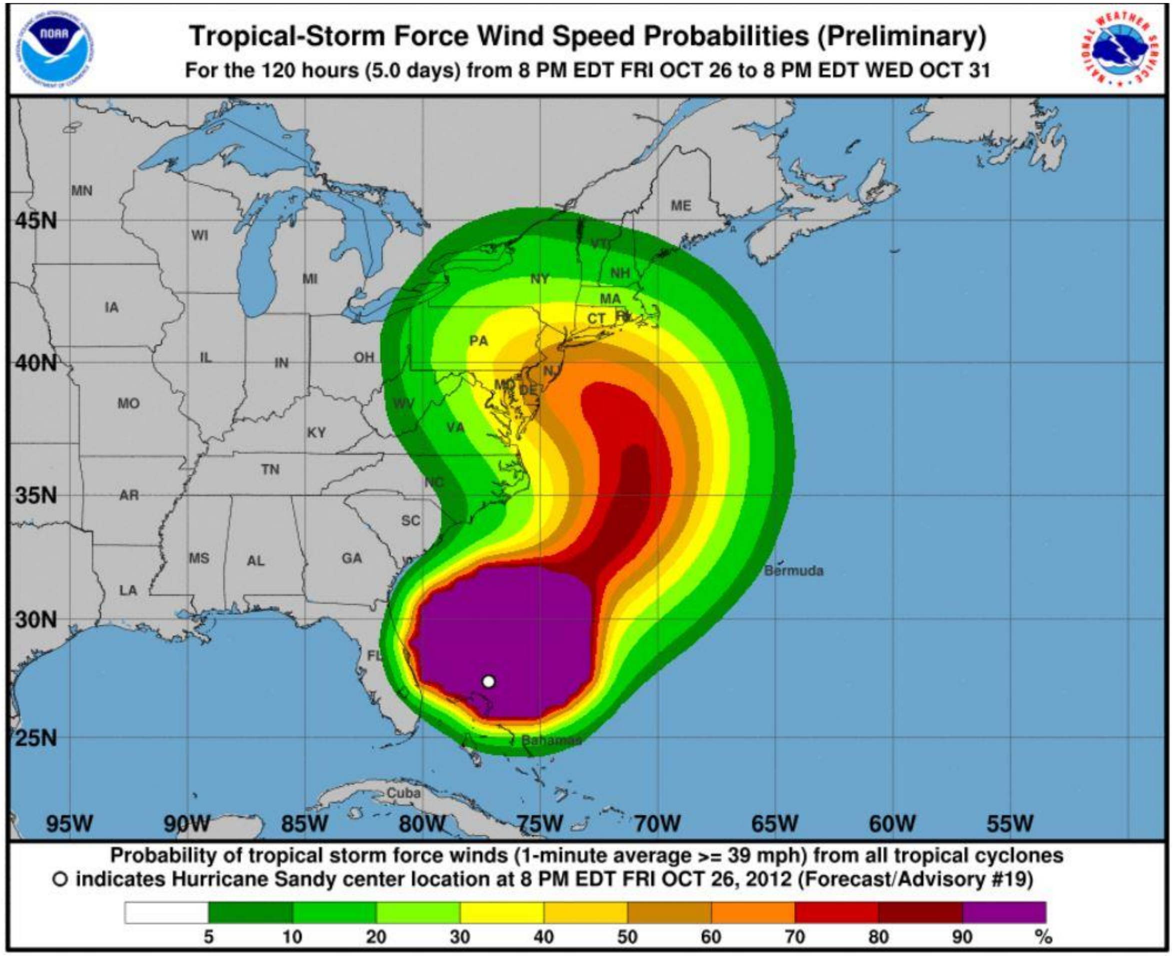


Figure 5. Alternate route via Old Bahama Channel (green) from Jacksonville to San Juan, compared with normal route (orange) and *El Faro*'s route on accident voyage (purple). (Coast Guard diagram)

Better information now available from NHC (1-2-3 Rule no longer generally recommended):



"What is an acceptable level of risk when lives and property may be at stake?"

Graphic from https://www.nhc.noaa.gov/aboutnhcgraphics.shtml?

Sailing Yacht Bayesian, sunk while at anchor in August, 2024 with 7 casualties

This tragic incident is still under investigation.

It is likely that downbursts played a large role in this sinking.

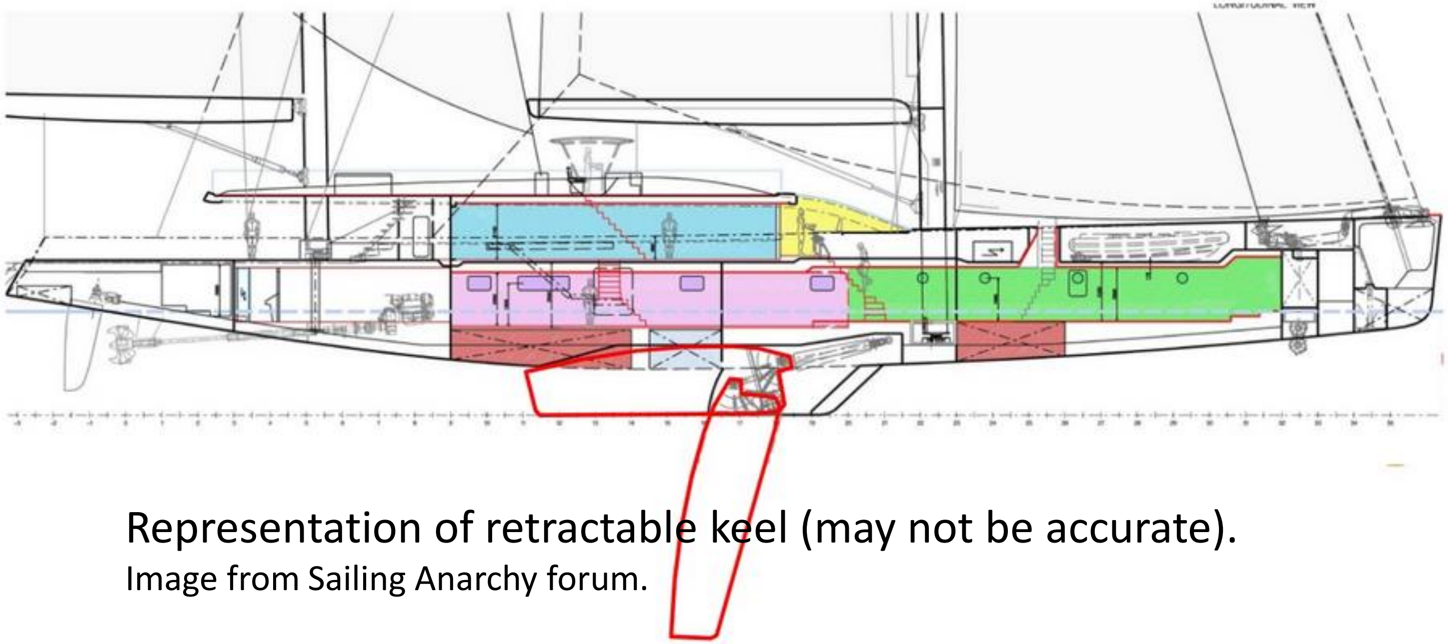
Downbursts and microbursts are rapidly descending masses of air from storm clouds that move horizontally as they approach the water/ground surface.

https://www.youtube.com/watch?v=dOSIjoZnHwI Note wind ferocity and vast amounts of rain

Video from 2 to 5 minute marks

- 56 m length (184 ft). Single 72 m high mast. The norm for these vessels is two shorter masts.

- Vessel has roughly 200 ton lead ballast, 60 tons of which are on a retractable keel extending about 6 m beyond the ship bottom. Total draft is 9.8 meters.



Representation of retractable keel (may not be accurate).
Image from Sailing Anarchy forum.

Sources: Stephen Edwards, skipper of Bayesian (2015-2020), Scuttlebutt Sailing news, August 27, 2024, and Perini Navi web site

- Stability is reduced when the keel is up: vessel does not right herself in rolls greater than 75 degrees.
- With keel down, vessel rights herself up to 90 degrees

- While anchored (sails furled), eyewitness reports say vessel was suddenly knocked down by wind during a thunderstorm.

- Ship was anchored with retractable keel up, as called for in ship operating instructions from Perini Navi (designers).

- Italian government prosecutors said sinking was due to a downburst (ANSA.it)

- Vents on side of ship for HVAC and electricity generators were probably open, so down-flooding angle was about 45 degrees.

Sources: Stephen Edwards, skipper of Bayesian (2015-2020), Scuttlebutt Sailing news, August 27, 2024, and Perini Navi web site

Once the vessel was on her side, water might also rush in from entry area at stern.
(image from itboat.com)

Downbursts are a recognized threat to aviation but mostly ignored for ships

- Downbursts are caused by rapidly sinking air in very tall storm-clouds, usually cumulonimbus. When the descending air approaches the surface of the earth, the flow of air spreads out horizontally. Downbursts cause wind-shear experienced by aircraft. Macrobursts are large downbursts, microbursts are smaller than 4 km.

- Modern forecasting tools usually give ample warning for hurricanes. Downbursts give little or no warning.

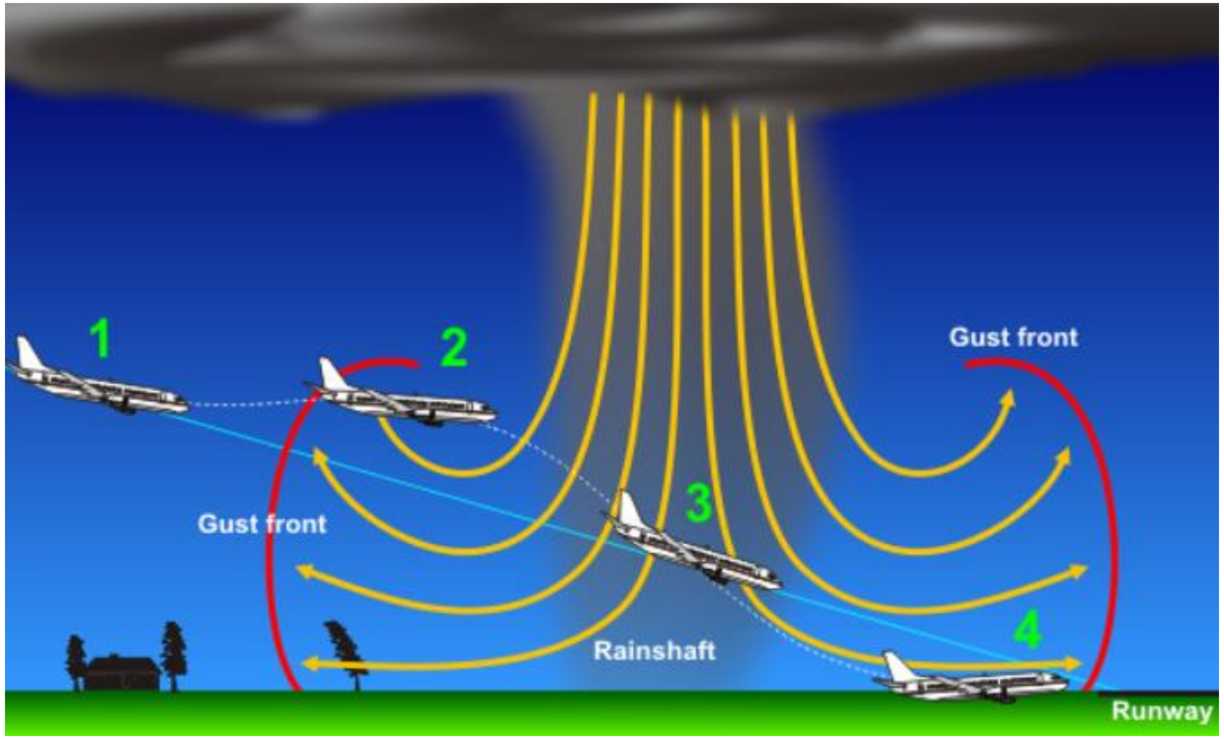


Image from noaa website

Discovery of the downburst

Meteorologist Ted Fujita noticed a “starburst” pattern of downed trees after a storm, similar to the photograph of a corn field shown at right. A tornado would leave a swirling pattern.

Fujita’s discovery was met with great skepticism. Meteorologists at the time believed that a downburst would have to lose its speed as it approached the ground.

The downburst hypothesis solved the riddle of the crash of Eastern airlines Flight 66 in June 1975 as it tried to land.

Fig. 2.5 An overall view of a microburst that descended on a cornfield near Gessie, Indiana on 30 September 1977. Photo by Fujita

- Fatal commercial aircraft accidents during landing and take-off led to federally-funded wind-shear research projects (JAWS and NIMROD) in the 1970’s and 1980’s.

- JAWS was conducted in Denver Colorado, May-August, in which 182 microbursts were detected. The fastest recorded downburst was 36 m/s (about 72 knots).

- Work by Fujita and others showed that downbursts could be as powerful as hurricanes and tornadoes, with winds up to about 130 knots, or 70 m/s.

- Underway sailing ships can be endangered by downbursts. If ships have even a short warning a downburst is coming, they can prepare to “fall off” (turn downwind) or de-power the sail (weather-vane into the wind)

- While anchored with a retractable keel up, the stability of a vessel is reduced. A sudden strong wind acting on a mast, rigging and ship superstructure could be more likely to roll an anchored sailing vessel to her downflooding angle than if the retractable keel were down.

https://www.youtube.com/watch?v=Z5vA4QvaH1Q

Downbursts are very difficult for sailors to spot:

A survivor from sinking of Pride of Baltimore recalls: “There was a line of squalls on the quarter and overcast skies on the beam. None of them appeared unduly threatening…. We were suddenly hit by a wall of wind and water with wind speeds of 70 knots and more… in what appeared to be slow motion the boat started laying over to port and in less than 60 seconds the boat was over on her side”.

In this incident, as in other similar sudden-wind events such as the sinking of S/V Albatross and Pamir, open hatches allowed water to enter the vessels once they were knocked down.

DOWNBURST/MICROBURST DETECTION

- Downbursts/wind shear are routinely detected by Doppler weather radar at airports and on-board commercial airliners.
- Ship radars are usually not Doppler type. While merchant ship radars detect the presence of storms and can be used to estimate the severity of rainfall, there is no detection capability for downbursts.
- Off shore oil rigs use LIDAR (Light detection and ranging) to detect strong winds. LIDAR is believed to be a better detector, but its greater cost and complexity may not be necessary for ships.

The loss of the 316 ft sailing vessel Pamir in 1957 with Hurricane Carrie:

- 80 people died, with 6 survivors.
- Gust knocked vessel down, and she never recovered.
- Barley cargo may have shifted since cargo was not bagged, as was normally done on ship.
- Hatches had been left open, permitting water in when vessel was knocked down.
- Ship should have run with the wind instead of beating into it, since it was in “navigable semi-circle”

Source: Tall Ships Down, by Daniel Parrot

Public Domain photo from Wikipedia

WHALE STRIKES and retractable keels

- The merchant sailing vessel of the future may require movable surfaces such as retractable keels and fins which extend below the vessel's normal draft (Woodward, 1975), such as used in Bayesian and other large vessels. These large appendages may be susceptible to whale strikes.

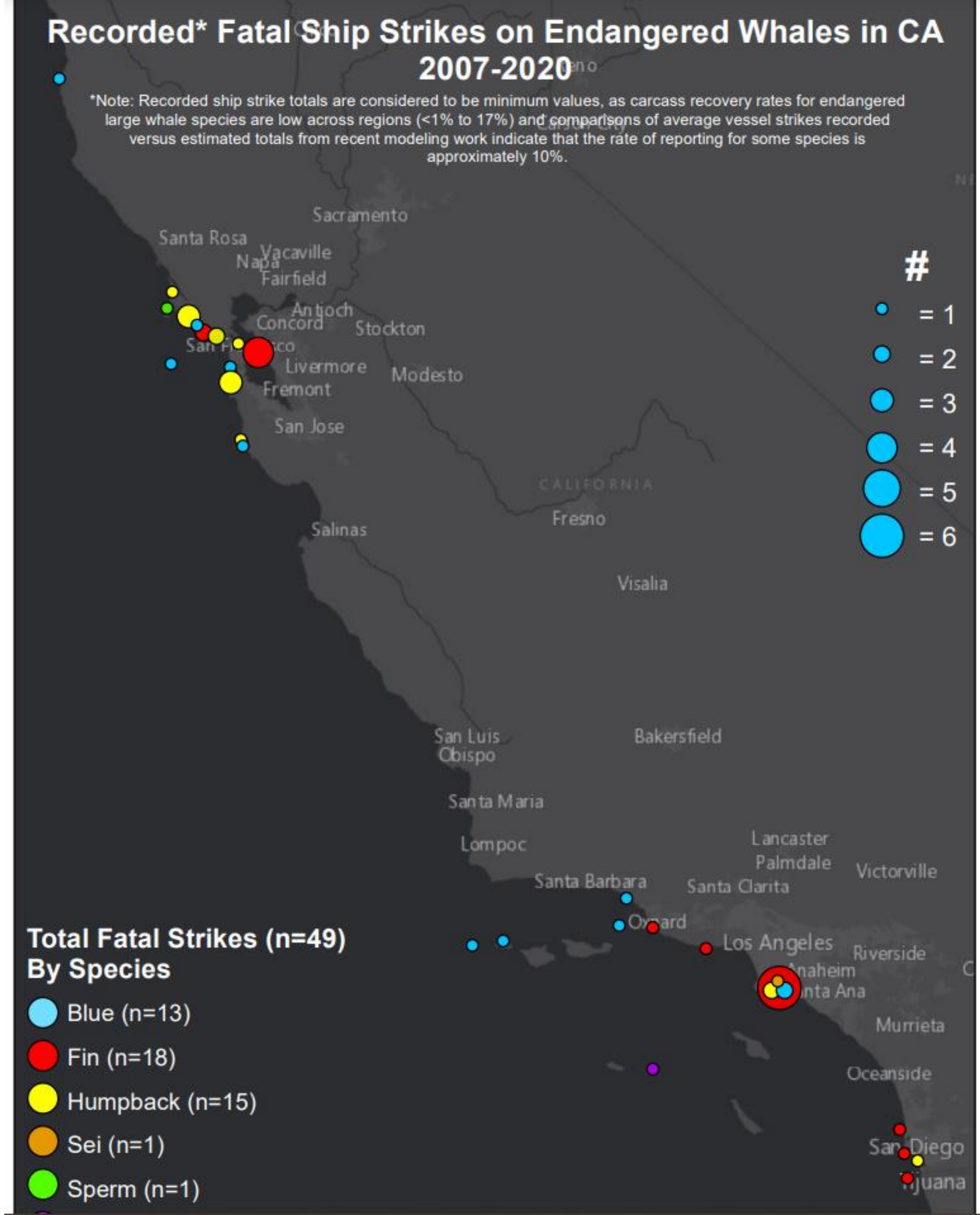
- While the steel hull of large modern ships may not be damaged by a whale strike, a fin extending beneath the hull would be more vulnerable. Whales can weigh as much as 300,000 lb (148,500 kg).

Asgard II, a tall ship training and cargo vessel, collided with an unknown underwater object in the Bay of Biscay. The collision resulted in the damaging of the hull and sinking of the vessel (MCIB, 2010). No lives lost.

While it is not certain that Asgaard II was sunk by a whale, the Bay of Biscay is a world-famous whale watching location.

WHALE STRIKES, continued

- Whales do not appear to avoid areas of heavy ship traffic, and their reaction to approaching ships is uncertain. Some whales descend, some don't move. There is no apparent response pattern, and loud sounds do not result in a flight response.
- Research suggests collisions may occur far more frequently than we know. Scientists estimate only about 10% of strikes are reported.
- Whales are detectable on common sonar used to locate fish.
- A release mechanism on movable control surfaces should be considered, much like the kick-up rudders on some catamarans.



A blue whale surfaces in close proximity to a large container ship. John Calambokidis, Cascadia Research

NOAA National Marine Fisheries Service Strandings Database

LESSONS LEARNED

1: Doppler radar used on aircraft should be considered for sailing merchant ships for the detection of downbursts and other sudden winds. Automatic sail de-powering should also be considered in the event of a sudden winds with sails up.

2: The vulnerability of vessels at anchor with retractable keels raised should be studied, in the event of sudden winds from downbursts or waterspouts.

3: Vents should be placed in a position where they are closer to amidships, in order to increase the downflooding angle. Hatches and vents should have some automatic closing mechanism if water enters from sudden rolls.

4: Sailing vessels with deep underwater appendages should use sonar to prevent collisions with whales.

5: “Kick-up” mechanisms should be studied for deep-draft underwater appendages.

6: We are all capable of making poor decisions. Discussion is needed dealing with how Captains and management can make better hurricane decisions. More mandatory training? Use AI ?

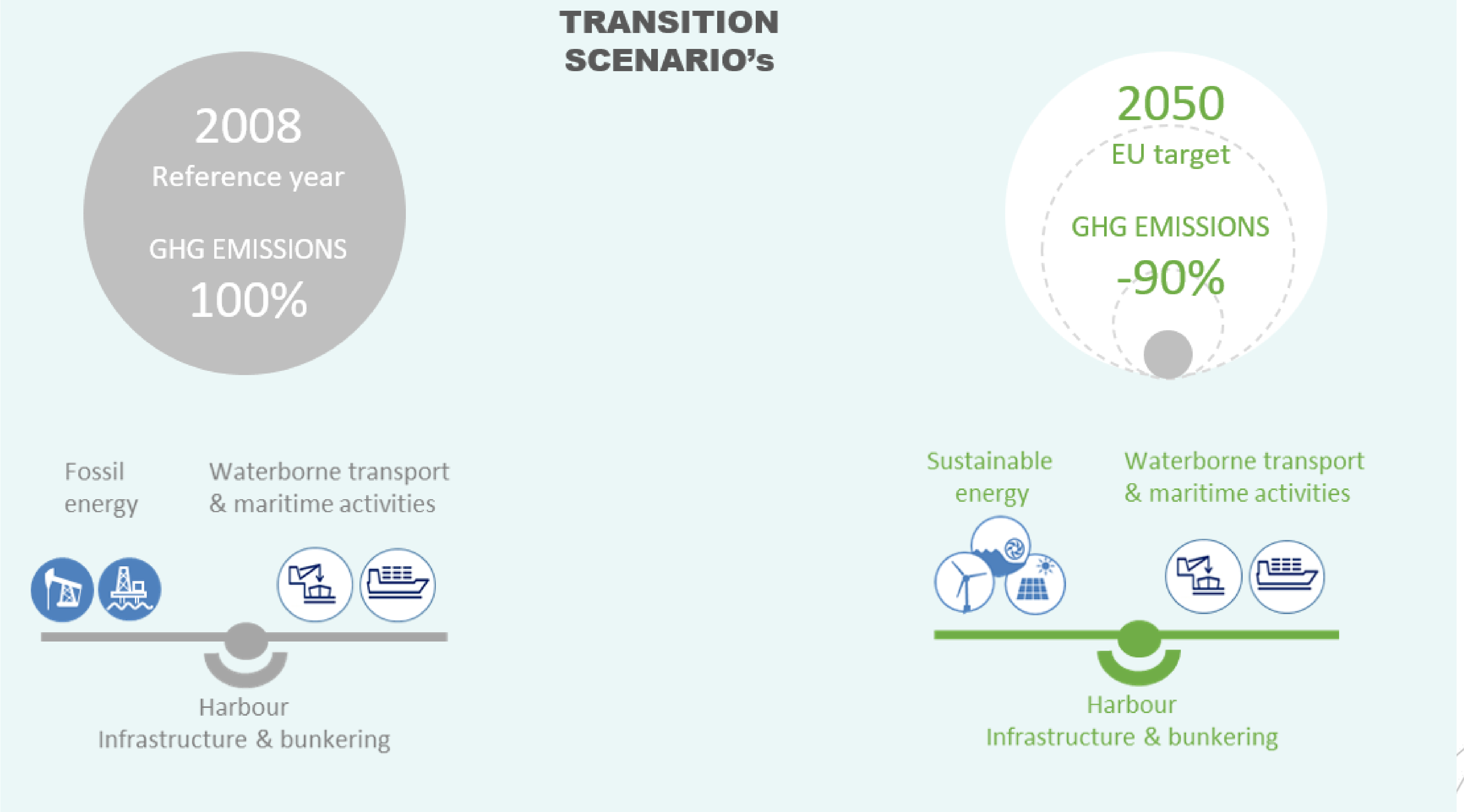
MARIN

BETTER SHIPS, BLUE OCEANS

NEEDS
A regional dynamic techno-economical scenario simulation model

Guilhem Gaillarde

MARIN
BETTER SHIPS, BLUE OCEANS



A dynamic **techno-economic model** of waterborne transport activities that allows to **evaluate sustainable fuel deployment strategies** for a fleet or regional waterborne network.

Characteristics and Objectives

- Model the current eco-system, used as benchmark
- Identify region-specific possibilities to meet emission targets (for fleet and energy)
- Create and discuss alternative solutions
- Elaborate and play transition pathways scenarios
- Evaluate and identify challenges and needs for harbour infrastructure, energy, operations and fleet
- Organise workshops to elaborate regional strategy with all stakeholders

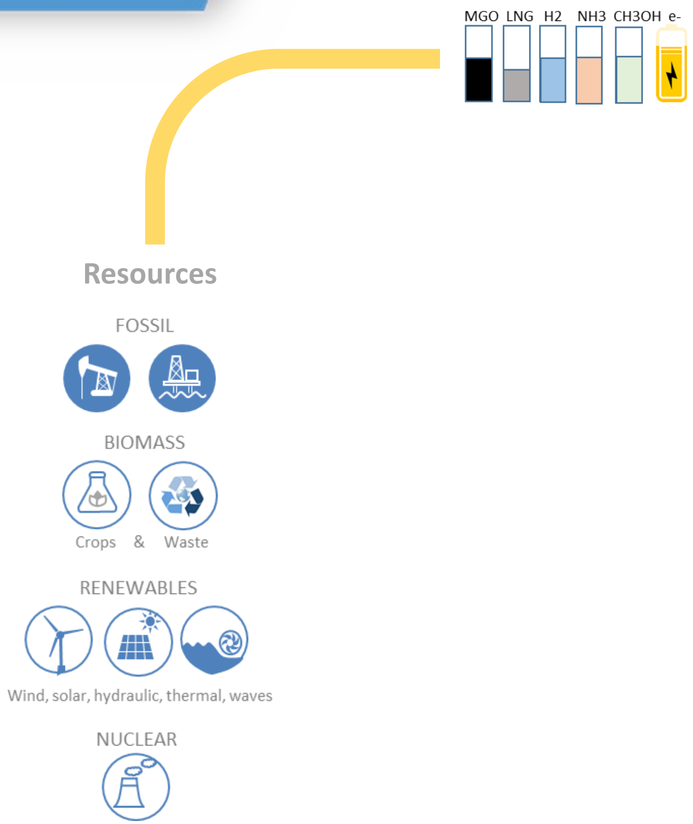
A regional waterborne ecosystem consists of 3 main actors

- **Energy**

  production, storage and supply
- **Infrastructure**

  harbours, waterways, bunker or charging locations
- **Ships**

  operational profile, transport capacity, power systems



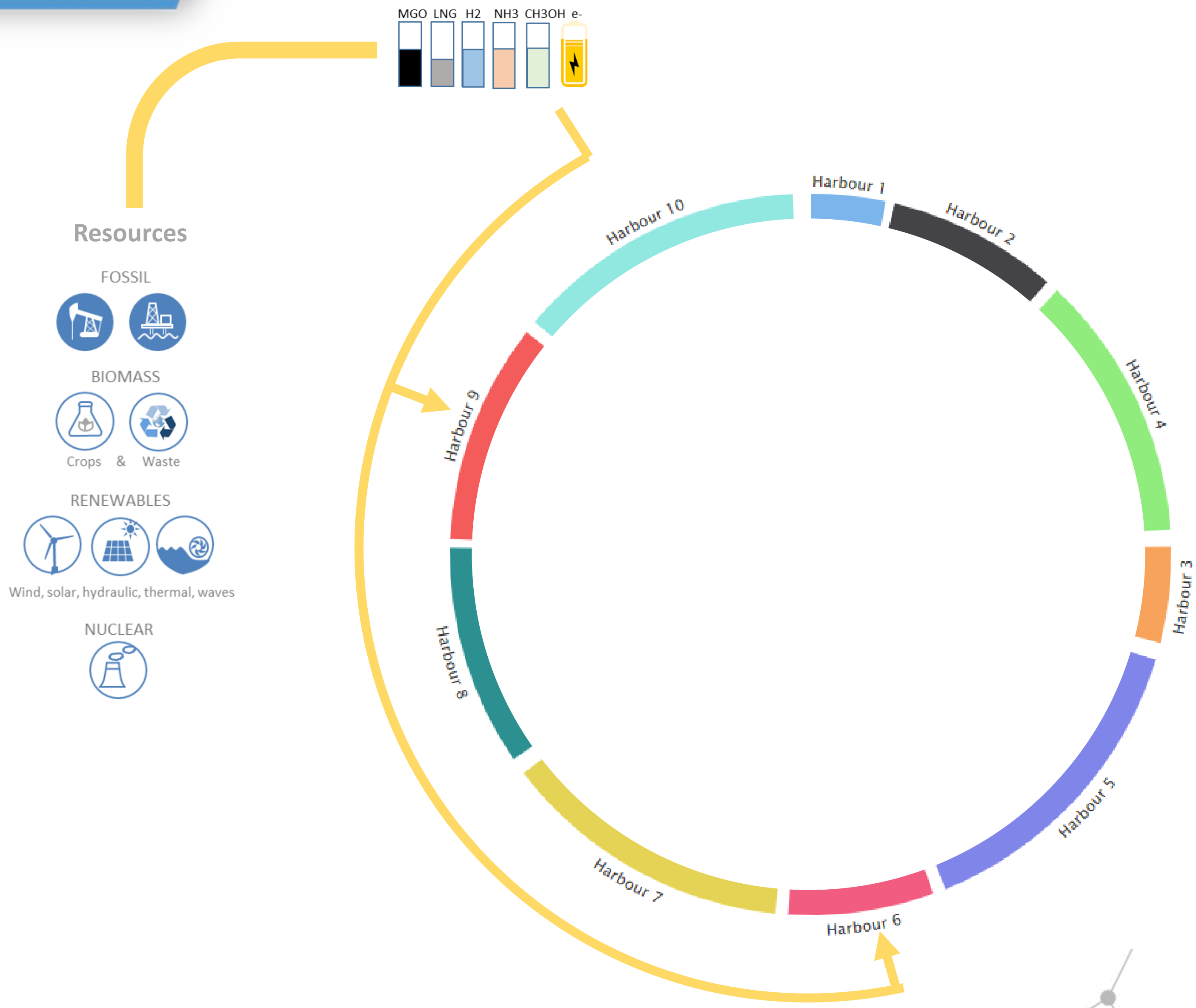
Energy carriers

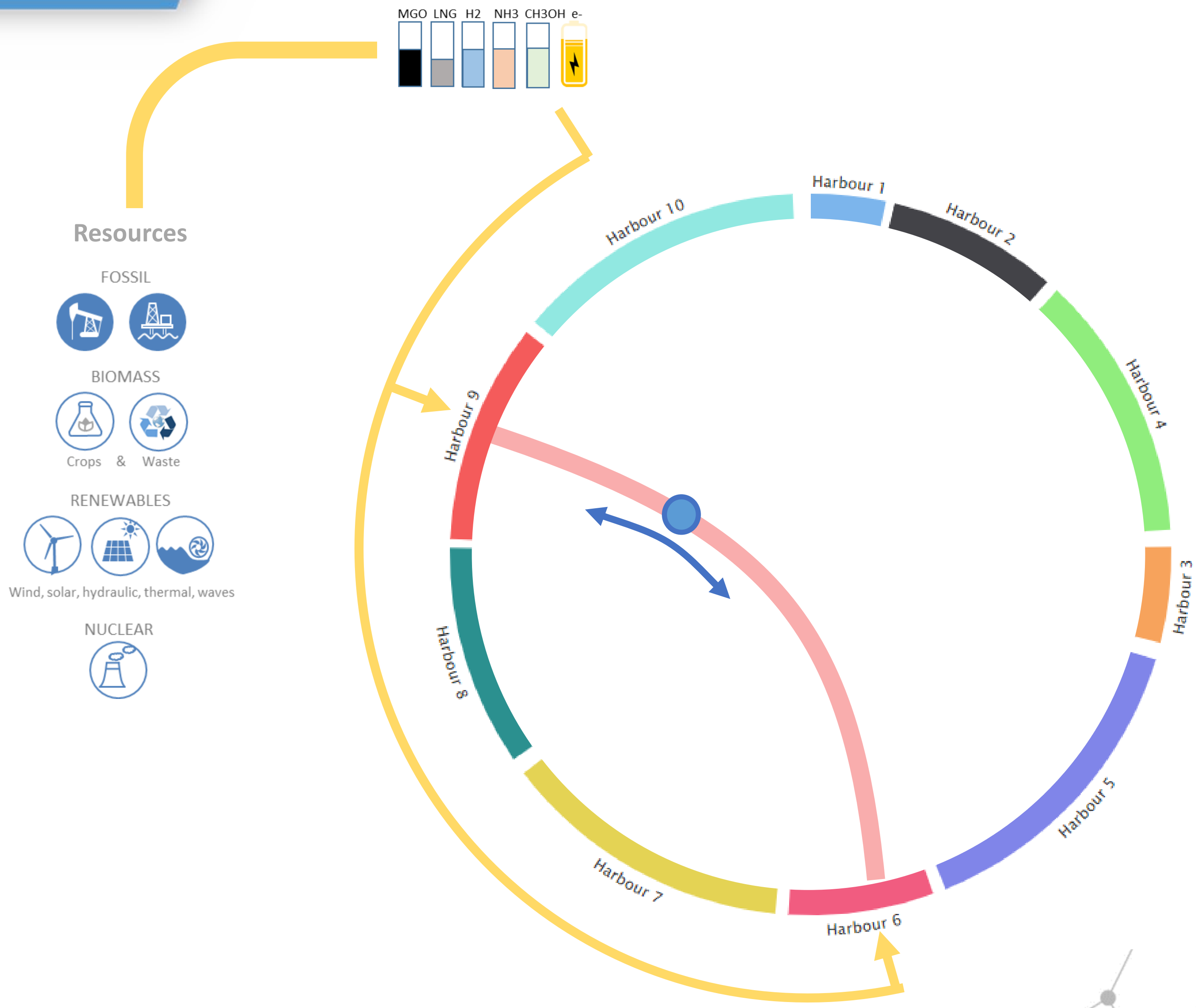
- Properties
- Production emissions
- Distribution
- Price development

MARIN
BETTER SHIPS, BLUE OCEANS

Harbour infrastructure

- Storage
- Supply





Waterborne transport activities

- Routes
- Ship characteristics
- Transport capacity
- Operational profile
- Available power systems
- Operational emissions
- OPEX

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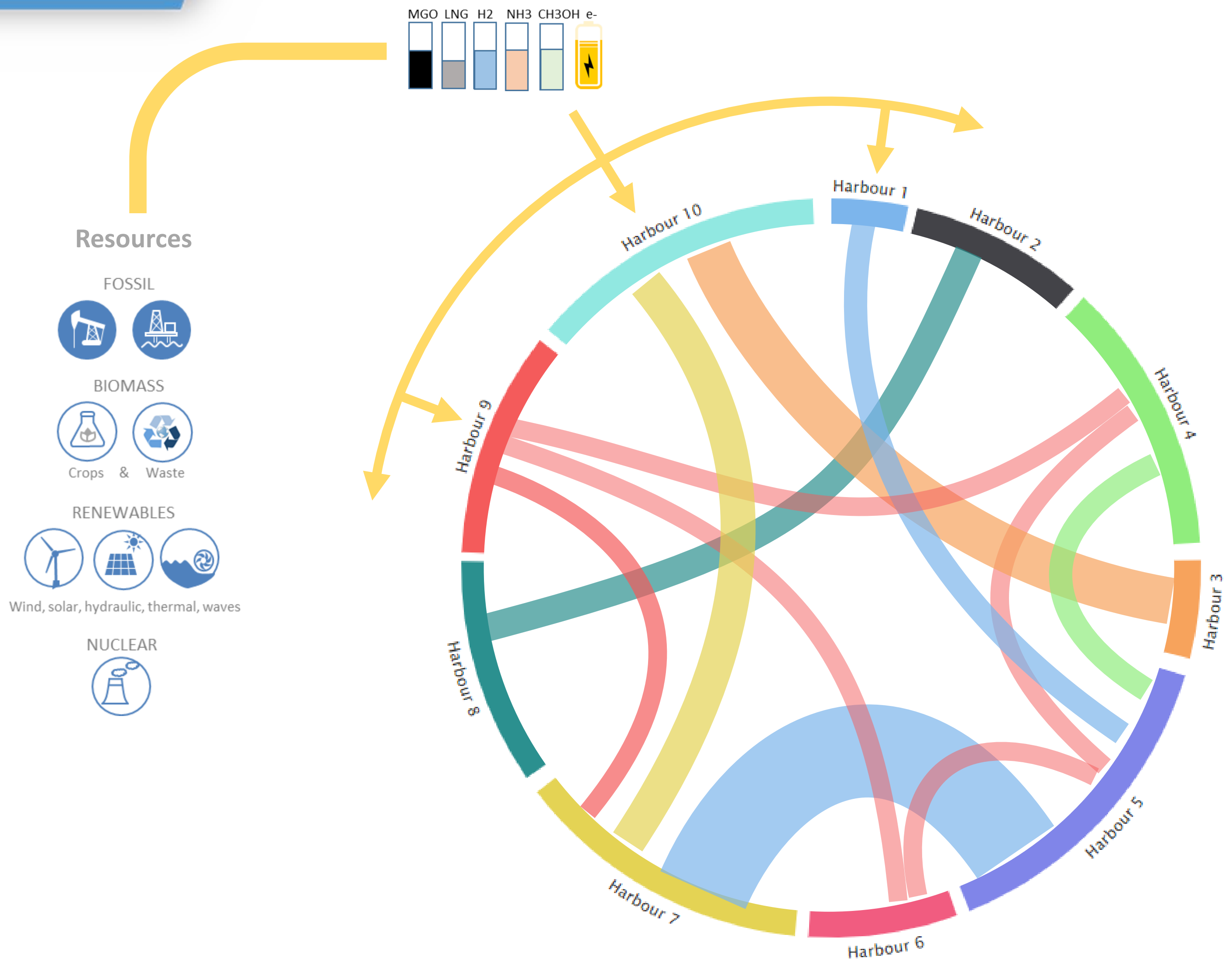
BETTER SHIPS, BLUE OCEANS



The model simulates the evolution of the waterborne regional network over time:

- **Free mode:** evolution based on model's economy (development of fuel prices, availability of energy carriers, readiness of power systems, …).
- **Forced mode:** imposed deployment of alternative technologies.

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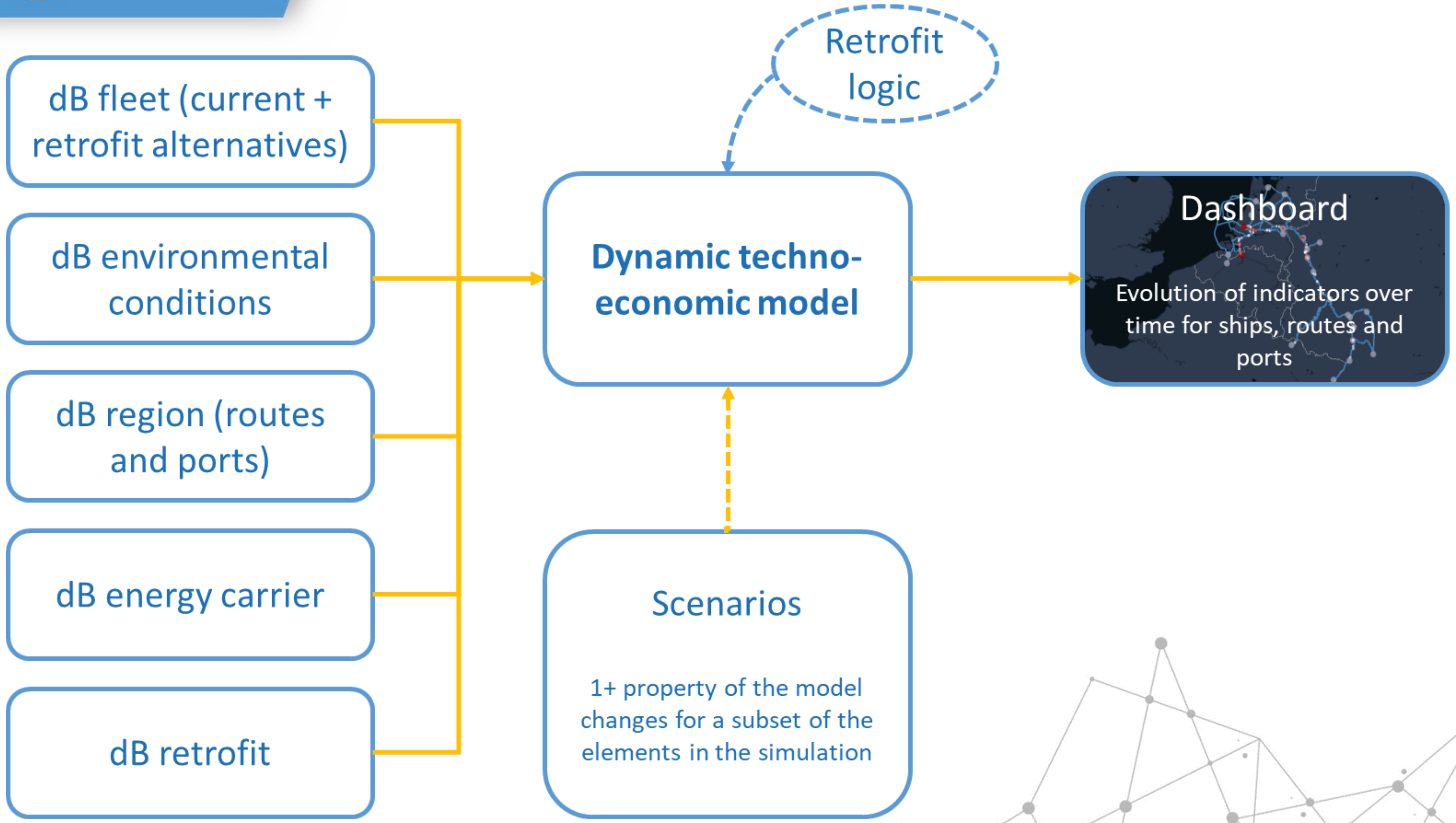
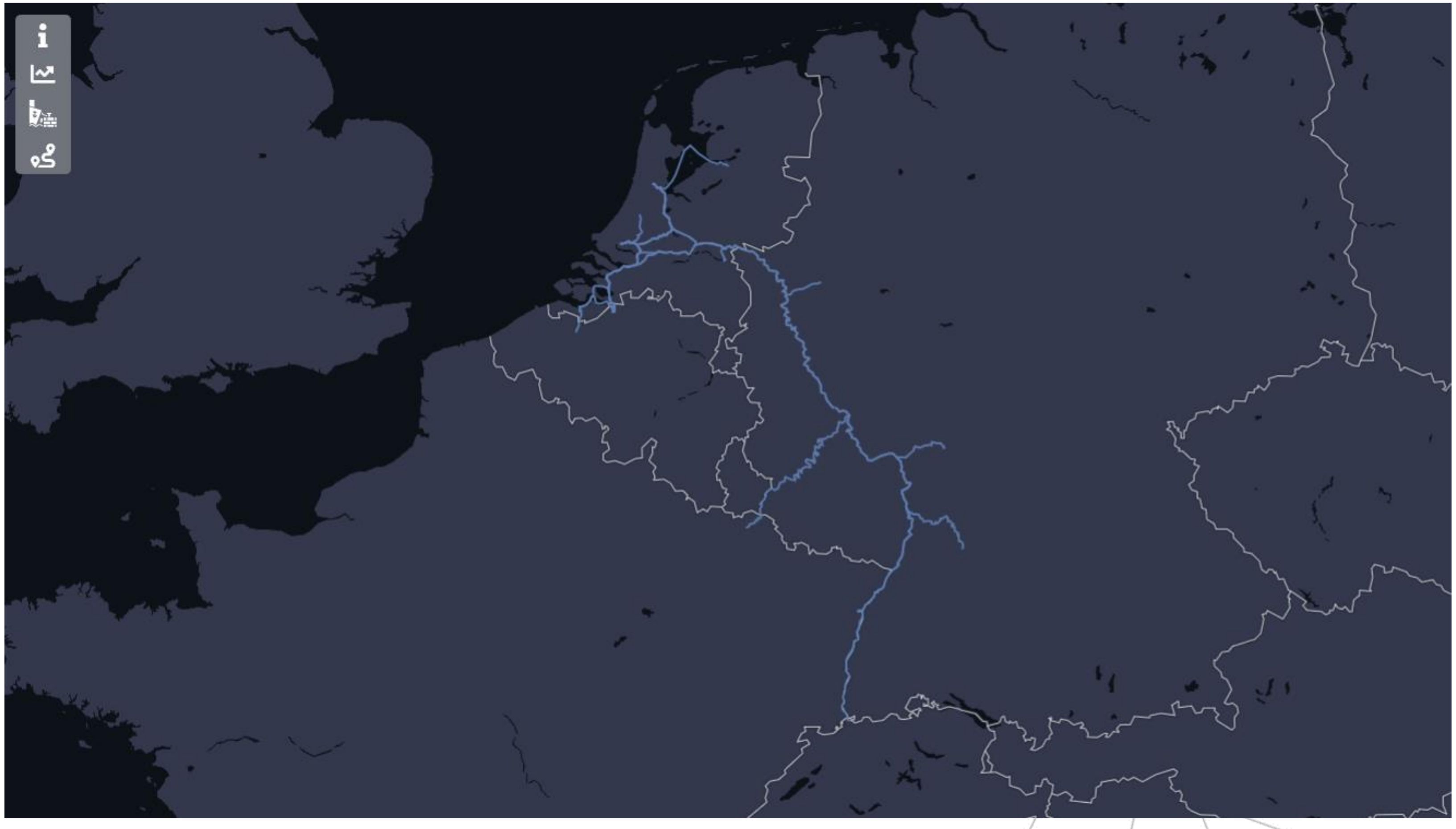
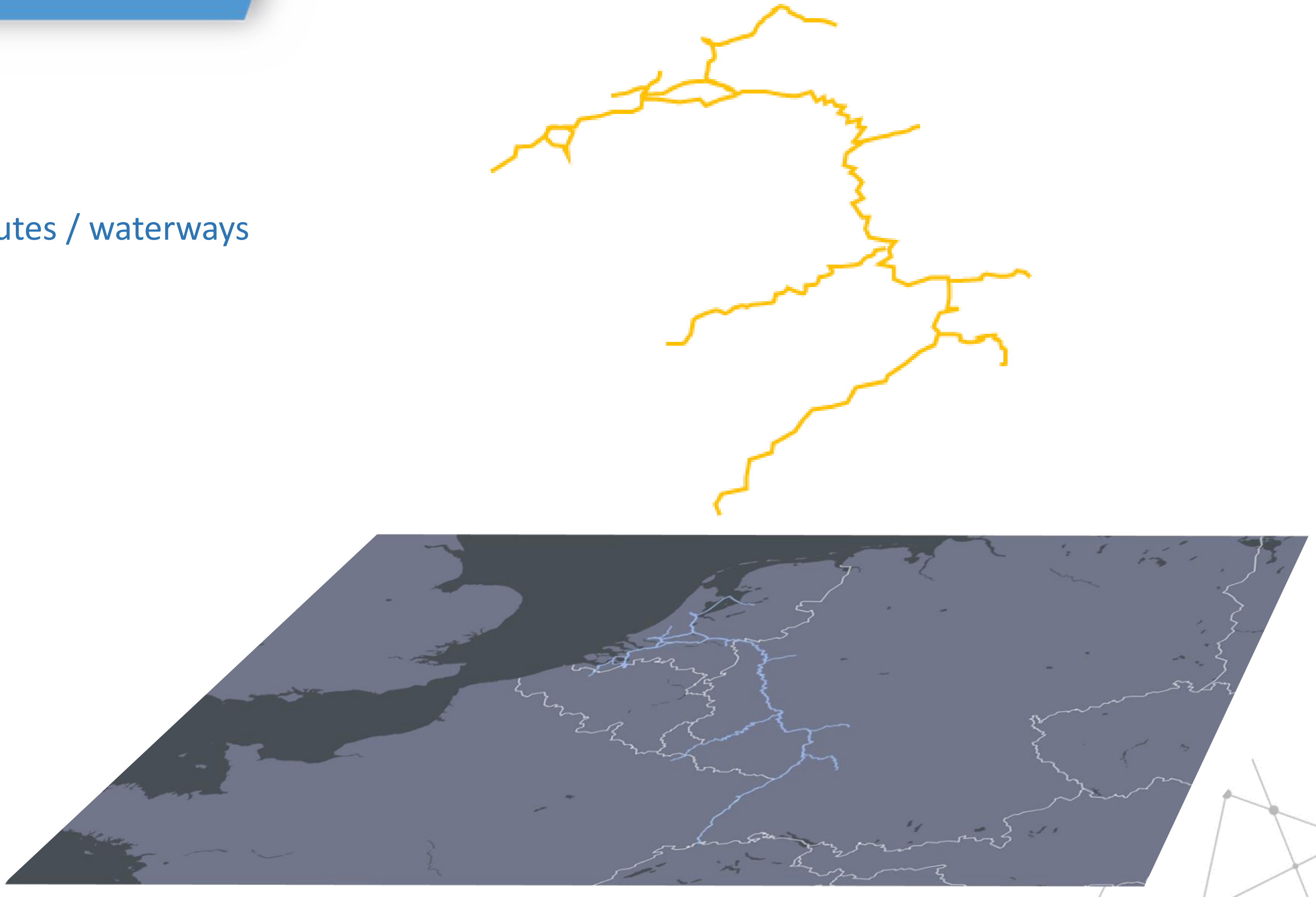
BETTER SHIPS, BLUE OCEANS



Example on the Rhine region

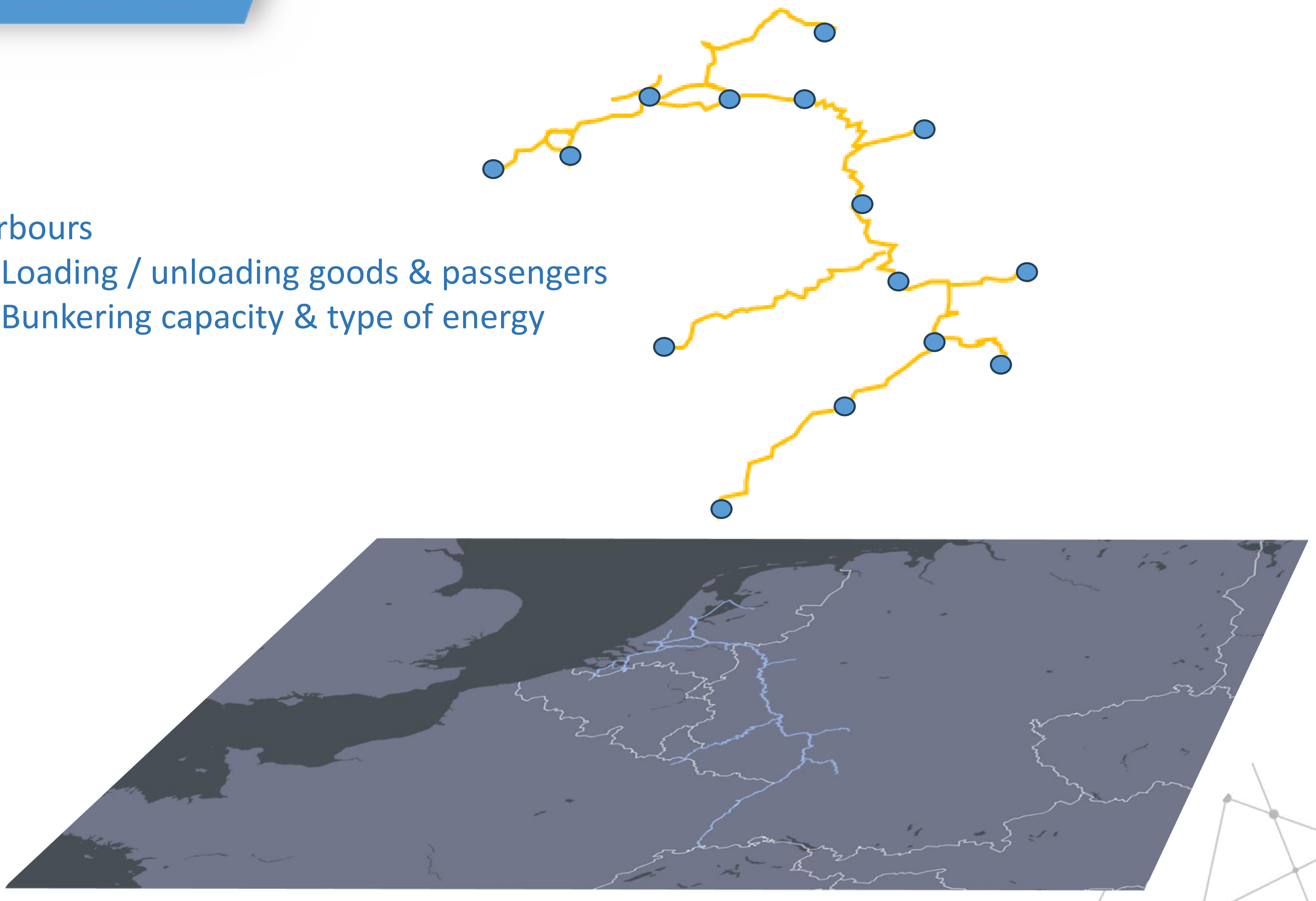


Routes / waterways



Region – waterways - harbours

Harbours
- Loading / unloading goods & passengers
- Bunkering capacity & type of energy



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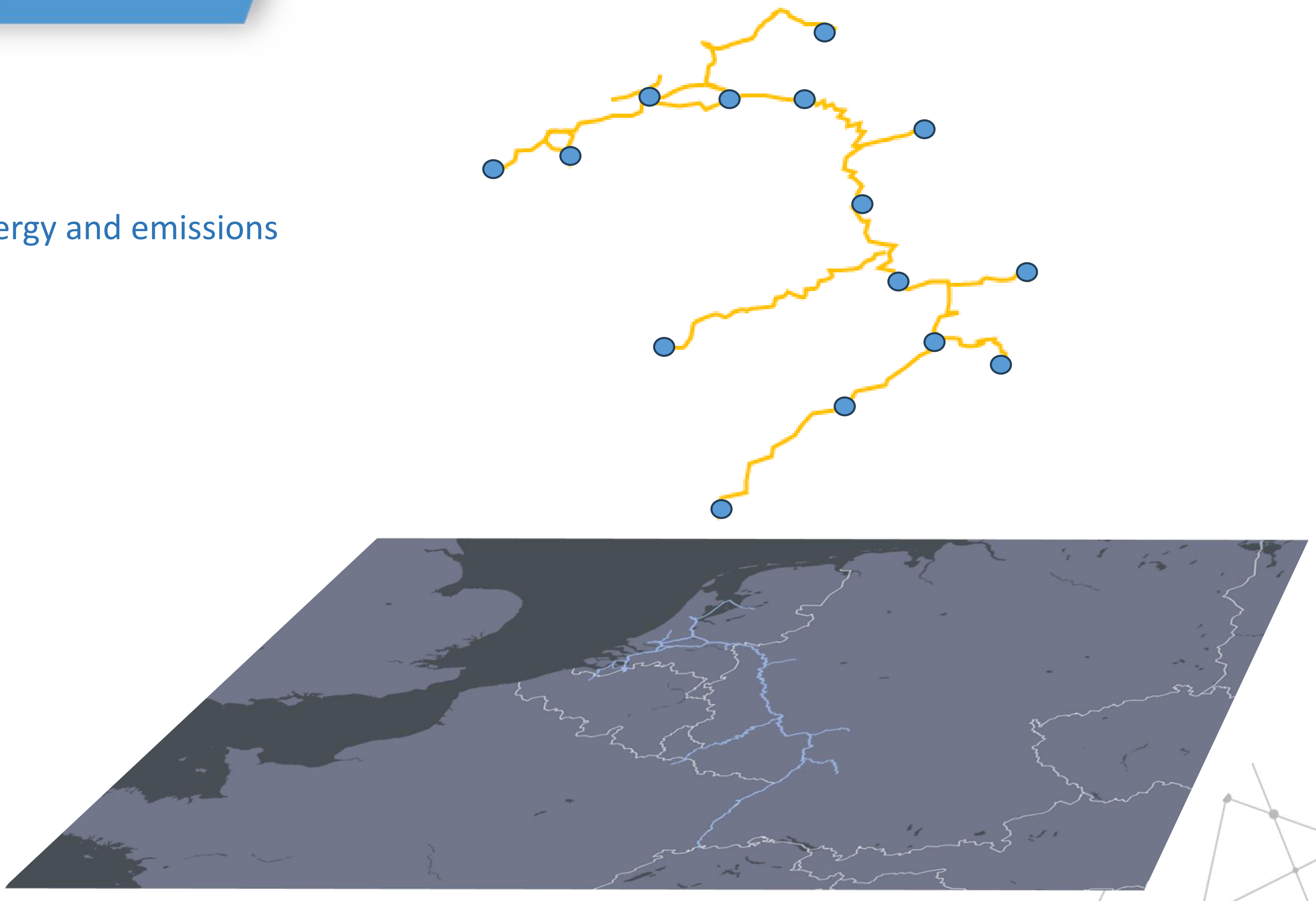
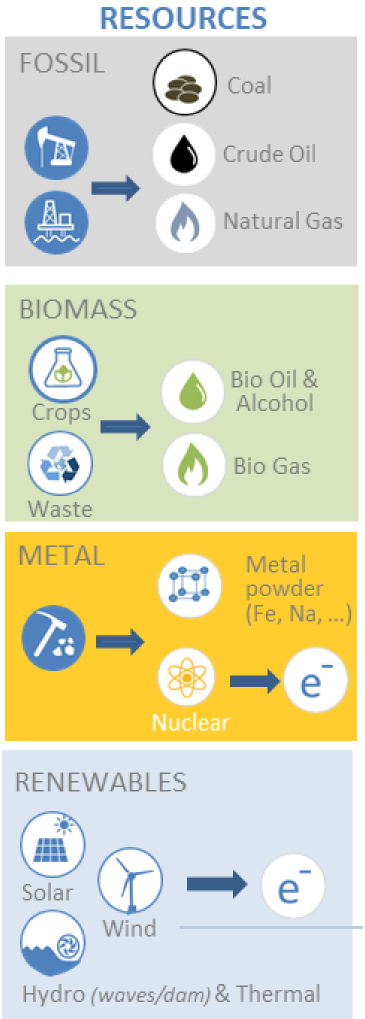
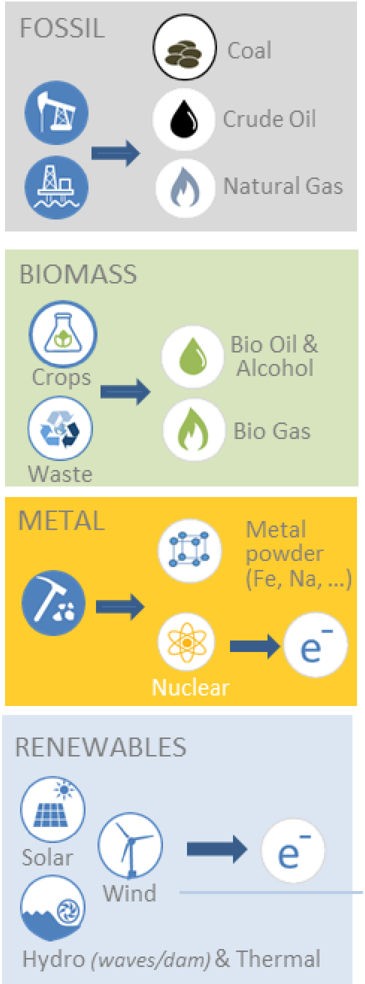
BETTER SHIPS, BLUE OCEANS

Energy and emissions

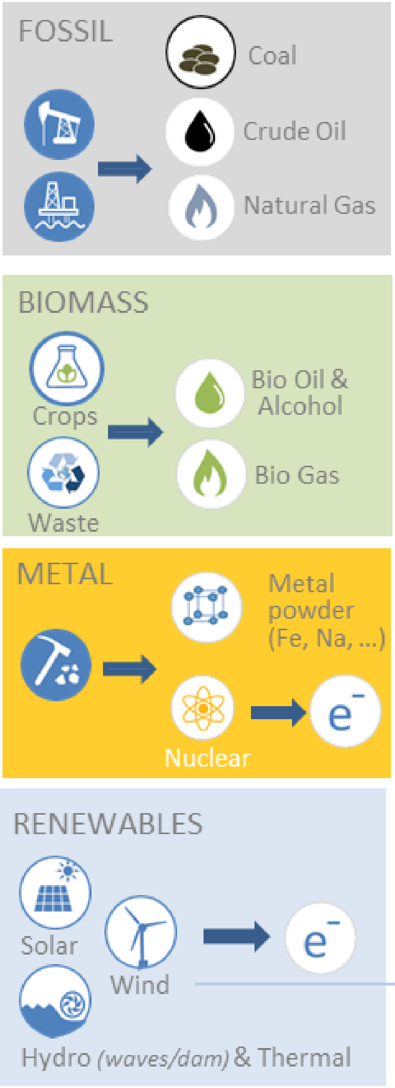




RESOURCES


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

RESOURCES


FOSSIL
Coal
Crude Oil
Natural Gas
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Crops
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Metal powder (Fe, Na, ...)
Nuclear
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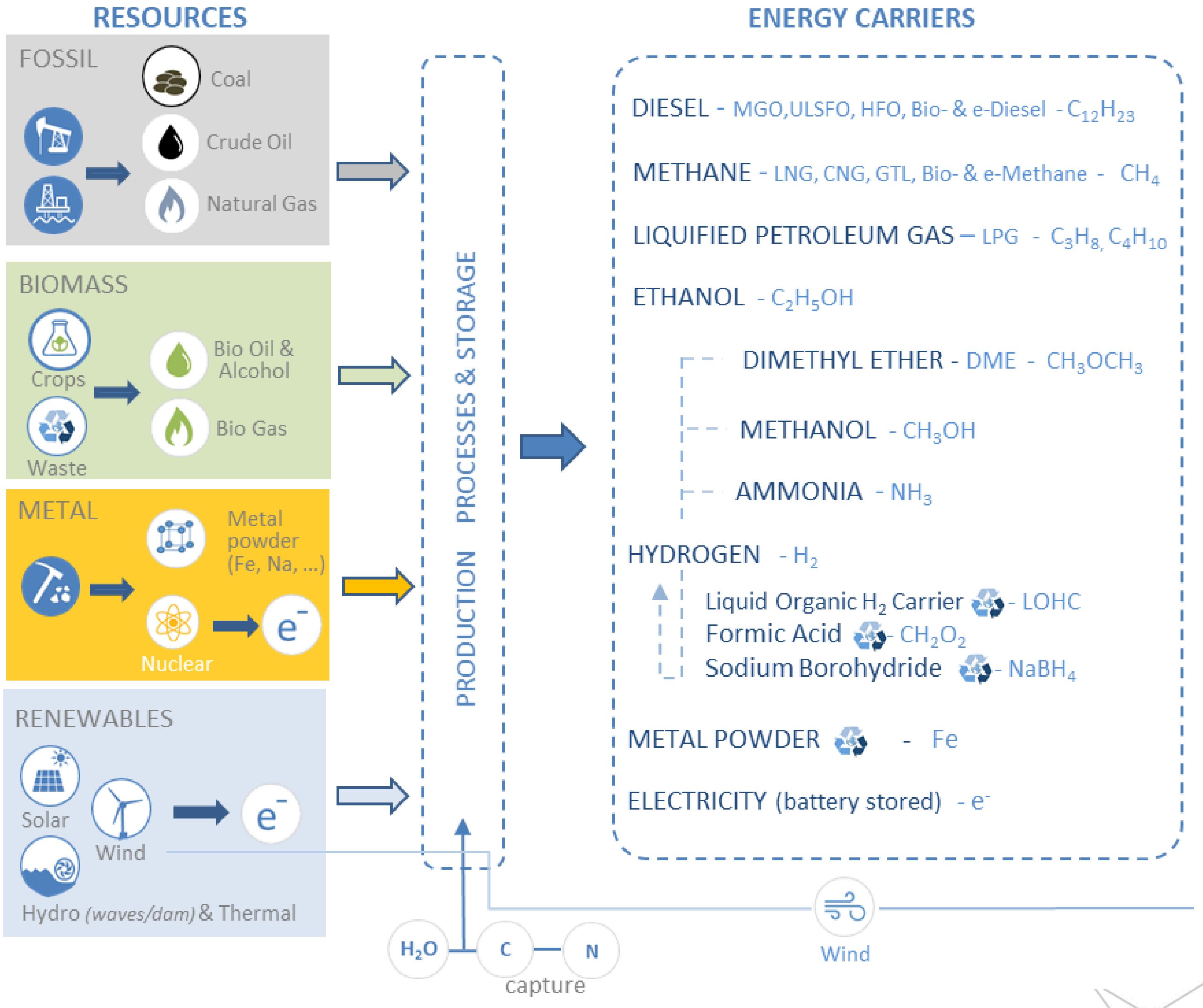
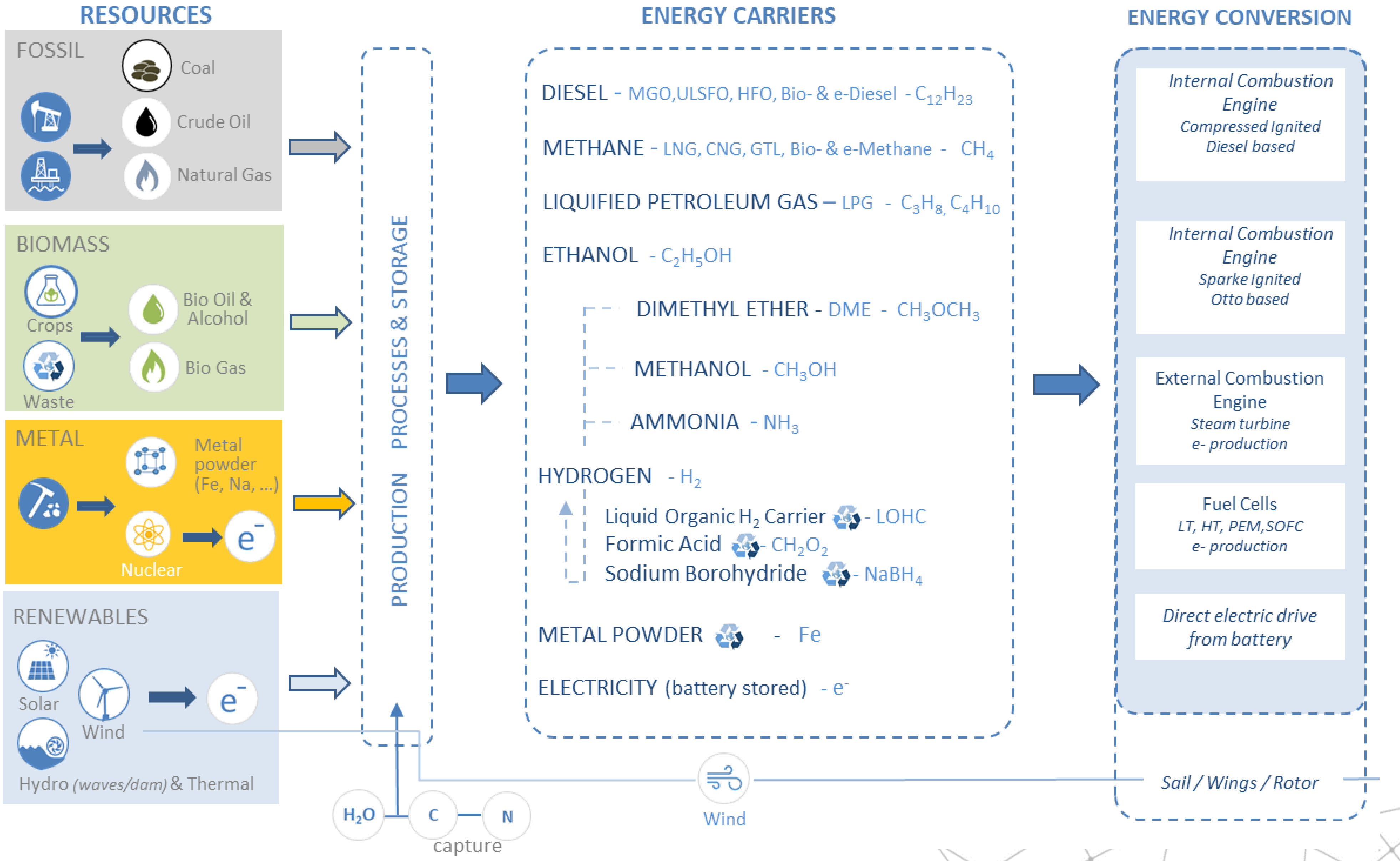
Hydro (waves/dam) & Thermal

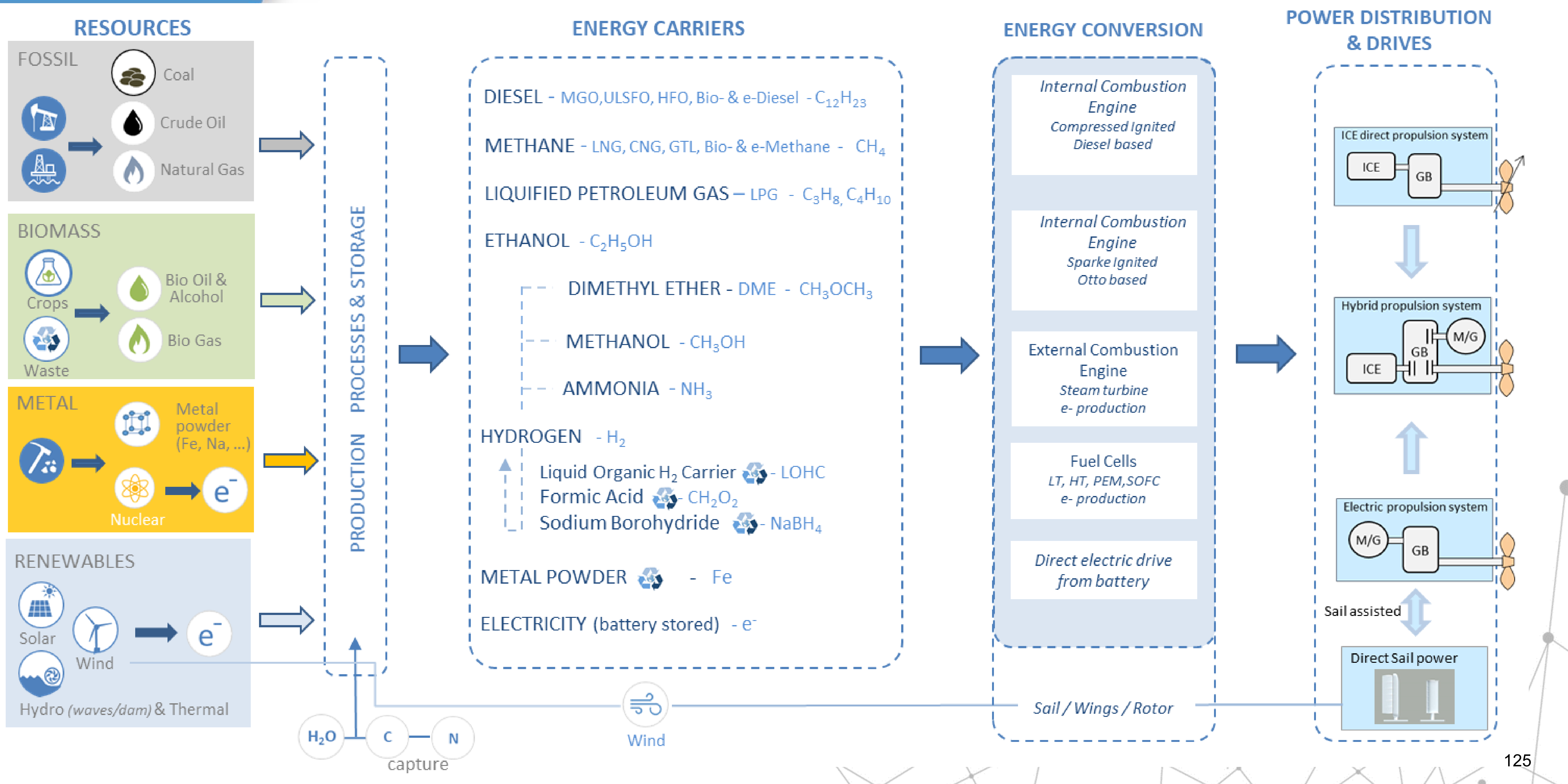

RESOURCES
FOSSIL
Coal
Crude Oil
Natural Gas
BIOMASS
Crops
Waste
Bio Oil & Alcohol
Bio Gas
METAL
Metal powder (Fe, Na, ...)
Nuclear
e^-
RENEWABLES
Solar
Wind
e^-
Hydro *(waves/dam)* & Thermal
PRODUCTION PROCESSES & STORAGE
ENERGY CARRIERS
DIESEL - MGO,ULSFO, HFO, Bio- & e-Diesel - $C_{12}H_{23}$
METHANE - 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^-
H_2O
C
N
capture
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
e-
Hydro (waves/dam) & Thermal
PRODUCTION PROCESSES & STORAGE
H2O
C
N
capture
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
HYDROGEN - H2
Liquid Organic H2 Carrier - LOHC
Formic Acid - CH2O2
Sodium Borohydride - NaBH4
METAL POWDER - Fe
ELECTRICITY (battery stored) - e-
Wind
ENERGY CONVERSION
Internal Combustion Engine
Compressed Ignited
Diesel based
Internal Combustion Engine
Sparke Ignited
Otto based
External Combustion Engine
Steam turbine
e- production
Fuel Cells
LT, HT, PEM,SOFC
e- production
Direct electric drive from battery
Sail / Wings / Rotor

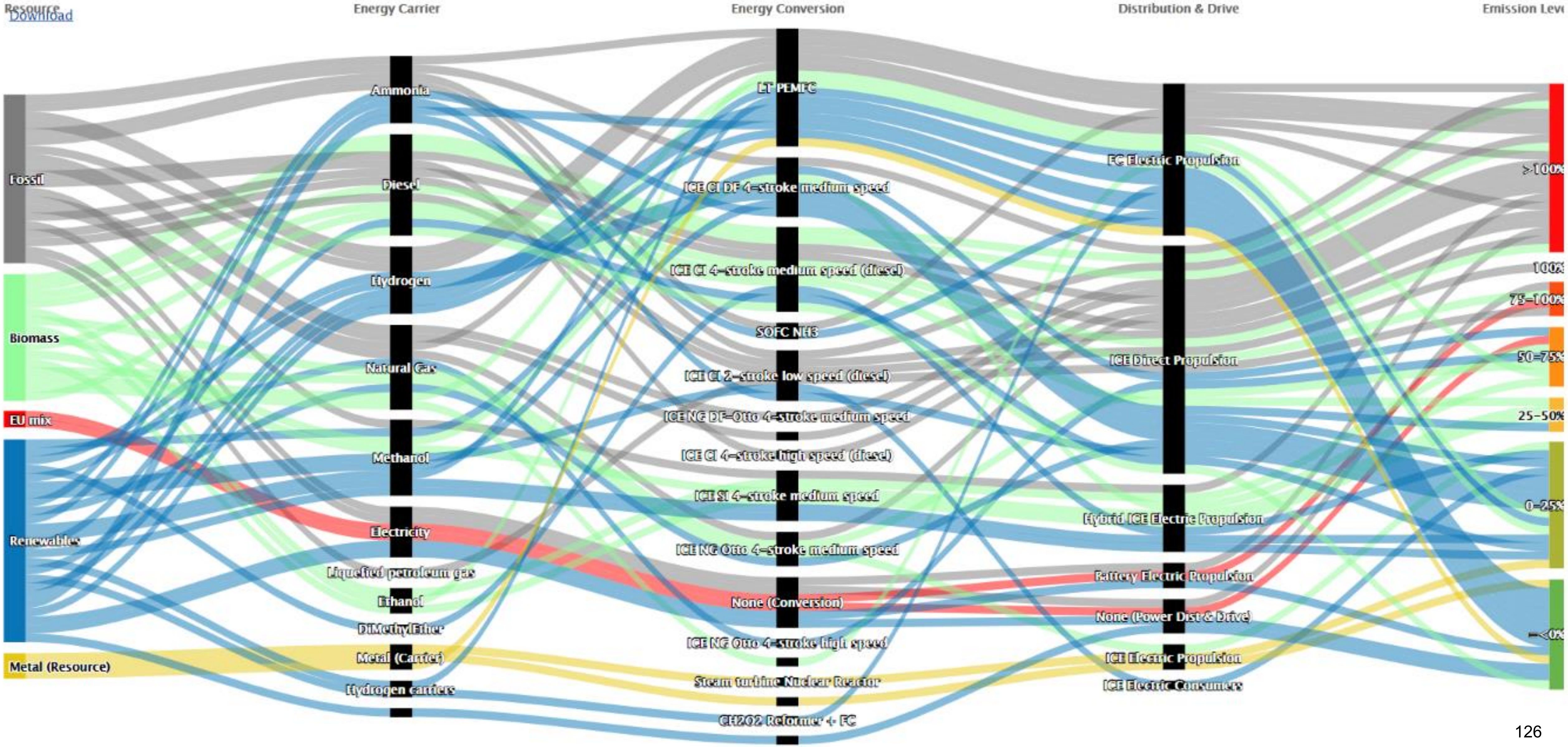
Needs

Region – waterways – harbours – energy

MARIN
BETTER SHIPS, BLUE OCEANS



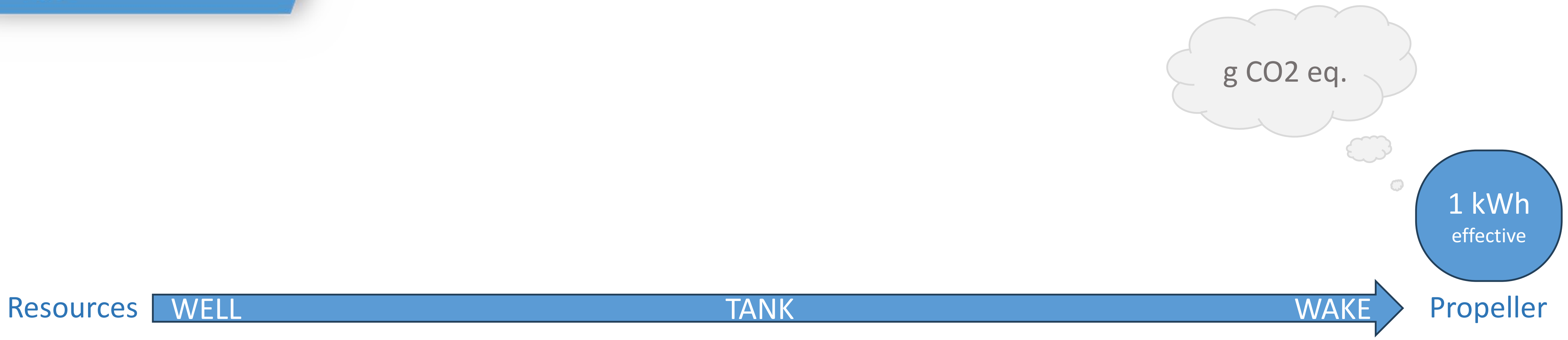
Download

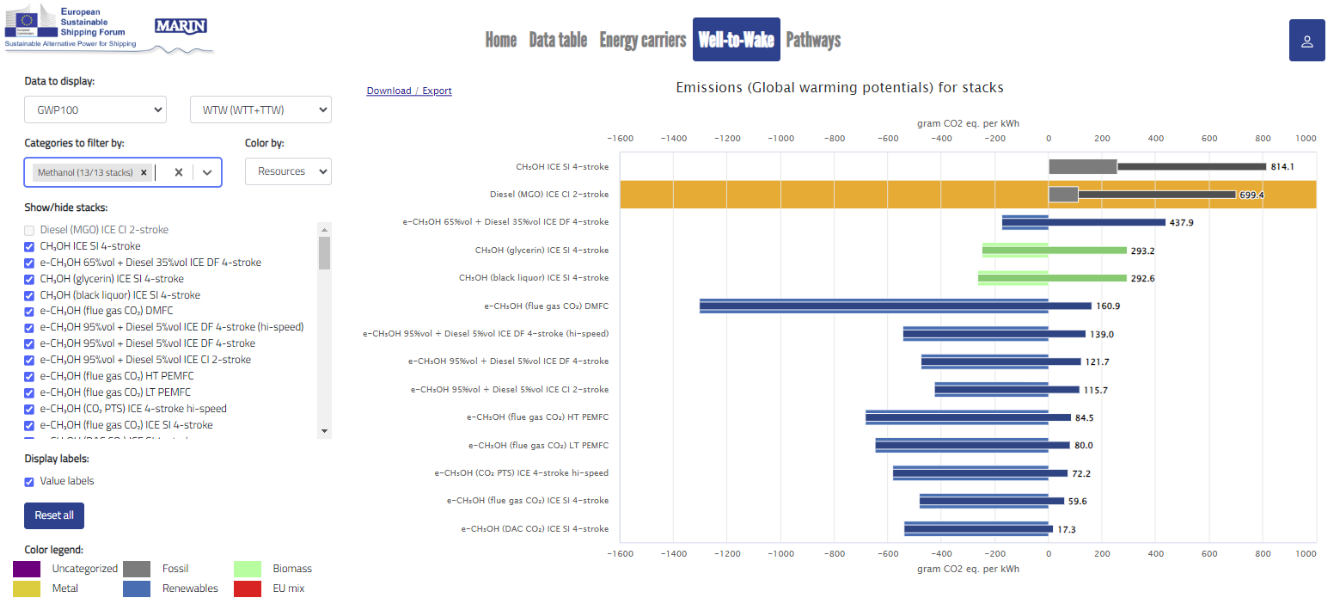

Resource
Energy Carrier
Energy Conversion
Distribution & Drive
Emission Leve
Fossil
Biomass
EU mix
Renewables
Metal (Resource)
Ammonia
Diesel
Hydrogen
Natural Gas
Methanol
Electricity
Liquefied petroleum gas
Ethanol
DiMethylEther
Metal (Carrier)
Hydrogen carriers
LT PEMFC
ICE CI DF 4-stroke medium speed
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%

Region – waterways – harbours – energy – emissions

MARIN
BETTER SHIPS, BLUE OCEANS

GWP100 or GWP20 (Global Warming Potential)

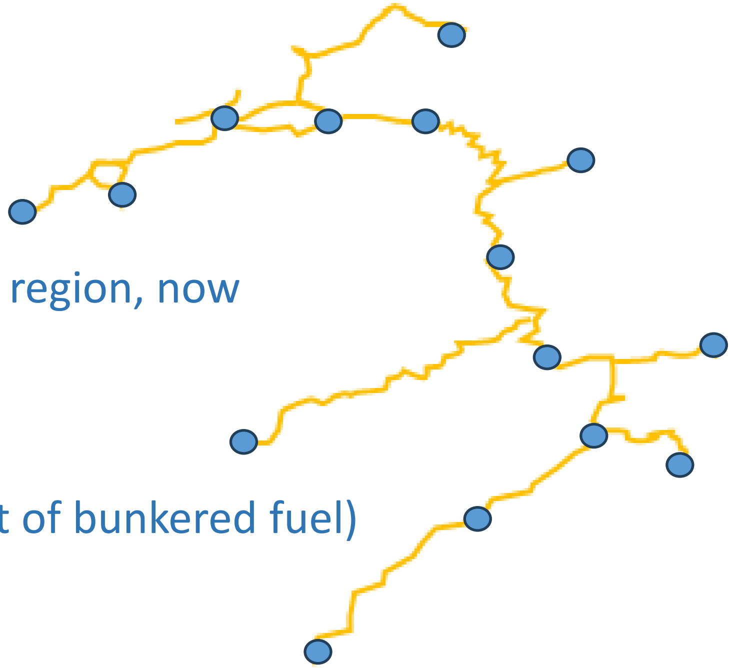


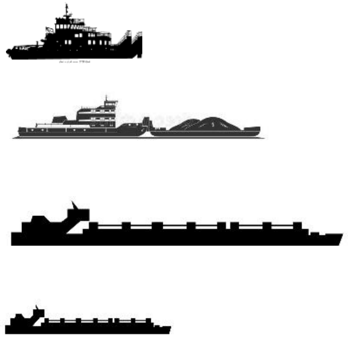


https://sustainablepower.application.marin.nl/

Needs

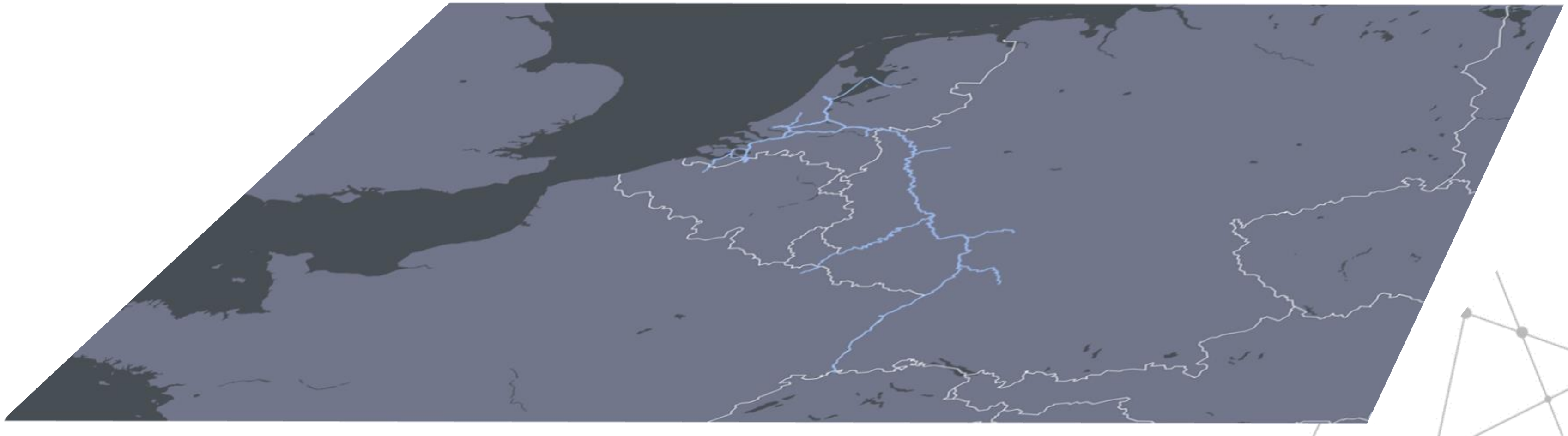
Region – waterways – harbours – energy – emissions - ships

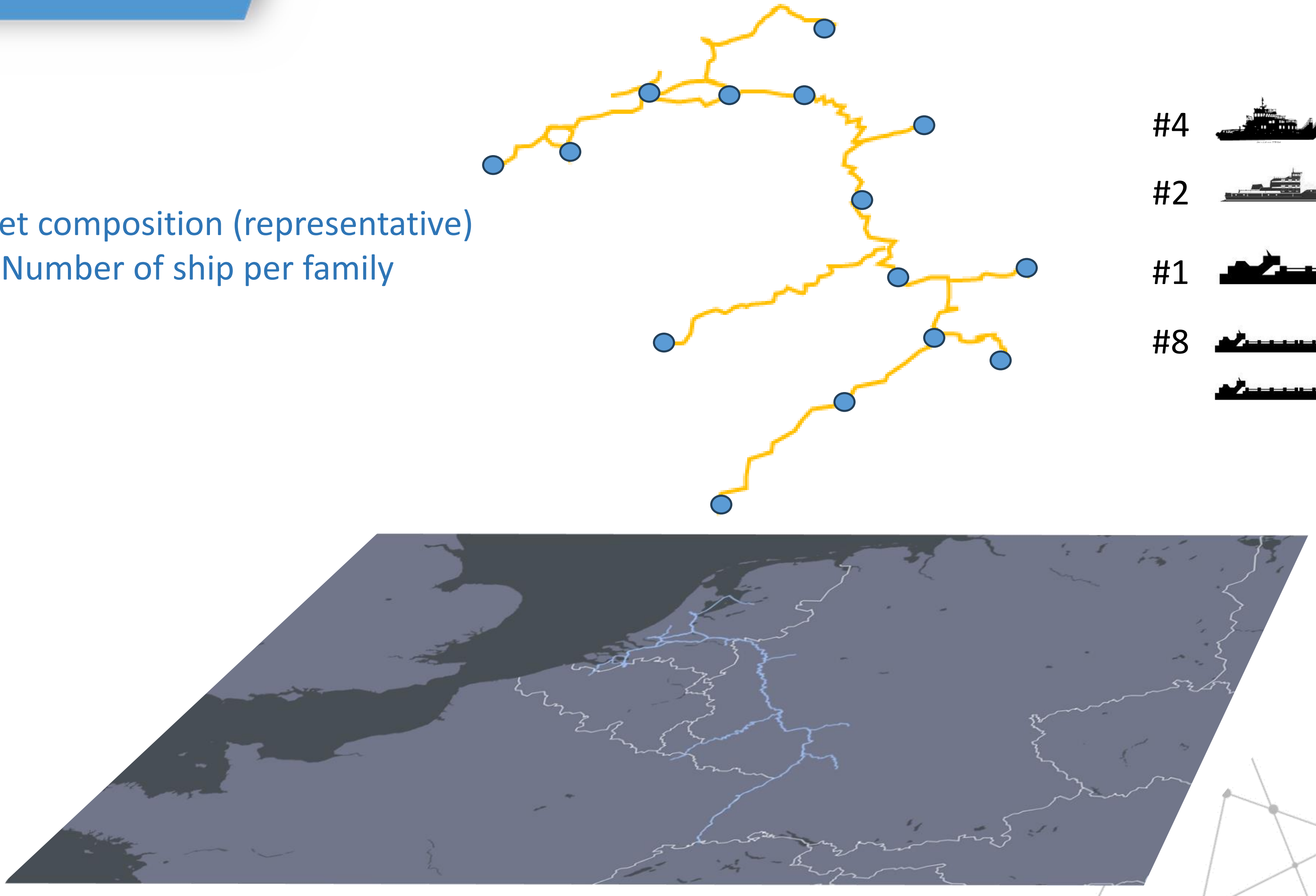




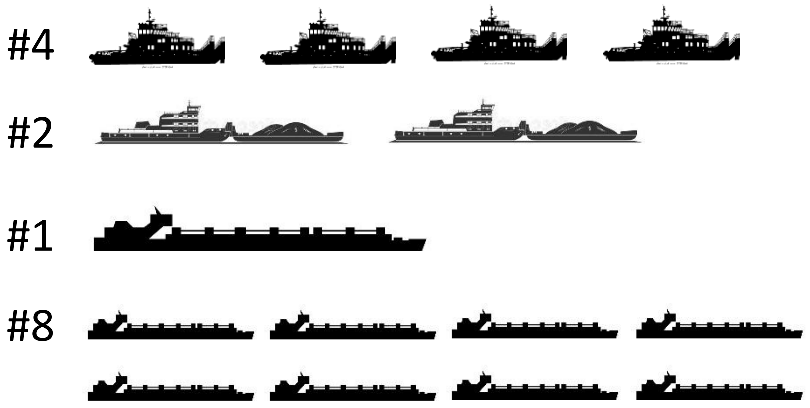
Families of ship types sailing in the region, now

- Characteritics
- Power performance
- Engine & power systems
- Endurance (autonomy / amount of bunkered fuel)
- Cargo capacity



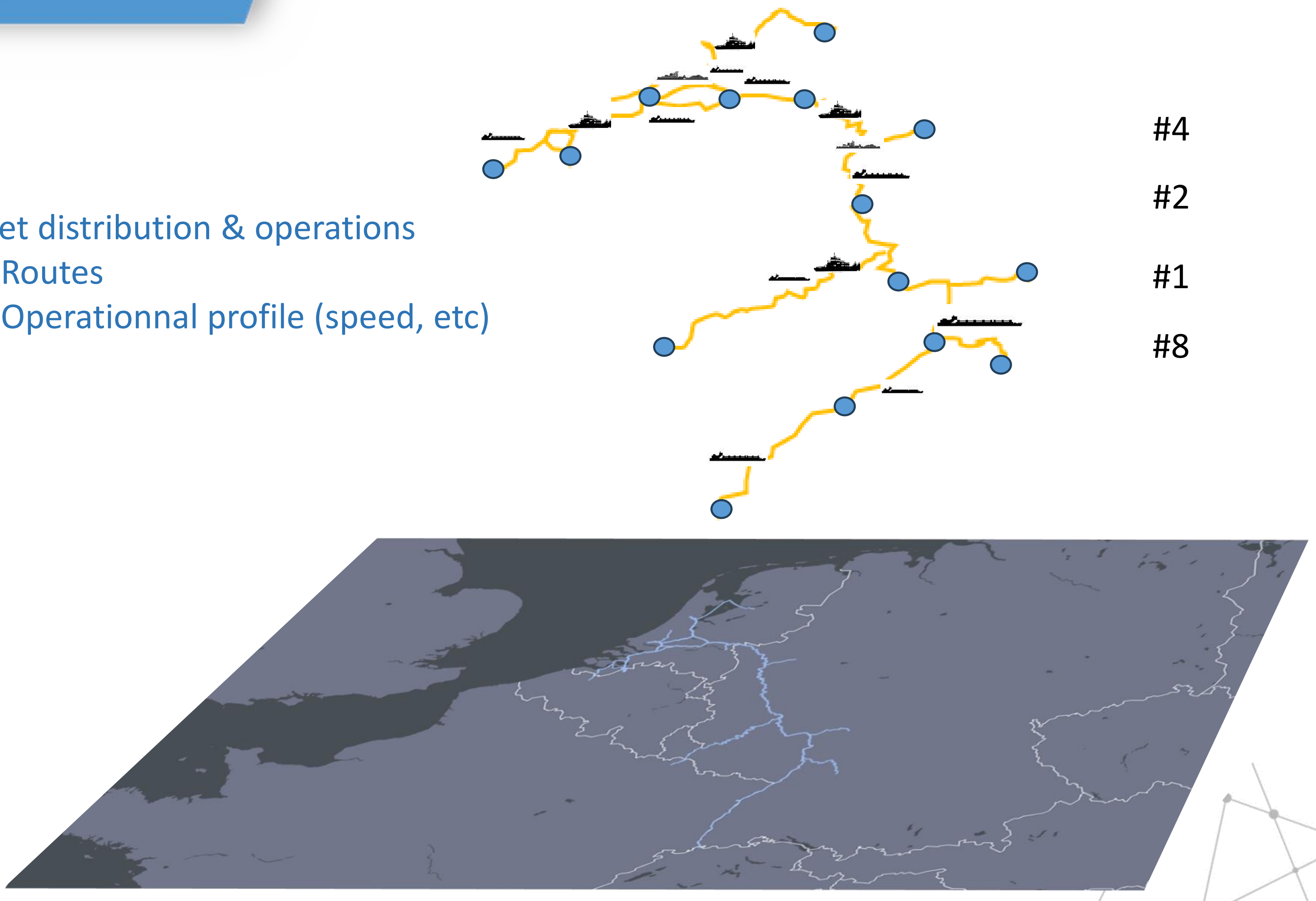


Fleet composition (representative)
- Number of ship per family



Fleet distribution & operations

- Routes
- Operationnal profile (speed, etc)



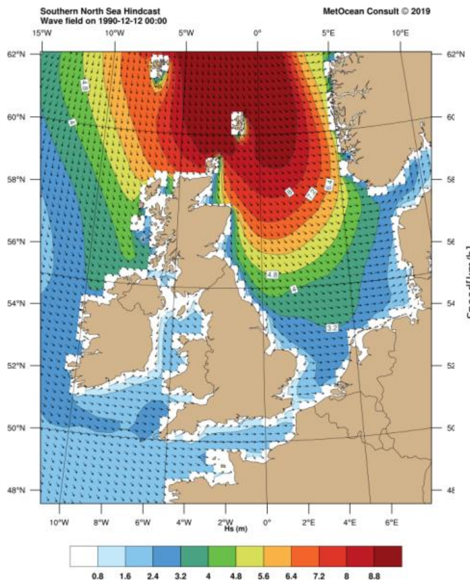
Vessel types and transport journeys

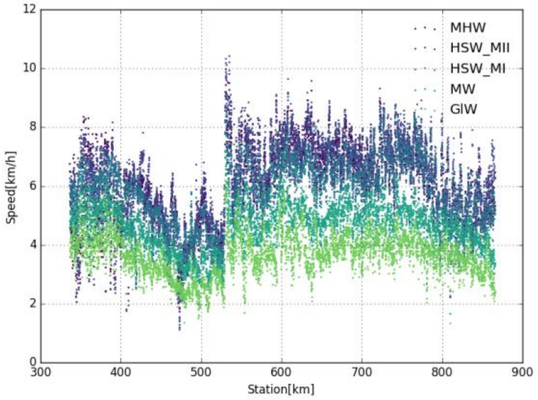
21.9 billion tkm covered by top 25 relations Representing approx. 20% of transport performance (tkm) in Rhine countries with main vessel types and commodities.

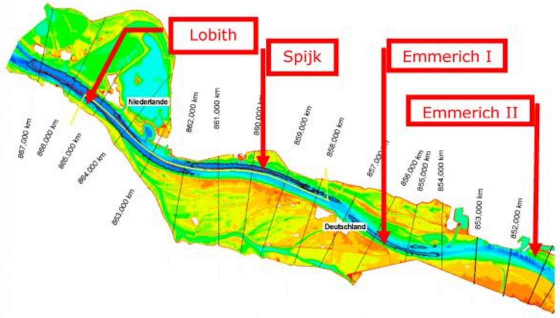
Nr	Port A	Port B	vessel type	Commodity	
1	Rotterdam	Duisburg	Push B4	Ore	9
2	Rotterdam	Antwerp	C3L/B	Containers	40
3	Rotterdam	Karlsruhe	MTS 135m	Crude oil	22
4	Amsterdam	Karlsruhe	C3L/B	Coal	17
5	Rotterdam	Basel	C3L/B	Containers	9
6	Antwerp	Thionville	MVS110m	Coal	16
7	Amsterdam	Antwerp	C3L/B	Containers	9
8	Rotterdam	Krotzenburg	C3L/B	Coal	5
9	Amsterdam	Rotterdam	MTS 135m	Oil	6
10	Antwerp	Mainz	MVS 135m	Containers	7
11	Breisach	Cuijk	MVS 110m	Sand&gravel	12
12	Antwerp	Duisburg	C3L/B	Containers	4
13	Rotterdam	Duisburg	MVS 110m	Containers	15
14	Rotterdam	Ludwigshafen	MTS 86m	Chemicals	16
15	Rotterdam	Kampen/Zwolle	MTS 110m	Oil	4
16	Rotterdam	Strassbourg	MVS110m	Agribulk	4
17	Amsterdam	Heilbronn	MVS 105m	Animal Fodder	4
18	Duisburg	Antwerp	MVS 110m	Metal products	3
19	Rotterdam	Alphen a/d Rijn	MVS 105m	Containers	10
20	Terneuzen	Rotterdam	MTS 110m	Chemicals	3
21	Wesel	Enkhuizen	MVS 67m	Sand&gravel	1
22	Rotterdam	Herne	MVS 86m	Metal (scrap)	2
23	Dusseldorf	Antwerp	MVS 110m	Agribulk	1
24	Antwerp	Gent	MVS 110m	Coal	2
25	Rotterdam	Duisburg	MVS 86m	Agribulk	1

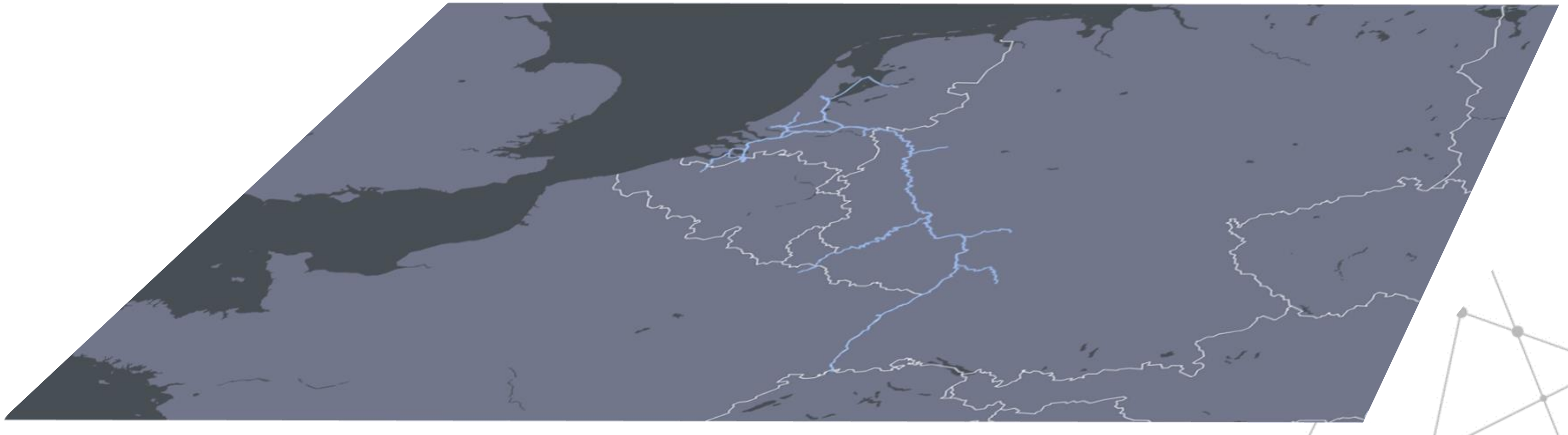
Match regional environmental conditions

- Variation over 30 years (hindcast data)
- Current speed
- Waterdepth
- Wind&Waves

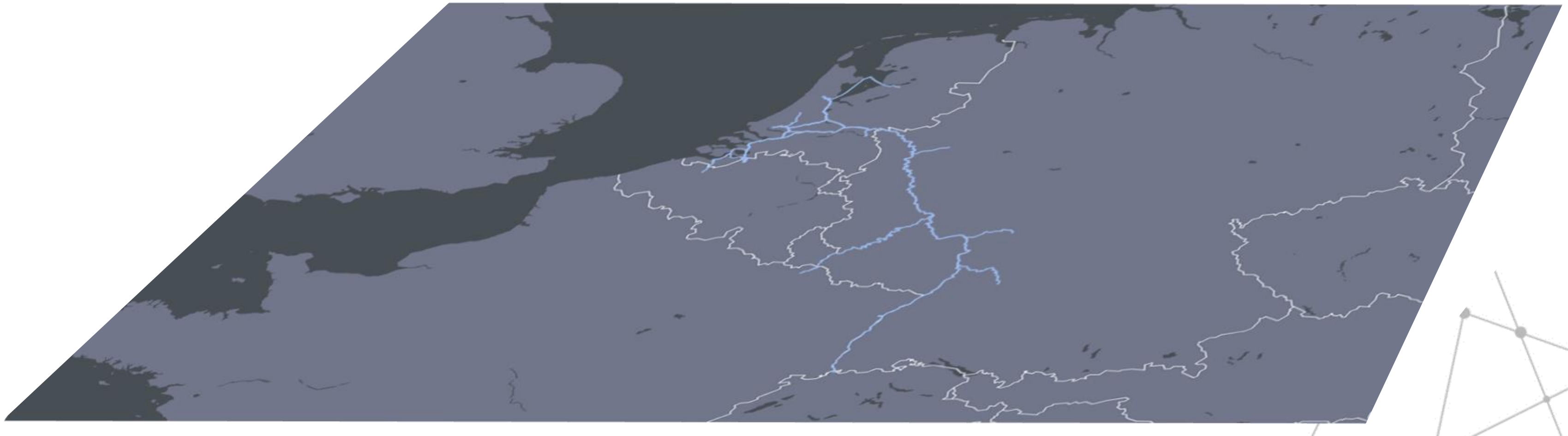








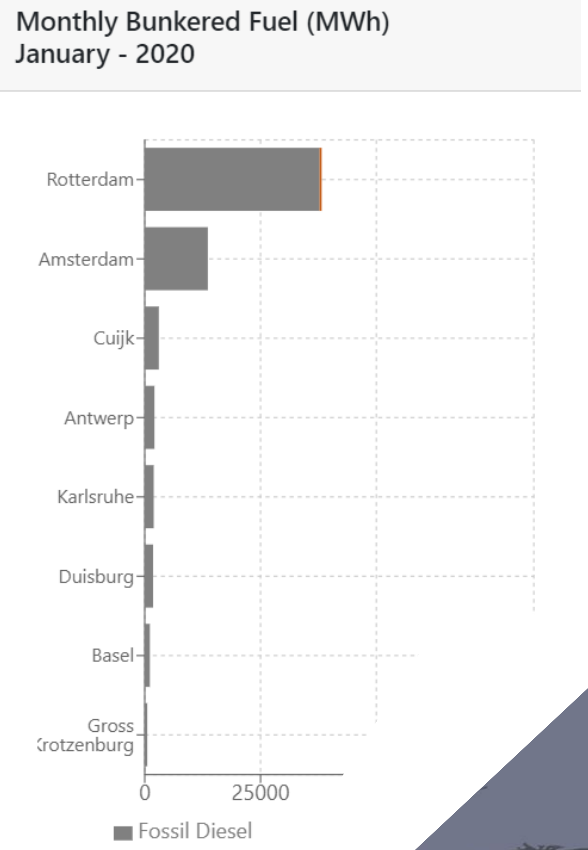
Set-up is ready to run the benchmark case:
current regional operations (business as usual)

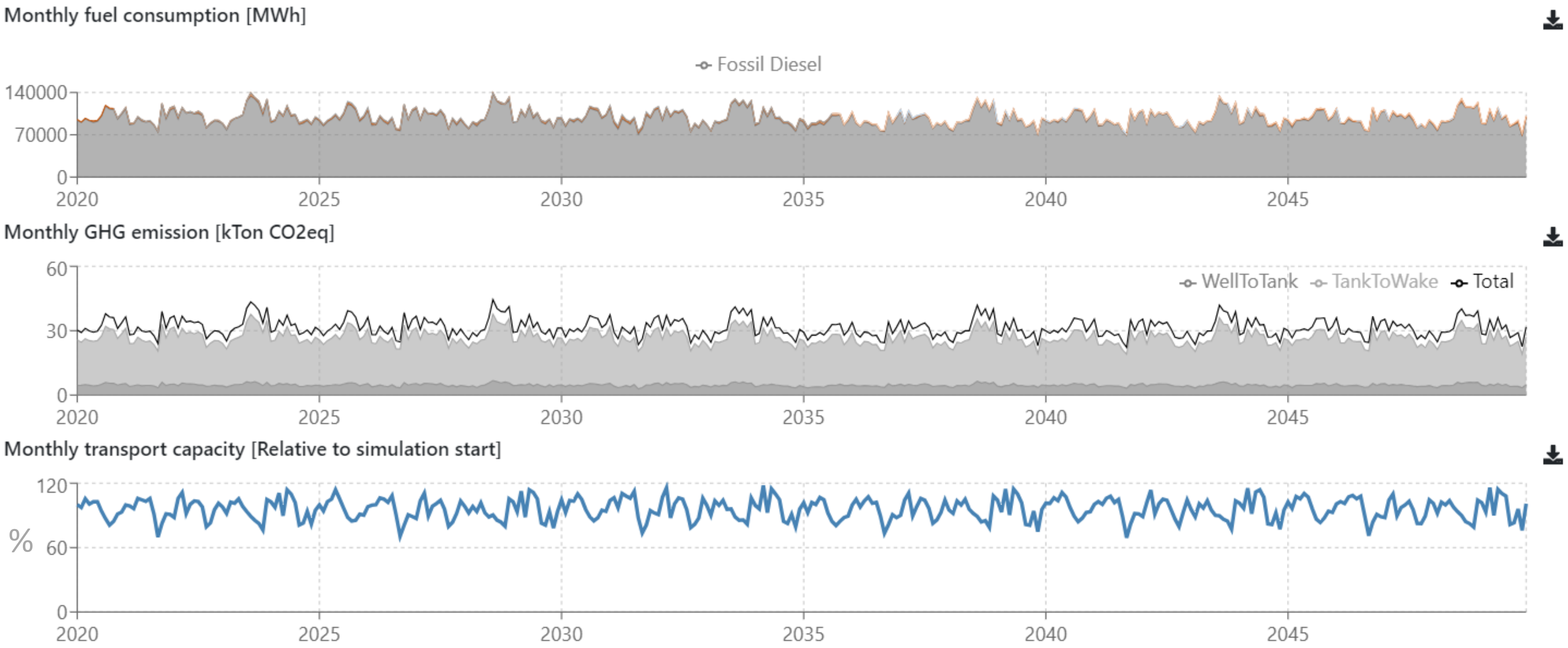


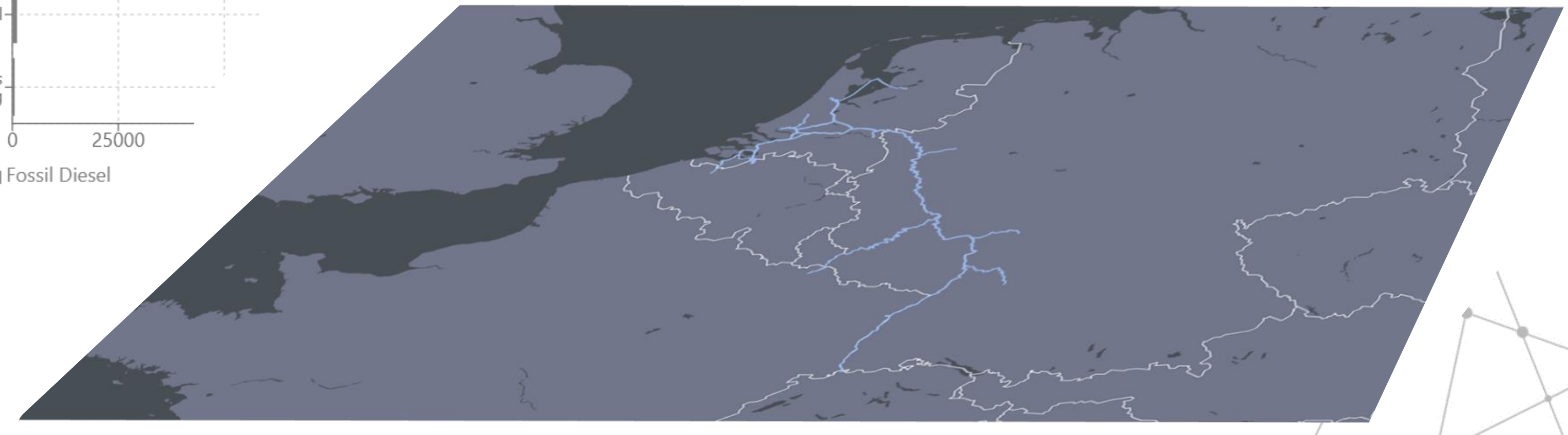
Needs

Region – waterways – harbours – energy – emissions – ships – operations - environment

BETTER SHIPS, BLUE OCEANS



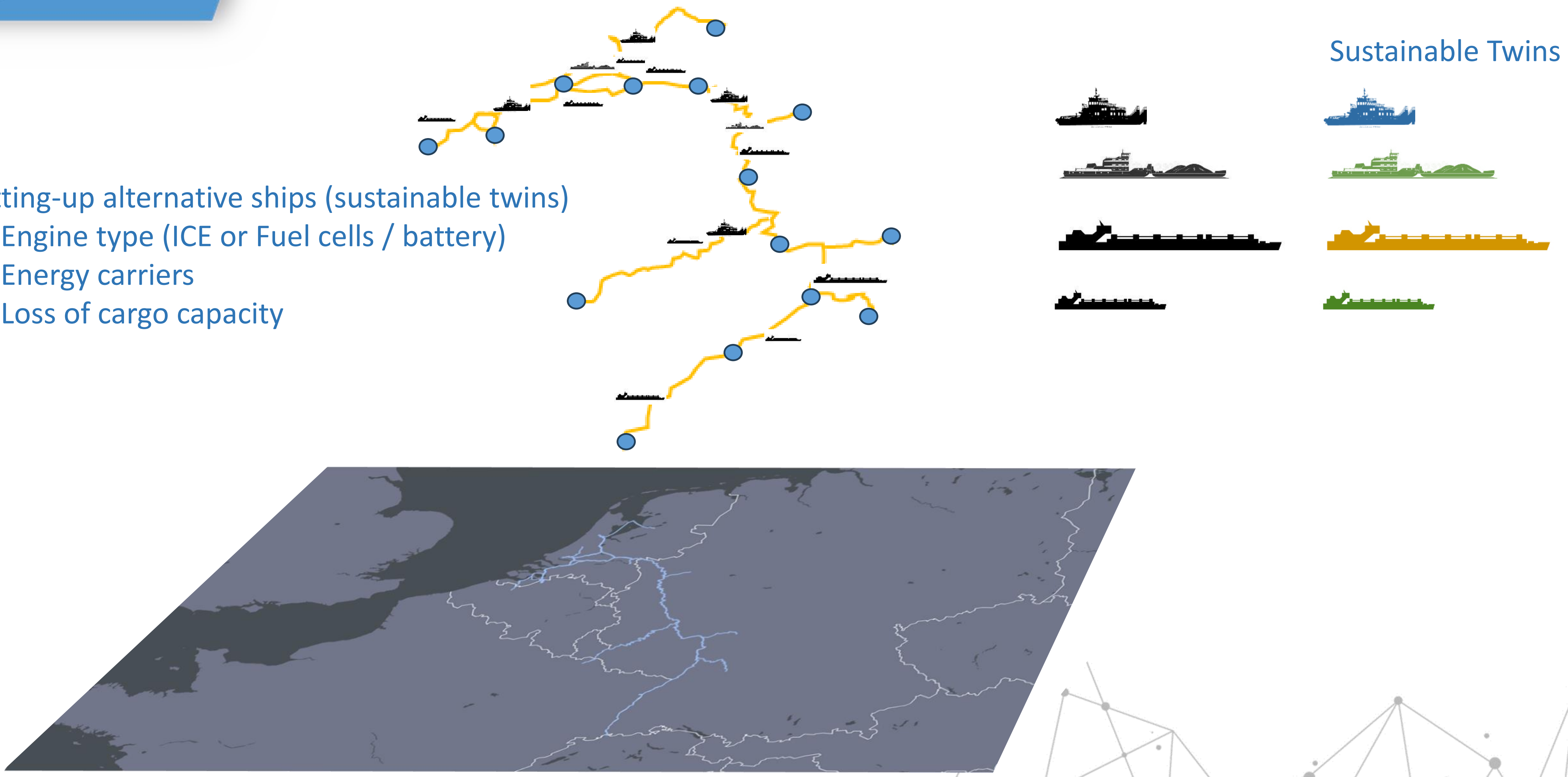




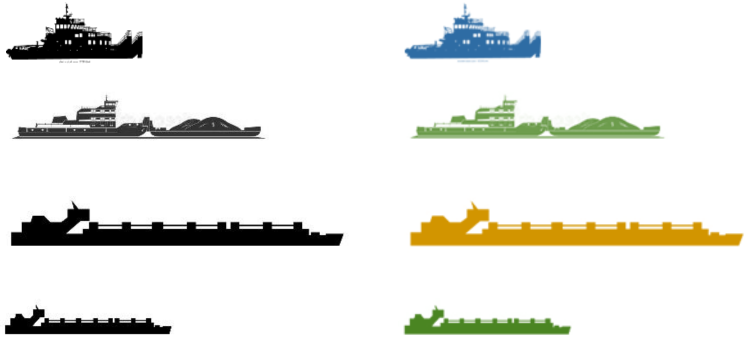
Setting-up alternative ships (sustainable twins)

- Engine type (ICE or Fuel cells / battery)
- Energy carriers
- Loss of cargo capacity

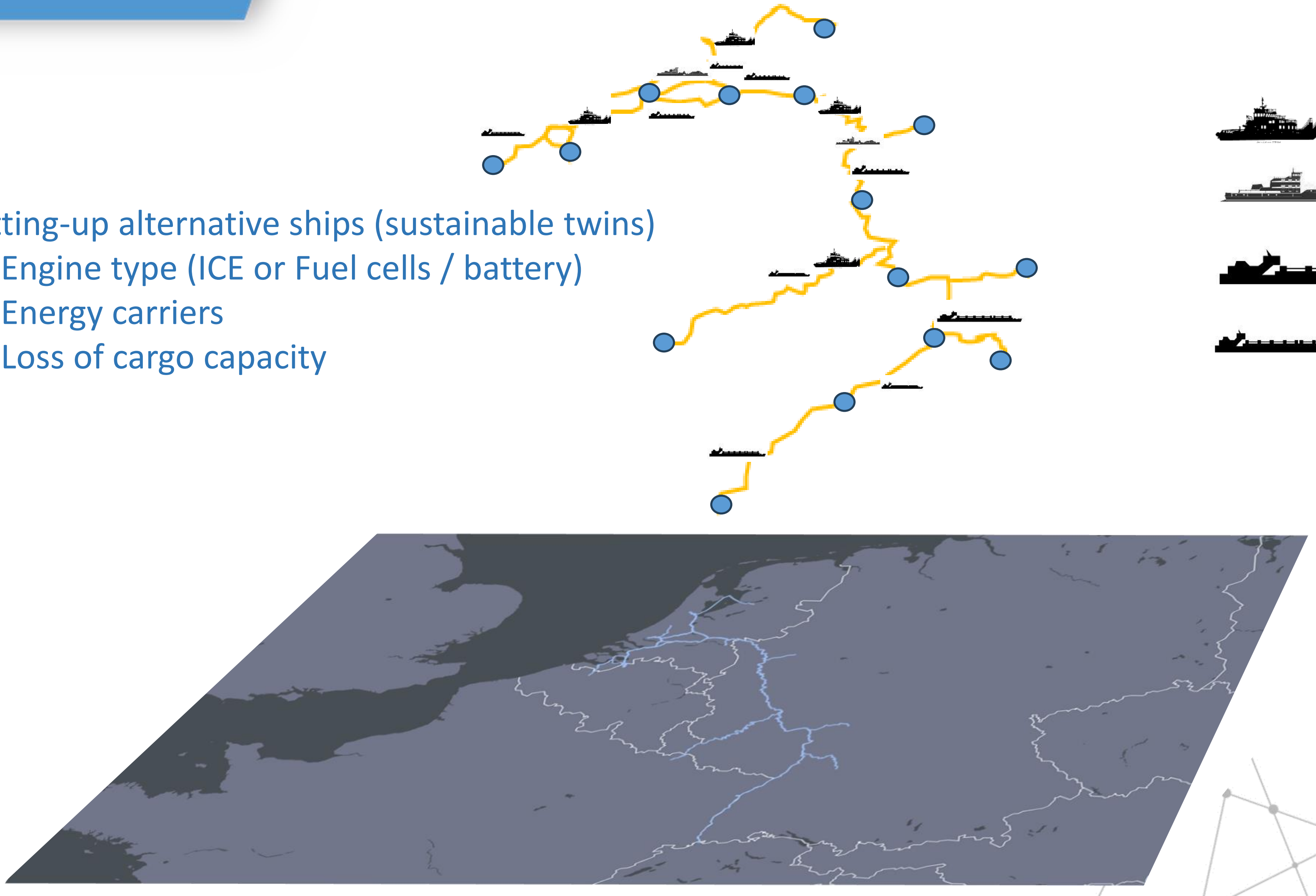
Sustainable Twins



Sustainable Twins



Setting-up alternative ships (sustainable twins)
- Engine type (ICE or Fuel cells / battery)
- Energy carriers
- Loss of cargo capacity

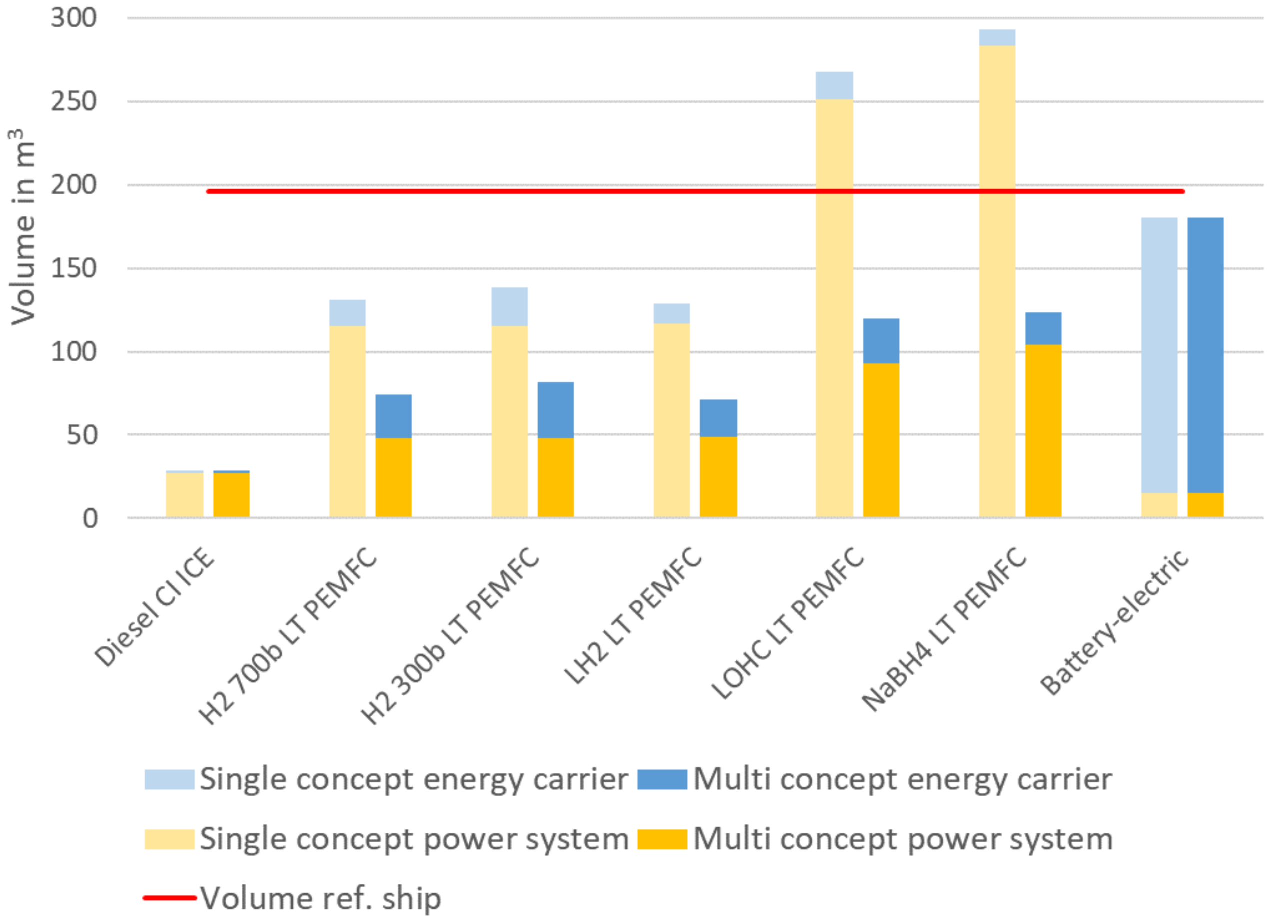


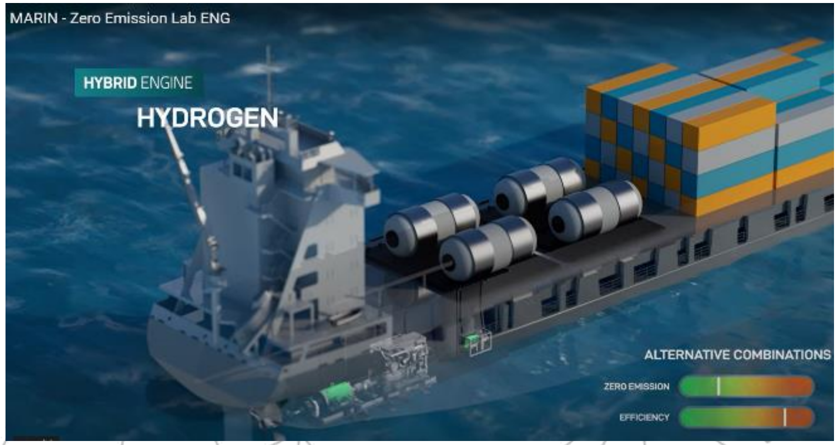
Sustainable Twins

For each developed sustainable alternative power system and energy carrier, the increase in volume/weight is taken into account and the reduction in payload capacity calculated

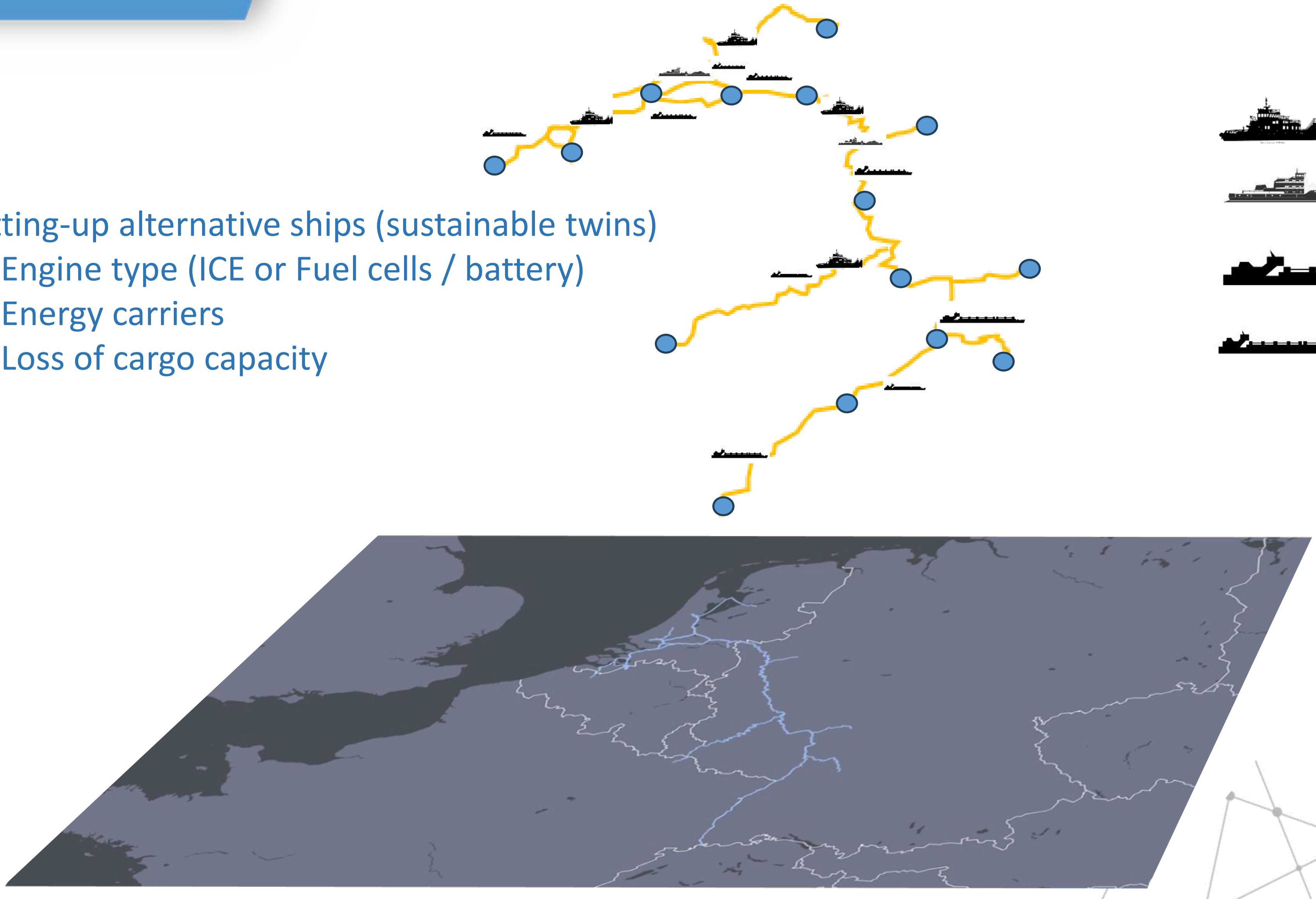
Because of the **lower energy density** of sustainable alternative energy carriers (compared to diesel), sustainable twins have **less range, less cargo capacity**, or both (less…)

Sustainable Twins

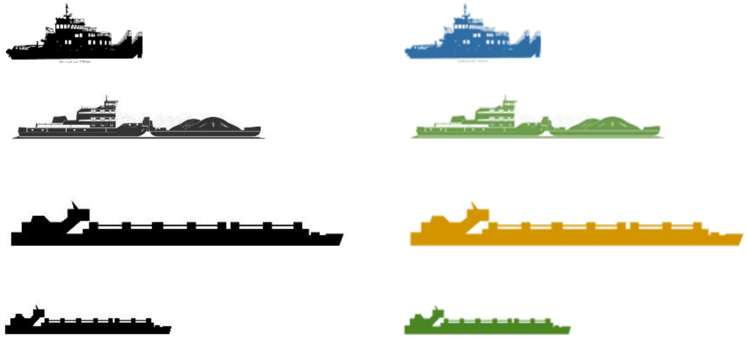




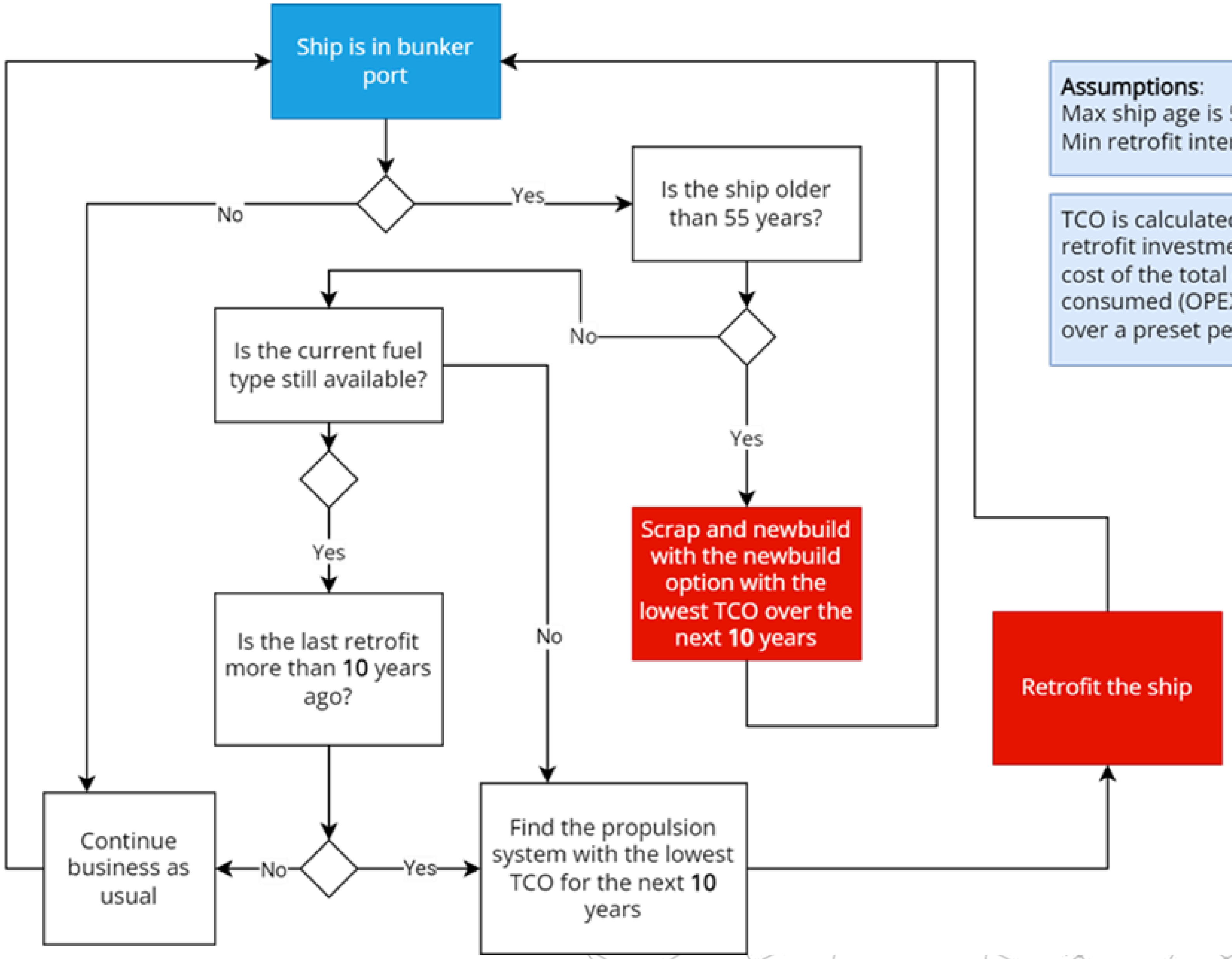
Setting-up alternative ships (sustainable twins)
- Engine type (ICE or Fuel cells / battery)
- Energy carriers
- Loss of cargo capacity



Sustainable Twins



Setting-up alternative ship:
- Engine type (ICE or Fuel
- Energy carriers
- Loss of cargo capacity

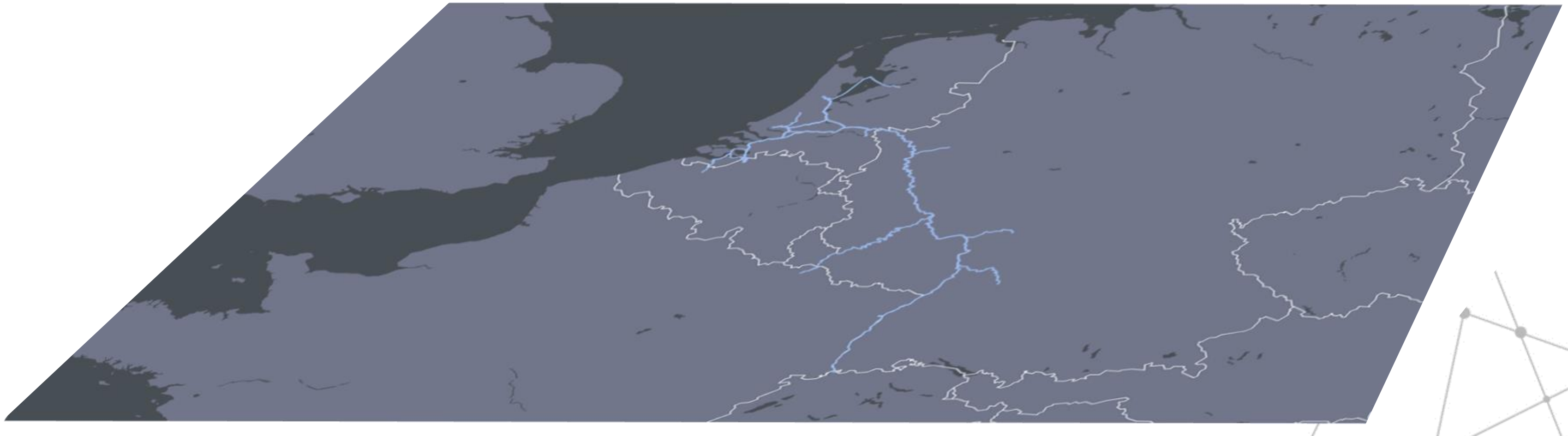


Assumptions:
Max ship age is 55 years
Min retrofit interval is 10 years

TCO is calculated by summing the retrofit investment (CAPEX) with the cost of the total energy consumed (OPEX) over a preset period of time

Set-up is ready to run alternative scenario’s

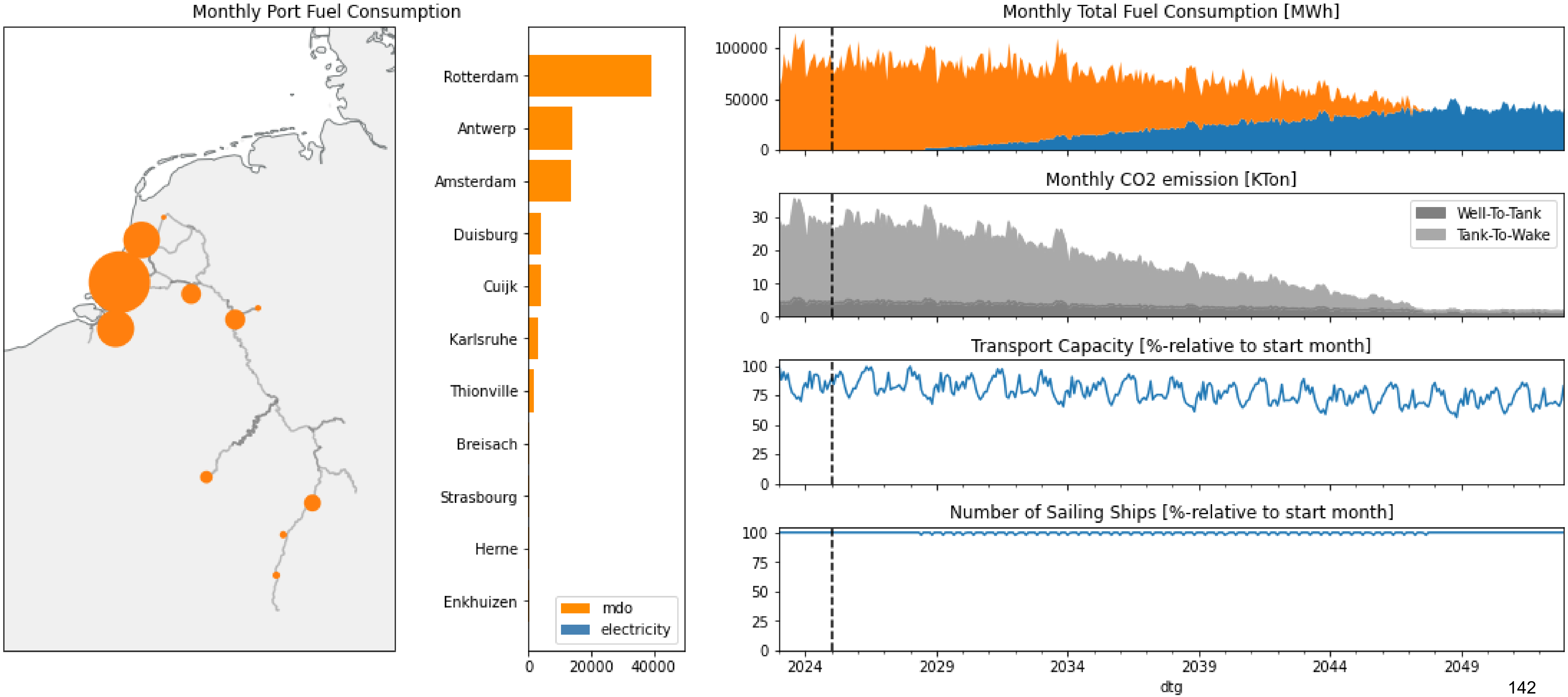
And here begins workshops / brainstorms / visions / discussions…



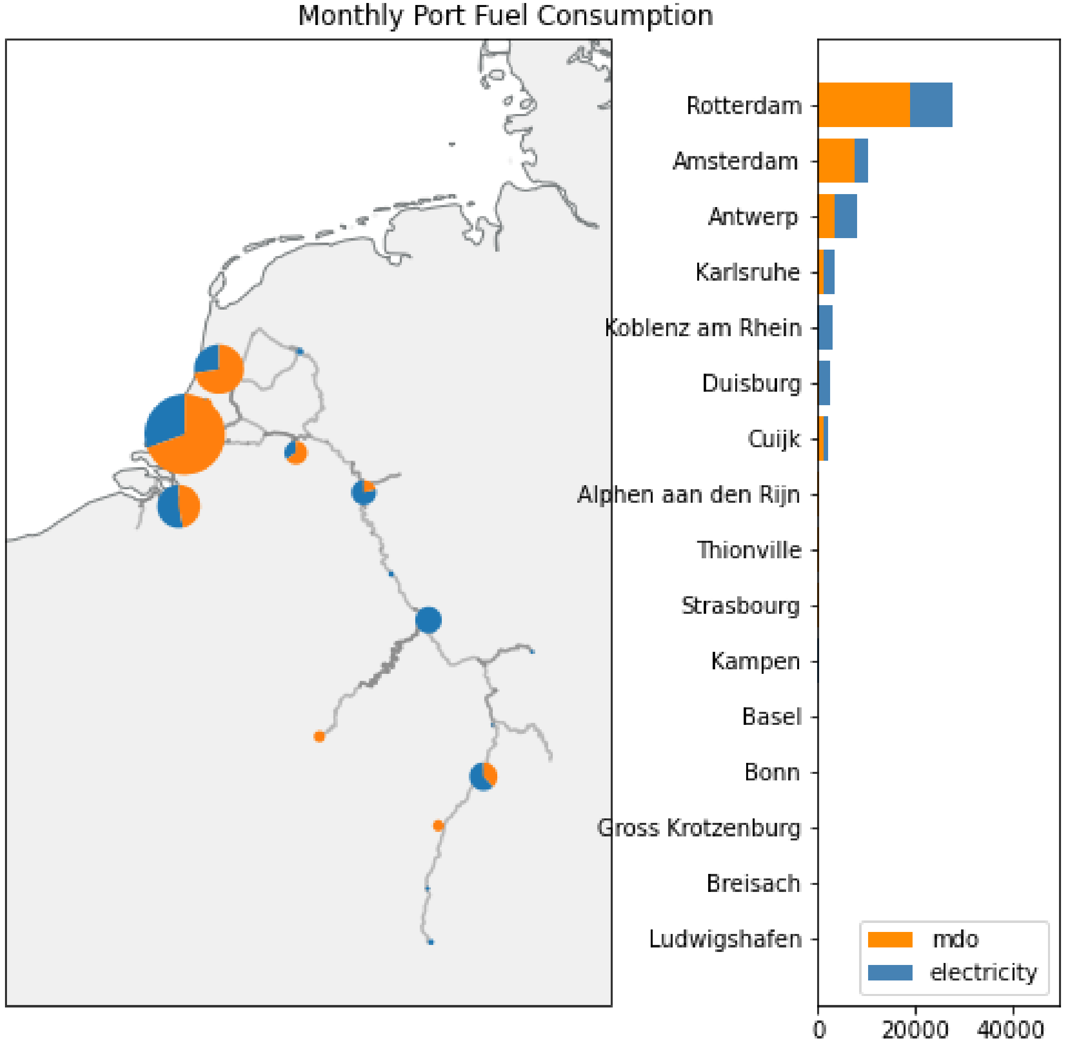
MARIN

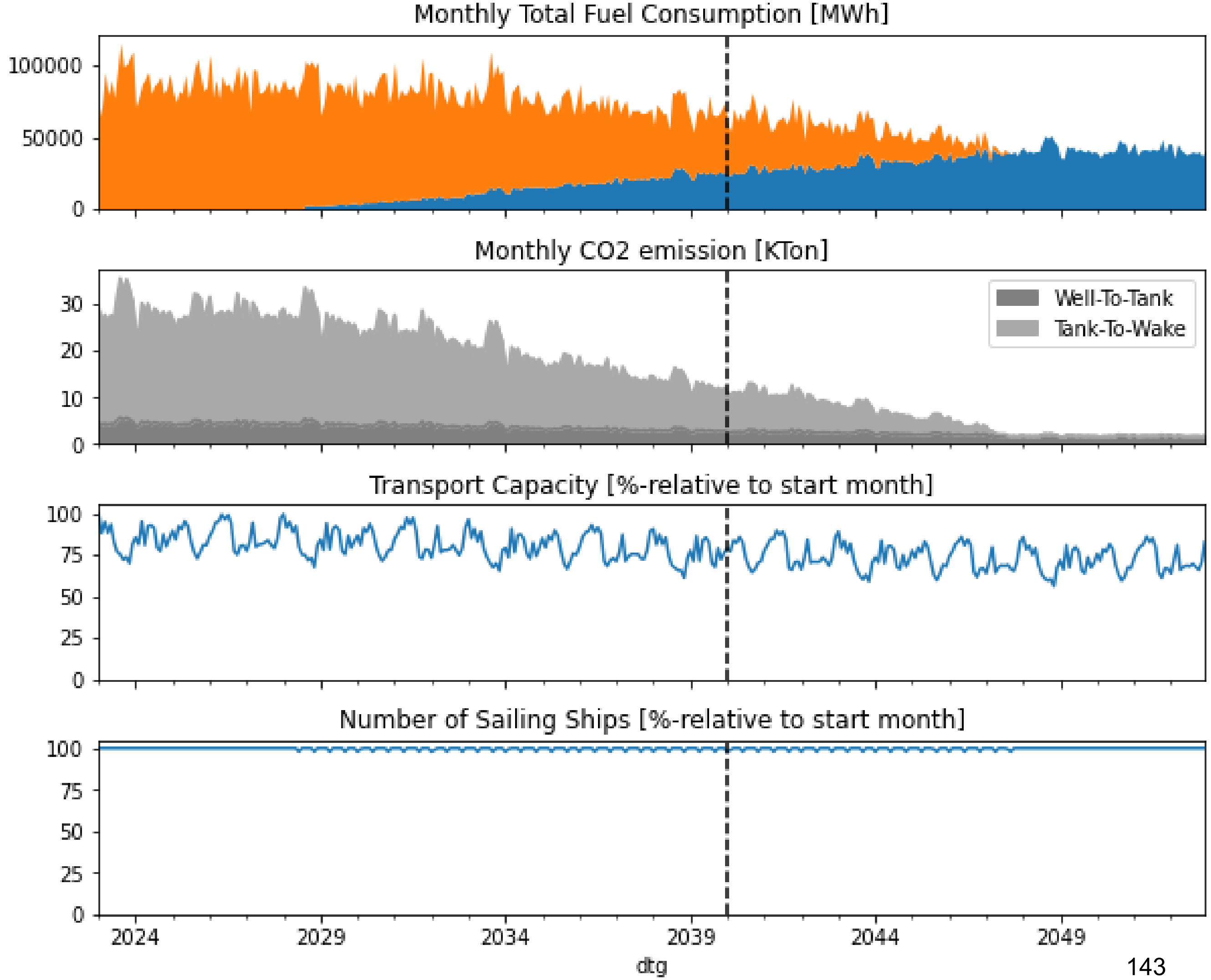
BETTER SHIPS, BLUE OCEANS

Scenario: To Electric, Battery Swapping
January 2025



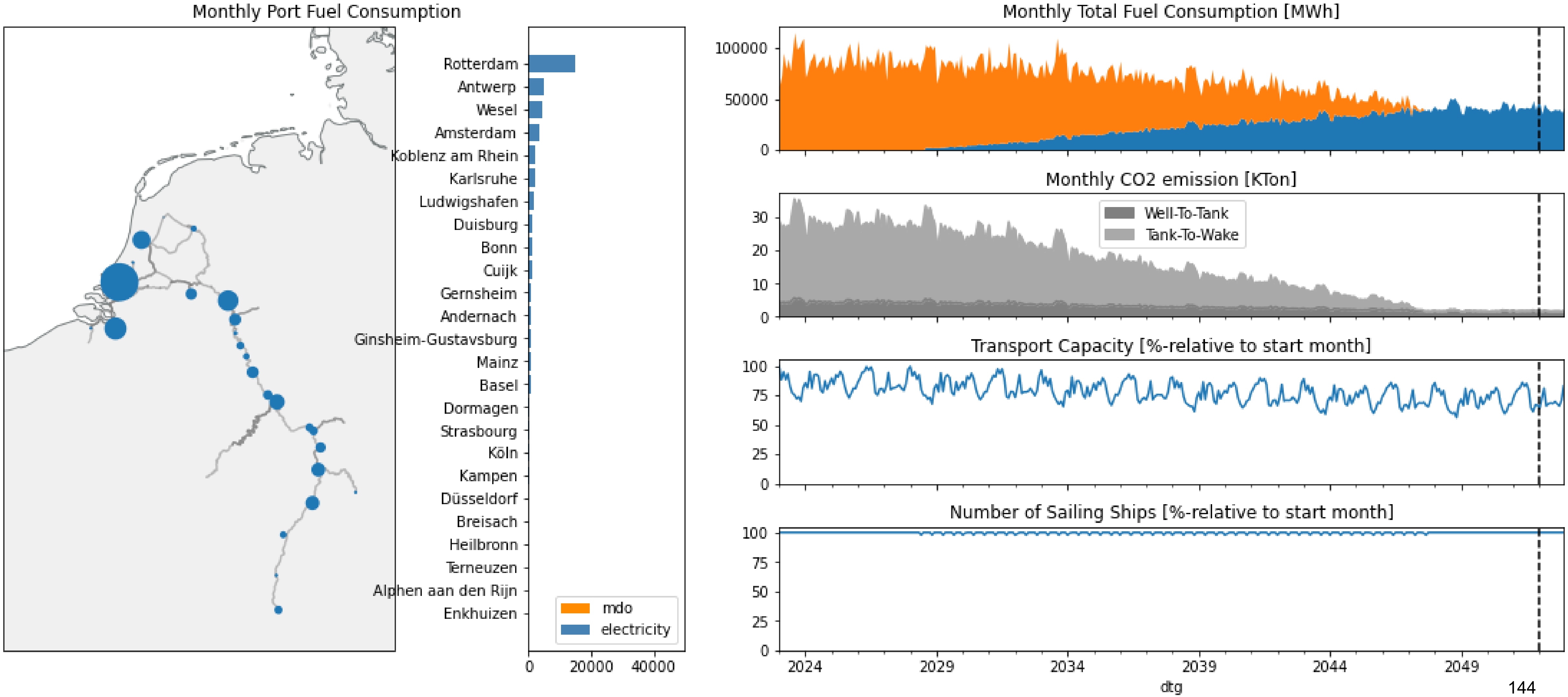
Scenario: To Electric, Battery Swapping
January 2040



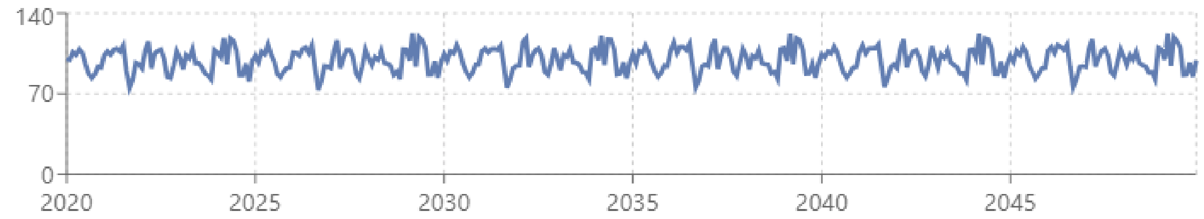


MARIN
BETTER SHIPS, BLUE OCEANS

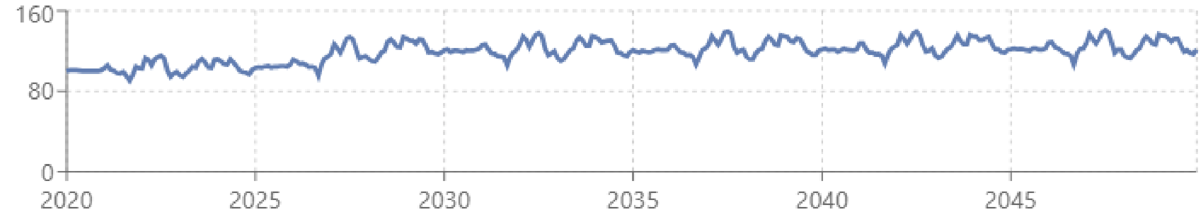
Scenario: To Electric, Battery Swapping
January 2052



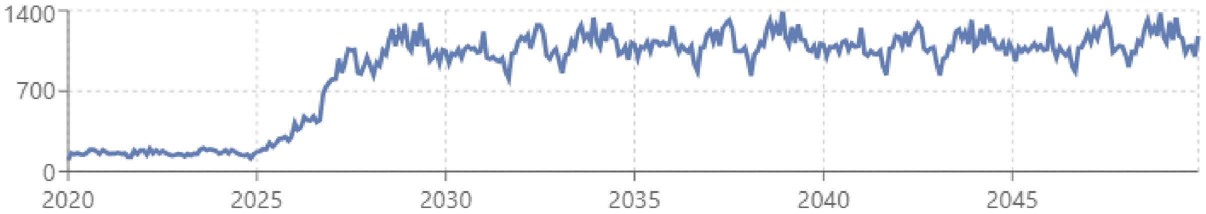
Monthly transport capacity [Relative to simulation start]



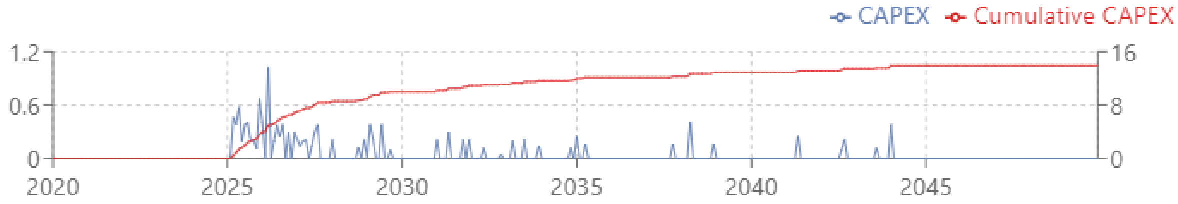
% of sailing ships [Relative to simulation start]



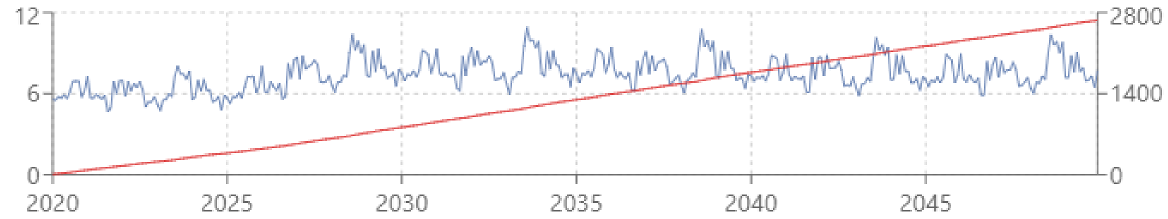
% of monthly bunker events [Relative to simulation start]



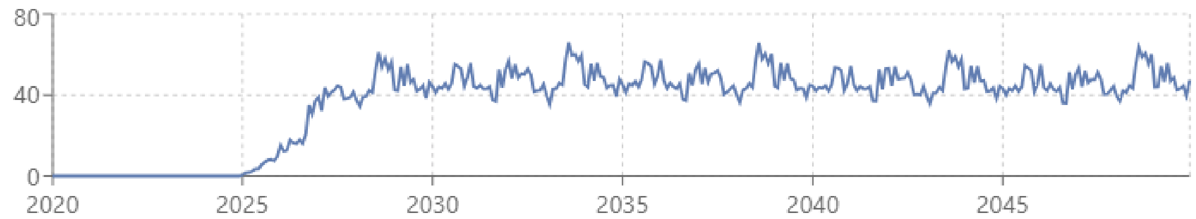
Monthly + cumulative capital expenditure [M€]



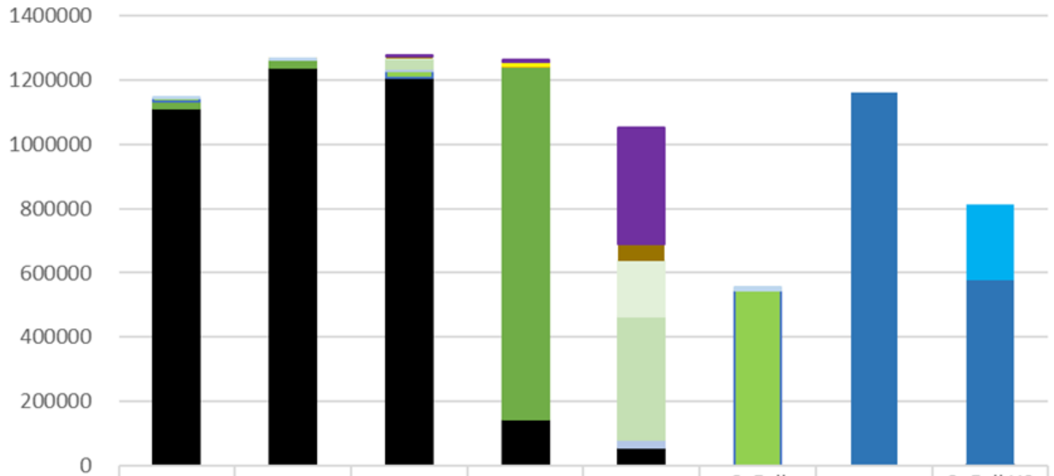
Monthly + cumulative operational expenditure [M€]



Total monthly electric energy demand [GWh]

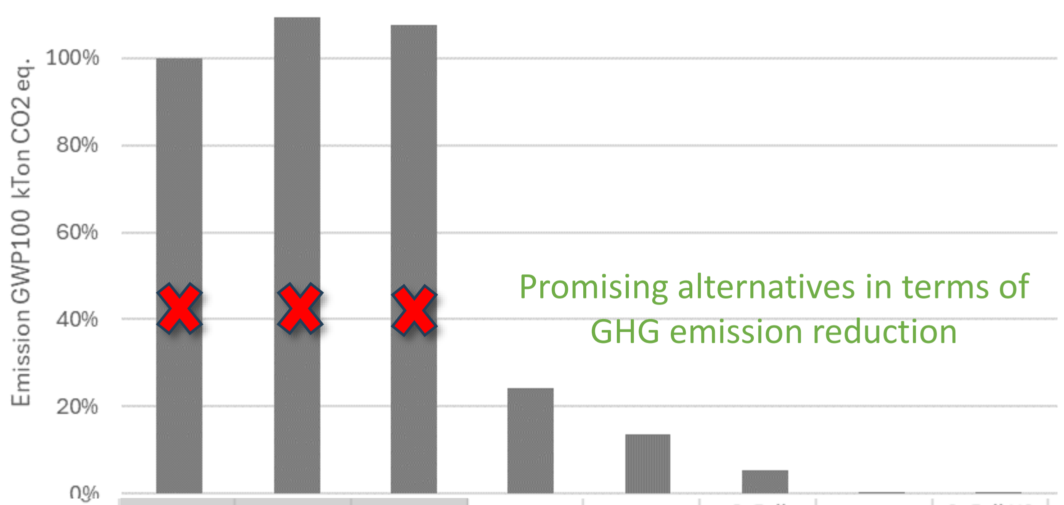


Energy mix in 2049 per scenario



	1. Business As Usual	2. Conservative	3. Innovative	4. Conservative early adopter	5. Innovative early adopter	6. Full battery electric sailing - swapping	7. Full H2 FC - swapping	8. Full H2 FC - bunkering and swapping
Ren H2 bunkering	0	0	0	0	0	0	0	235248
Fossil H2 bunkering	0	0	0	0	0	0	0	389
Ren H2 Swapping	0	0	0	0	0	0	1161957	576786
Fossil H2 Swapping	0	0	0	0	0	0	0	325
Ren Methanol	0	0	293	7435	359167	0	0	0
Bio Methanol	0	0	8256	2320	55590	0	0	0
Ren Electricity Charging	0	0	102	0	169581	0	0	0
Ren Diesel	0	0	31825	0	384453	0	0	0
Grid Electricity Charging	0	0	5570	0	23890	0	0	0
Bio LNG	0	0	0	8100	0	0	0	0
Ren electricity Swapping	85	1608	363	0	0	11596	0	0
Grid electricity Swapping	10271	0	21046	0	0	545511	0	0
Fossil LNG	0	1212	0	2110	0	0	0	0
HVO	20666	23948	0	1095509	0	0	0	0
Fossil Diesel	1112590	1238059	1206008	145855	57132	0	0	4

Impact on GHG emissions



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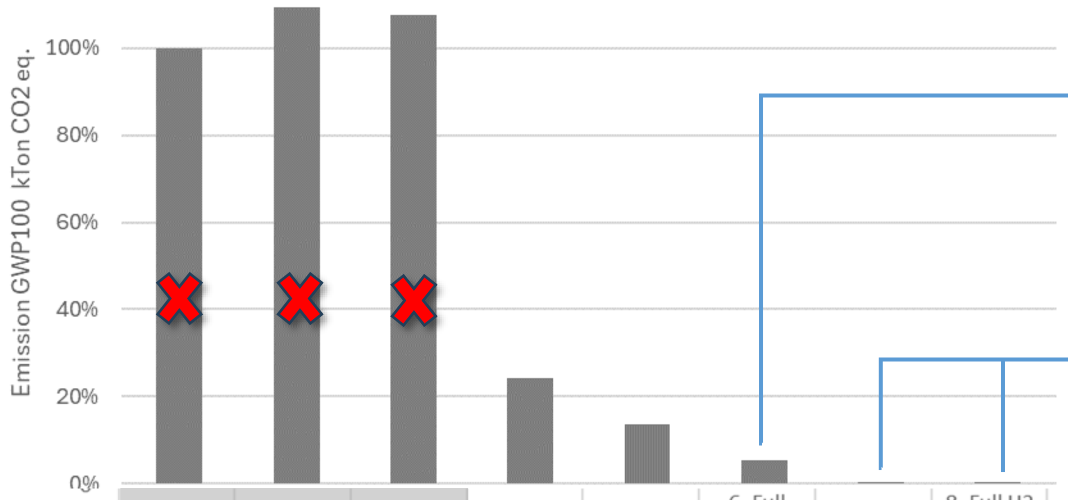
Impact on GHG emissions



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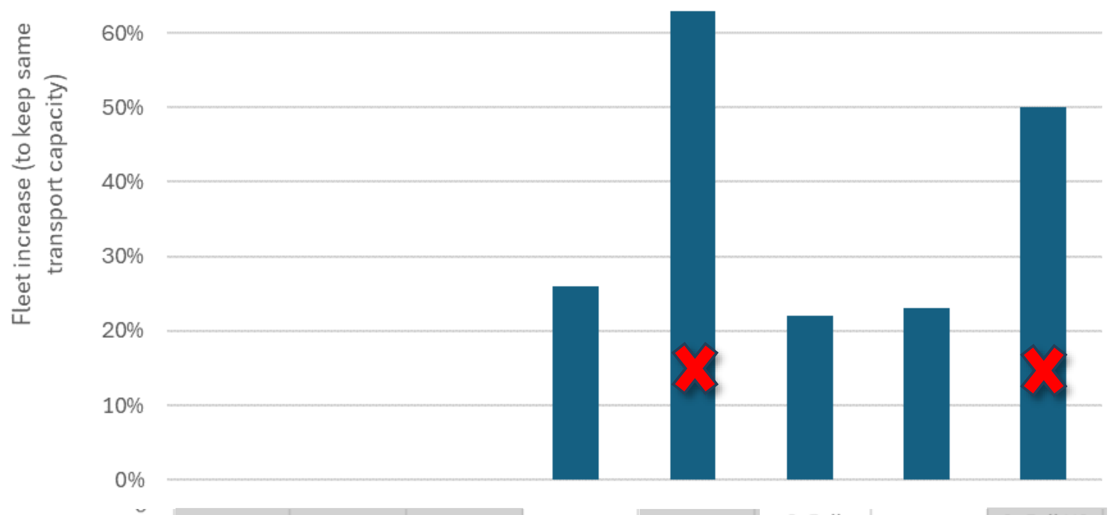
Electricity issued from European electricity mix (containing also fossil based electricity production)

“biased” assumption: H2 produced based on 100% renewable electricity…

Fleet increase (transport capacity) need



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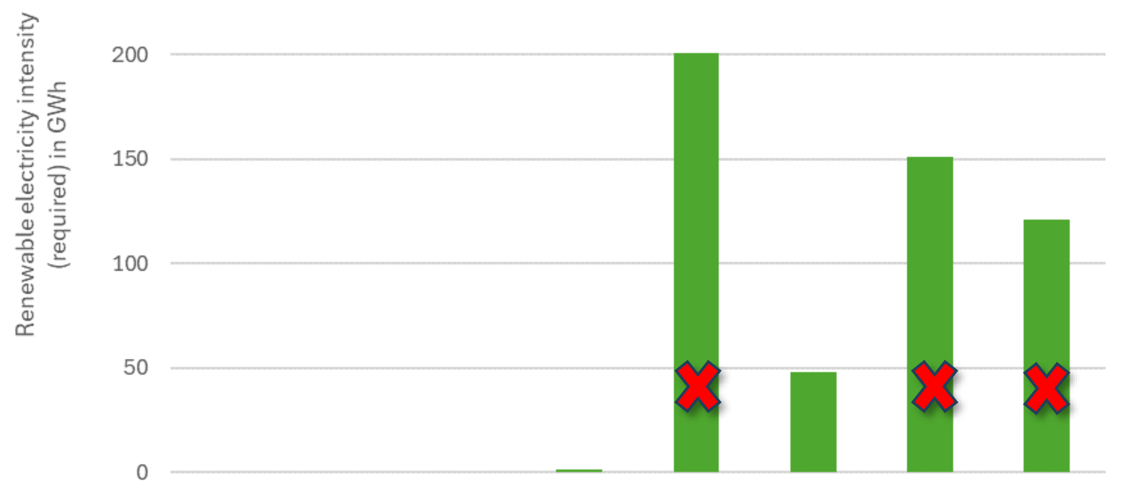
In scenario 5 & 8, onboard energy capacity was chosen to minimize the number of additional bunker events (maximize range). This had a drastic effect on the loss of cargo thus transport capacity, yielding a large fleet increase need.

Renewable Electricity need

MARIN
BETTER SHIPS, BLUE OCEANS



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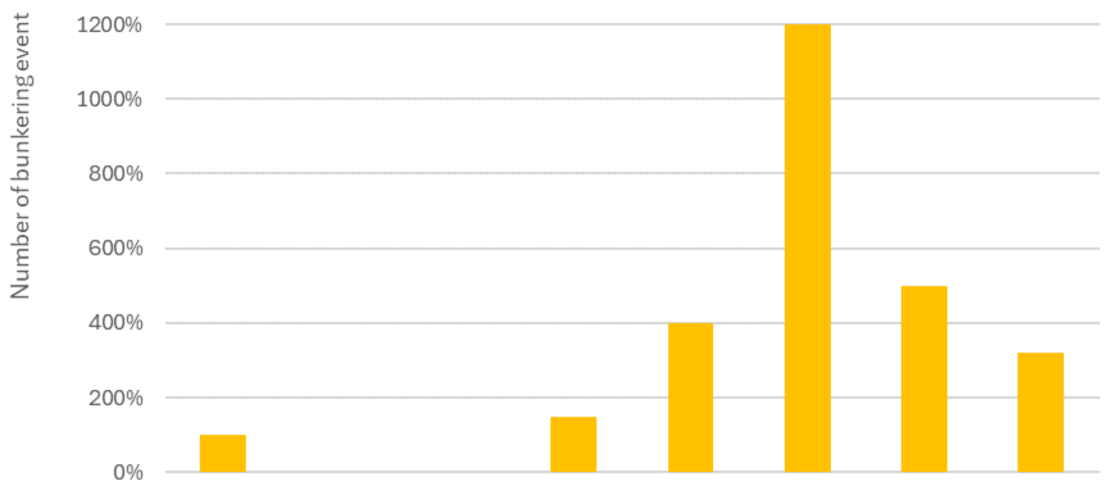
Bunkering event need



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HVO / BIODIESEL + others

Best in class for limited operationnal change,
"Only" 2 times more bunkering events
Acceptable emission reduction: -75%
Limited renewable electricity need
Affordable Capex
But…

- 26% fleet increase
- No reduction of polluting emission (Nox, Sox, PM, …)
- GHG reduction only valid with good HVO!
- Availabity of such HVO?

FULL ELECTRIC WITH BATTERY SWAPPING

Best in class for GHG emission reduction -95%!
Can up to -100% with only renewable e-
Best in class for polluting emission reduction (Sox, PM, …)
But…

- 14 times more bunkering events (battery swaping infrastructure to be deployed!)
- 50 GWh e- per month
- 20% fleet increase

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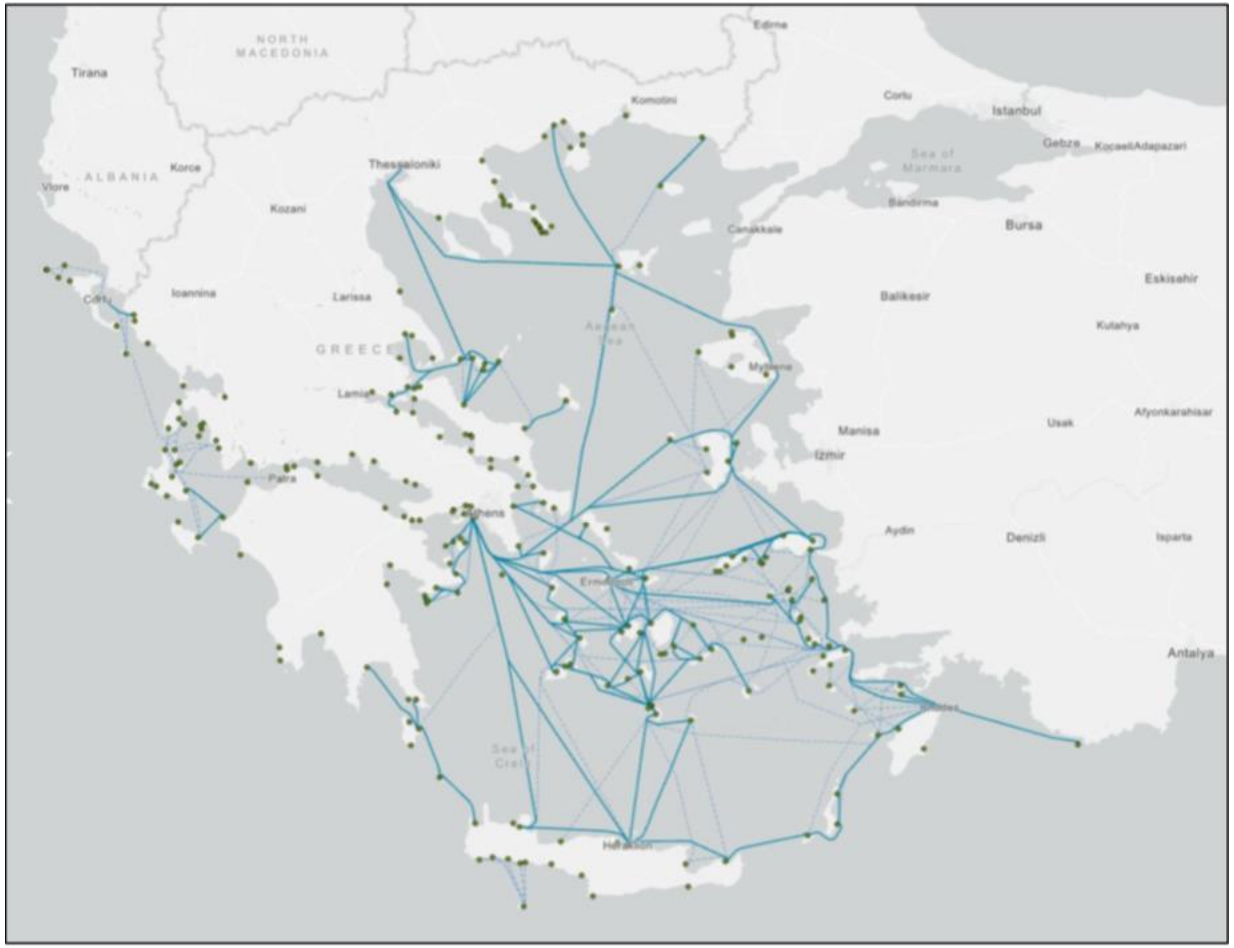
Needs

https://needs.application.marin.nl/dashboard

MARIN
BETTER SHIPS, BLUE OCEANS

Greece maritime network



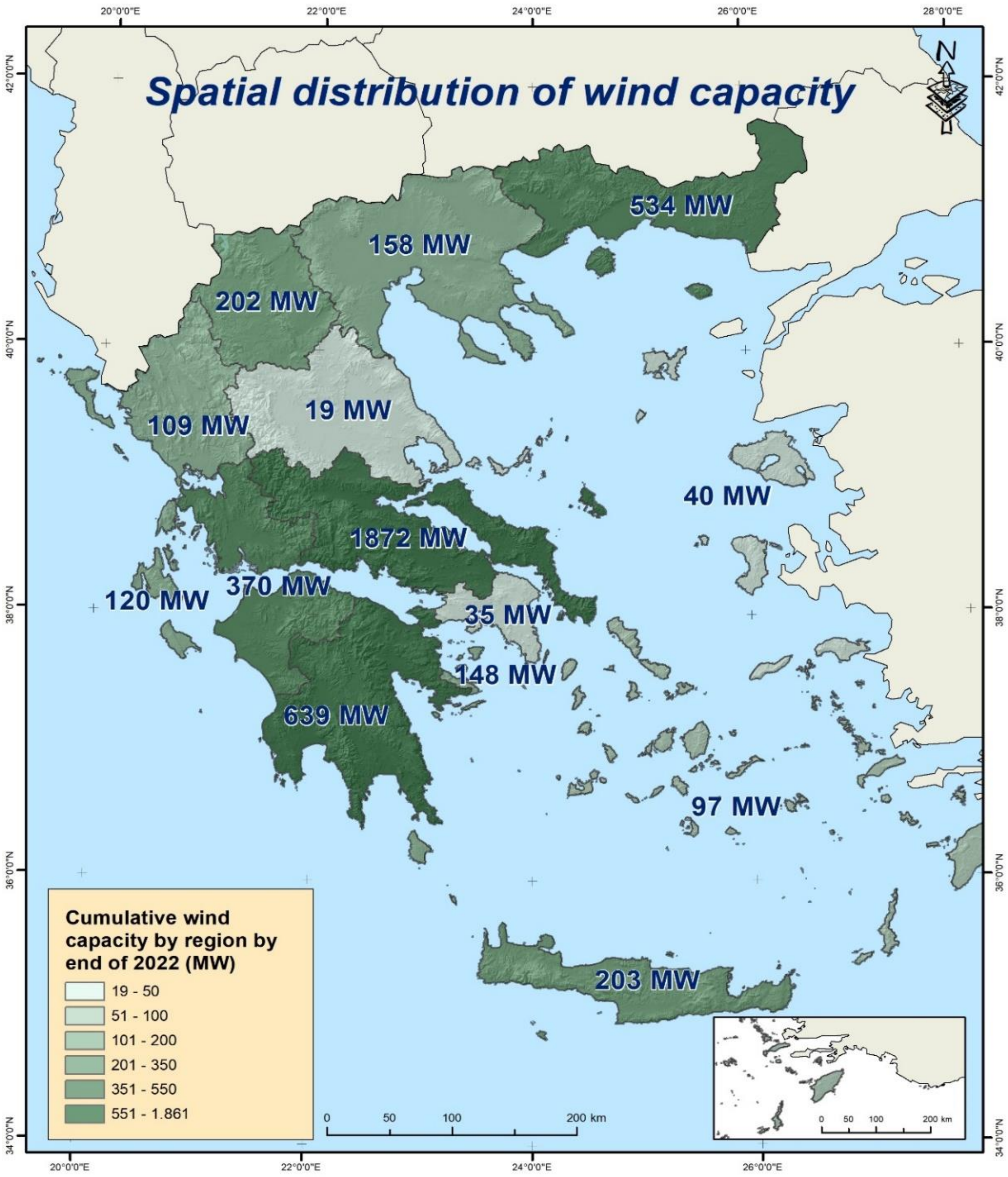
- *74 routes (60 served by only one of the selected vessels)*
- *843 transport journeys performed (62% of all services provided in 2021)*

Catamarans	LPP [m]	Breath [m]	Draft [m]	Speed [knots]	Power [kW]	Capacity [Pax No]	Capacity [Cars No]
	Group characteristics						
Group 1	74	25	4	40	28.300	1.103	207
Group 2	73	23	3	36	26.000	1.142	159
Group 3	65	26	2,6	35	14.600	700	75
Group 4	77	25	3,8	40	28.800	1.040	210
Group 5	36	10,4	1,9	35,4	4.550	339	7
Group 6	48	12,5	1,6	43	9.050	426	-

RoPax (medium)	LPP [m]	Breath [m]	Draft [m]	Speed [knots]	Power [kW]	Capacity [Pax No]	Capacity [Cars No]
	Group characteristics						
Group 1	61,2	11,7	3	14	1.200	780	60
Group 2	61,26	14	3,8	13	1.900	453	150
Group 3	71,5	14,8	3	16	2.940	660	127
Group 4	74	14	3,7	15,7	3.650	562	106
Group 5a	77	14,7	3,7	17	5.300	939	98
Group 5b					2.880		
Group 6	86,4	16,8	4,2	17	5.400	867	190
Group 7	65	22	5	18	8.300	1.225	175
Group 8	108	19	4,2	21,8	10.740	1.100	180

RoPax (large)	LPP [m]	Breath [m]	Draft [m]	Speed [knots]	Power [kW]	Capacity [Pax No]	Capacity [Cars No]
	Group characteristics						
Group 1	191,22	26,4	7,3	29	67.200	2.289	711
Group 2	177,8	28	6,8	23	23.000	1.872	696
Group 3	133,3	21	5,2	26	31.800	2.024	424
Group 4	132	23	5,6	19,3	11.100	1.172	333
Group 5	160,6	25,7	6,5	27	44.500	1.854	780
Group 6	114	19,2	5,1	22,5	13.400	1.547	250
Group 7	105	19	4,5	19	7.700	1.004	261


SOLAR RESOURCE MAP
PHOTOVOLTAIC POWER POTENTIAL
GREECE
WORLD BANK GROUP
ESMAP
SOLARGIS
Kavala
Alexandroupolis
Thessaloniki
Ioannina
Larissa
Volos
Patras
Athens
Tripoli
Kalamata
Heraklion
© 2019 The World Bank
Source: Global Solar Atlas 2.0
Solar resource data: Solargis
100 km
Long term average of PVOUT, period 1994-2018
Daily totals: 3.6 3.8 4.0 4.2 4.4 4.6 4.8
kWh/kWp
Yearly totals: 1314 1387 1461 1534 1607 1680 1753
This map is published by the World Bank Group, funded by ESMAP, and prepared by Solargis. For more information and terms of use, please visit http://globalsolaratlas.info.

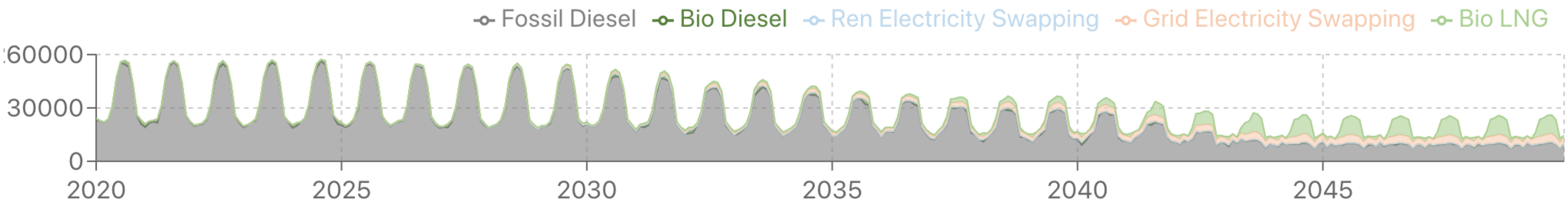

Spatial distribution of wind capacity
534 MW
158 MW
202 MW
19 MW
109 MW
40 MW
1872 MW
370 MW
120 MW
35 MW
148 MW
639 MW
97 MW
203 MW
Cumulative wind capacity by region by end of 2022 (MW)
19 - 50
51 - 100
101 - 200
201 - 350
351 - 550
551 - 1.861
0 50 100 200 km

Needs

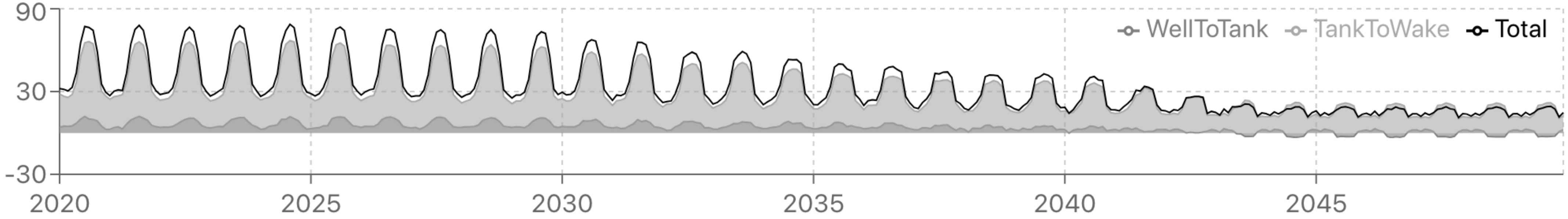
https://needs.application.marin.nl/dashboard

MARIN
BETTER SHIPS, BLUE OCEANS

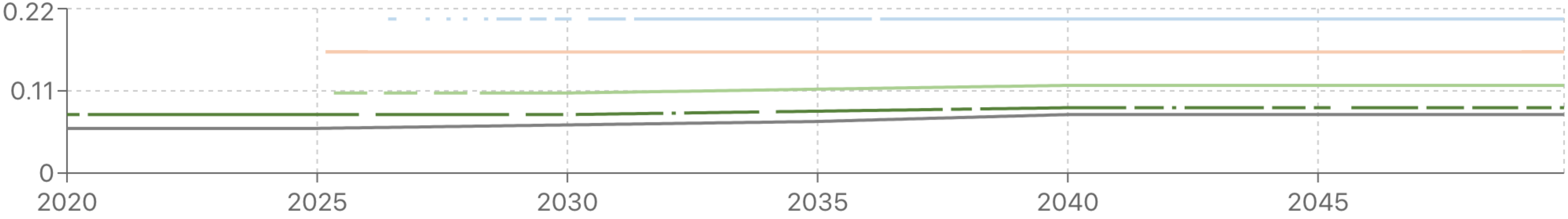
Monthly Fuel Consumption [MWh]



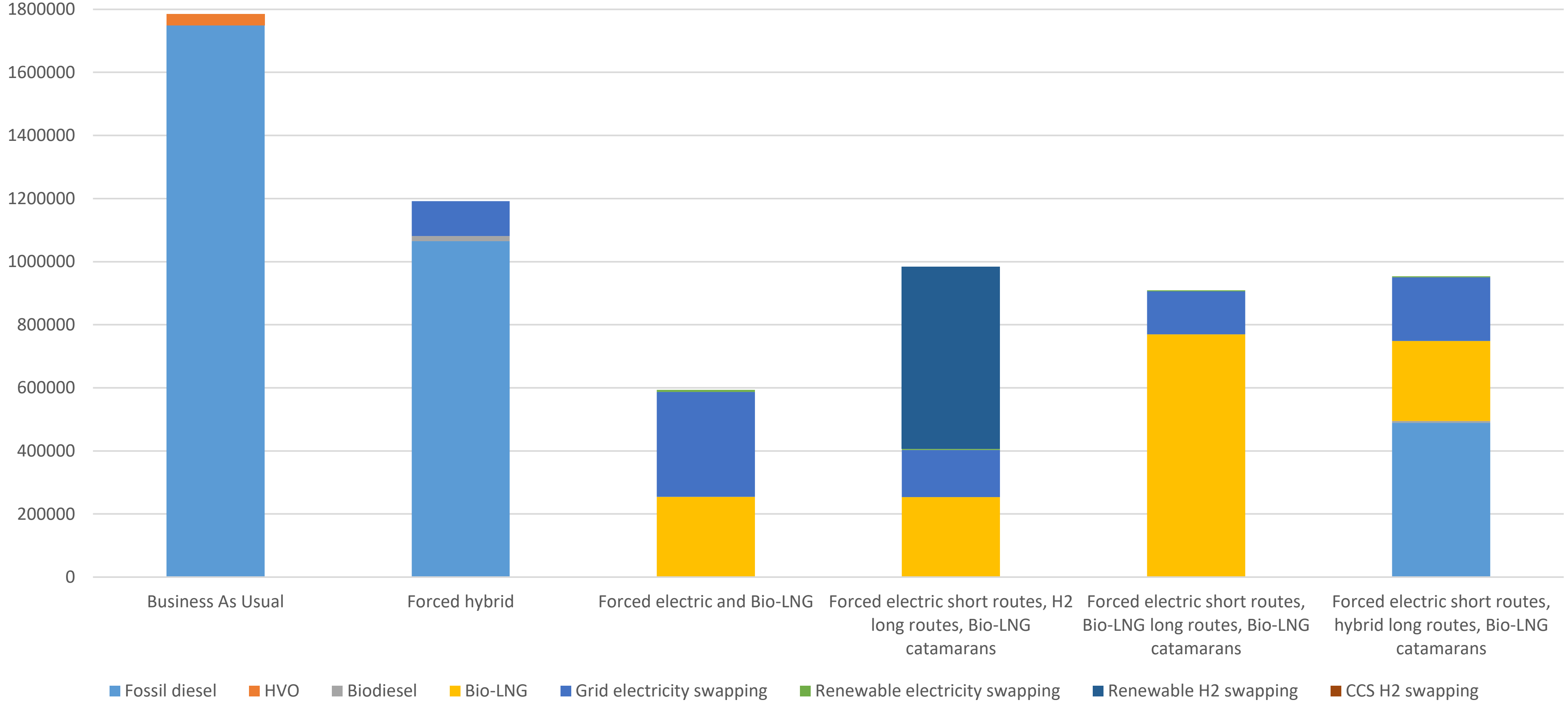
Monthly GHG emission [kTon CO2eq]



Monthly Fuel Price [Euro per kWh]



GHG emissions:	-47%	-94%	-95%	-90%	-75%
Monthly ren. e- demand:	12 GWh	33 GWh	104 GWh	14 GWh	21 GWh
Capex (30 years):	500 M$	220 M$	2000 M$	400 M$	380 M$



THANK YOU!

Driving Maritime Talent through the Marine Energy Transition

François Lambert
Directeur Général
ENSM
ÉCOLE NATIONALE SUPÉRIEURE MARITIME

What is ENSM ?

HISTORY

- First **School of Hydrography,** created by Charles IX in Marseille in 1571
- **Creation of** Ecole Nationale Supérieure Maritime (ENSM): 2010
- **Public** scientific, cultural and professional **establishment** (EPSCP)
- Grand établissement, teaching and research missions
- Ministry of the Sea and Fisheries
- Head office in Le Havre

ENSM
ÉCOLE NATIONALE SUPÉRIEURE MARITIME

1 SCHOOL, 4 LOCATIONS

More than 60 000 hours of classes/ year

I BASIC TRAINING (FI)

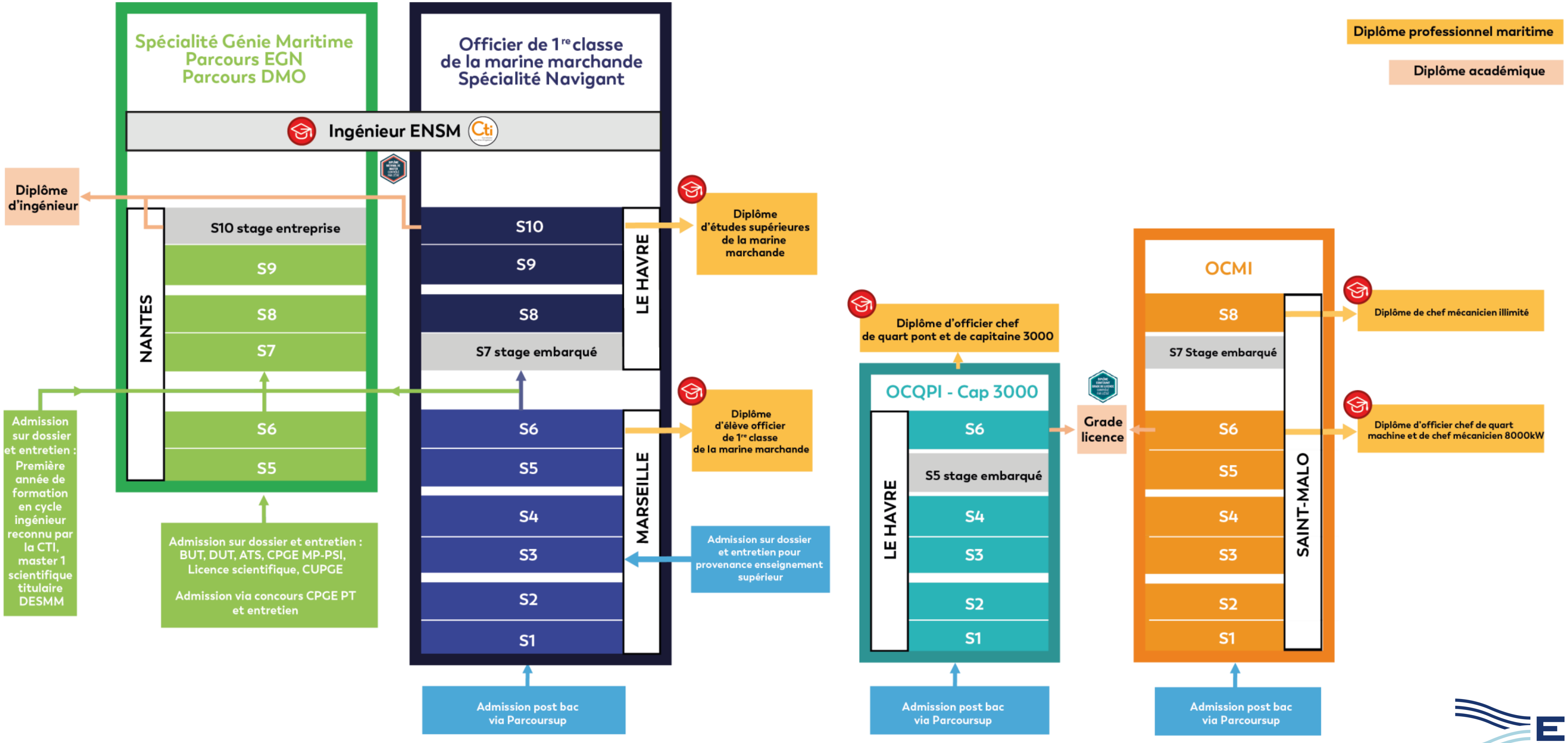
- High school + 5 Engineer
  - Sailing Engineer (dual purpose)
  - Marine Engineer
- High school + 3 (Bridge ou Engine)
- **I VOCATIONAL TRAINING (FP)**
- Navigating officers

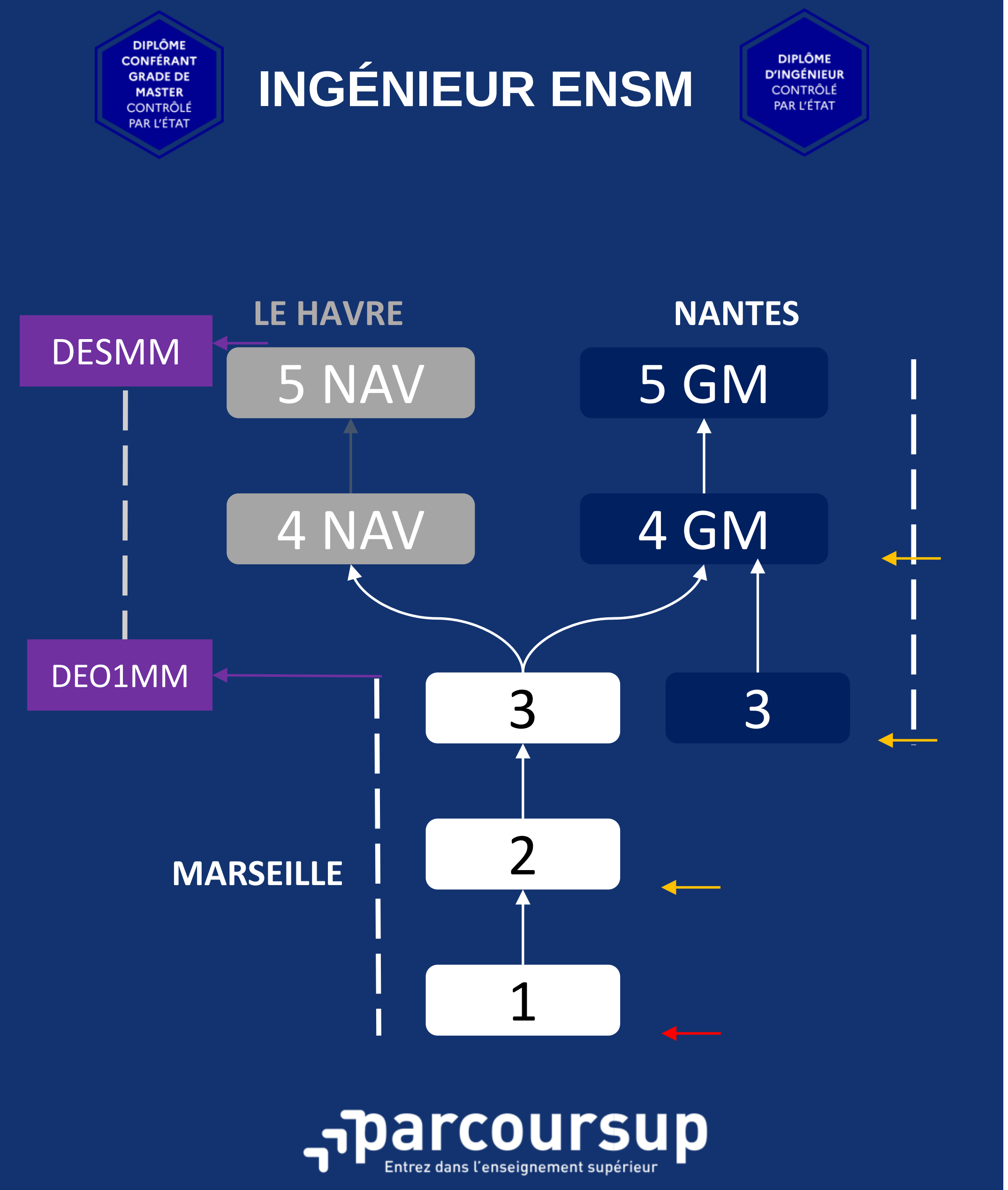
I CONTINUING TRAINING (FC)

ENSM
ÉCOLE NATIONALE SUPÉRIEURE MARITIME

TRAINING COURSES

4 FORMATIONS INITIALES





High school + 5 Engineer

BASIC TRAINING

1 Engineer diploma, 2 courses :

Sailing Engineer (dual purpose)

Diplôme Etudes Supérieures Marine Marchande

On-board ship internships, including a full semester 7 during 4th year

Location : Marseille 3 years + Le Havre 2 years

Marine Engineer

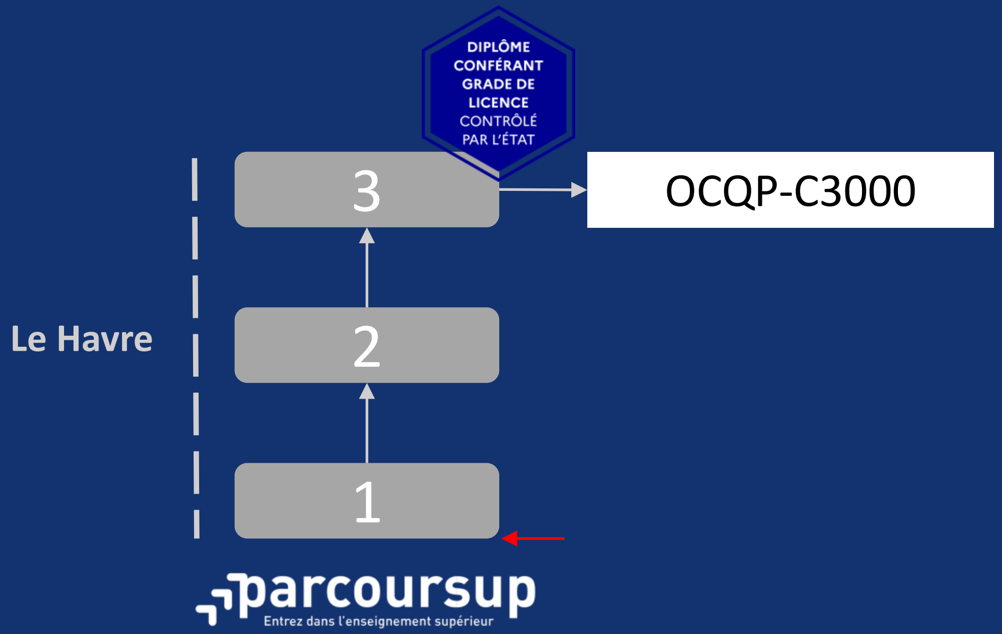
- Eco Ship Management (EGN)
- Deployment and Maintenance of Offshore Systems (DMO)

Internships, including a full semester 10 at the end of 5th year

Location: Nantes

ENSM ÉCOLE NATIONALE SUPÉRIEURE MARITIME

Monovalent Bridge Officer

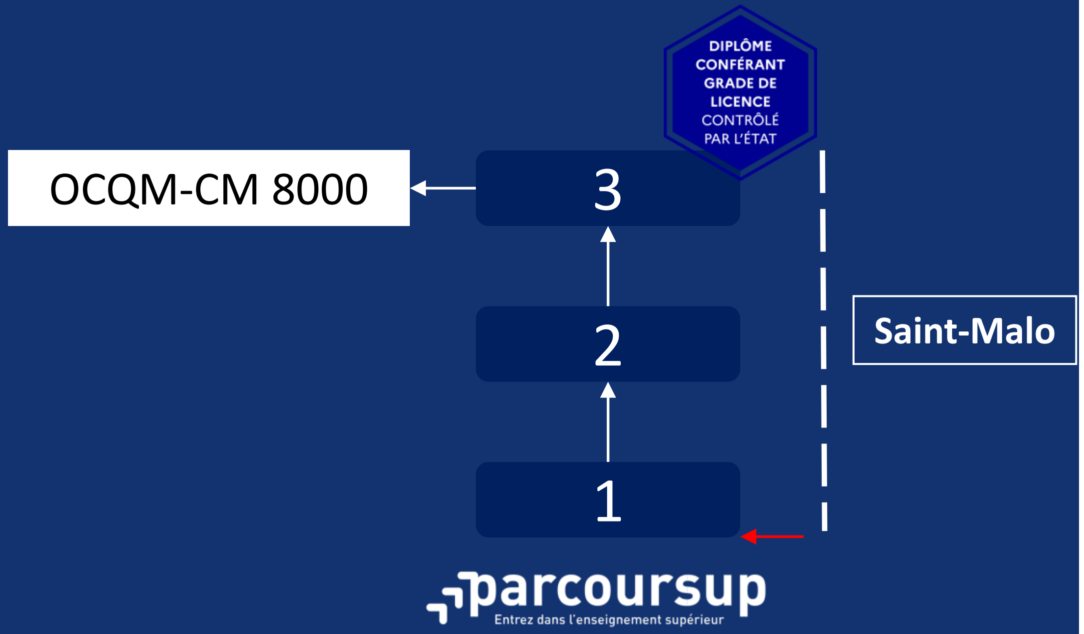


BASIC TRAINING

Officier Chef de Quart Passerelle / Capitaine 3000

Location : Le Havre

On-board ship internships, including full semester 5 during 3rd year



Monovalent Engine Officer

FORMATION INITIALE

Officier Chef de Quart Machine

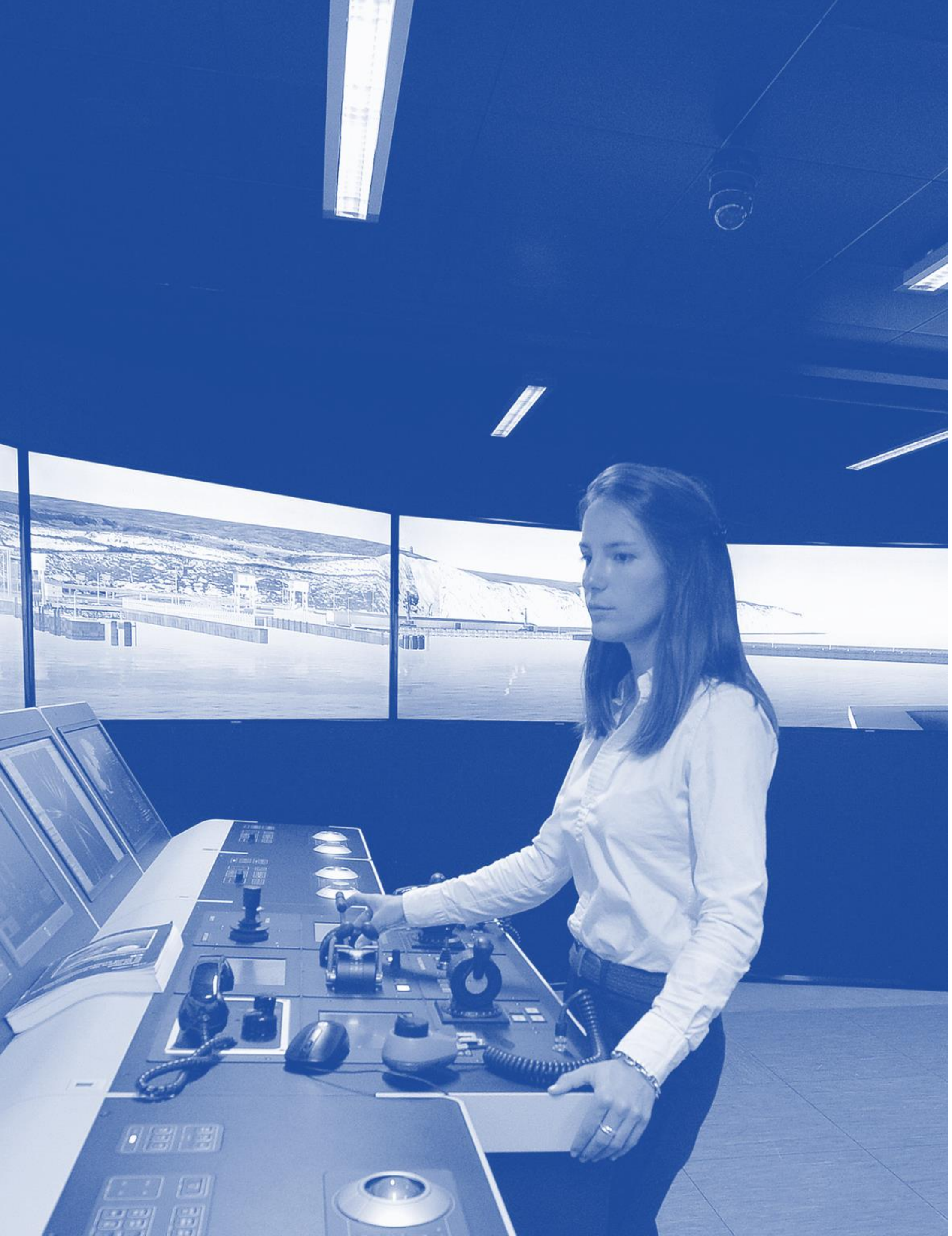
Chef Mécanicien 8000

Location : Saint-Malo

On-board ship internships available

ENSM
ÉCOLE NATIONALE SUPÉRIEURE MARITIME

EDUCATIONAL EQUIPMENTS



Equipment adapted to international maritime regulatory requirements (STCW) on the various ENSM sites.

I SIMULATORSS

navigation, engine, loading, …

I SHIP-IN-SCHOOL

I WORKSHOPS

Electric and diesel engines, Coupling benches, …

I EDUCATIONAL INNOVATION

Pédagolab, Navirothèque

I CESAME

Sea Rescue and Survival Center

ENSM
ÉCOLE NATIONALE SUPÉRIEURE MARITIME

STUDENT LIFE

I STUDENT OFFICES (Burals)

- Livening up student life
- Keeping merchant navy traditions alive
- One bural per site

I ACTIVITIES BY SITE

- Merchant Navy galas and student parties throughout the year
- Associative activities (orienteering, Laser Game, Olympiads, running races, regattas)
- Choir and sea chanteys

ENSM
ÉCOLE NATIONALE SUPÉRIEURE MARITIME

10 GOOD REASONS TO COME TO ENSM

N°1 -Crew spirit

N°2 -Openness to the world / cultural richness

N°3 - Career prospects and development and rapid assumption of responsibility

N°4 - Strict wage equality between men and women

N°5 - Attractive salaries

N°6 - Managerial responsibilities based on the values of our time: energy transition, combating psycho-social risks, etc.

N°7 - Contributing to national sovereignty (French merchant fleet)

N°8 - The most beautiful office in the world and the opportunity to live anywhere in the world

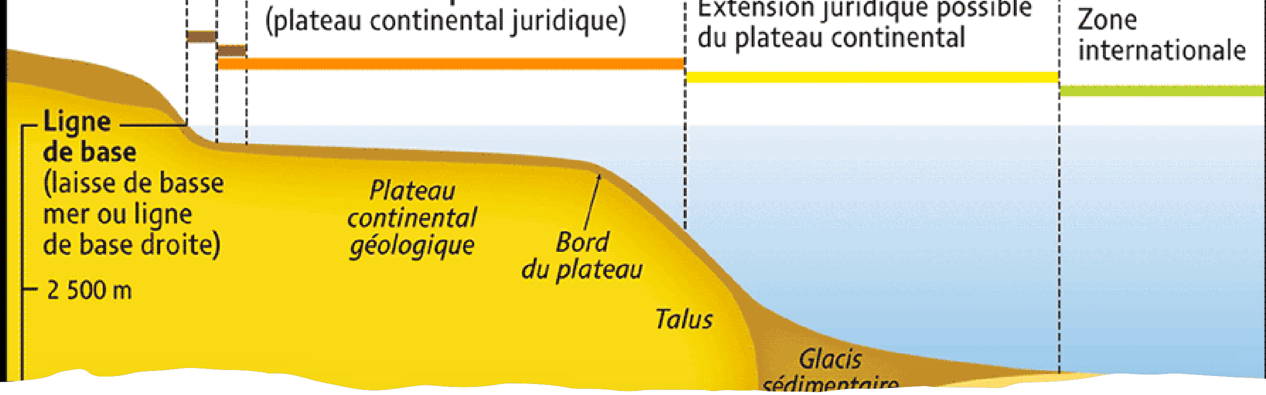
N°9 - Up to 6 months' vacation per year

N°10 - Year-round travel

ENSM
ÉCOLE NATIONALE SUPÉRIEURE MARITIME

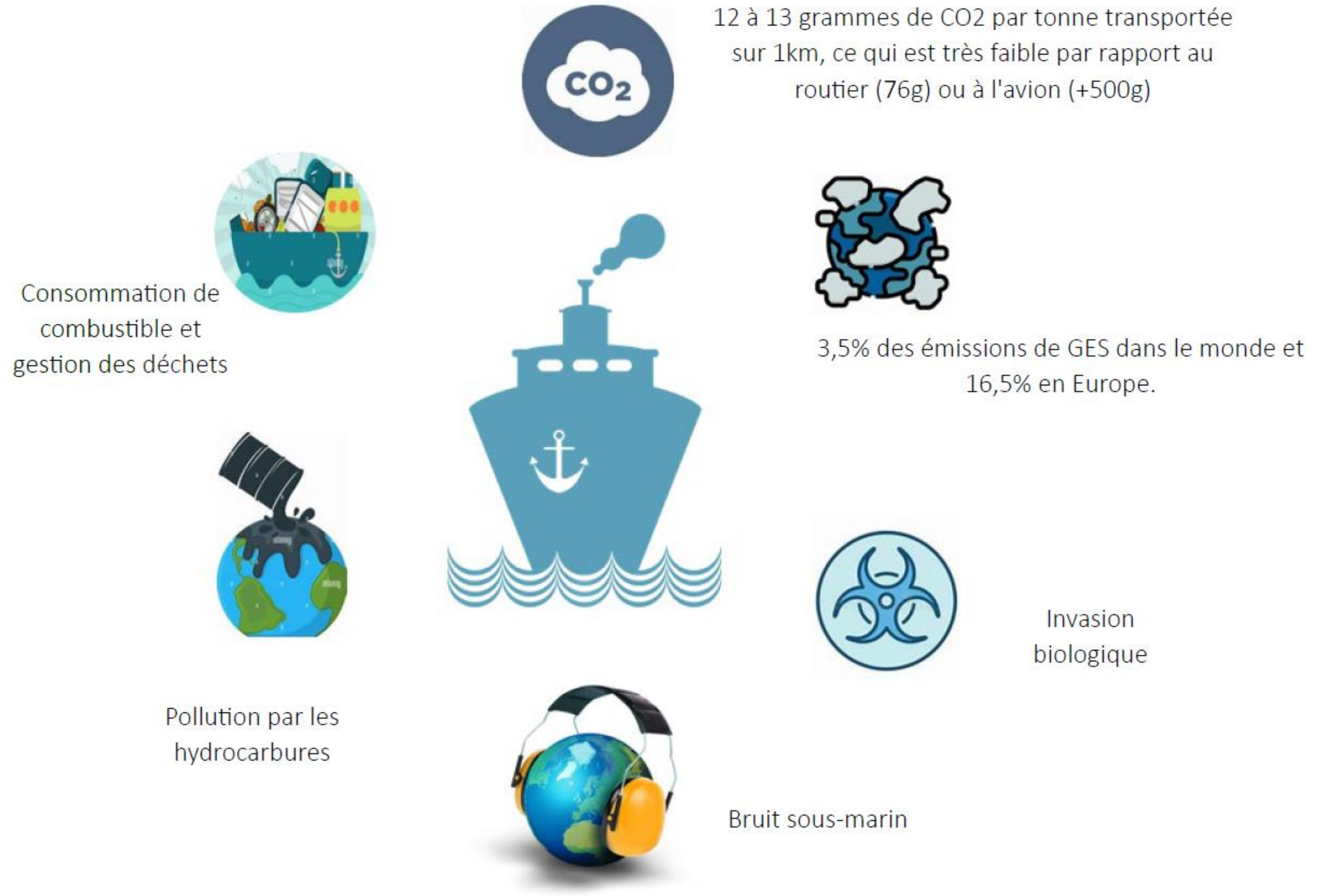
What drives to ENSM today ?


What you can see

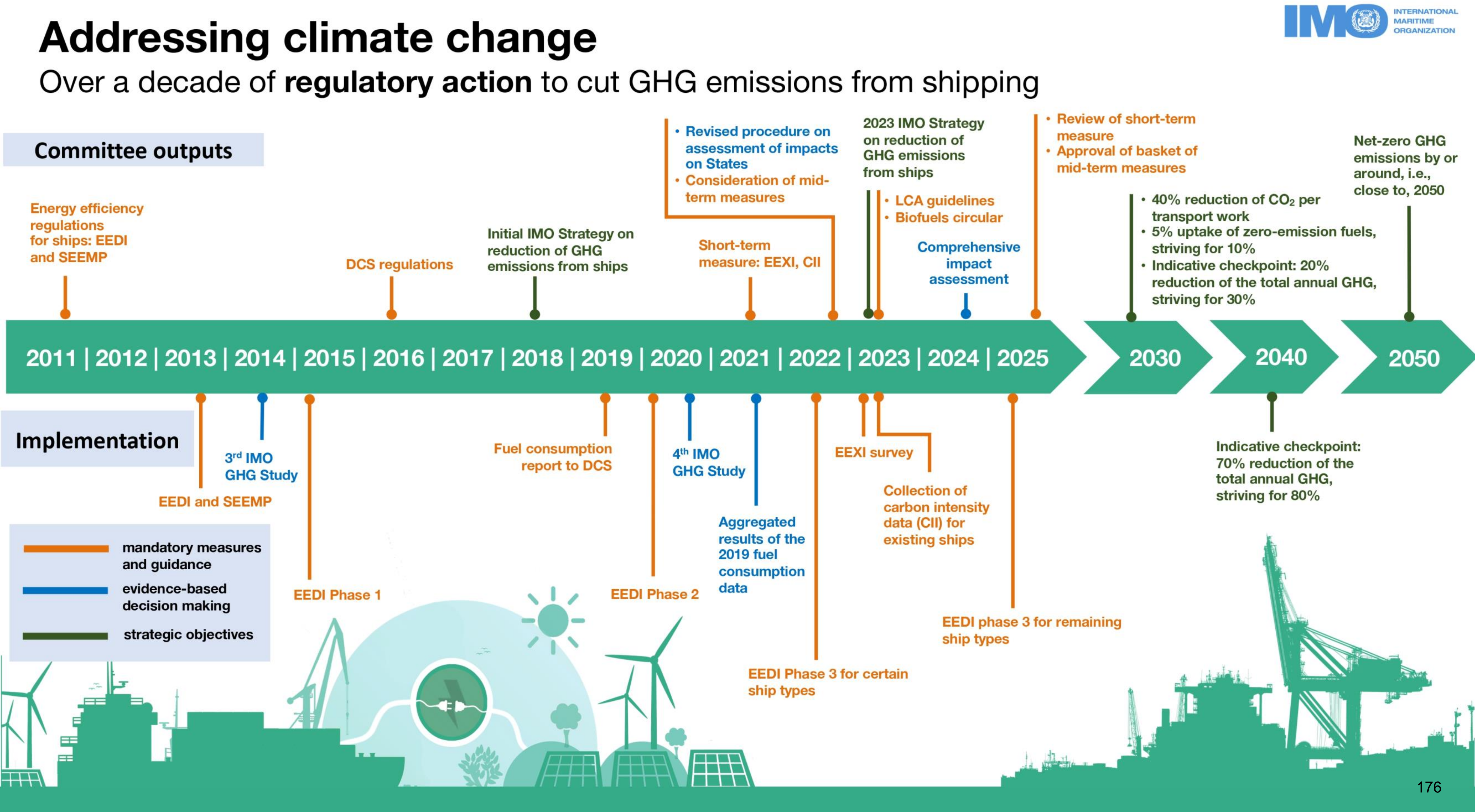
What you can’t see

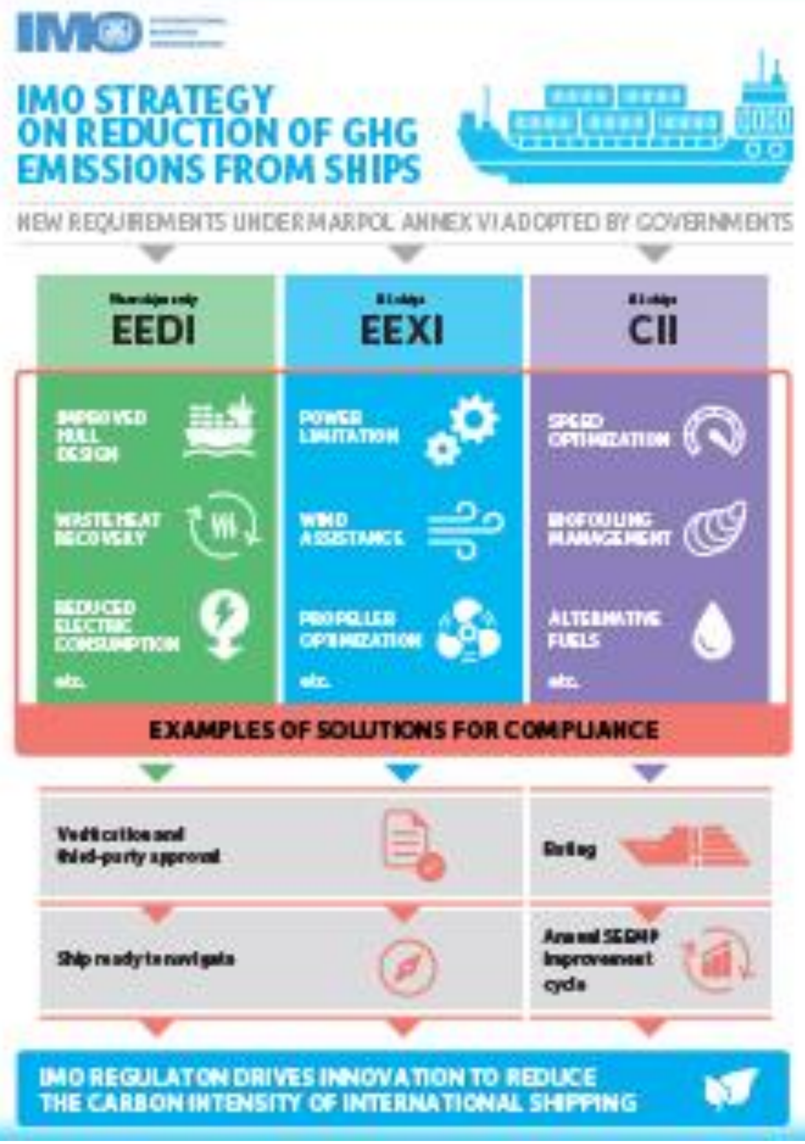
enim
le régime social des marins


12 à 13 grammes de CO2 par tonne transportée sur 1km, ce qui est très faible par rapport au routier (76g) ou à l'avion (+500g)
CO2
Consommation de combustible et gestion des déchets
3,5% des émissions de GES dans le monde et 16,5% en Europe.
Invasion biologique
Pollution par les hydrocarbures
Bruit sous-marin

Addressing climate change

Over a decade of **regulatory action** to cut GHG emissions from shipping




IMO
IMO STRATEGY
ON REDUCTION OF GHG
EMISSIONS FROM SHIPS
NEW REQUIREMENTS UNDER MARPOL ANNEX VI ADOPTED BY GOVERNMENTS
EEDI
EEXI
CII
IMPROVED HULL DESIGN
WASTE HEAT RECOVERY
REDUCED ELECTRIC CONSUMPTION
etc.
POWER LIMITATION
WIND ASSISTANCE
PROPELLER OPTIMIZATION
etc.
SPEED OPTIMIZATION
BIOFOULING MANAGEMENT
ALTERNATIVE FUELS
etc.
EXAMPLES OF SOLUTIONS FOR COMPLIANCE
Verification and third-party approval
Rating
Ship ready to navigate
Annual SEEMP improvement cycle
IMO REGULATON DRIVES INNOVATION TO REDUCE
THE CARBON INTENSITY OF INTERNATIONAL SHIPPING

Improving energy efficiency to reduce consumption and greenhouse gas emissions

-Optimizing ship shape to minimize drag

-Improved equipment: advanced navigation system

-Optimizing all energy consumed on board

Eco-design of ships: manufacturing processes and end-of-life management

Energy and infrastructure

Less carbon-intensive fossil fuels (LNG)

-Biofuels

-E-fuels (synthetic fuels made from decarbonized electricity)

-Hybridization and electrification of ships and ports

-Vehicle propulsion and other renewable energies

What makes that ENSM will keep students?

ENSM ÉCOLE NATIONALE SUPÉRIEURE MARITIME

- AXE 1 -

ENSEIGNER LA MER DE TOUTES NOS FORCES

CONTRAT D'OBJECTIFS & DE PERFORMANCE
2023-2027

- AXE 2 -

NATIONALISER LA FORMATION SUPÉRIEURE MARITIME

CONTRAT D'OBJECTIFS & DE PERFORMANCE
2023-2027

- AXE 3 -

SOUTENIR L'ÉCONOMIE DE LA MER

CONTRAT D'OBJECTIFS & DE PERFORMANCE
2023-2027

- AXE 4 -

MARITIMISER LES ESPRITS ET DÉVELOPPER LE SENS MARIN

CONTRAT D'OBJECTIFS & DE PERFORMANCE
2023-2027

IMO Website

Raising crew awareness in wind propulsion for commercial ships

a first online training to prepare for a safe and optimised operation

©Tom van Oossanen

Wind propulsion is gaining credibility within maritime decarbonisation pathway. Therefore, dedicated crew training is increasingly important to enable pioneering projects and shipping companies that use wind propulsion. So their crew can meet appropriate technical knowledge to safely and sustainably operate wind-assisted and wind-powered vessels.

The French Association Wind Ship, the French Maritime Academy (ENSM) and the company D-ICE Engineering facilitated a fruitful collaboration among Maritime Academy, operators (shipowners, charterers) and equipment manufacturers. Therefore, creating a quickly available and widely accessible training course on wind propulsion for ships.

CINAV CHOISIR LES INDUSTRIES DE LA MER · Wind Ship association · ENSM ÉCOLE NATIONALE SUPÉRIEURE MARITIME · D-ICE ENGINEERING

INVESTIR L'AVENIR

Project 50% funded by French State within the framework of the workforce adaptation and qualification – IFPAI operation – Investment for the Future program by the Caisse des Dépôts

Three question to open discussion

Train

Grow

Convince


Thanks for your attention

BETTER SHIPS, BLUE OCEANS

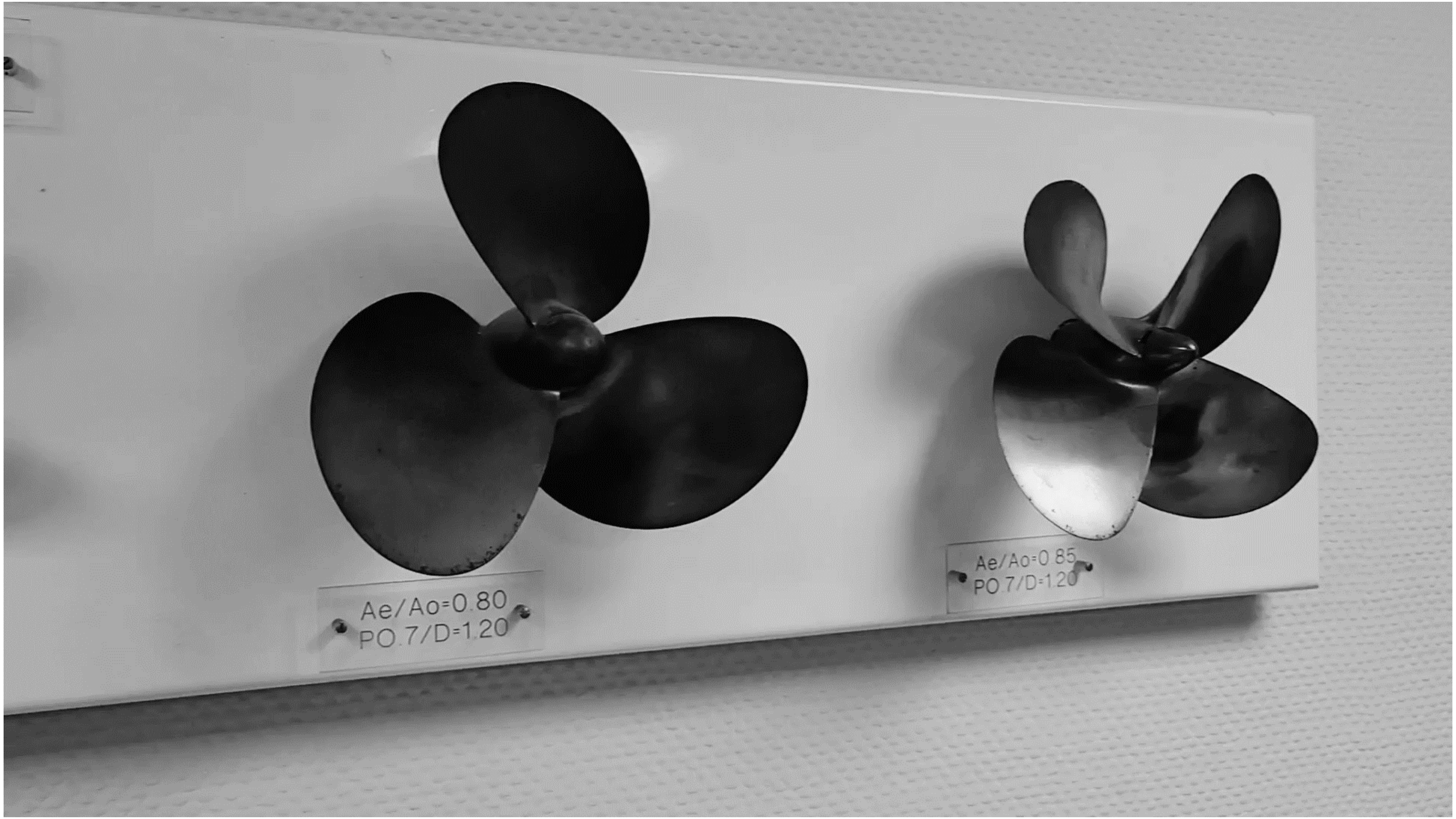
A Crew-Centered Operational Approach to Implement Sustainable Technologies in Ship Design

Dr. Bas Buchner (President)

MARIN: Maritime Research Institute Netherlands, Wageningen

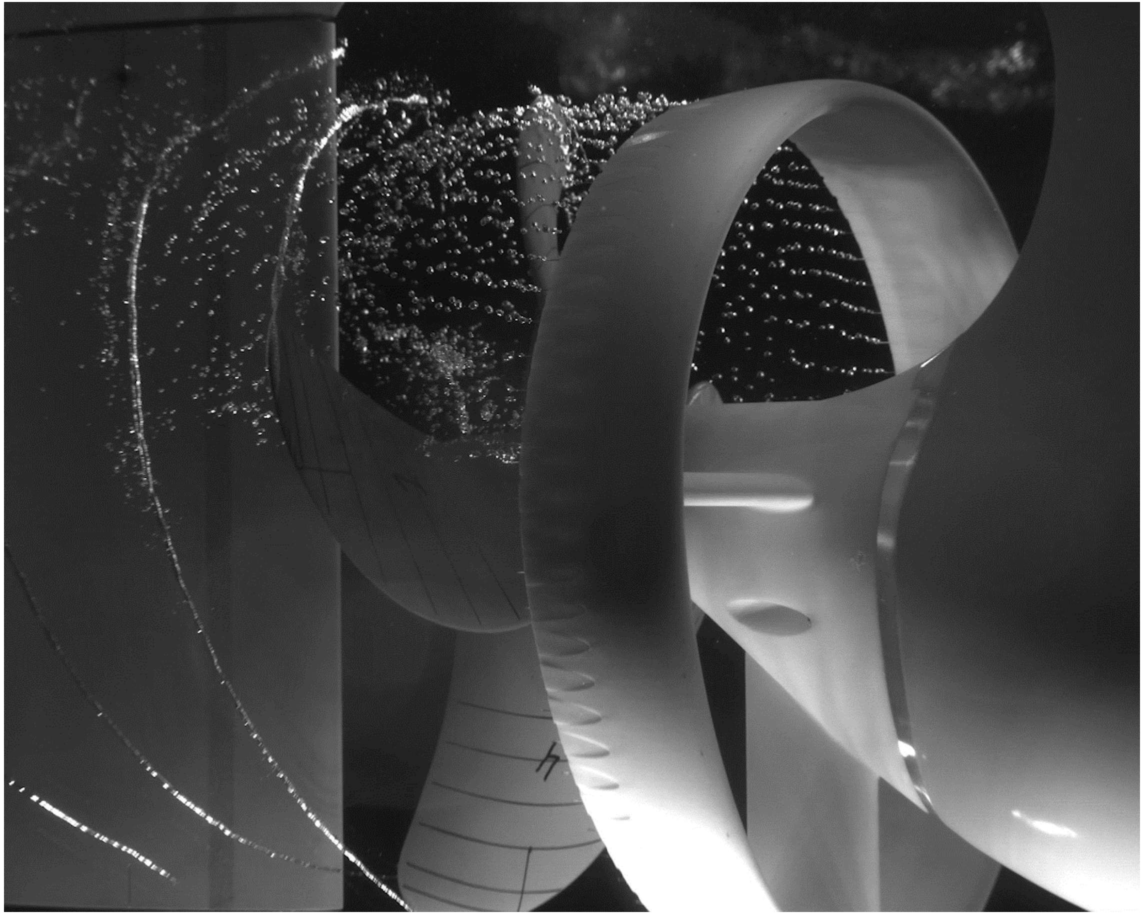
Model tests ocean liner ‘Oranje’ at NSMB/MARIN in 1937

Wageningen B-series propellers

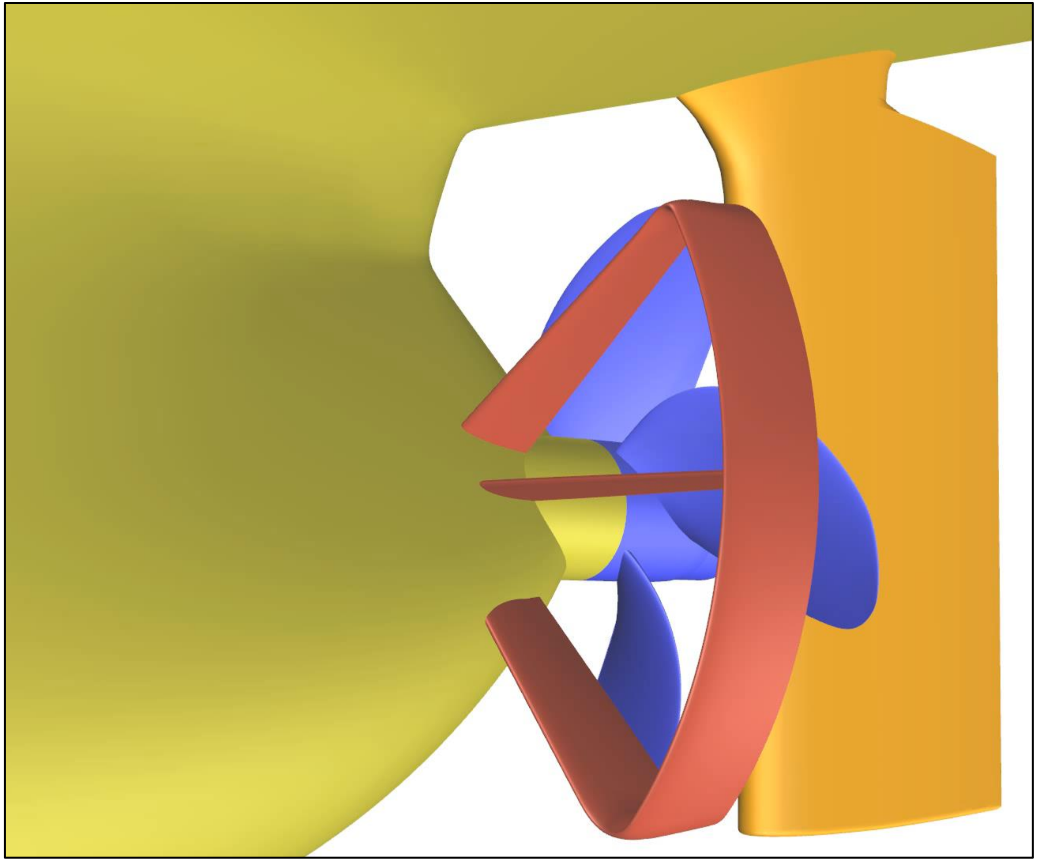


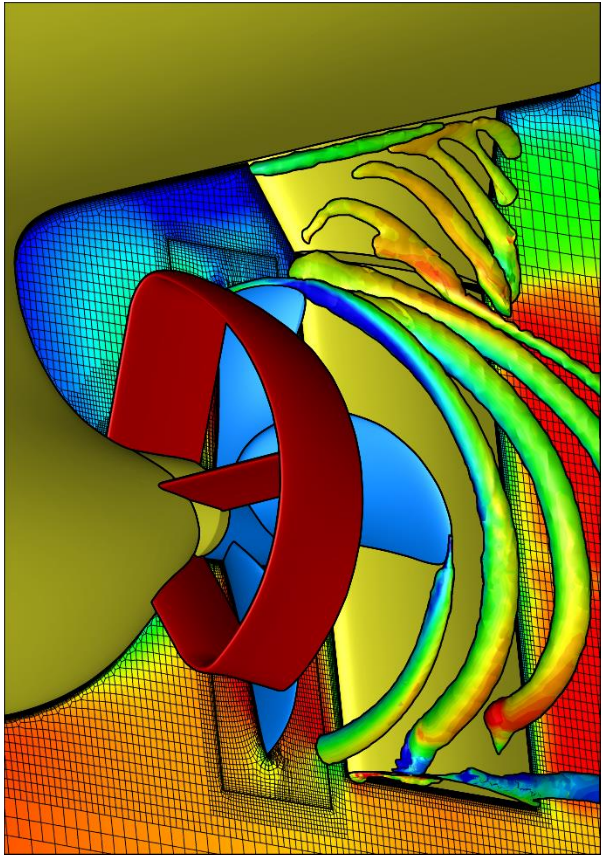
Wageningen F-series propellers (updated B-series)

Cavitation reduction by air bubbles injection (SATURN)

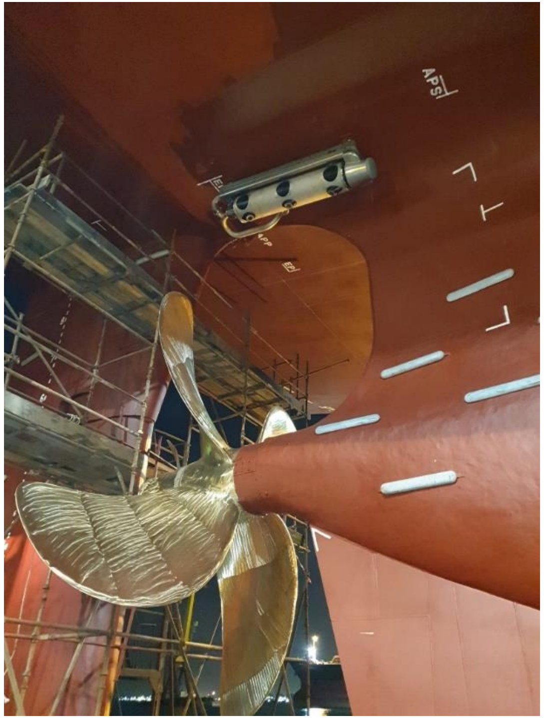


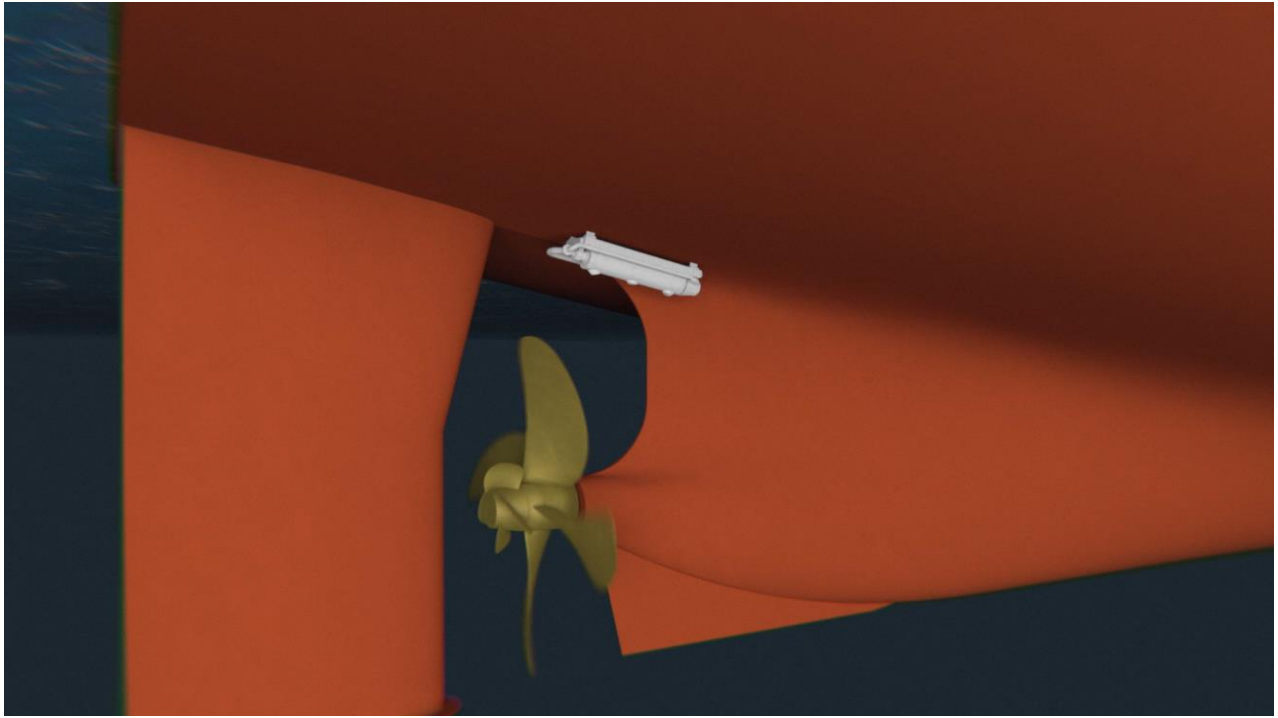
Multi-objective optimization of Energy Saving Devices (CFD)





‘FlowPike’ full scale Particle Image Velocimetry (PIV)

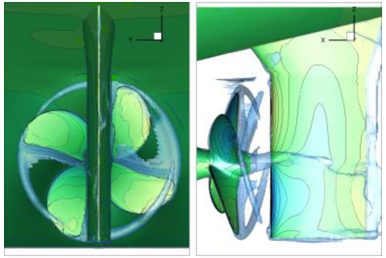




Full scale cavitation observation

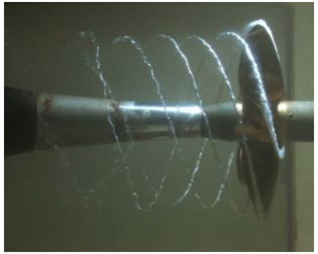
From Design to Operation with all our tools

CONCEPT ⟷ DESIGN ⟷ OPERATION



Computations

CFD / Time domain



Model tests

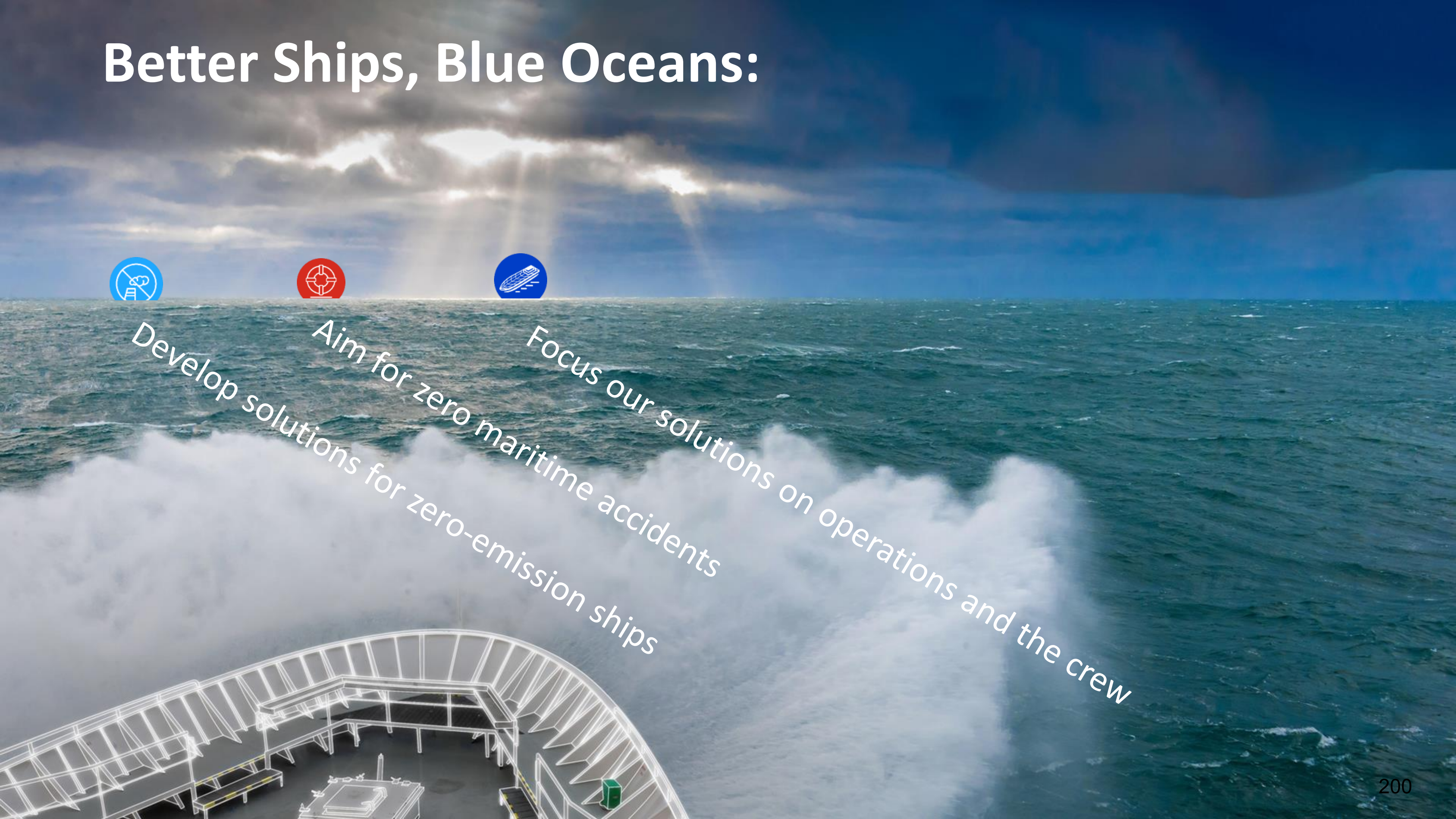
Scaled reality

Monitoring

Data science


MARIN
BETTER SHIPS BLUE OCEANS
Beyond the horizon
MARIN STRATEGY PLAN 2022-2025
Clean, safe and smart shipping,
sustainable and secure use of the seas

Better Ships, Blue Oceans:



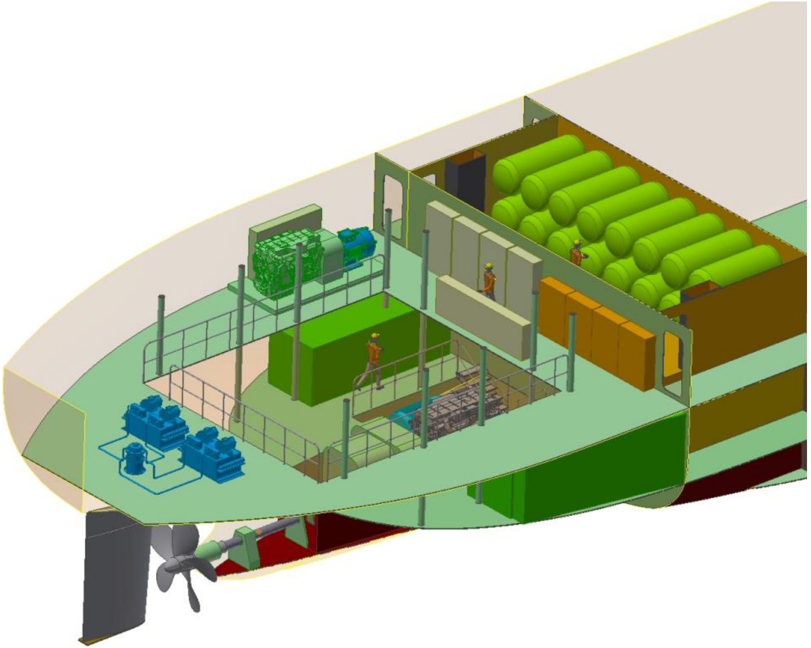
Develop solutions for zero-emission ships

Aim for zero maritime accidents

Focus our solutions on operations and the crew

Use case: Zero emission freighter (hydrogen and wind assist)

Use case: Zero emission freighter (hydrogen and wind assist)

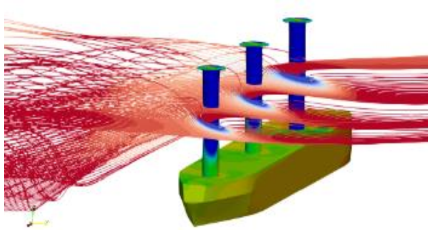


Challenges:

- Aerodynamic efficiency (including interactions)
- Sail control (VPP), crew roles in sail handling, route optimization
- Hydrodynamic design (slightly drifting, propeller inflow)
- Seakeeping and stability in heavy weather
- Course keeping and maneuvering (busy traffic, ports, channels)
- Hydrogen availability, bunkering and safety
- Hybrid power train dynamics and responsivity (compare to diesel)
- Optimization wind and hydrogen propulsion (energy management)
- Crew training for new complex systems

Wind Propulsion from Concept to Operation

CONCEPT ⟷ DESIGN ⟷ OPERATION



Simulation

Computer

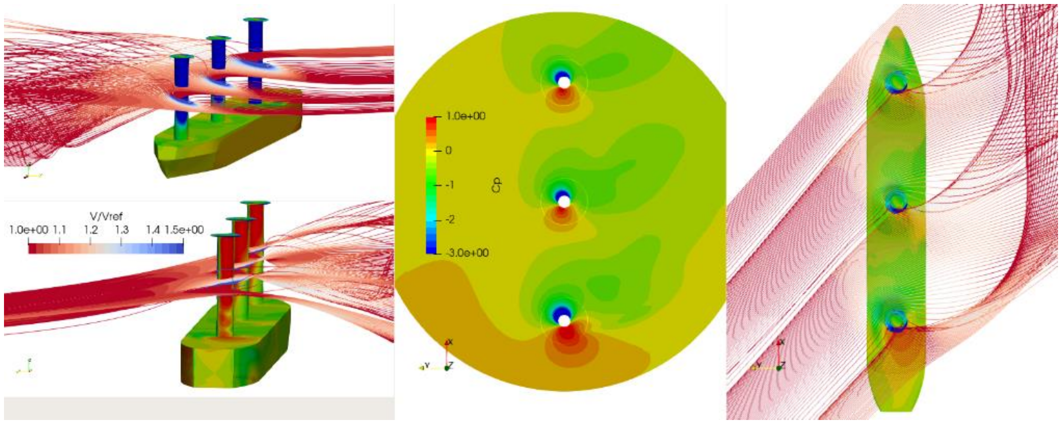
Modeltests

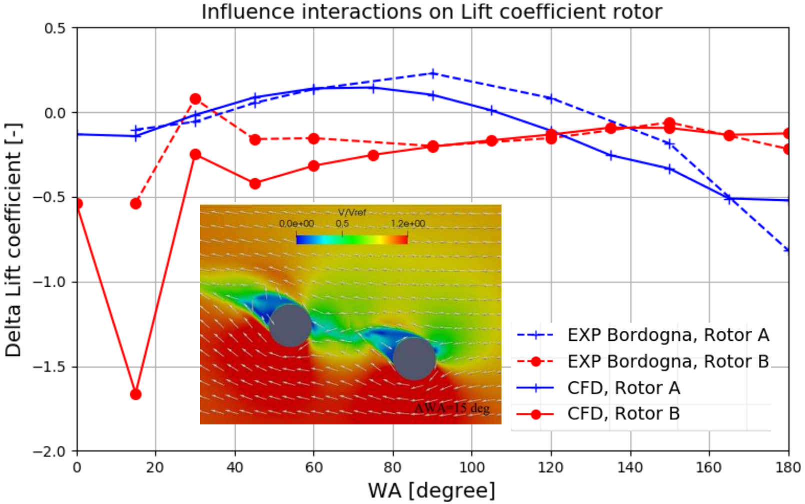
Prototype

Monitoring

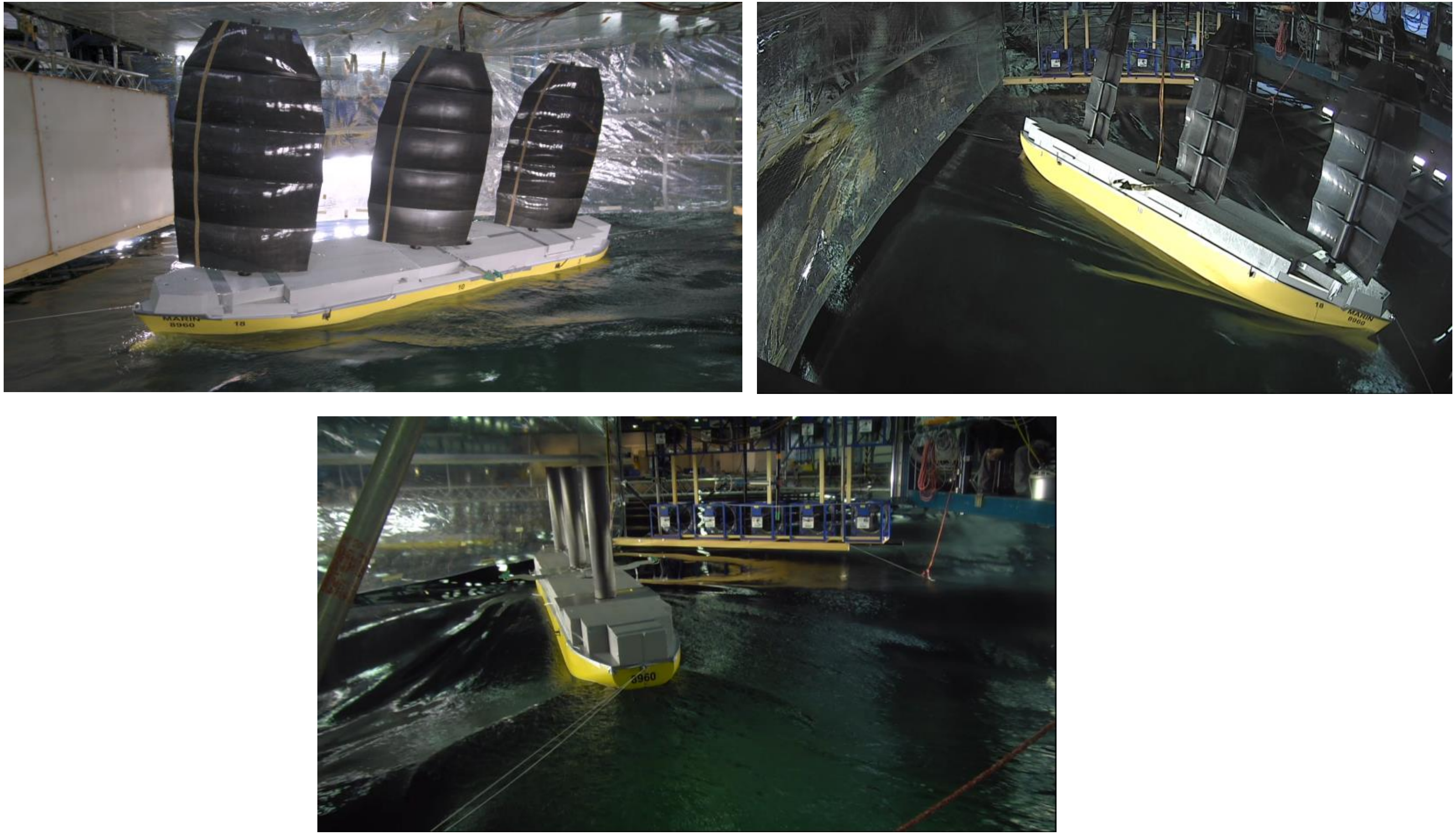
Big data / AI

CFD: Hydro/Areodynamics and Interaction effects





Seakeeping, course keeping and maneuvering



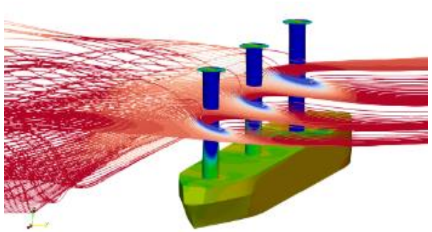
Dynarigs and Flettner rotors

Wind (Assisted Ship) Propulsion at Sea

Instrumented suction sails with lidar measurement of the wind field

Wind Propulsion from Concept to Operation

CONCEPT ⟷ DESIGN ⟷ OPERATION



Simulation

Computer

Modeltests

Prototype

Monitoring

Big data / AI

Enough for these challenges?

- Aerodynamic efficiency (including interactions)
- Sail control (VPP), crew roles in sail handling, route optimization
- Hydrodynamic design (slightly drifting, propeller inflow)
- Seakeeping and stability in heavy weather
- Course keeping and maneuvering (busy traffic, ports, channels)
- Hydrogen availability, bunkering and safety
- Hybrid power train dynamics and responsivity (compare to diesel)
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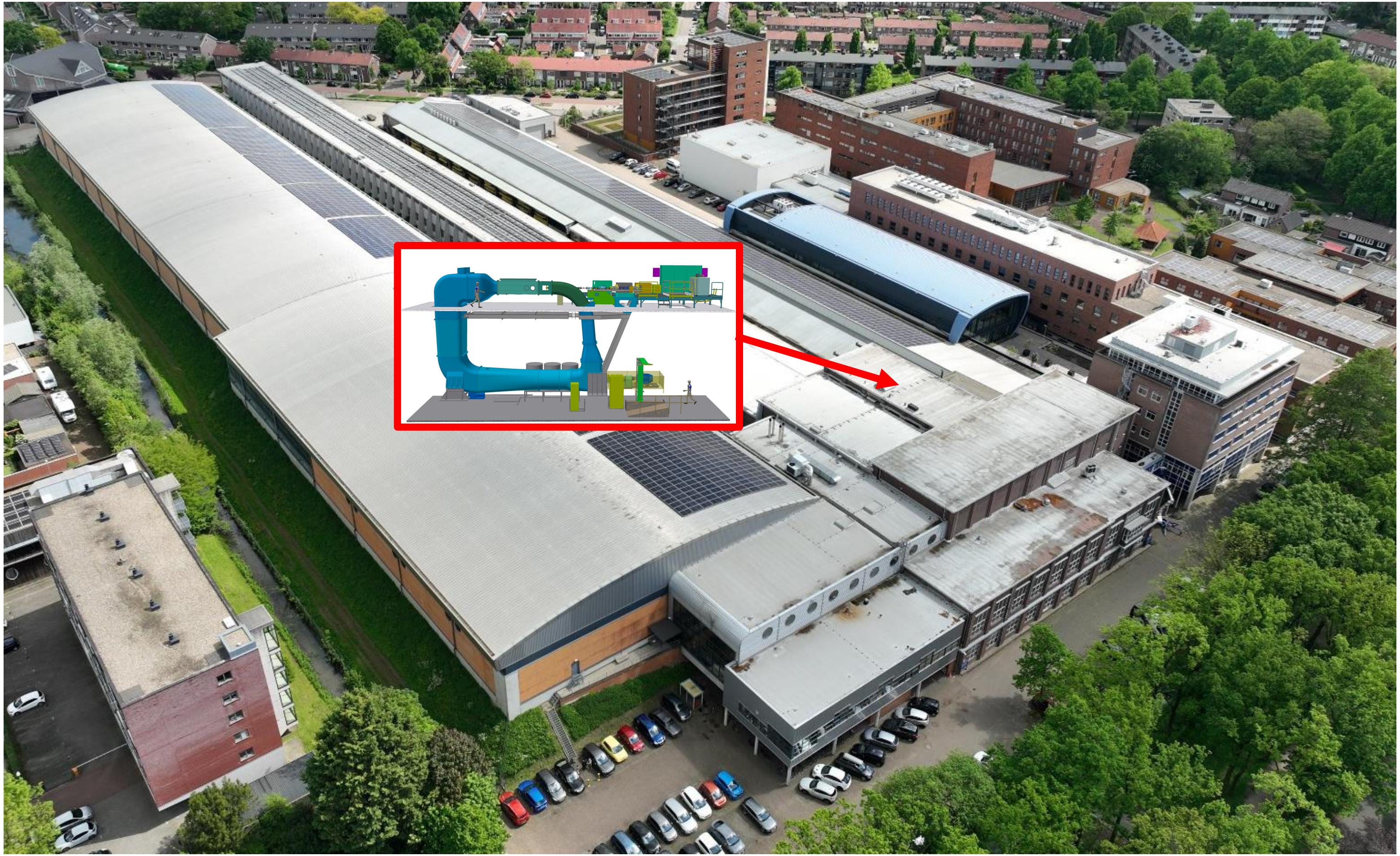
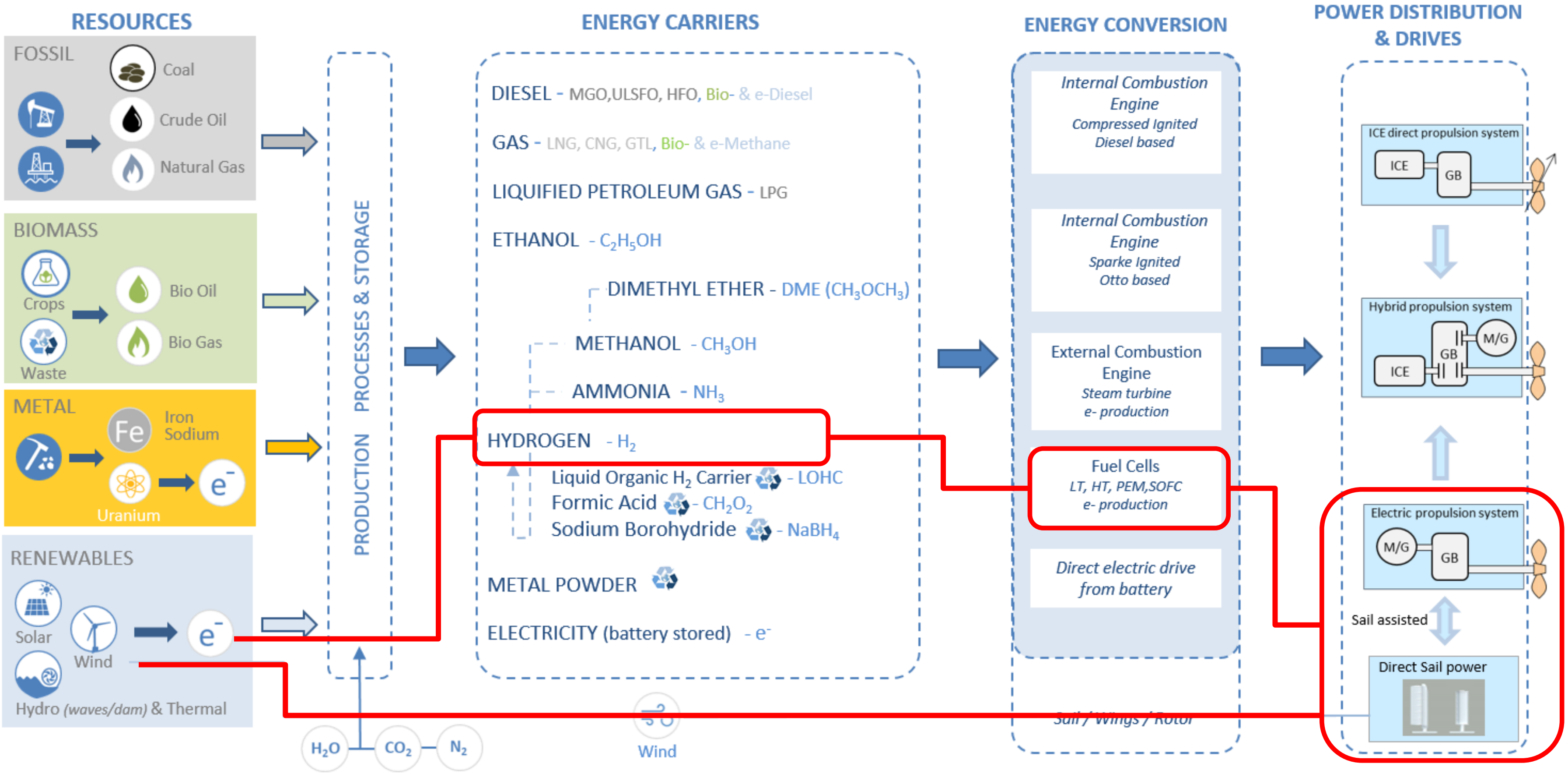
Zero Emission Lab (ZEL): Engine Room of the Future



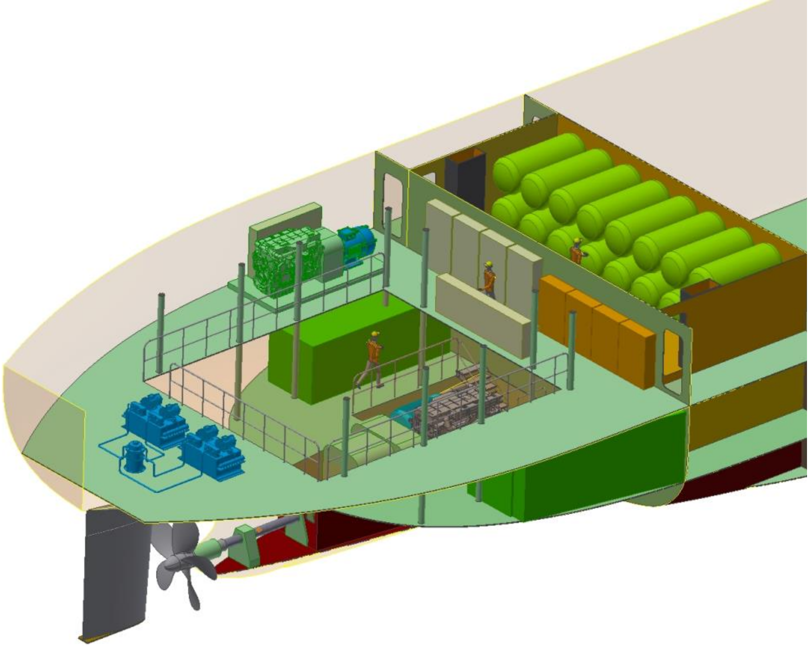
Many combinations possible to power a ship



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

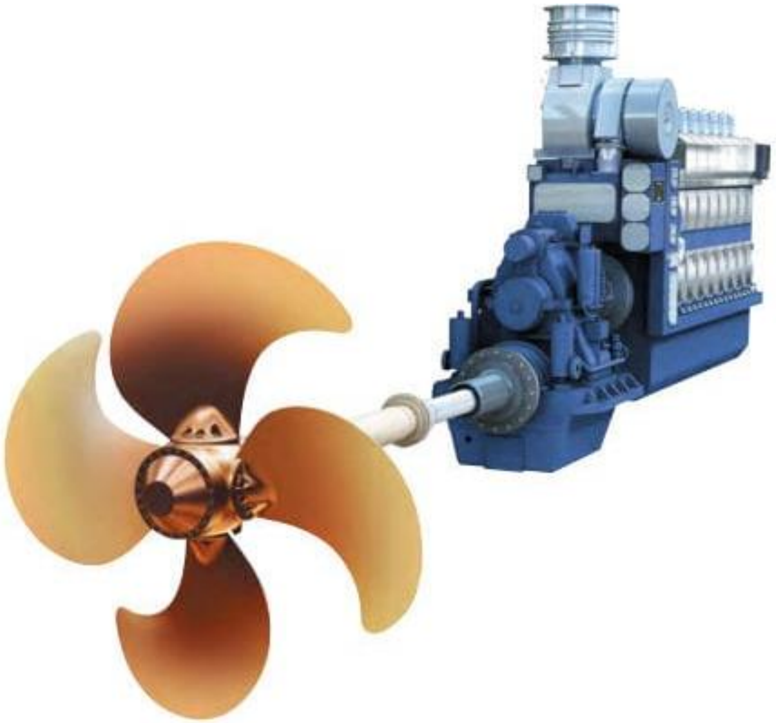
Use case: Zero emission freighter (hydrogen and wind assist)

MARIN

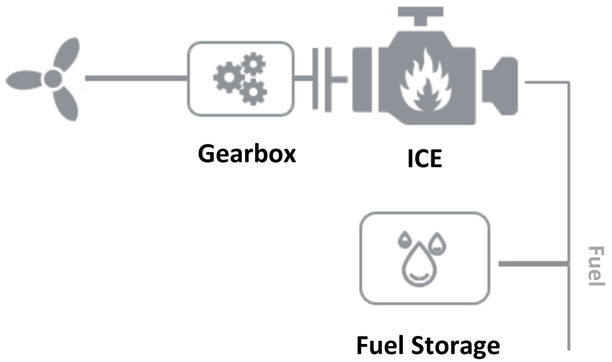


Simple power train: diesel engine, gearbox, propeller

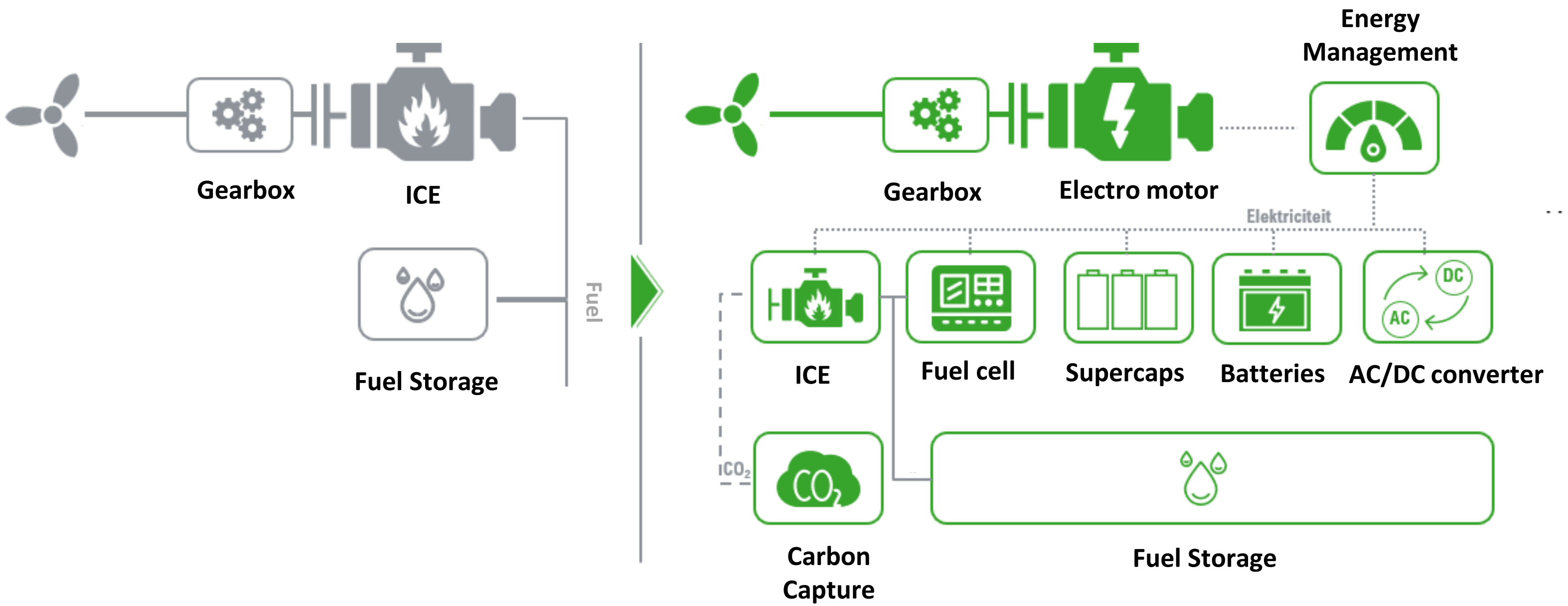
MARIN



Simple power train: diesel engine, gearbox, propeller



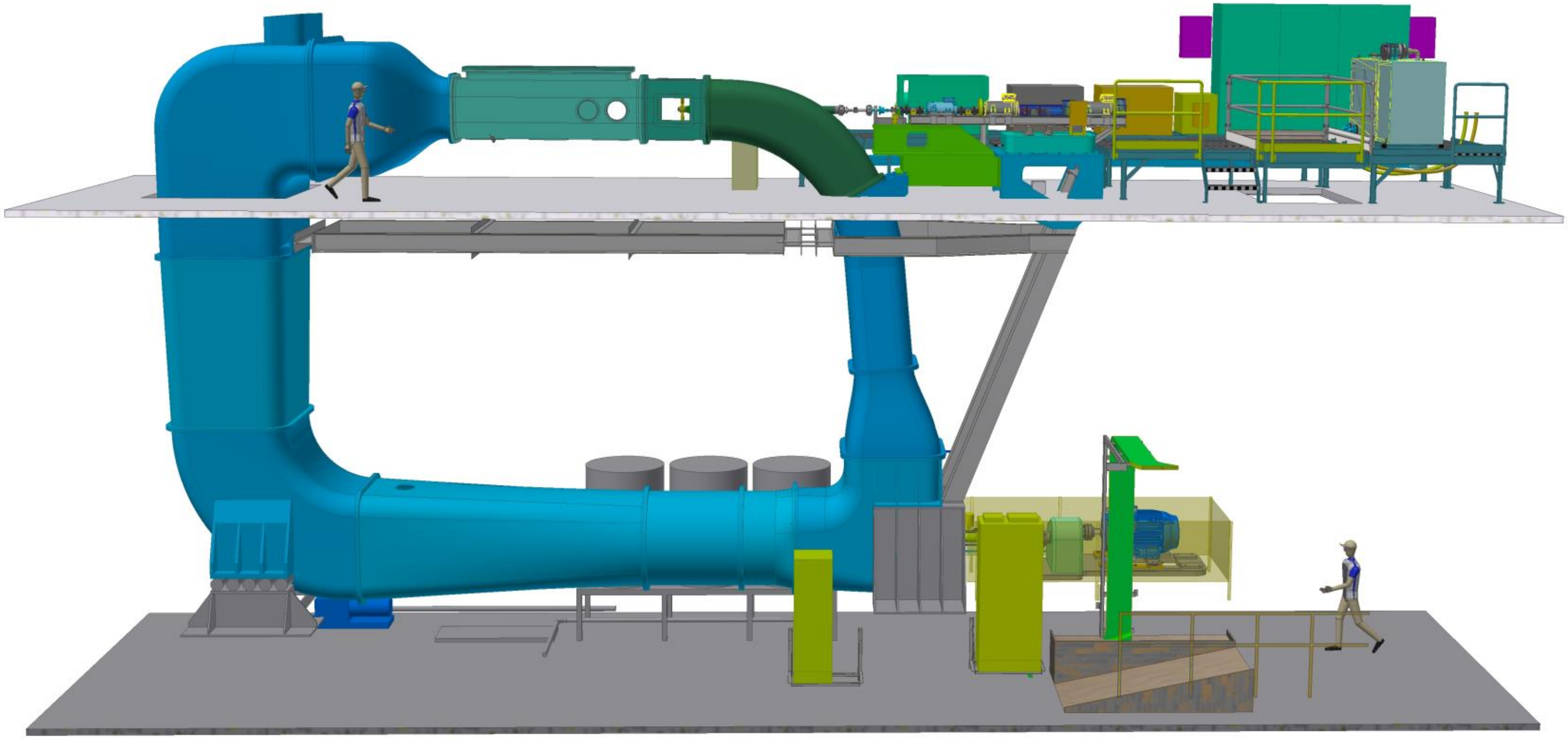
Much more complex zero emission power train



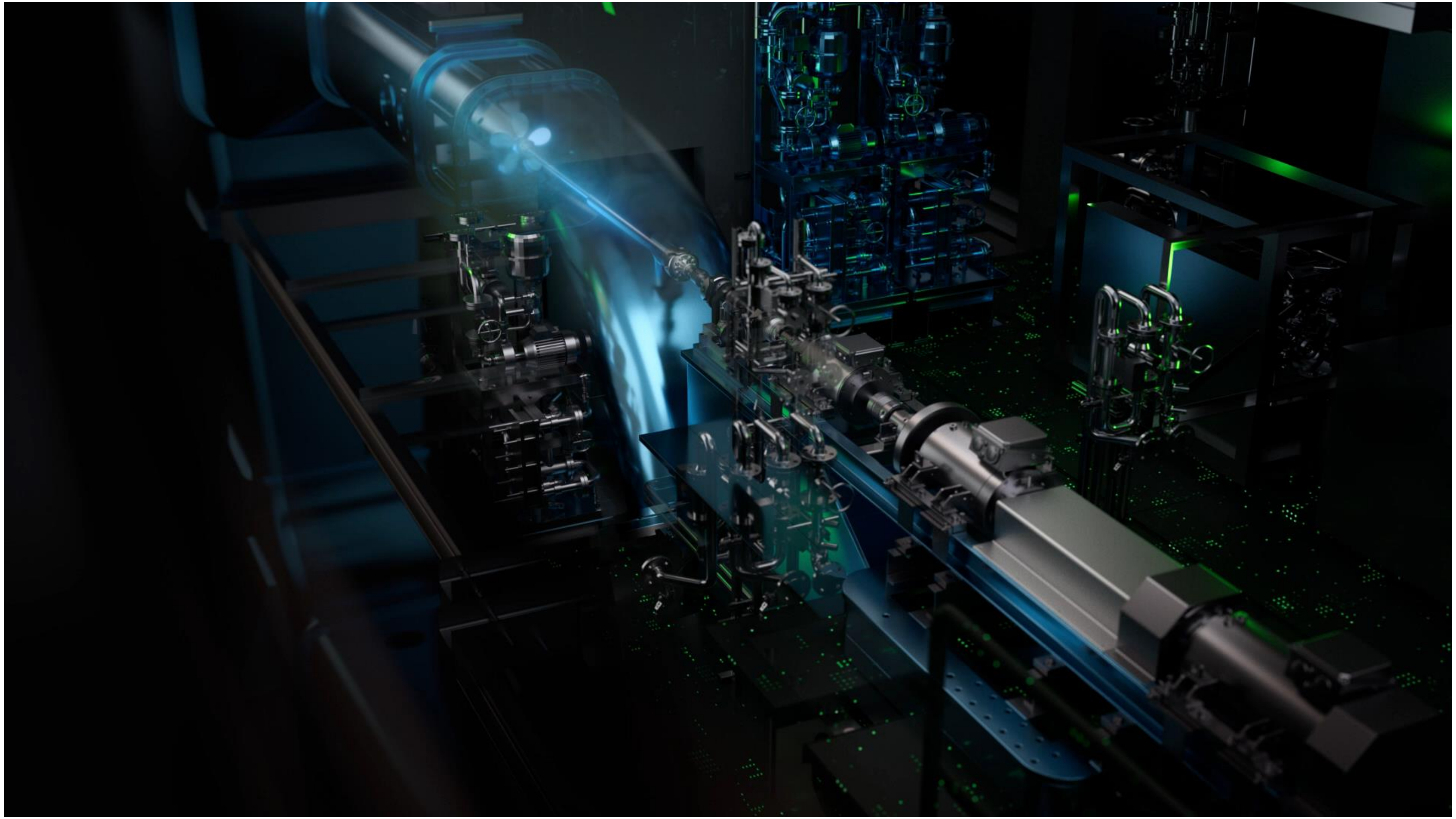
Challenges in Hydro-Systems Integration:

- Hydrogen availability, bunkering and safety
- System complexity and maintenance
- Hybrid power train dynamics and responsivity (compare to diesel):
  - Accelerating
  - Cavitation
  - Maneuvering
  - Seakeeping
  - Ventilation
  - Stopping
- Crew training for new complex systems

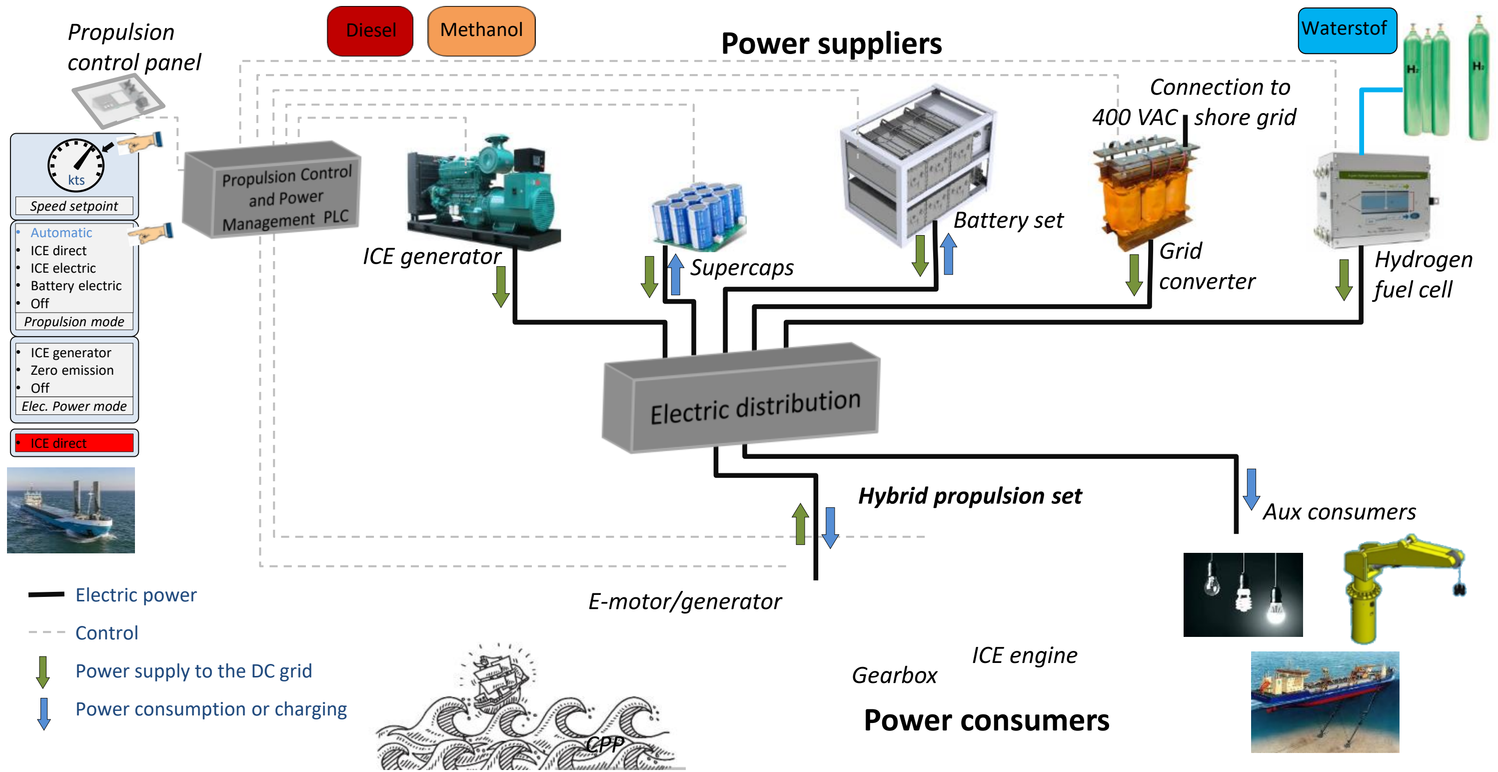
Cavitation tunnel (1939) became Zero Emission Lab (ZEL)



Zero Emission Lab (ZEL): Engine room of the future



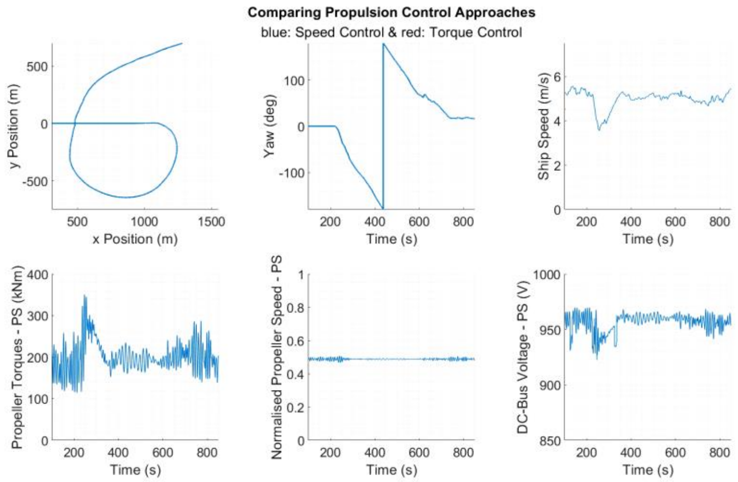
Much more complex zero emission power train

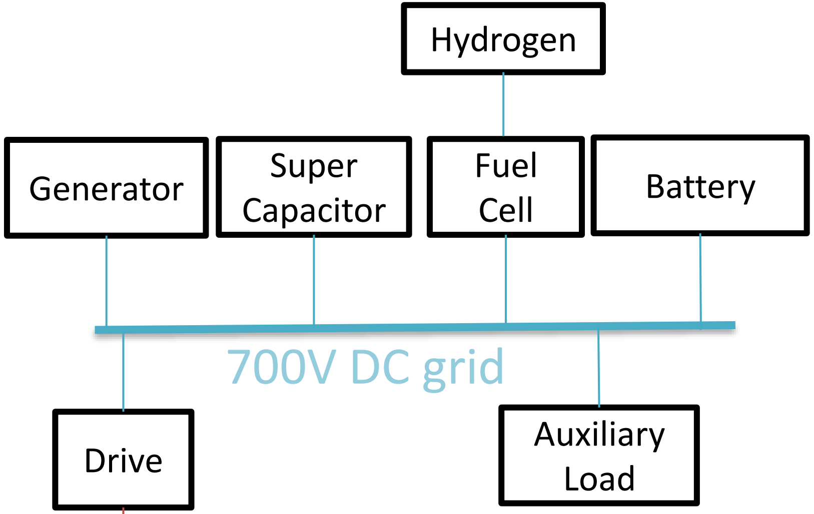


Hydro-systems integration: dynamics of the complete power train

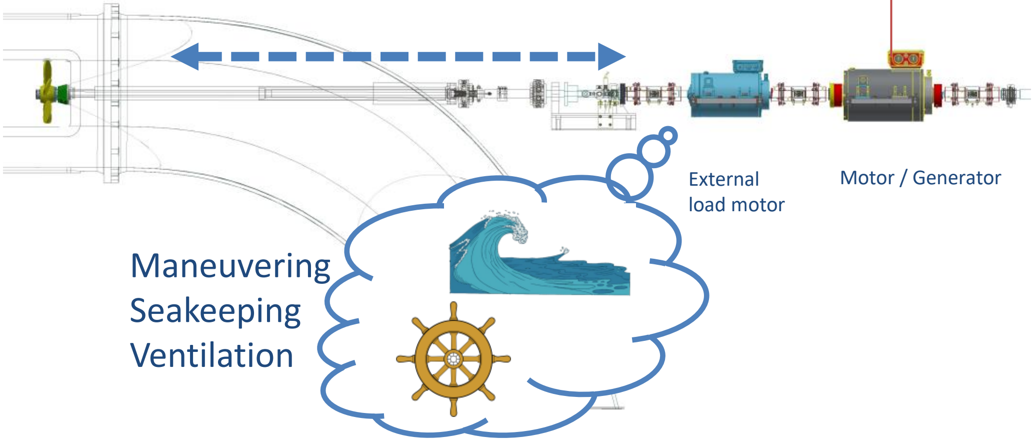
ZEL: Hydro-Systems integration and crew involvement

Hydro-systems integration in dynamic conditions





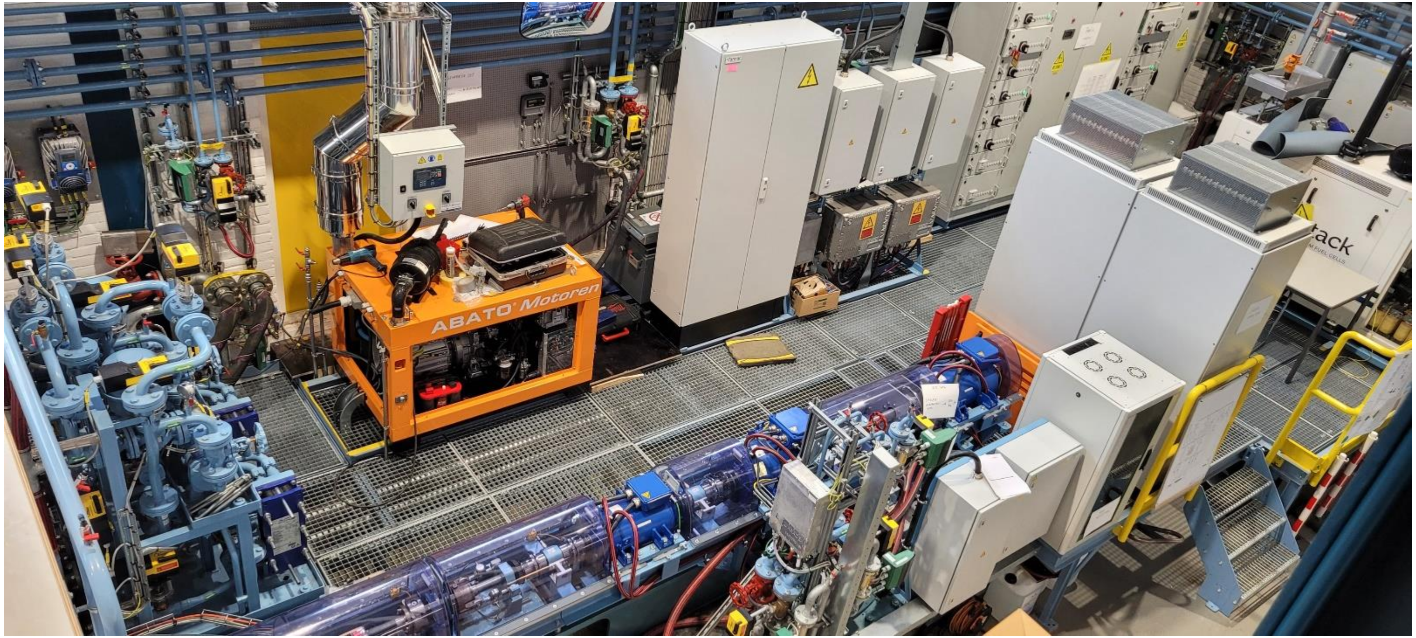
Efficiency
Acceleration
Stopping
Caviation

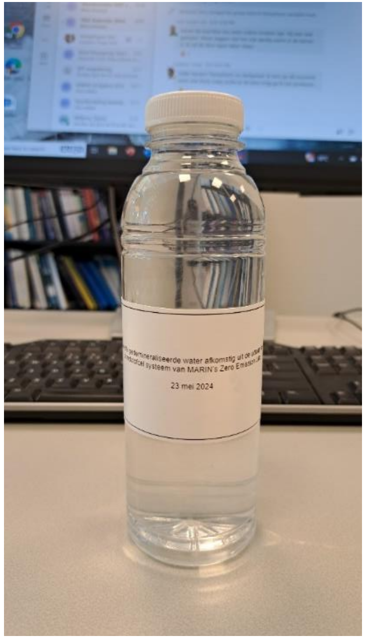


ZEL: Hydro-Systems integration and crew involvement

MARIN

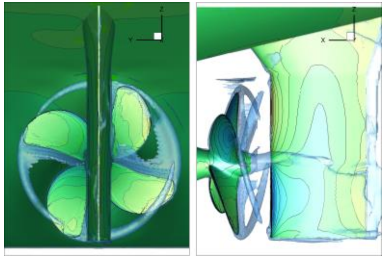
First bottle of clean exhaust from ZEL's fuel cell!





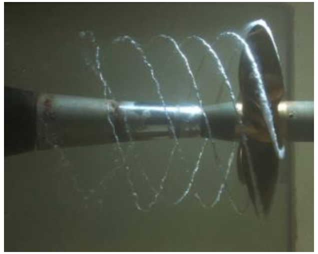
From Design to Operation with all our tools

CONCEPT ⟷ DESIGN ⟷ OPERATION



Computations

CFD / Time domain



Model tests

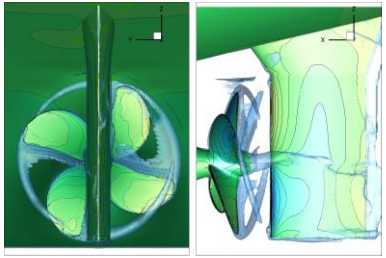
Scaled reality

Monitoring

Data science

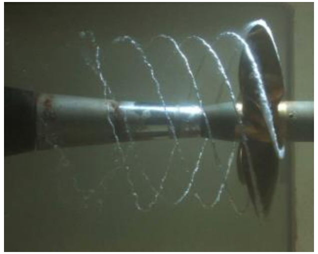
Hydro-systems integration including power train dynamics

CONCEPT ⟷ DESIGN ⟷ OPERATION



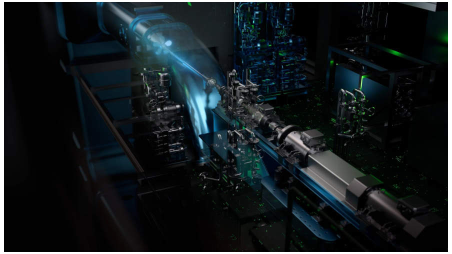
Computations

CFD / Time domain



Model tests

Scaled reality



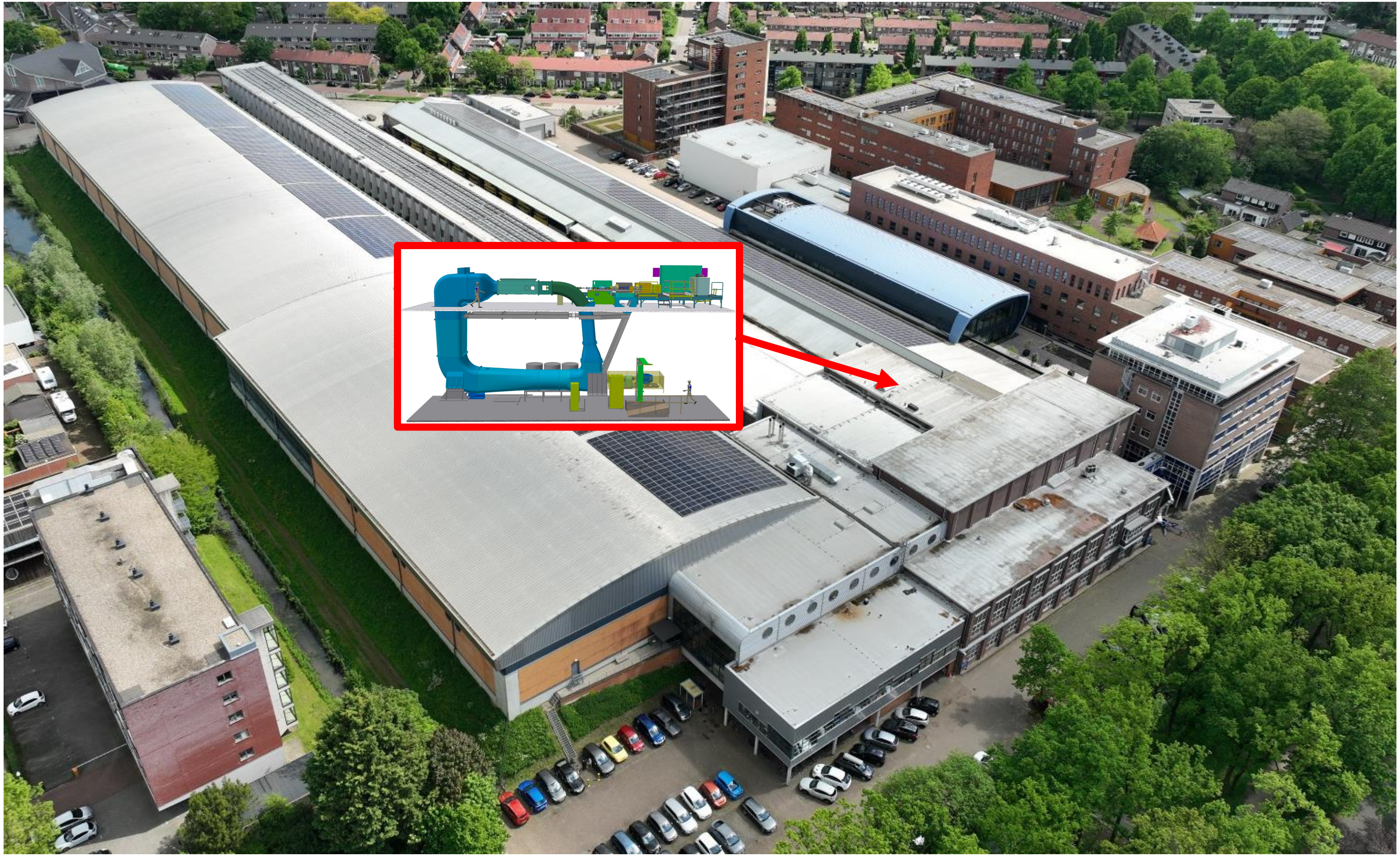
Zero Emission Lab

Power train dynamics

Monitoring

Data science

Zero Emission Lab (ZEL): Engine Room of the Future



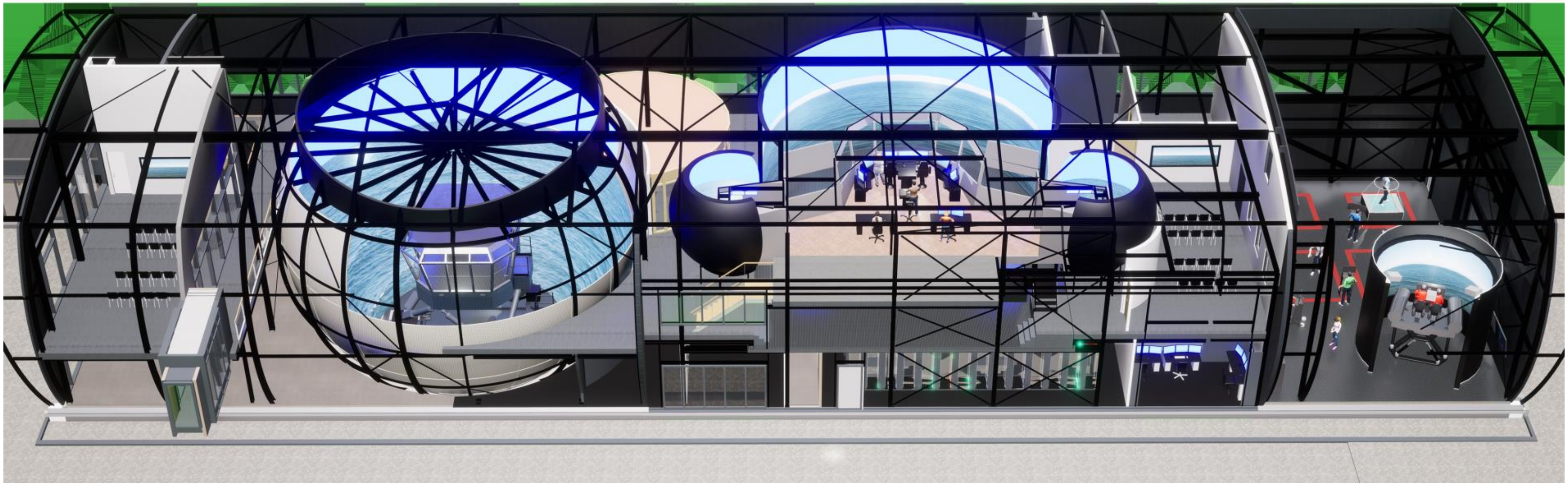
A Crew-Centered Operational Approach…

Seven Oceans Simulator centre (SOSc)

Seven Oceans Simulator centre (SOSc)

Seven Oceans Simulator centre (SOSc)

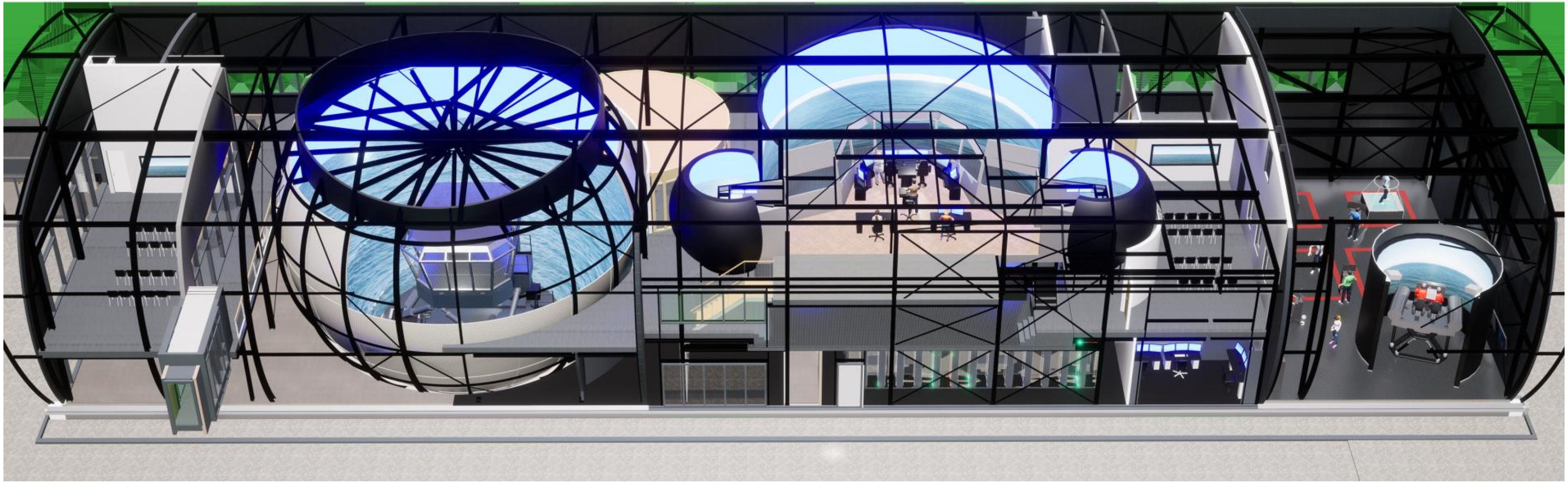
Safe and efficient maritime operations through the most realistic simulations by bringing people and technology together



The SOSc was opened by our King on May 28

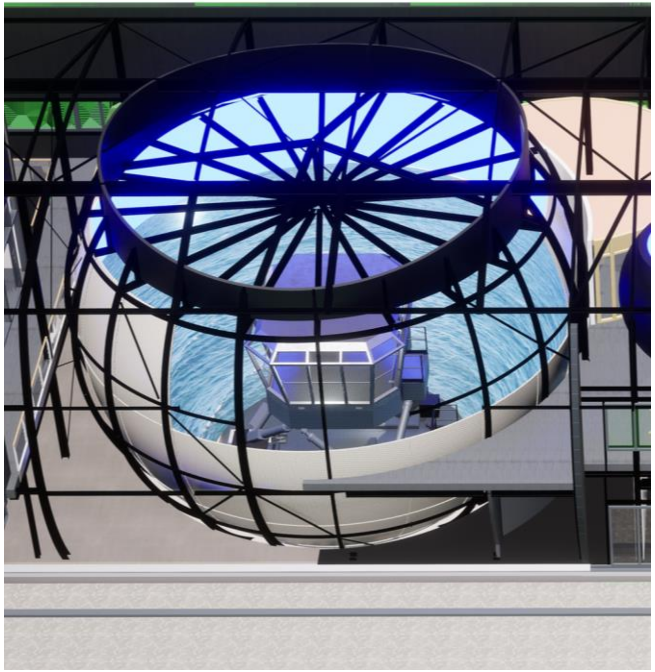
The SOSc was opened by our King on May 28

Large Motion Simulator (LMS)



Large Motion Simulator (LMS): 16 m diameter dome

MARIN

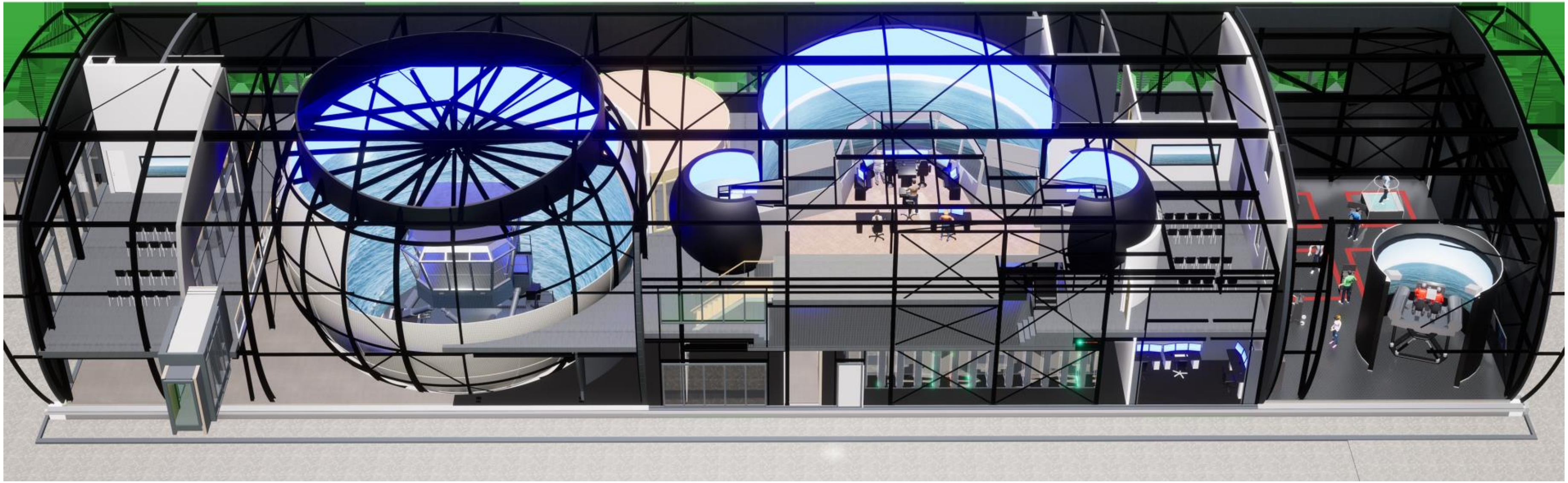


Bridge 4,5 x 5,5 m (14 ton max), 6 degrees of freedom motion

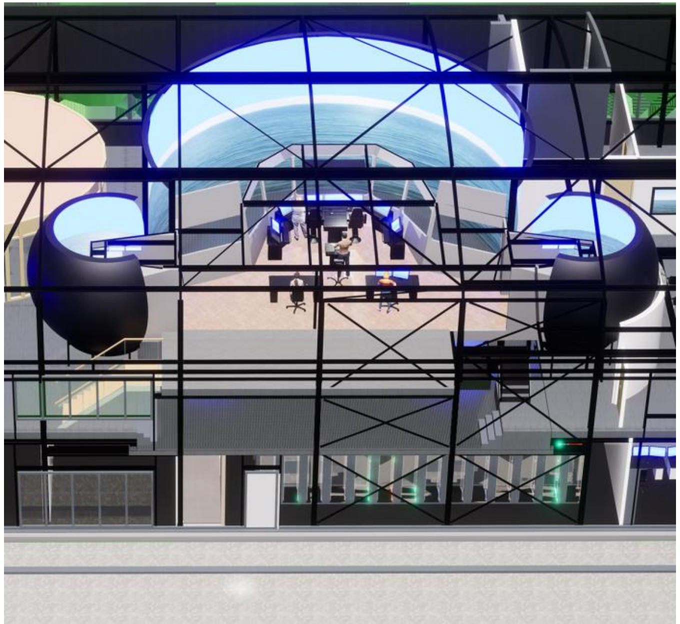
Crew-centered: step on board the ship before it is built

Crew-centered: step on board the ship before it is built

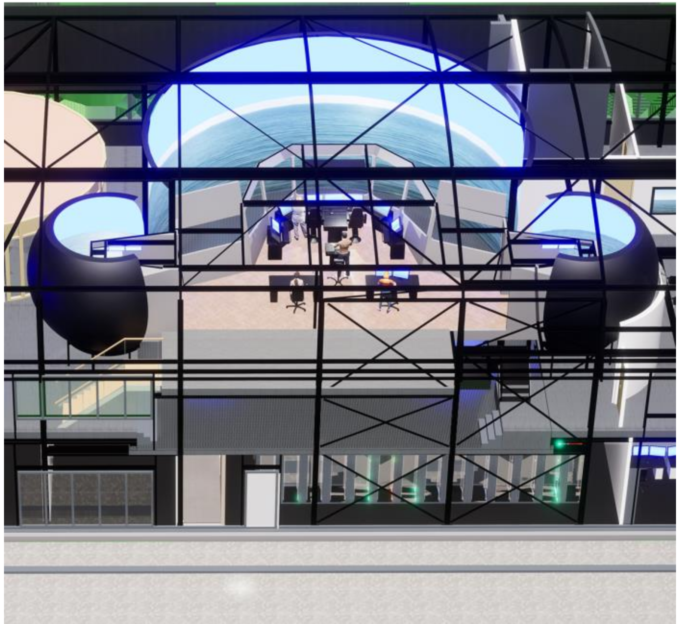
Full Mission Bridge



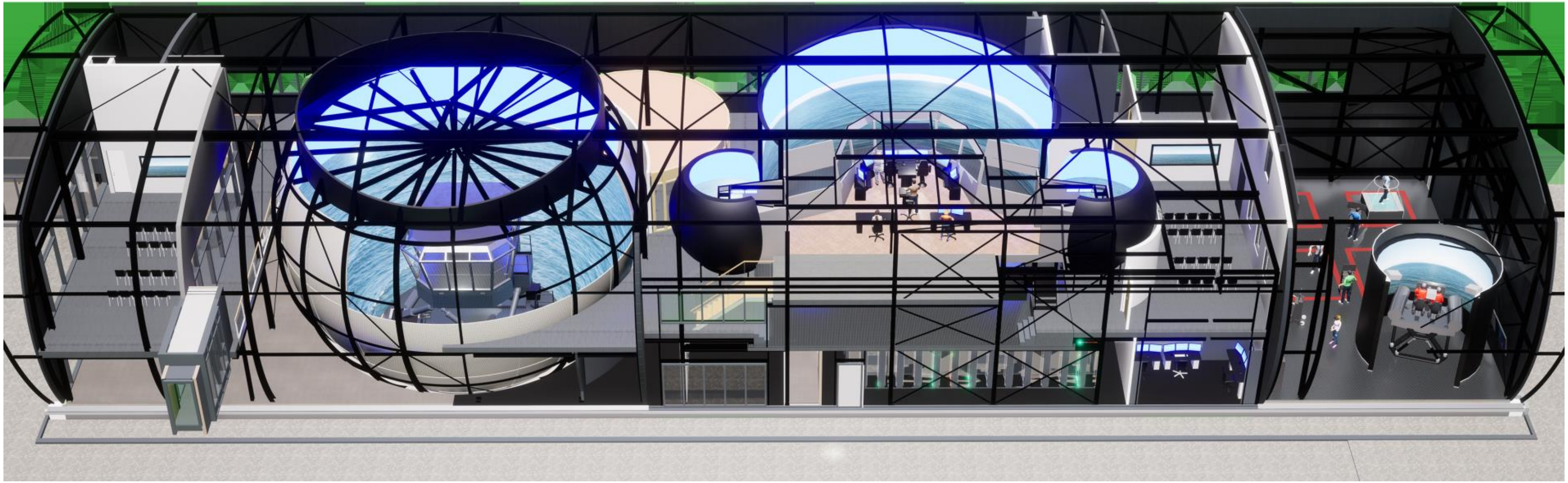
Full Mission Bridge (16 m wide: domes around bridge wings)



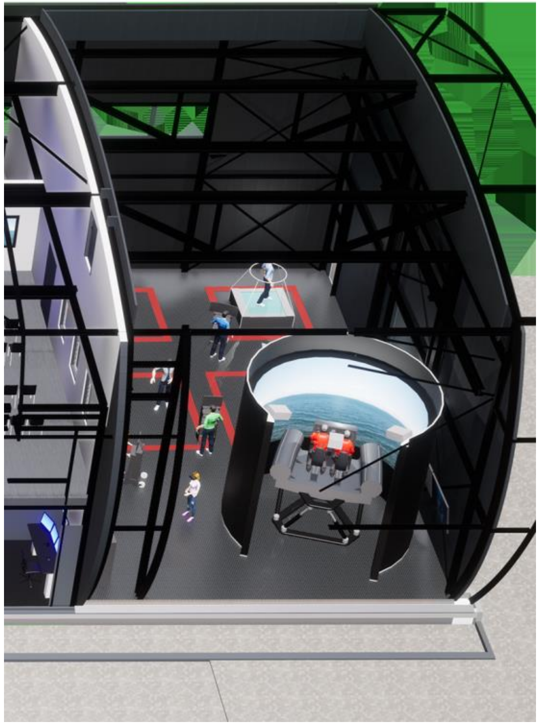
Full Mission Bridge (16 m wide: domes around bridge wings)



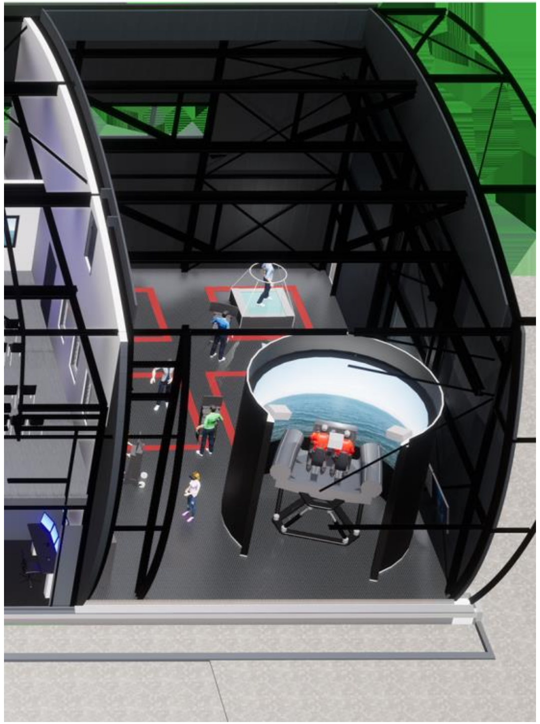
Fast Small Ship Simulator (FSSS)



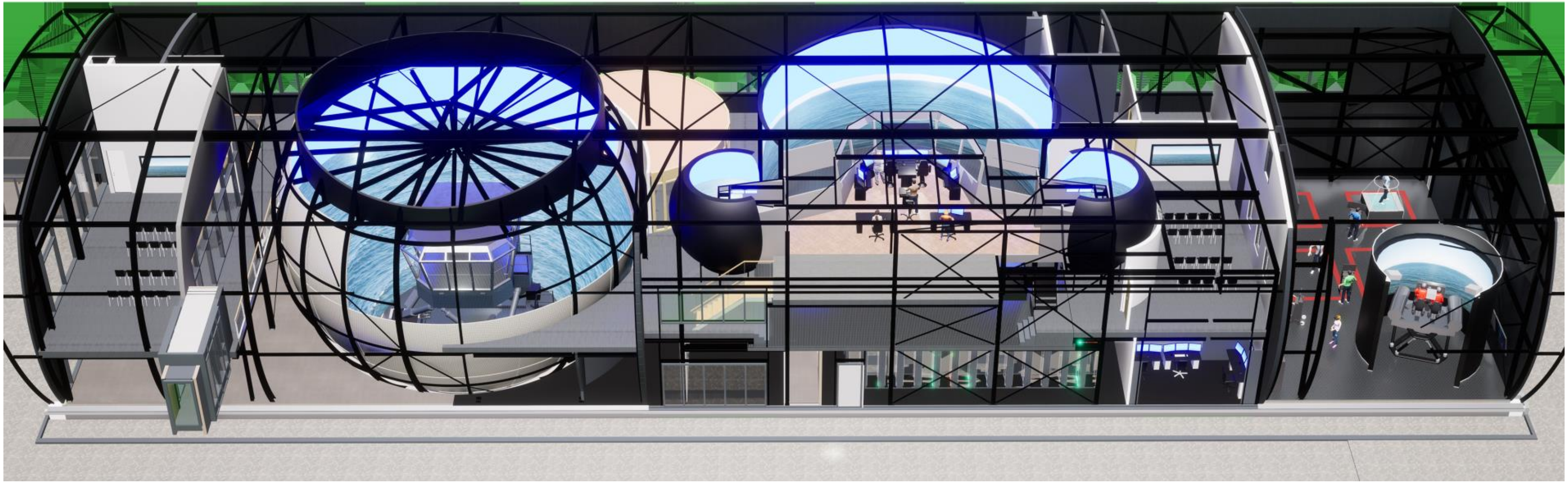
Search and Rescue Boat on Fast Small Ship Simulator (FSSS)



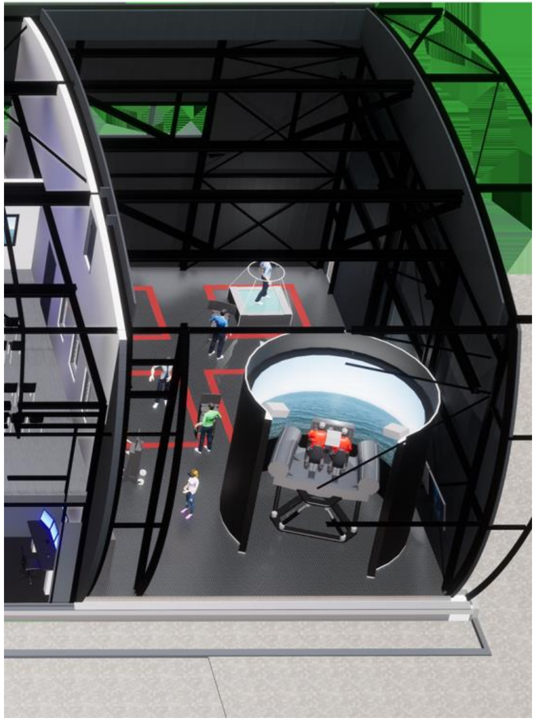
Search and Rescue Boat on Fast Small Ship Simulator (FSSS)



Maritime eXperience Lab (MX Lab): VR/AR & mixed reality



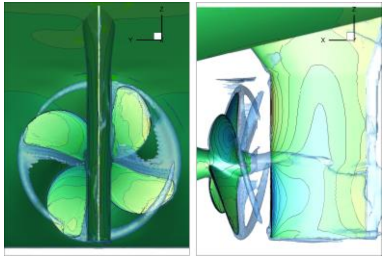
Maritime eXperience Lab (MX Lab): VR/AR & mixed reality



Maritime eXperience Lab (MX Lab): VR/AR & mixed reality

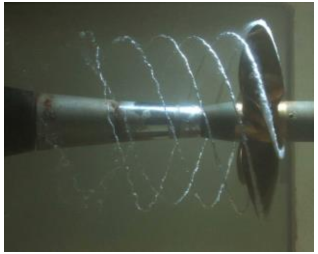
From Design to Operation with all our tools

CONCEPT ⟷ DESIGN ⟷ OPERATION



Computations

CFD / Time domain



Model tests

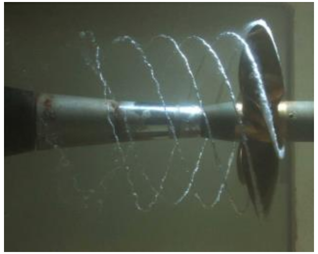
Scaled reality

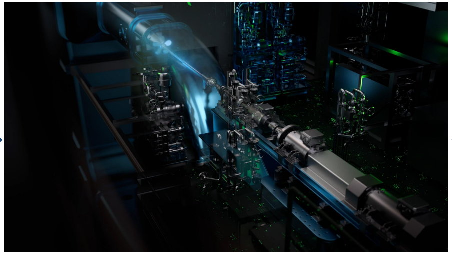
Monitoring

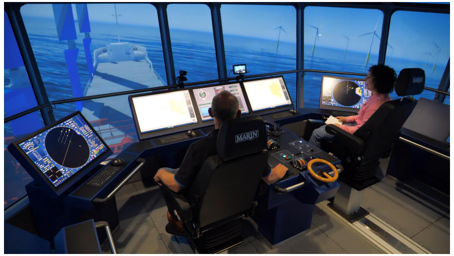
Data science

Crew-centered Operational Ship Design: ZEL & SOSc

CONCEPT ⟷ DESIGN ⟷ OPERATION







Model tests

Scaled reality

Zero Emission Lab

Power train dynamics

Seven Oceans Simulator

Human Factors

Crew-centered: step on board the ship before it is built!

Crew-centered: step on board the ship before it is built!

Crew-centered: step on board the ship before it is built!

A Crew-Centered Operational Approach to Implement Sustainable Technologies in Ship Design

Dr. Bas Buchner (President)

TOWT
TRANSPORT À LA VOILE

CONFÉRENCE DE PRESSE

28 OCTOBRE 2024


TOWT
ANEMOS
SERFRIGO

NOTRE MISSION :

Faire de la filière vélique un incontournable de la scène logistique.

TOWT EN 2024

- 2 navires entrés en opération en aout
- **Anemos et Artemis** : des voiliers-cargos pouvant transporter plus de 1100 tonnes de marchandises par trajet
- Décarbonation à hauteur de **95%**
- Le Label Anemos a été créé pour prouver cette décarbonation

DES NAVIRES HAUTEMENT TECHNOLOGIQUES

Une technologie de voile inspire des courses de voiliers

Système de gréement semi-automatique et entièrement mécanisé

Optimisation de la coque grâce à des études CFD avancées

Hydrogénération optimisée de l'énergie de sillage, grâce à des alternateurs, dynamos et hélices à pas variable

Penons électroniques pour un réglage automatisé du gréement

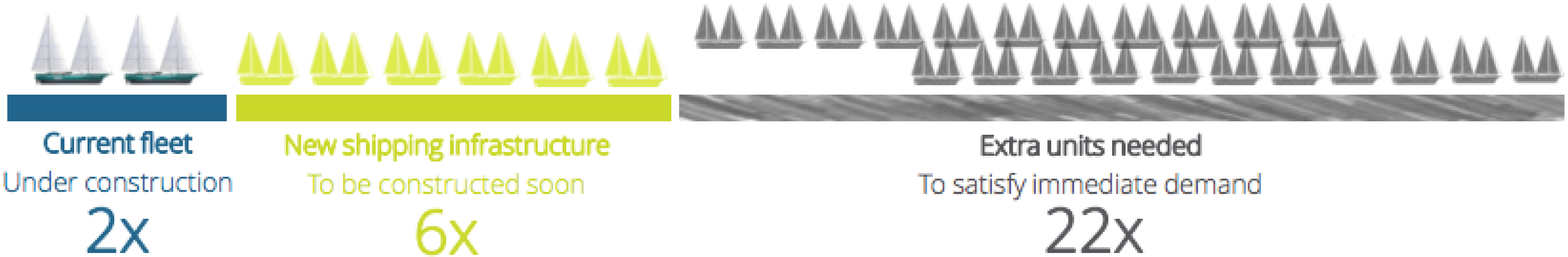
Système unique de dérives retractables et pivotantes

UN VOYAGE INAUGURAL COURONNÉ DE SUCCÈS

- 3 escales : New-York, Santa Marta, Québec
- Le Havre / New-York **en 15 jours**
- Des leads time respectés
- Chargement / déchargement autonome et efficace
- Vitesse moyenne de 10 nœuds (record de vitesse à plus de 16 nœuds battu)

L'AVENIR

- **La plus grande flotte au monde avec 8 navires**
- Construction déjà en cours au Vietnam sur les chantier Piriou
- L'ouverture de nouvelles routes



UN 3e NAVIRE DÉJÀ EN CONSTRUCTION : ATLANTIS

Cérémonie de la pose de la quille au Vietnam

LA PAROLE À NOS PARTENAIRES :

Martell Mumm Perrier-Jouët
Pernod Ricard

BELCO
WHERE SOURCING MAKES SENSE

NEOLINE

Presentation Neoline

Wind powered cargo ship

Our vision

INDUSTRIAL
COMPETITIVE
ZERO EMISSION

Neoliner 136m roro

Capacity of 1200 ml or 400 cars or 5300 tons

80% to 90% of consumption reduction

NEOLINE

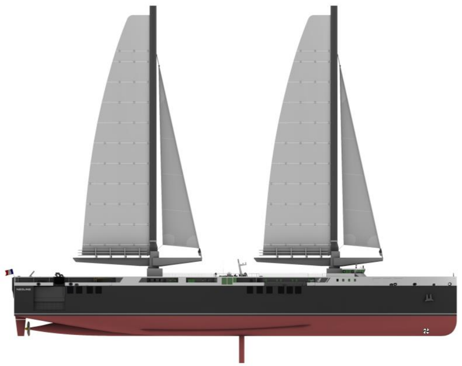
Illustration Pierre Zan

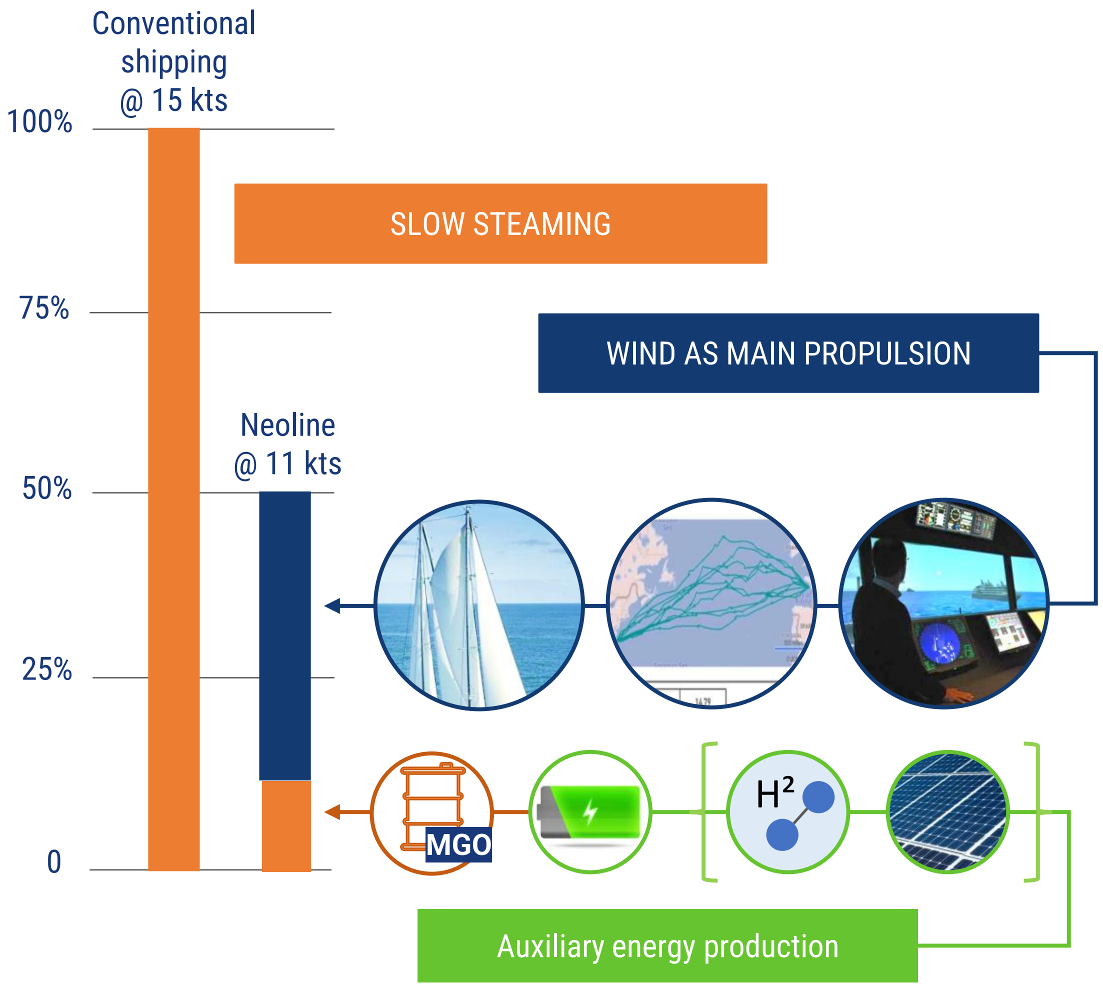
Our solution

Decarbonized energy mix:

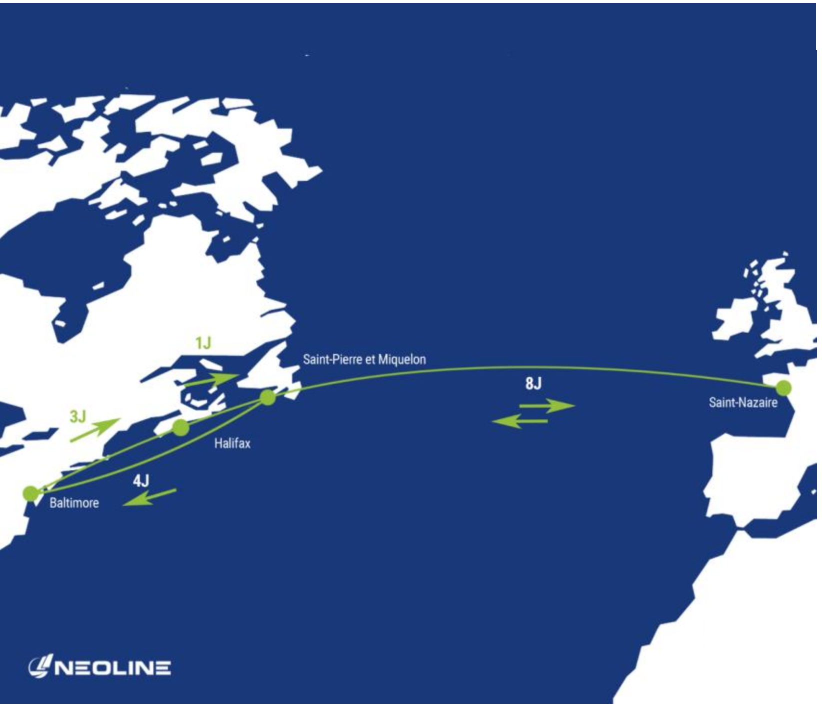
Pilot vessel: 80% to 90% of fuel consumption reduction.

Mid-term objective: « quasi 0 emission ».





NEOLINE



THE PILOT LINE

A new regular transatlantic route

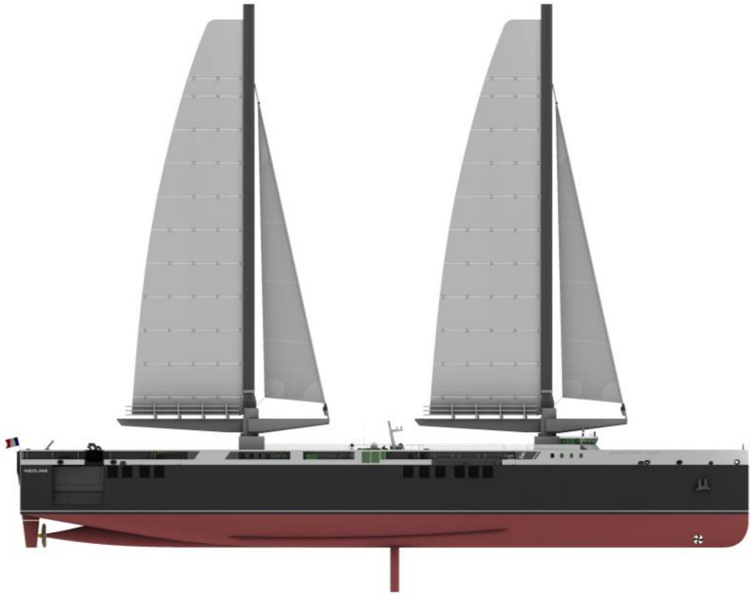
- Original secondary route
- Ideal from wind perspective
- New hinterlands proximities

Shippers are already involved :

New market, corresponding to a booming CSR demand

Signed transport commitments with:

NEOLINER ORIGIN



Technical partners:

RMK MARINE, CHANTIERS DE L'ATLANTIQUE, MAURIC sea novators, D-ICE ENGINEERING, FOURÉ LAGADEC UNE SOCIÉTÉ DU GROUPE SNEF

NEOLINE

Main particulars

- **Dimensions** .... **446 x 79 ft**
- **Sail surface**..**3000 m²**
- Auxiliary propulsion ....diesel-electric 4000 kW
- Commercial speed .... 11 kts
- Engine maximum speed.. 14 kts
- Air draft ....reductible to 136 ft
- Water draft ....reductible to 16 ft
- Displacement .... 11 000 MT
- Crew .... 13 (+12 passengers)

Specialized for **oversized** and **heavy freights**

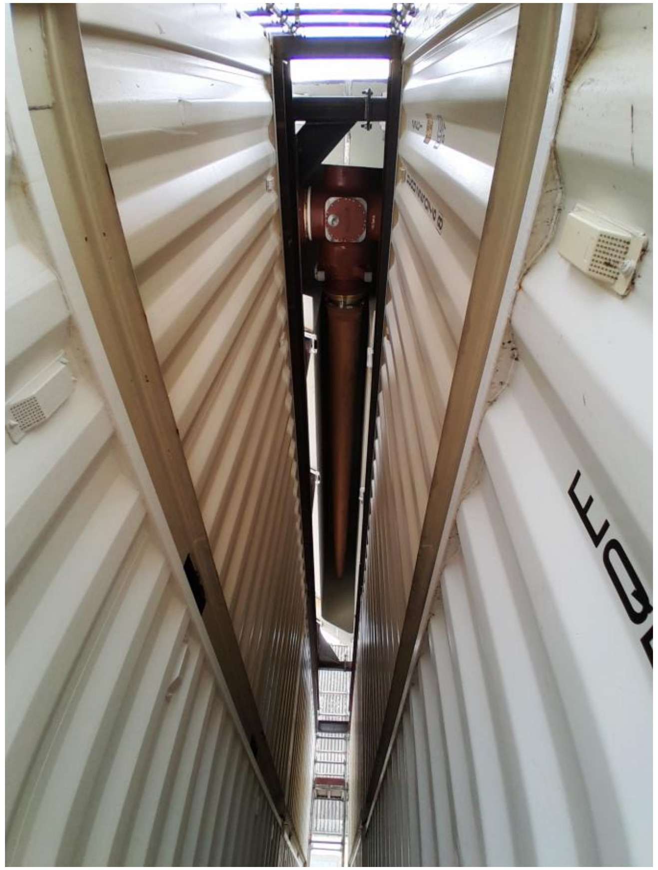
- Max height .... 30 ft
- Roro capacity ....1200 lm
- Cars capacity ....400 CEU
- Containers capacity ....265 TEU
- Breakbulk .... 5 300 MT
- Reefer plugs 30

Credits: Neoline / Mauric

FOCUS ON SOLID SAIL

NEOLINE

FOCUS ON ANTI DRIFTING FINS



NEOLINE

NEOLINER ORIGIN CONSTRUCTION

Construction’s steps

Start of 2025:

- Lauching

Summer 2025:

- Comissioning

NEOLINE

Keel laying (2024-02-14)

Solidsail tilting trial (April 2023)

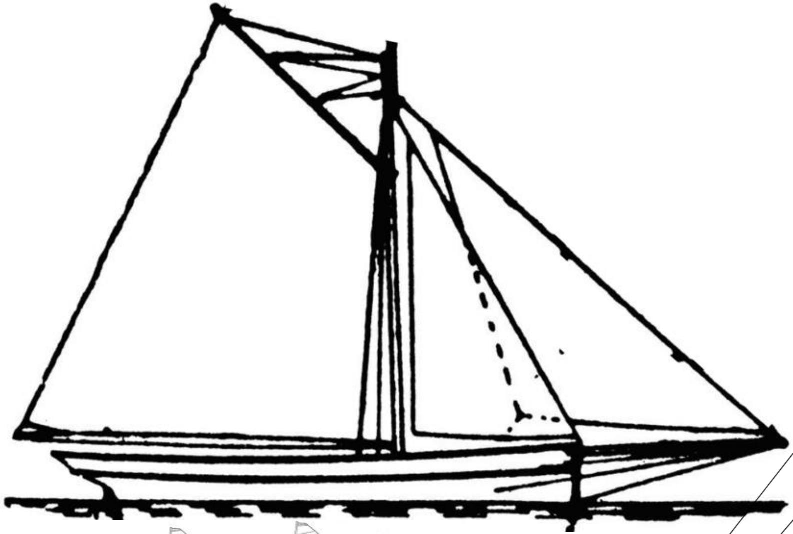
Tank test (March 2023)

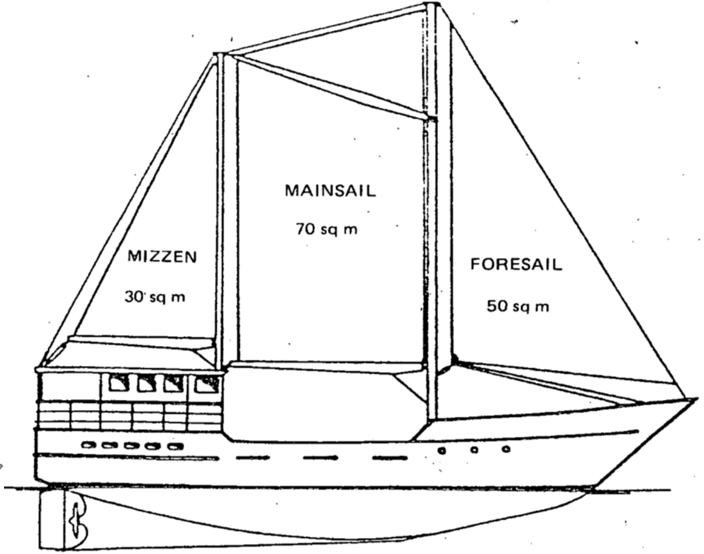
contact@neoline.eu
www.neoline.eu

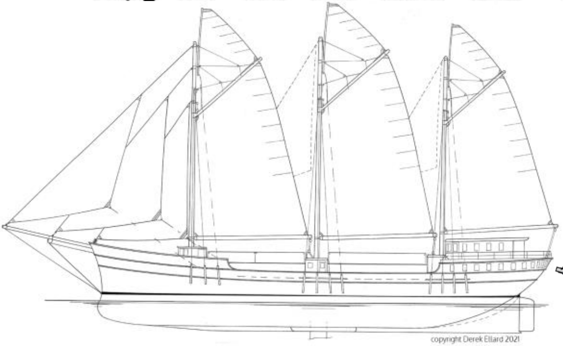
Economic Viability Of Small Sail Freighters In The Northeast United States

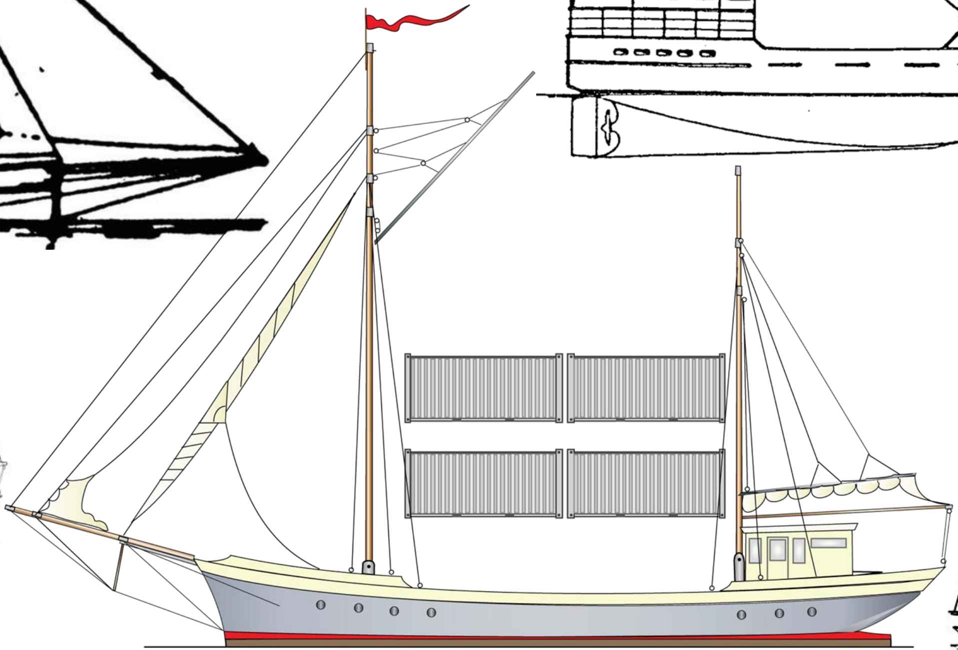
Steven Woods
Center for Post Carbon Logistics

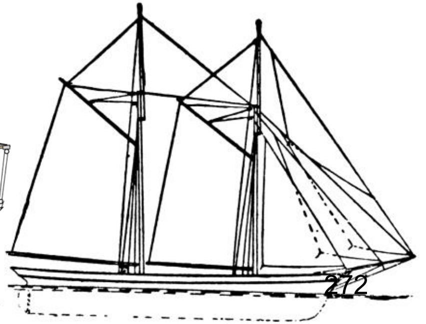
Small Vessel Sector:








Electric Clipper 100 © Derek Ellard

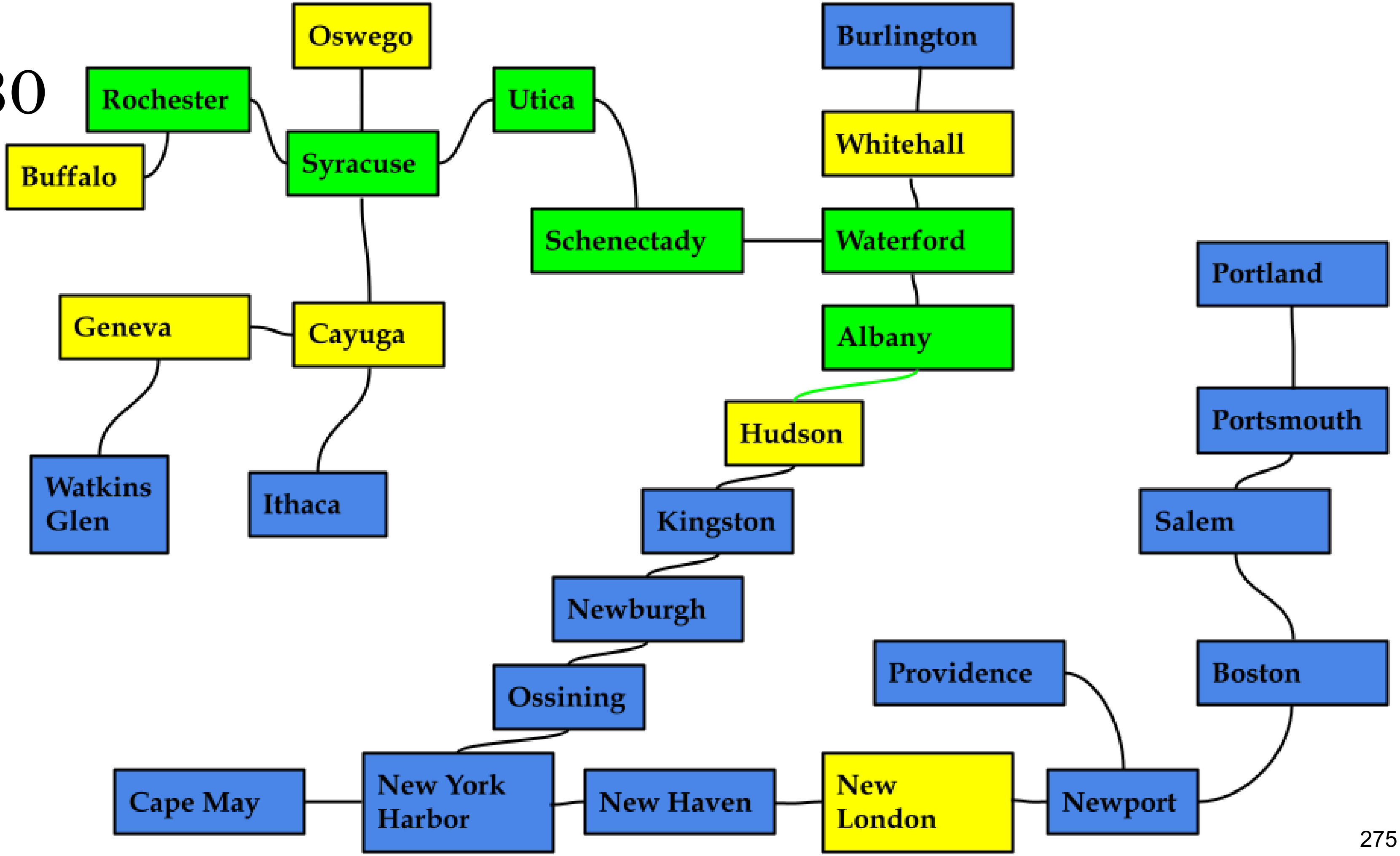


The Center for

Post Carbon Logistics


M-90
VT
NH
M-95
NY
M-87
MA
AREA OF INTEREST
CT
RI
77
PA
NJ
M-295

2030


Oswego
Rochester
Utica
Burlington
Buffalo
Syracuse
Whitehall
Schenectady
Waterford
Portland
Geneva
Cayuga
Albany
Hudson
Portsmouth
Watkins Glen
Ithaca
Kingston
Salem
Newburgh
Providence
Boston
Ossining
Cape May
New York Harbor
New Haven
New London
Newport

Less-than Truck Load (LTL) Shipping

Consolidates many small shipments into one large truckload.

Most loads of 1-4 pallets each.

Truck drives a route making pickups and dropoffs throughout.

Generally more expensive per unit than FTL (Full Truck Load) shipping.

This is the most logical customer base for small sail freighters in early stages.

The Example Cargo

4x4x4 foot pallet of Malt.

Weight 2000 Lbs.

Stowage Factor 64 cubic ft per short ton.

Non-hazardous, non-alcoholic.

Delivered with no extra accommodations or requirements (lift gate, etc)

TABLE 2: ROUTE INFORMATION

Route	Sailing Miles	Days Sailing	Voyages/yr	Truck Miles
Portland-Boston	100	1	320	107
Boston-New York	400	4	85	216
New York-Cape May	128	2	180	158
New Haven-Port Jefferson	23	1	350	117
Newport-Martha's Vineyard	45	1	350	45
Newport-Block Island	26	1	350	40[12]
Buffalo-Albany (via Erie Canal)	363	5	36	288
Burlington-New York (Via Champlain Canal)	267	5	36	298

TABLE 1: VESSEL ASSUMPTIONS

Assumption	15 GRT	25 GRT	50 GRT	100 GRT	Notes
Fuel per day	4 gal	4 gal	4 gal	4 gal	At $5/gallon
Crew strength	2	4	6	6	
Hold Capacity, ft^3	480	960	2,240	4,480	64 ft^3 per pallet
Cargo Deadweight Tonnage	7.5	15	35	70	Short tons
Construction Cost ($)	500,000	750,000	1,000,000	2,000,000	
Length Over Spars (ft)	45	60	72	95	For docking fees

Values from Woods. "A Service-Pattern Sail Freighter: The Need for a Scalable Open-Source Sail Freighter Design." *Proceedings of the Sustainability in Ship Design and Operation Conference 2023.* Glen Cove: Webb Institute, 2024.

TABLE 4: REQUIRED FREIGHT RATES BY FREIGHTER CAPACITY AND ROUTE

ROUTE	15 GRT	25 GRT	50 GRT	100 GRT
Portland-Boston	186.64	161.90	112.97	91.00
Boston-New York	549.02	477.33	305.40	157.08
New York-Cape May	294.95	258.33	172.25	130.95
Port Jefferson-New Haven	163.24	146.48	104.81	84.84
Newport-Martha's Vineyard	163.24	146.48	104.81	84.84
Newport-Block Island	~~163.24~~	~~146.48~~	104.81	84.84
Buffalo-Albany via Erie Canal	~~1,027.72~~	~~692.56~~	~~385.98~~	~~338.55~~
Burlington-New York via Champlain Canal	~~1,027.72~~	~~692.56~~	385.98	338.55

Notes: Non-Competitive routes are ~~struck through.~~ Competitive Rate is any within 10% of rate quoted above. RFRs calculated using a 10 year payoff for vessel construction.

Portland-Boston:	$ 222	($2.07 /ton-mile)
Boston-New York:	$ 521	($2.41 /ton-mile)
New York-Cape May:	$ 285	($1.80 /ton-mile)
New Haven-Port Jefferson:	$ 280	($2.39 /ton-mile)
Newport-Martha's Vineyard:	$ 738	($16.40 /ton-mile)
Newport-Block Island:	$ 130	($3.25 /ton-mile)
Buffalo-Albany:	$ 192	($0.66 /ton-mile)
Burlington-New York:	$ 470	($1.58 /ton-mile)

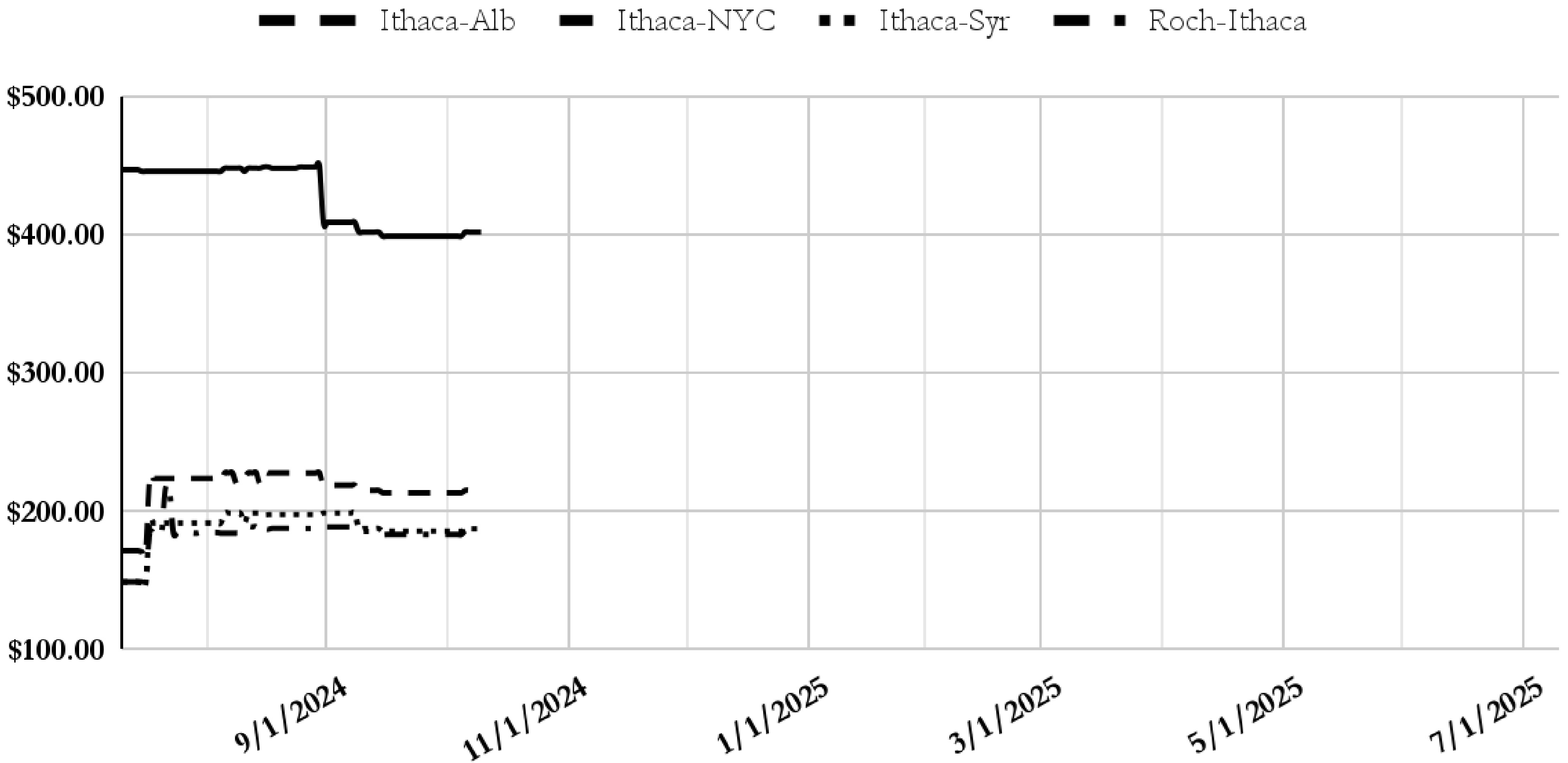
TABLE 3: BREAKEVEN LOAD FACTOR BY FREIGHTER CAPACITY AND ROUTE

ROUTE	15 GRT	25 GRT	50 GRT	100 GRT
Portland-Boston	83%	73%	51%	41%
Boston-New York	~~F&D~~	91%	59%	43%
New York-Cape May	~~F&D~~	90%	60%	46%
Port Jefferson-New Haven	58%	52%	38%	31%
Newport-Martha's Vineyard	22%	20%	15%	12%
Newport-Block Island	~~F&D~~	~~F&D~~	81%	65%
Buffalo-Albany via Erie Canal	~~F&D~~	~~F&D~~	~~F&D~~	~~F&D~~
Burlington-New York via Champlain Canal	~~F&D~~	~~F&D~~	81%	71%

Notes: Non-viable routes are ~~struck through.~~ F&D represents "Full and Down" condition.[17]

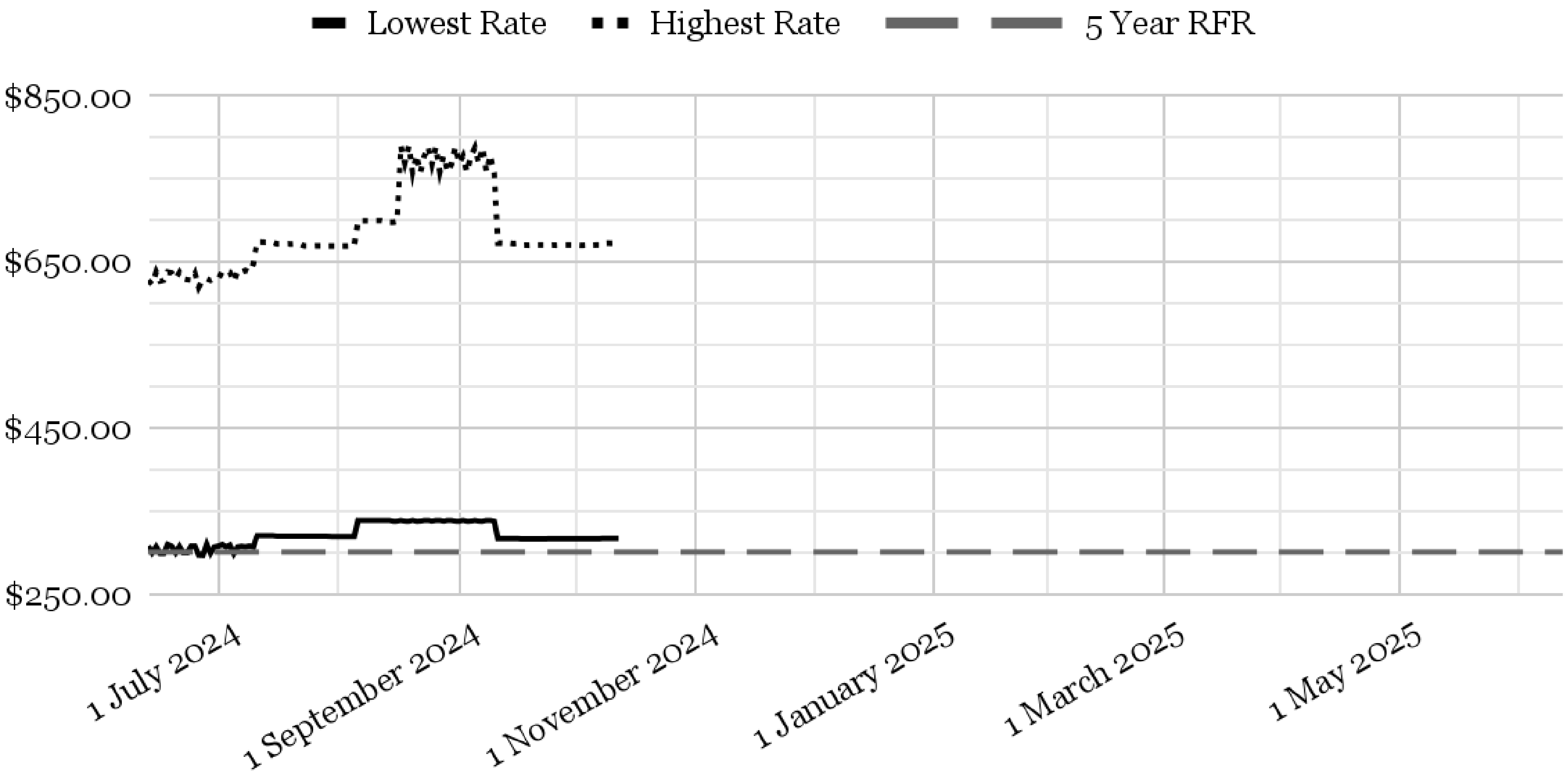
Ithaca Trade Route Rates

64 Cubic Foot Pallet Of Malt Weighing 2,000 Pounds.



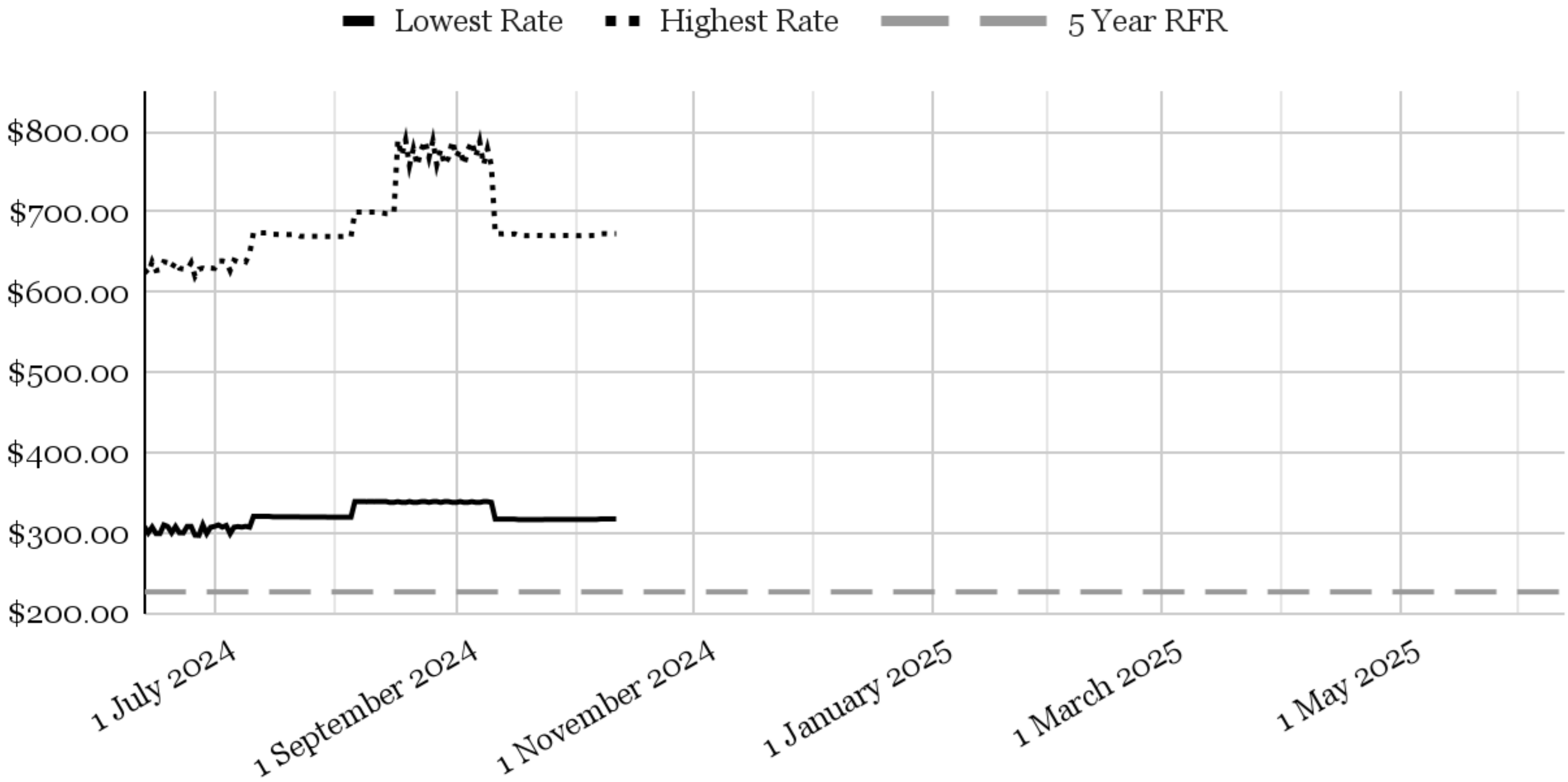
Trucking Rates from Boston to Provincetown

Highest and Lowest Rate for 64 Cubic Foot pallet of Malt weighing 2,000 Pounds.



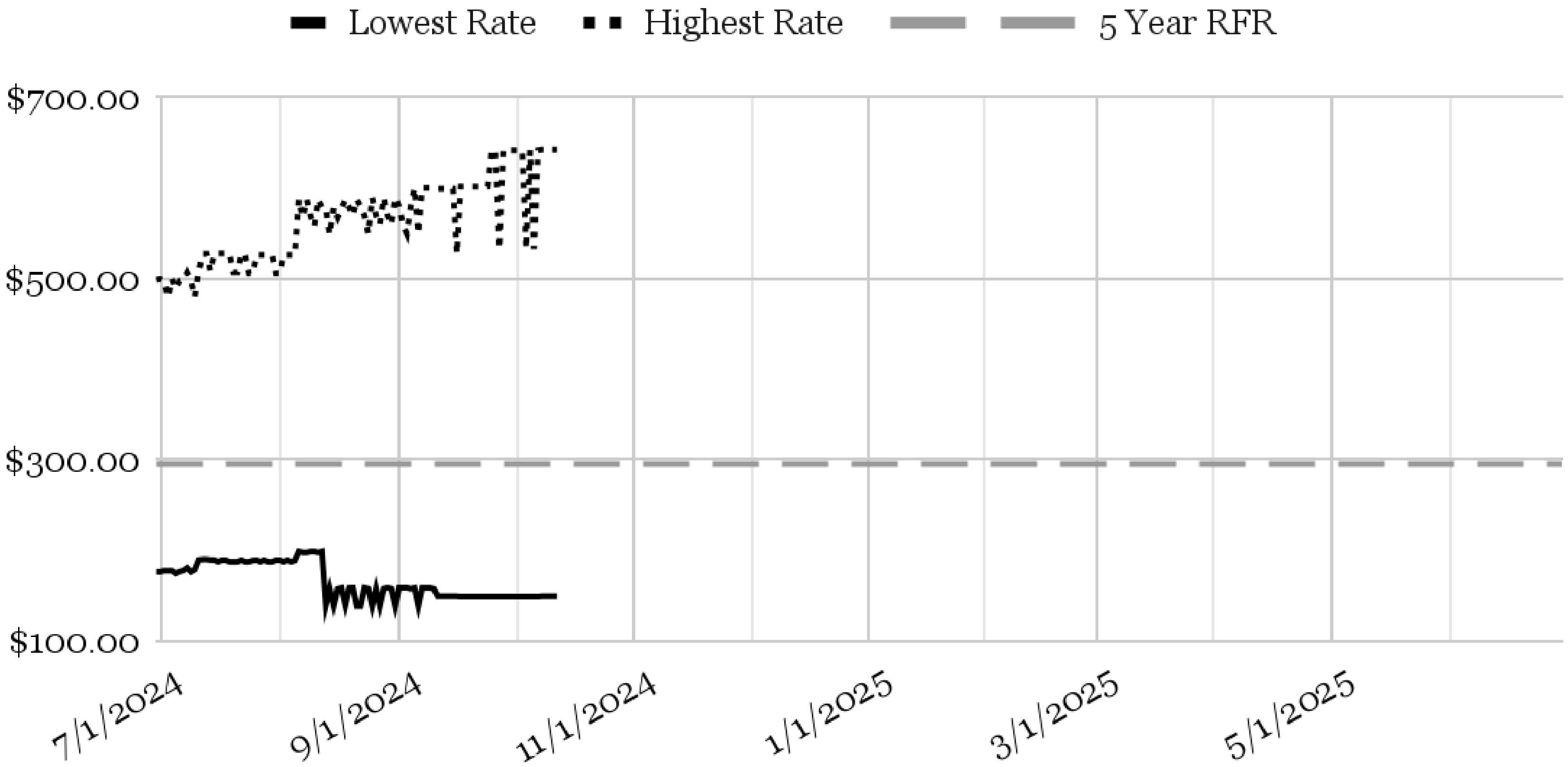
Boston-Provincetown Price Competition Data

64 Cu Ft Pallet of Malt weighing 2000 pounds. 25 GRT/18 CDWT Schooner.



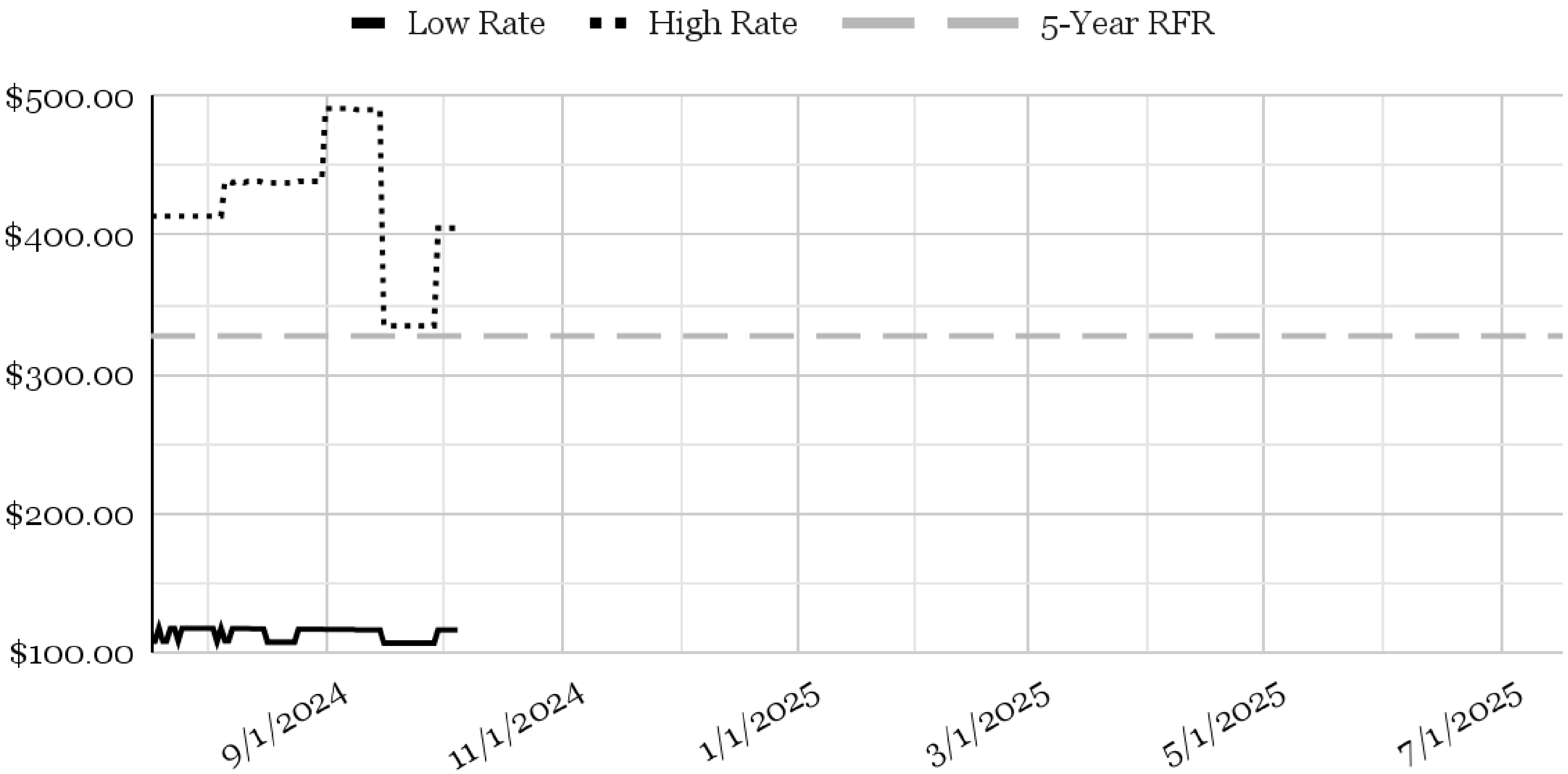
Trucking Rates From Boston to Gloucester

Highest and Lowest Rate For 64 Cu Ft Pallet of Malt weighing 2,000 pounds.



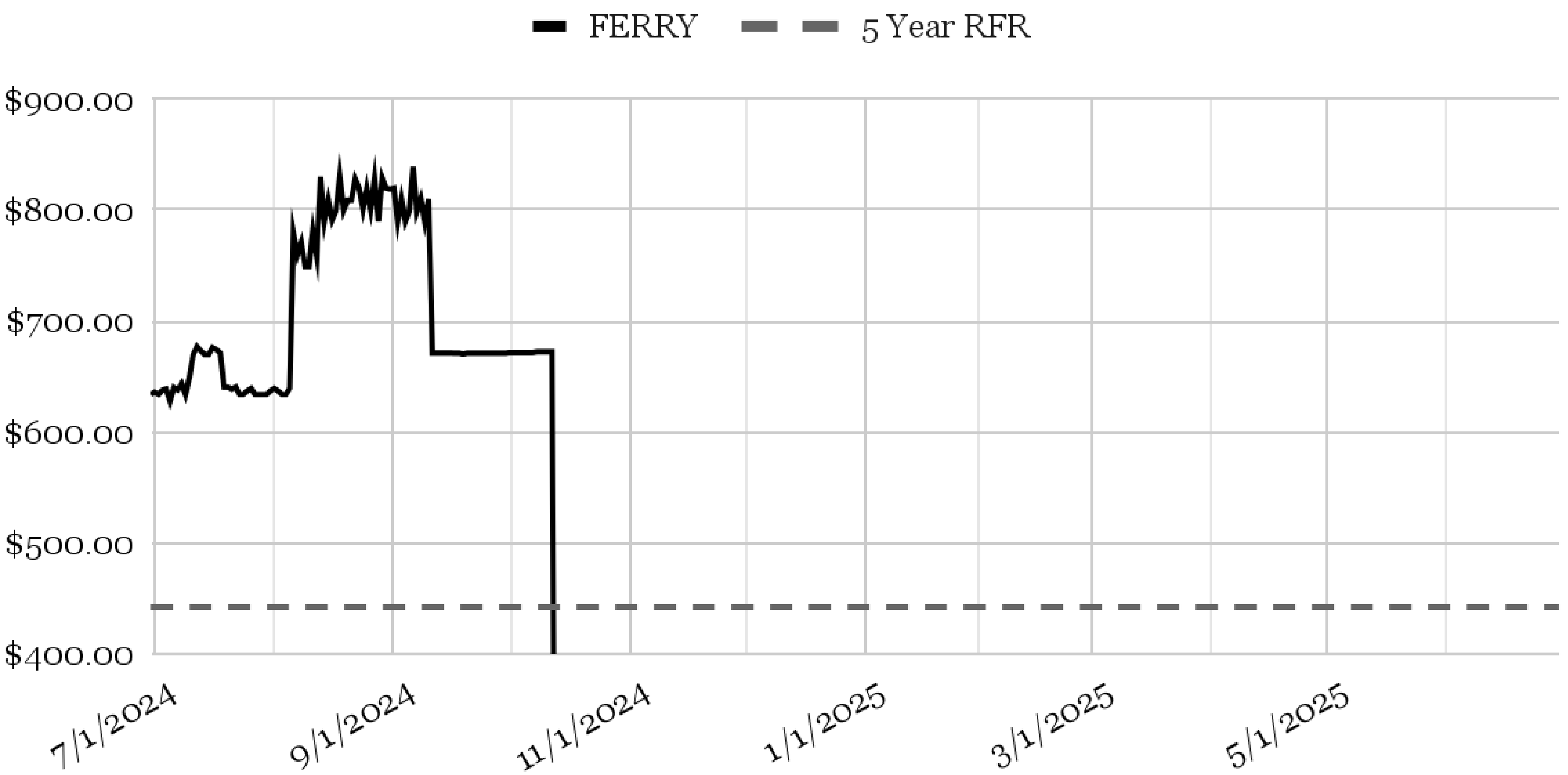
Newport-Block Island Freight Rate Information

64 Cu Ft pallet of malt weighing 2000 lbs.



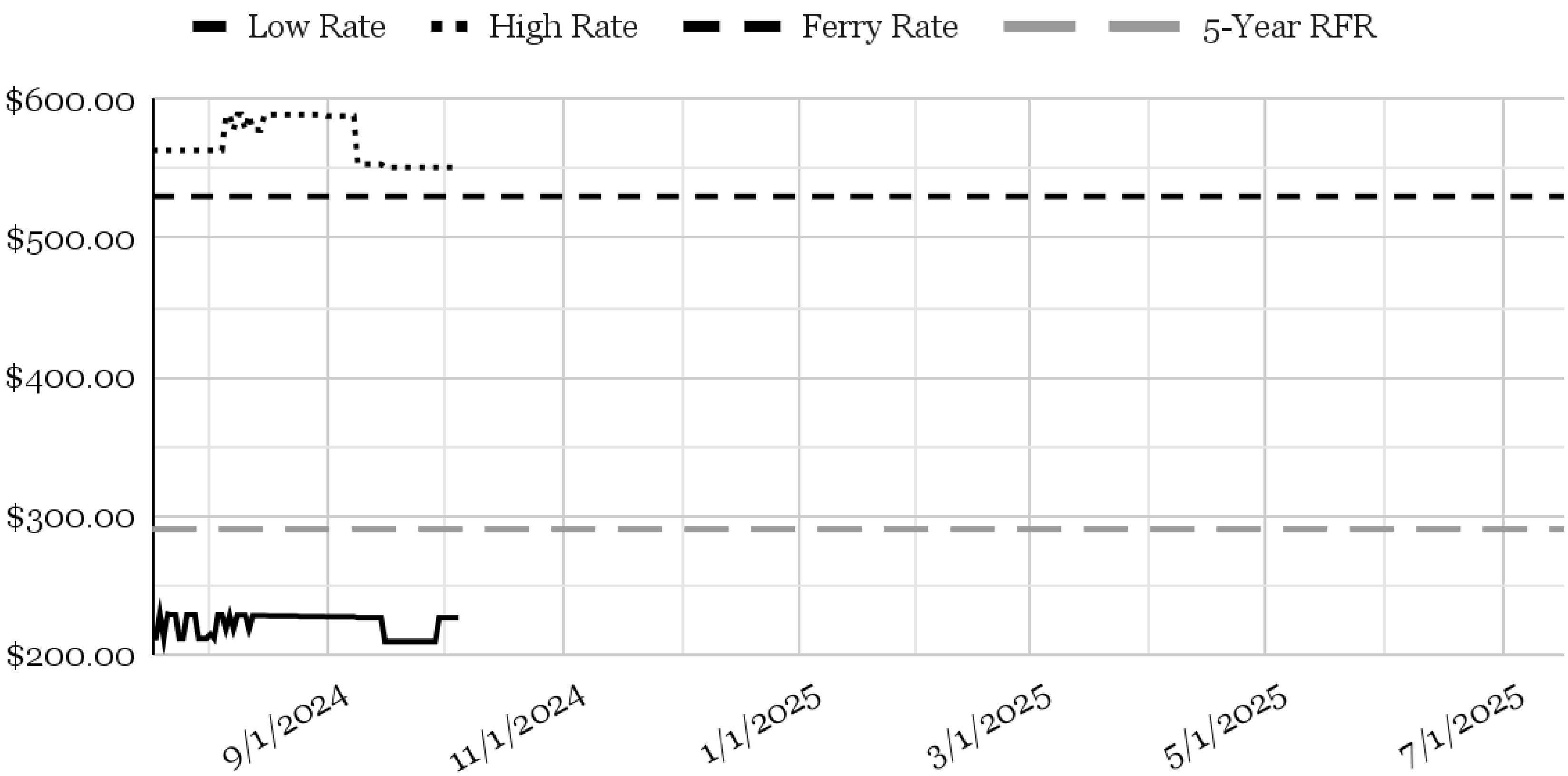
Ferry Rates From New Bedford To Vineyard Haven.

2,000 lb, 64 C.Ft Pallet. Boston - Vineyard Haven fare minus Boston - New Bedford fare.



New Bedford-Hyannis Ferry Rates Window

64 Cu Ft 2000 lb pallet of malt. 10 CDWT Schooner, No Backhaul.



This Presentation Uses 10 CDWT Vessels.

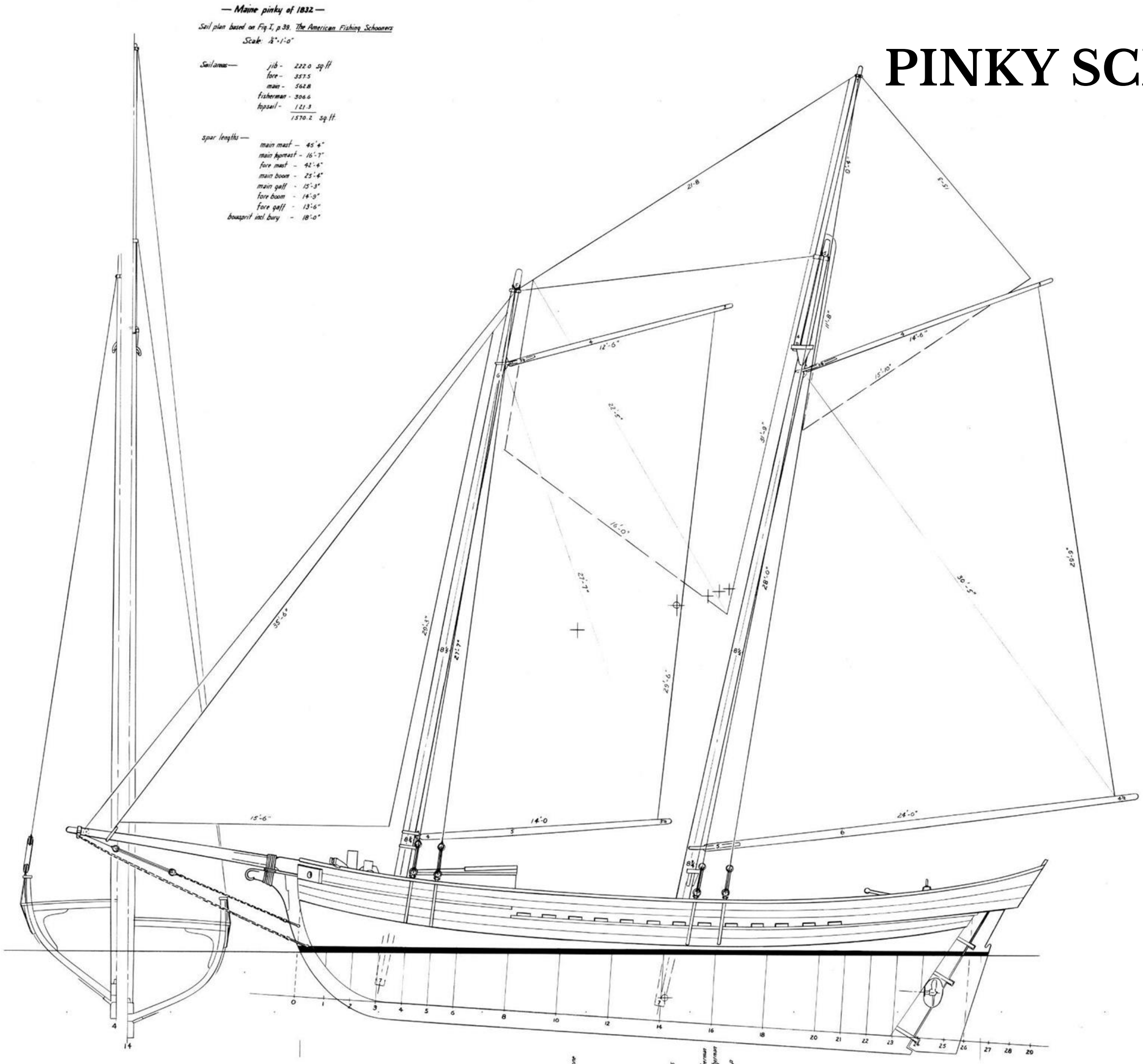
Routes Shown Assume Undercutting Trucks.

Detailed Financials Are Available By Request.

Route Analysis Available By Request.

Paper In Journal Of Merchant Ship Wind Energy.

PINKY SCHOONER
MAINE

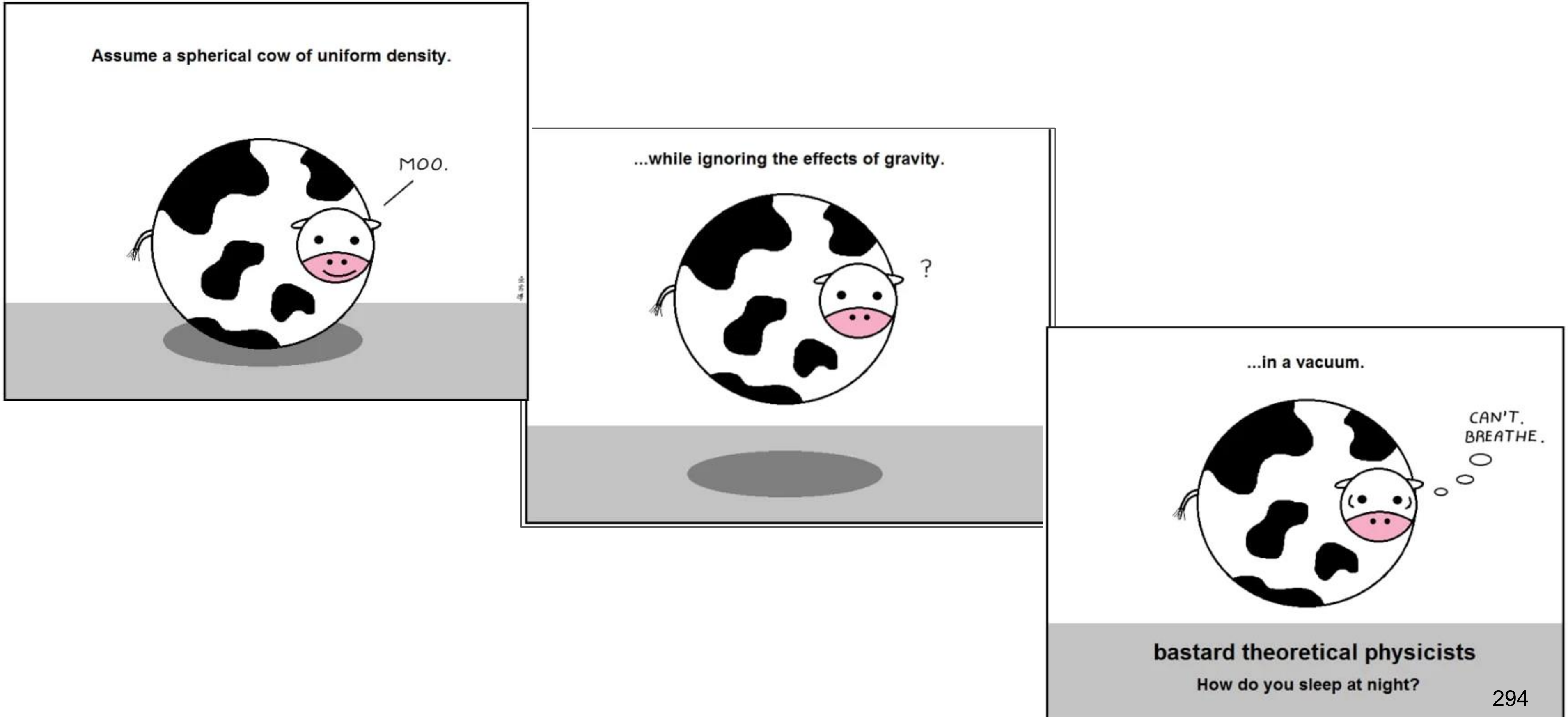


ASSUMPTIONS:

Ship Building: $500,000 Insurance: 10%
Longshore Fee: $20/Port Crew: 2

Maintenance: 10% Fuel: 0.125 gal/day@ $5
Marina Membership: $500/ft Port Fees: $9/ft
No Backhaul Cargo 130 Voyages/Year

Spherical Cows Are Friends (Not Food)



IS IT REALLY VIABLE?

Can Sailors Afford To Take This Job?

☛ US Average Income in 2022 was $51,123 (US Census Bureau)

☛ $200 Per Sailor Day gives approximately $52,000 per year on most routes.

☛ Additional $25 per sailor day for provisioning gives + $6,500 per year.

☛ Employee Ownership Program can increase sailor income, if available.

☛ A Living Wage for a single person in Boston is $62,000 Gross Income.

TABLE 5: ANNUAL EMISSIONS IMPACT BY ROUTE IN METRIC TONS CO2

ROUTE	15 GRT	25 GRT	50 GRT	100 GRT
Portland-Boston	141.3	295.4	706.2	1,425.3
Boston-New York	69	151.6	372	757.5
New York-Cape May	113.6	241.6	582.8	1,180.1
Port Jefferson-New Haven	170.3	354.6	846	1705.9
Newport-Martha's Vineyard	56.9	127.8	316.8	647.5
Newport-Block Island	49	112	280	574
Buffalo-Albany via Erie Canal	39.5	86.1	210.5	428.3
Burlington-New York via Champlain Canal	41.1	89.4	218.1	443.4
One Vessel Working Each Route:	**680.7**	**1,458.5**	**3,478.4**	**7,162**

This table gives the maximum carbon emissions each sail freighter can save by mode shifting cargo away from trucking.

SAIL FREIGHT PROJECT FINANCIAL PROJECTIONS

ROUTE: Boston-Provincetown

VESSEL: Pinky Schooner Maine

YEAR 1: 130x 2-Day Voyages, Full & Down, 10 CDWT. No Backhaul.

Line-Item	Quantity	Per Unit	Amount
Stock, Sold By Shares	5,000	$100.00	500,000.00
Honorary Shipowner Certificates	-	$35.00	-
Gross Revenue, Freight	1,300	$310.86	404,117.45
Gross Revenue			**904,117.45**
Vessel Purchase	1	$500,000.00	500,000.00
Insurance	1	$50,000.00	50,000.00
Crew Labor, per Sailor Day	520	$200.00	104,000.00
Winter Storage, per ft	44	$0.00	-
Seasonal Marina Slip, per foot	44	$500.00	22,000.00
Fuel, Diesel, Per Gallon	33	$5.00	162.50
Maintenance Costs	1	$50,000.00	50,000.00
Provisioning, per person-day	520	$25.00	13,000.00
Longshore Labor Fees, per pallet	2,600	$20.00	52,000.00
Port Fees Per Day	235	$0.00	-
Total Expenses			**791,162.50**
Net Income			**112,954.95**

SAIL FREIGHT PROJECT FINANCIAL PROJECTIONS

ROUTE: Boston-Glocester

VESSEL: Pinky Schooner Maine

YEAR 1: 160x 2-Day Voyages, Full & Down, 10 CDWT. No Backhaul.

Line-Item	Quantity	Per Unit	Amount
Stock, Sold By Shares	5,000	$100.00	500,000.00
Honorary Shipowner Certificates	-	$35.00	-
Gross Revenue, Freight	1,300	$184.66	240,058.43
Gross Revenue			**740,058.43**
Vessel Purchase	1	$500,000.00	500,000.00
Insurance	1	$50,000.00	50,000.00
Crew Labor, per Sailor Day	520	$200.00	104,000.00
Winter Storage, per ft	44	$0.00	-
Seasonal Marina Slip, per foot	44	$350.00	15,400.00
Fuel, Diesel, Per Gallon	33	$5.00	162.50
Maintenance Costs	1	$50,000.00	50,000.00
Provisioning, per person-day	520	$25.00	13,000.00
Longshore Labor Fees, per pallet	2,600	$20.00	52,000.00
Port Fees Per Day	365	$0.00	-
Total Expenses			**784,562.50**
Net Income			**(44,504.07)**

SAIL FREIGHT PROJECT FINANCIAL PROJECTIONS

ROUTE: New Bedford-Martha's Vineyard

VESSEL: Pinky Schooner Maine

YEAR 1: 130x 2-Day Voyages, Full & Down, 10 CDWT. No Backhaul.

Line-Item	Quantity	Per Unit	Amount
Stock, Sold By Shares	5,000	$100.00	500,000.00
Honorary Shipowner Certificates	0	$35.00	-
Gross Revenue, Freight	1,300	$646.86	840,920.60
Gross Revenue			**1,340,920.60**
Vessel Purchase	1	$500,000.00	500,000.00
Insurance	1	$50,000.00	50,000.00
Crew Labor, per Sailor Day	520	$200.00	104,000.00
Winter Storage, per ft	44	$0.00	-
Seasonal Marina Slip, per foot	44	$500.00	22,000.00
Fuel, Diesel, Per Gallon	33	$5.00	162.50
Maintenance Costs	1	$50,000.00	50,000.00
Provisioning, per person-day	520	$25.00	13,000.00
Steamship Authority License, 20%	1	$168,184.12	168,184.12
Longshore Fees	2,600	$20.00	52,000.00
Total Expenses			**959,346.62**
Net Income			**381,573.98**

SAIL FREIGHT PROJECT FINANCIAL PROJECTIONS

ROUTE: New Bedford-Martha's Vineyard

VESSEL: 50 GRT Schooner with 6 Crew

YEAR 1: 130x 2-Day Voyages, Full & Down, 35 CDWT. No Backhaul.

Line-Item	Quantity	Per Unit	Amount
Stock, Sold By Shares	10,000	$100.00	1,000,000.00
Honorary Shipowner Certificates	0	$35.00	-
Gross Revenue, Freight	4,550	$646.86	2,943,222.10
Gross Revenue			**3,943,222.10**
Vessel Purchase	1	$1,000,000.00	1,000,000.00
Insurance	1	$100,000.00	100,000.00
Crew Labor, per Sailor Day	1,560	$300.00	468,000.00
Winter Storage, per ft	72	$0.00	-
Longshore Fees	9,100	$20.00	182,000.00
Fuel, Diesel, Per Gallon	260	$5.00	1,300.00
Maintenance Costs	1	$100,000.00	100,000.00
Provisioning, per person-day	1,560	$25.00	39,000.00
Steamship Authority License, 20%	1	$588,644.42	588,644.42
Port Fees Per Day	365	$648.00	236,520.00
Total Expenses			**2,715,464.42**
Net Income			**1,227,757.68**

SAIL FREIGHT PROJECT FINANCIAL PROJECTIONS

ROUTE: Boston-Provincetown

VESSEL: Salvage 36 ft Sailboat

YEAR 1: 130 Voyages, Full & Down, 5 CDWT.

Line-Item	Quantity	Per Unit	Amount
Stock, Sold By Shares	250	$100.00	25,000.00
Honorary Shipowner Certificates	-	$35.00	-
Gross Revenue, Freight	650	$310.86	202,058.72
Gross Revenue			**227,058.72**
Vessel Purchase	1	$25,000.00	25,000.00
Insurance	1	$2,500.00	2,500.00
Crew Labor, per Sailor Day	520	$200.00	104,000.00
Winter Storage, per ft	36	$0.00	-
Seasonal Marina Slip, per foot	36	$500.00	18,000.00
Fuel, Diesel, Per Gallon	33	$5.00	162.50
Maintenance Costs	1	$2,500.00	2,500.00
Provisioning, per person-day	520	$25.00	13,000.00
Longshore Labor Fees, per pallet	1,300	$20.00	26,000.00
Port Fees Per Day	365	$0.00	-
Total Expenses			**191,162.50**
Net Income			**35,896.22**

BOSTON-PROVINCETOWN ROUTE

EXTERNALITY BALLANCE SHEET: FINANCIAL / Kg CO2e

OPERATIONAL SCOPE 1 ONLY.

SOCIALLY NET POSITIVE?

BENEFITS, USD		LIABILITIES, USD	
Transportation	$66,239.[illegible]	Fuels Burned	$725.[illegible]
Road Maint. Avoided	$5,500.[illegible]3	Cooking Fuels Burned	$[illegible]98.8[illegible]
Physical Plant & Equip	$0.[illegible]0	Physical Plant & Equip	$[illegible]19.72
Inventory	$0.00	Inventory	$0.00
TOTAL ASSETS:	**$71,740.22**	**TOTAL LIABILITIES:**	**$1,144.05**

BENEFITS, CO2e		LIABILITIES, CO2e	
Transportation	[illegible]0,054.35	Propulsion Fuels	329.16
NON-GHG Values	[illegible]	Cooking Fuel Burned	135.60
Physical Plant & Equip	0.00	Physical Plant & Equip	54.32
Inventory	0.00	Inventory	
TOTAL ASSETS:	**30,054.35**	**TOTAL LIABILITIES:**	**519.08**

NOTES:

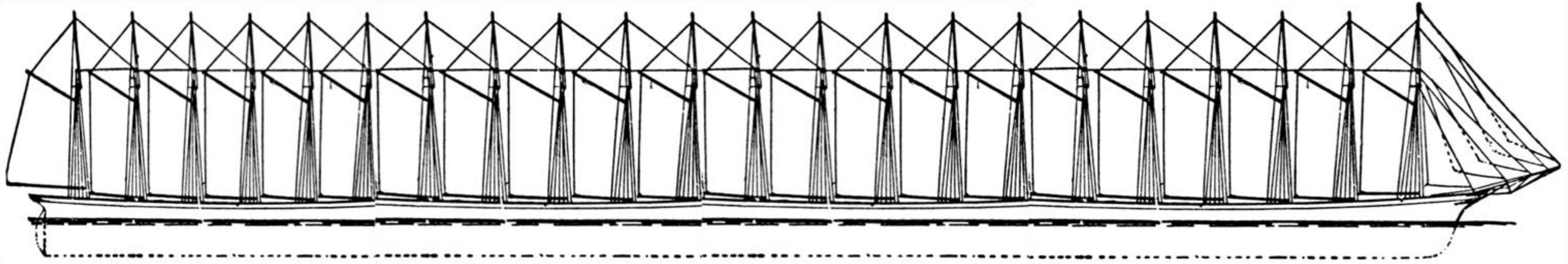
Cooking Emissions will be eliminated through electrification within two seasons.

Benefits of 0-Carbon Last-Mile transp. exclusive.

Upgrades to electric auxilary propulsion will eliminate propulsion liabilities in future years.

Social Cost of Carbon per EPA: $2.204/kg CO2e.


EXIT 8
Atlantic Street
NEXT RIGHT
EXIT 7
137
NORTH
Greenwic
Avenue



Questions?

Steven@PostCarbonLogistics.org

Construction/Testing of the Suction Wing for the Generation of High Lift Forces

MIDN Robert Novak 1/C, Prof. Sergio Perez
United States Merchant Marine Academy

Introduction

- **Suction Wing** technology is a unique way to generate high lift forces for maritime vessels

- We assembled and began preliminary tests on a suction wing device, for generating high lift forces on ship-mounted wing-sails.

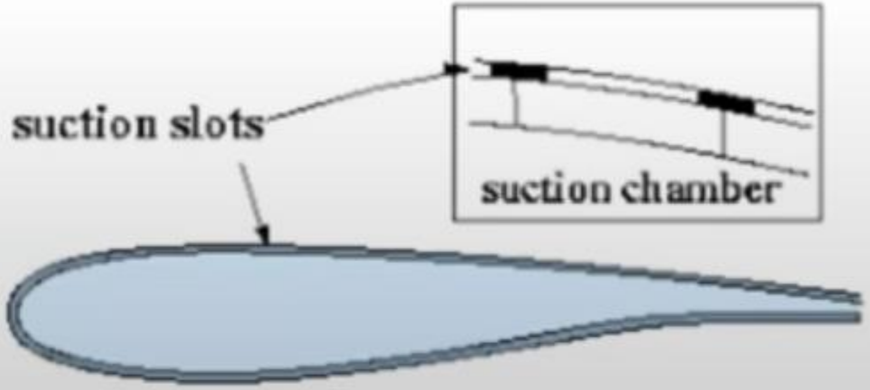
- Our model wing's preliminary results showed a marked increase in aerodynamic lift force, as compared to without suction

- The wide scale use would reduce oceangoing vessel fuel consumption (15 - 35%) and air emissions

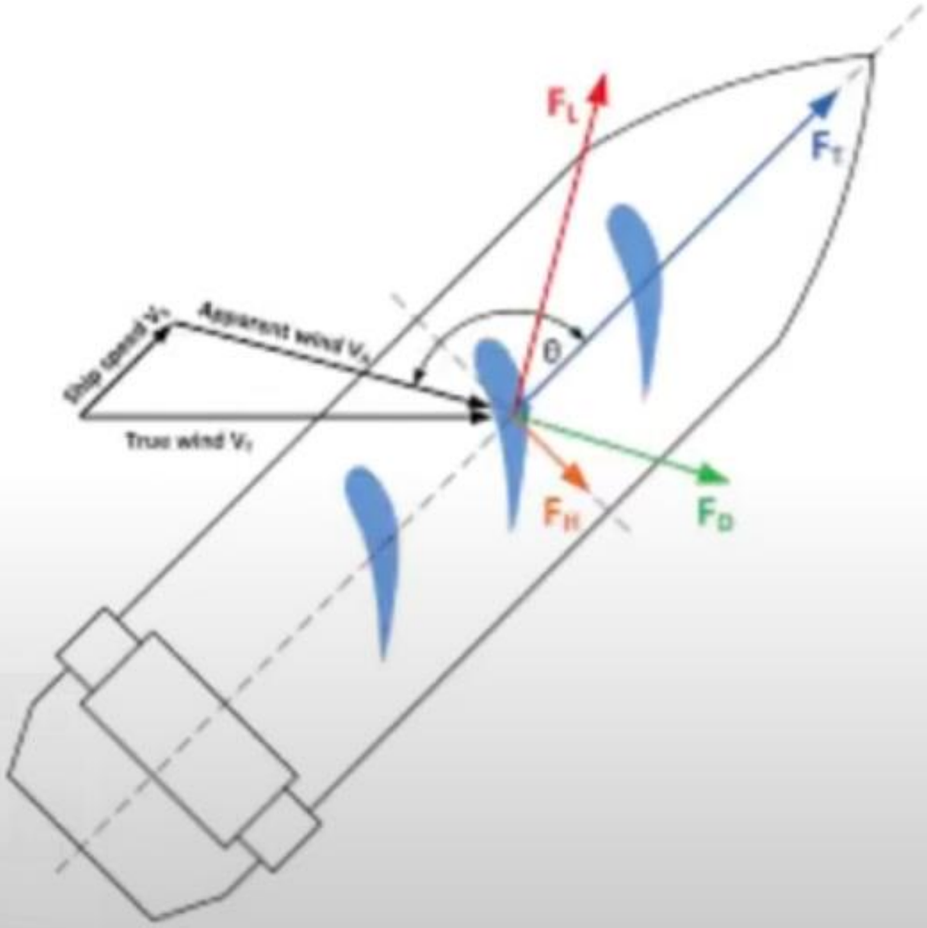
Background

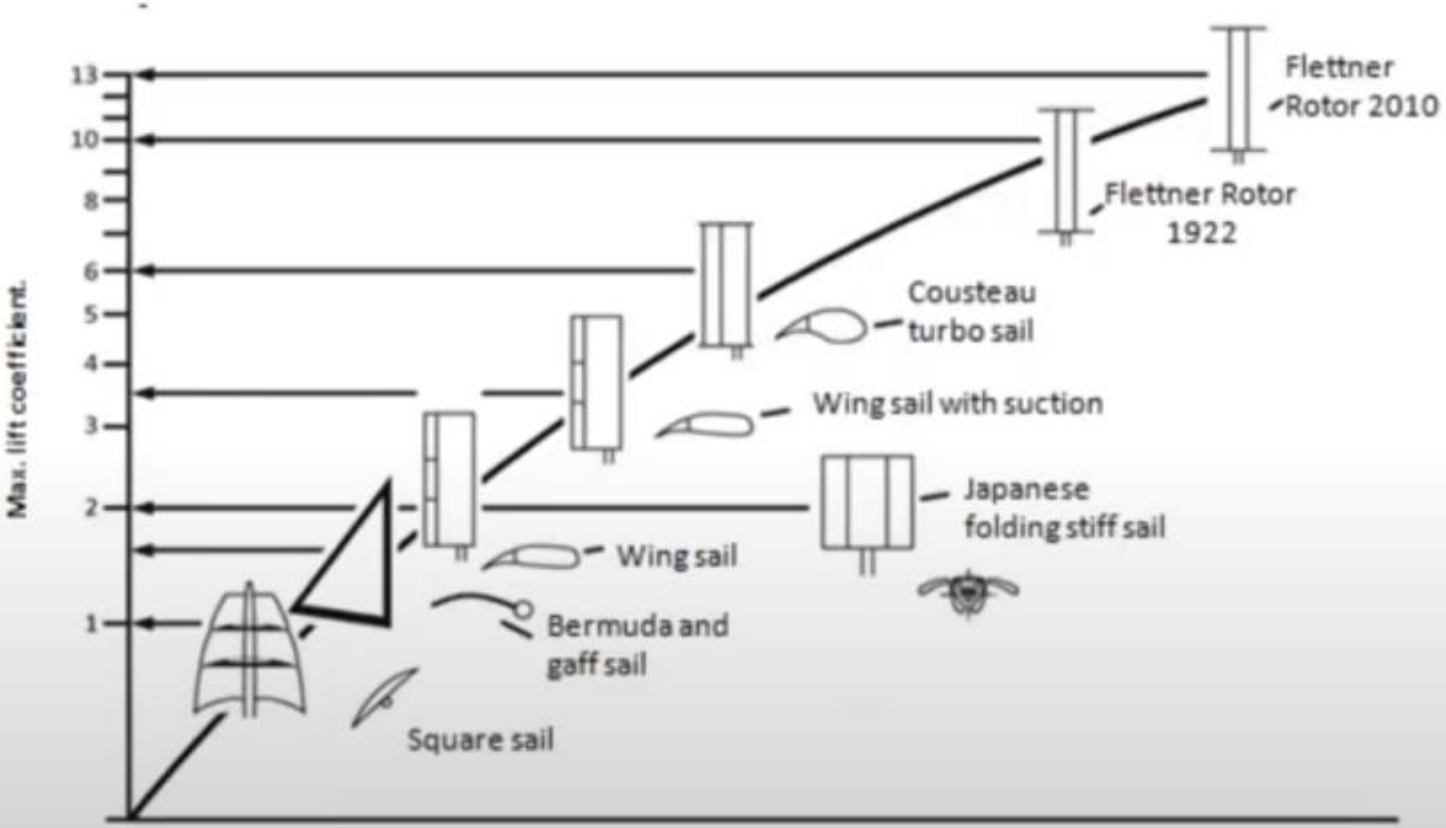
- Based on 1900's concept of Boundary Layer Suction
- Jacques - Yves Cousteau
- Suction allows use of thicker airfoils at high angles of attack
- Size of masts and sails can be reduced
- Reduces fuel consumption and air emissions

The Alcyone (1985)

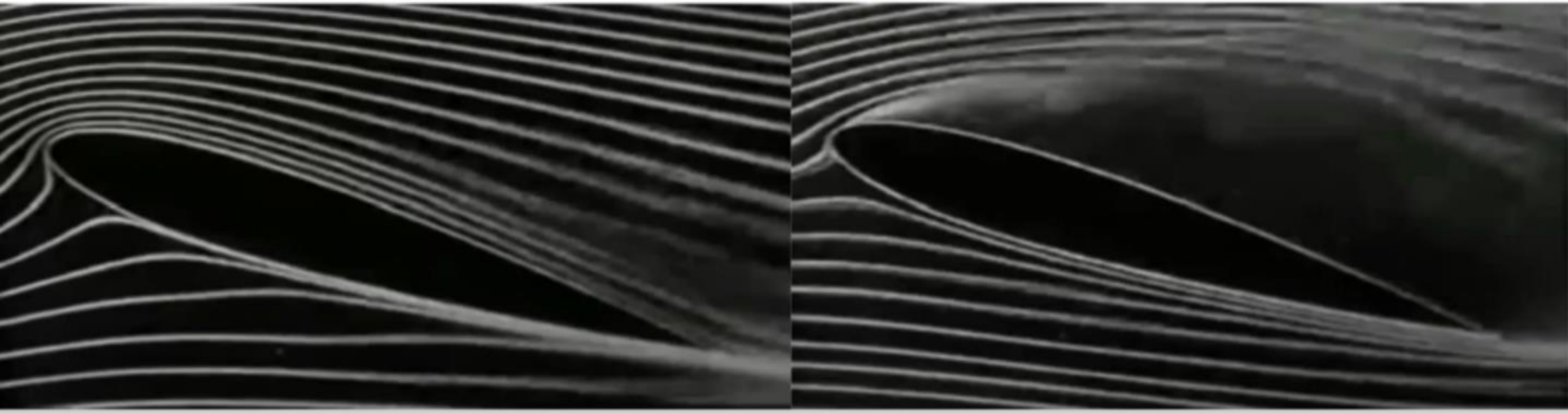


Operating Principle & Hypothesis





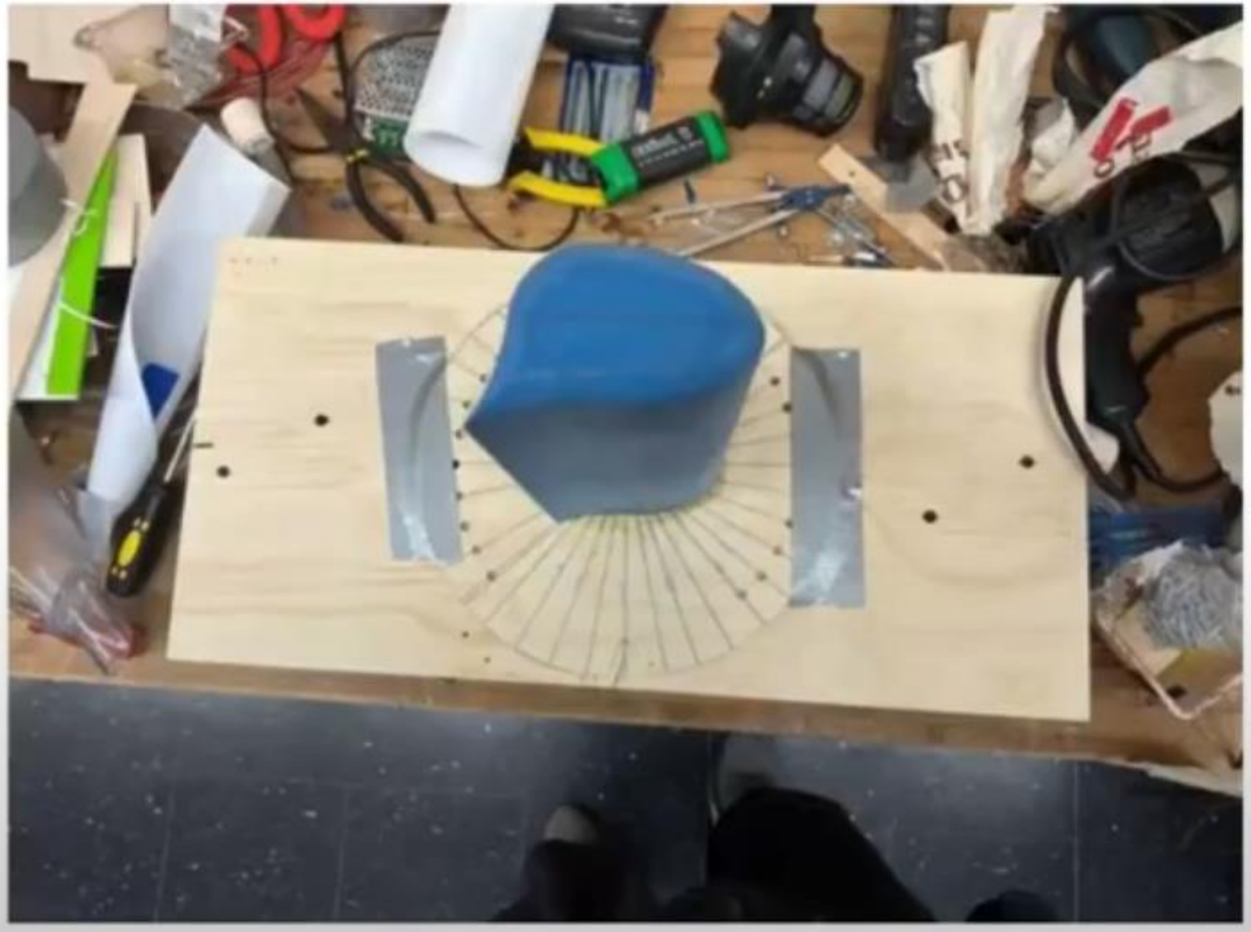
Visual Analysis

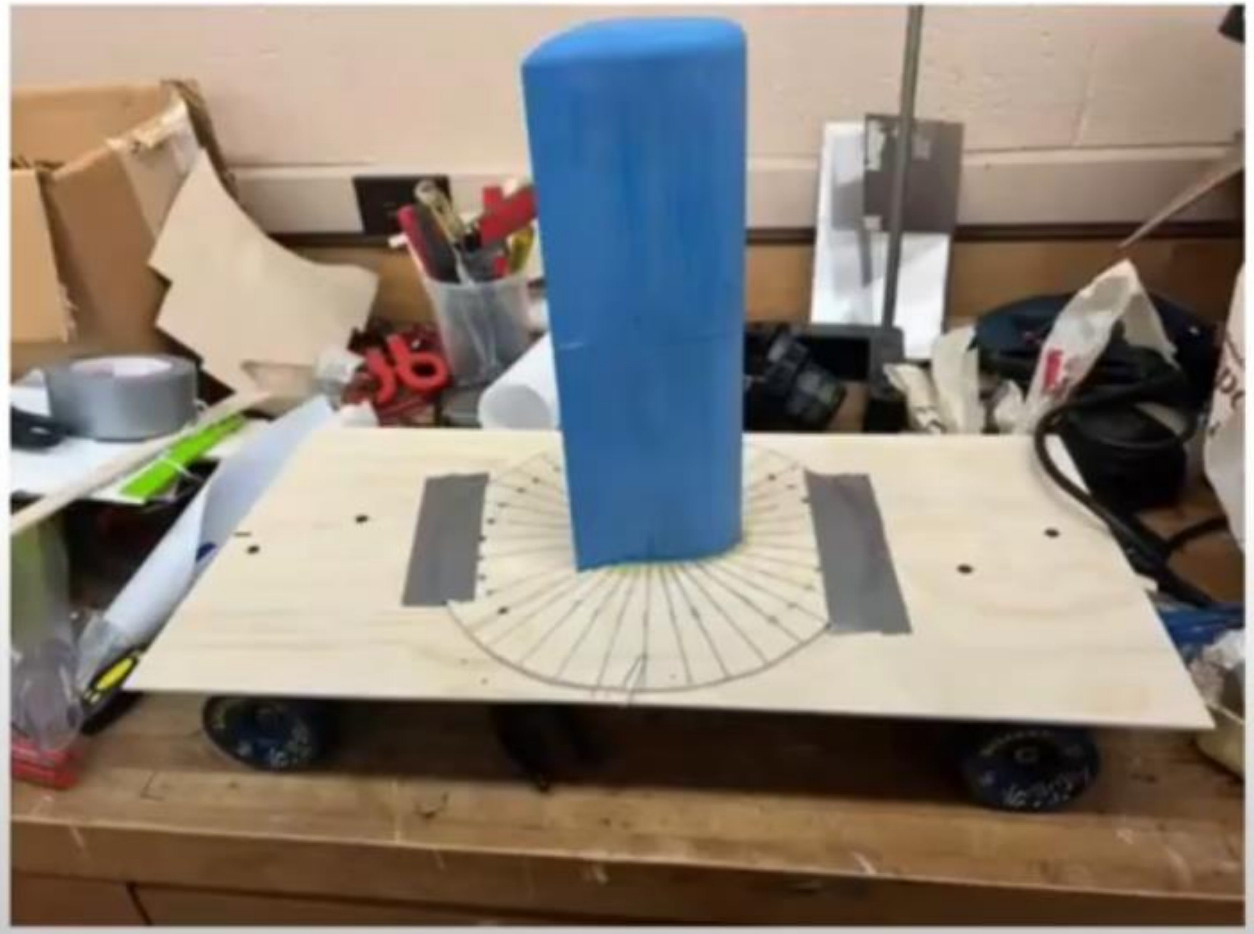


Cart Modeling Process

- 3D printed, large, hollow model of an airfoil
  - Open slits on the upper camber, towards the airfoil trailing edge.
- Wooden cart with rotating disk (fixed lifting body for the airfoil) when testing forces
- Adhesive to the airfoil onto a rotating disk
- Marked 10° intervals to vary the angle of attack.

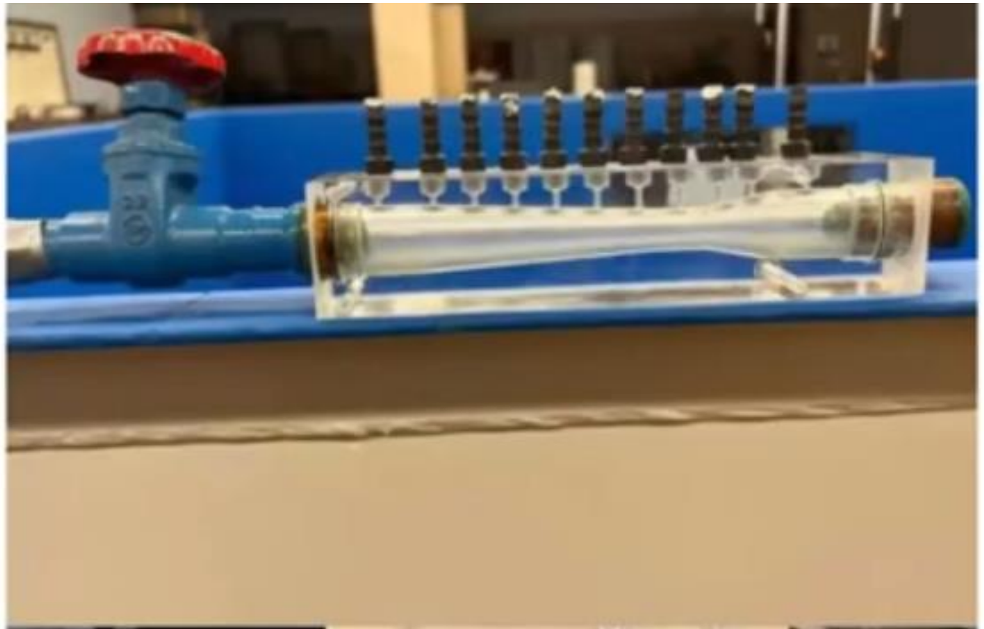
Suction Wing Design

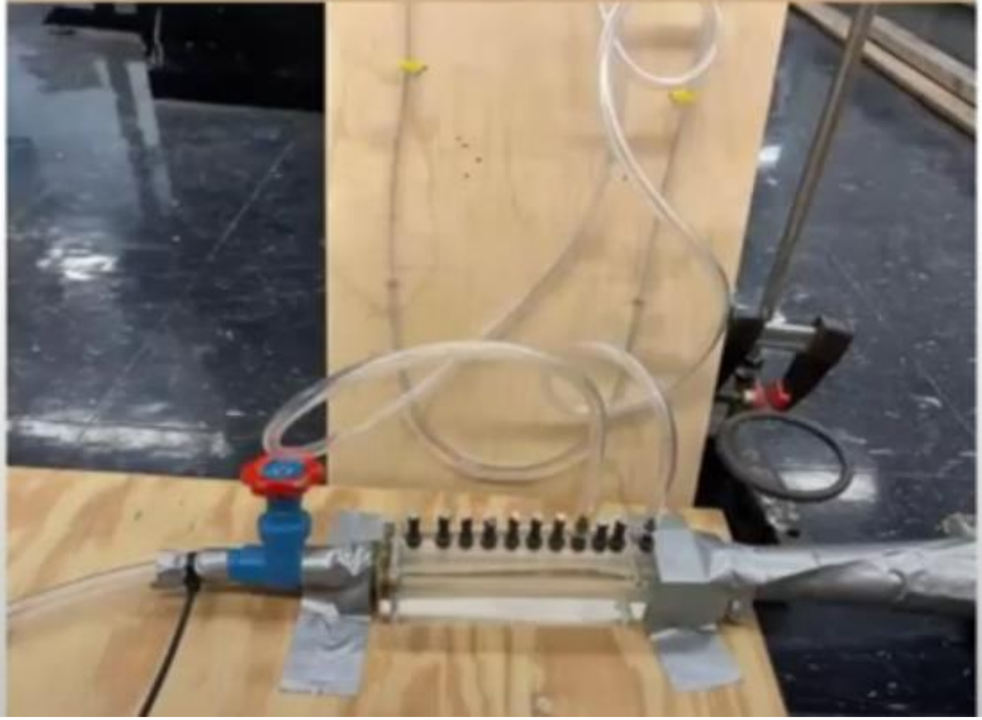




Suction Modeling Process

- Directioned PVC elbow pieces through the cart and disk
- Flexible rubber hosing: Venturi Tube -> Elbow Piece
- Man-made Manometer on Venturi tube
  - Pressure Differential -> Volumetric Flow Rate & Air Velocity
- Flexible Silicone Nozzle taped: Shop vacuum -> Venturi tube
- Hand-Held vacuum soldered to PWM and power supply
  - Amps and Volts measured
  - Low air flow rate (head losses)
- Larger 5 HP shop vacuum

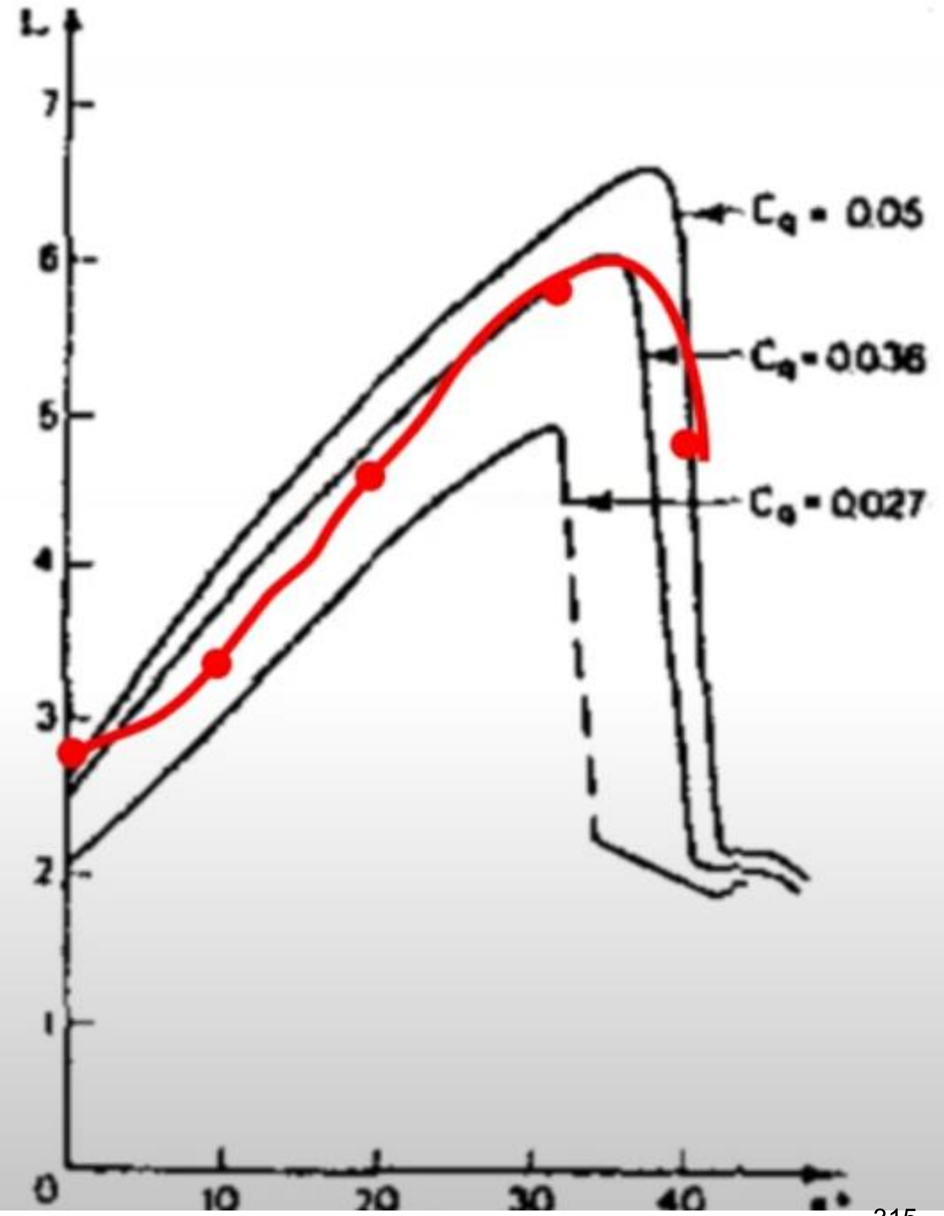






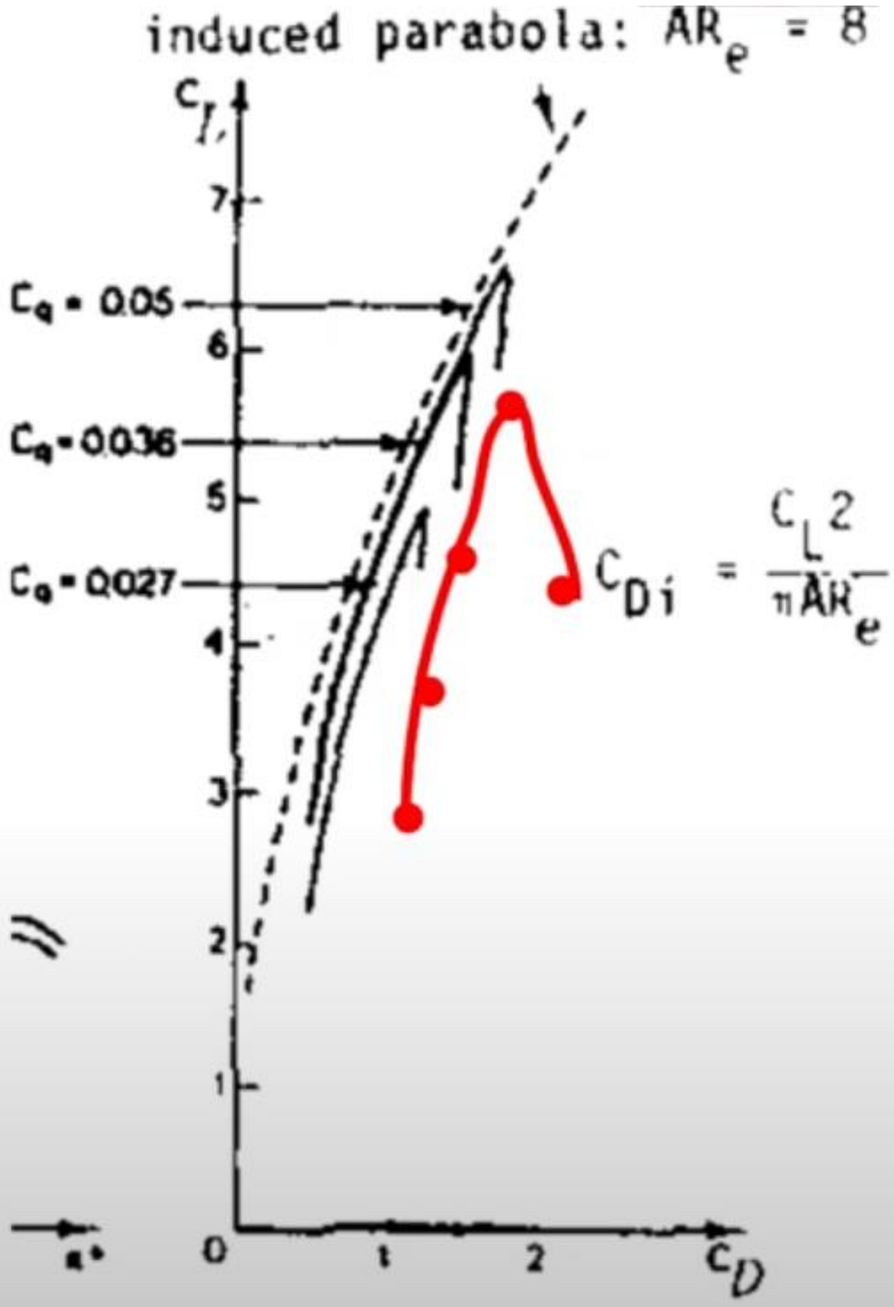

Exhibited Performance Vs. Cousteau Report

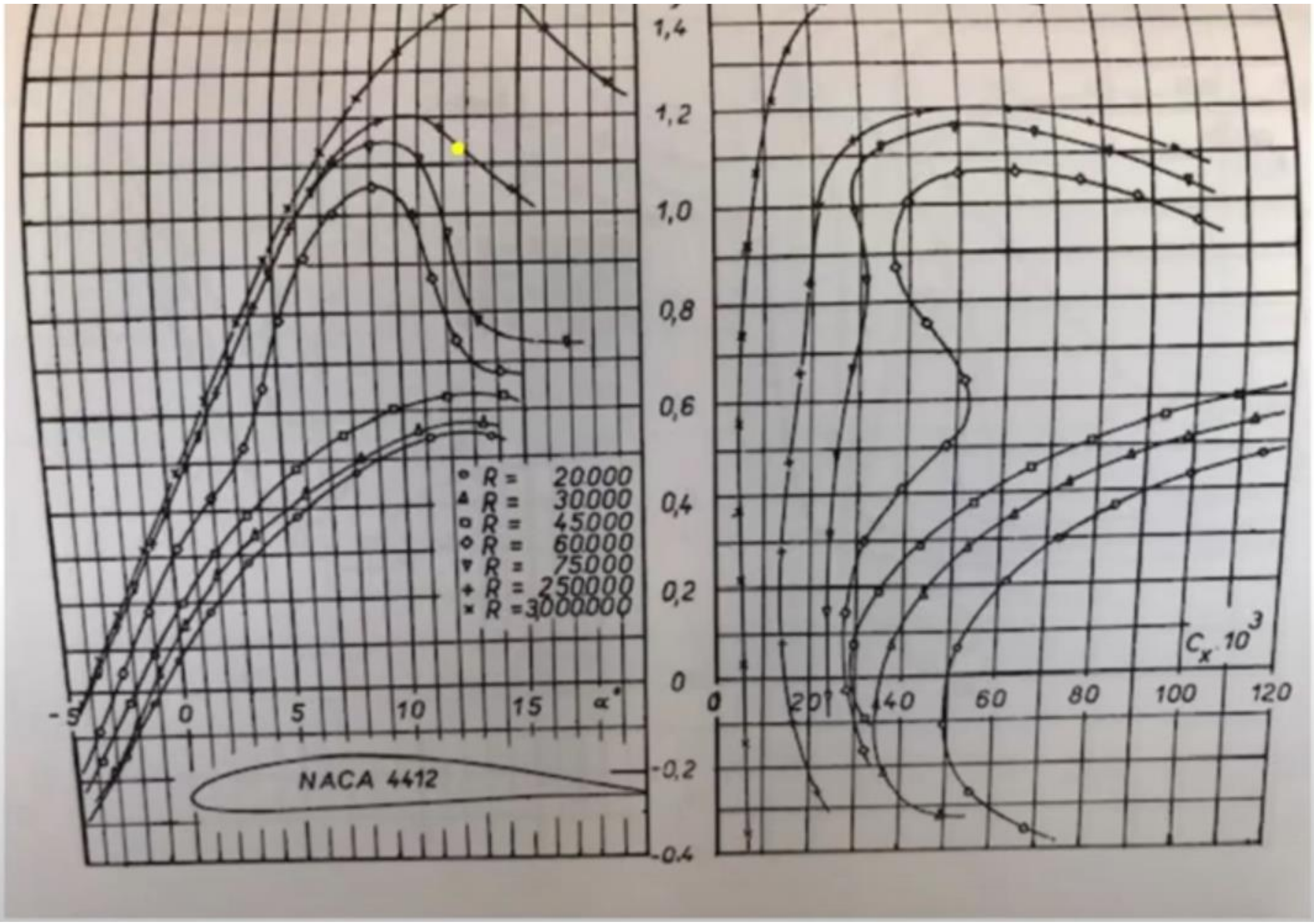
- AR = 2.80 < 4.0
- Cq = Q/(S*W) = **0.0391**
  - Q = volume flow rate of air
  - S = Wing Surface Area
  - W = Average Wind Speed
- Wind Tunnel Performance (red line)
- Cousteau Results (black lines)



Lift/Drag Coefficient Relation Vs. Cousteau

- ARe = 5.6 < 8.0
- Majority of drag was induced drag





1,4
1,2
1,0
0,8
0,6
0,4
0,2
0
-0,2
-0,4
-5
0
5
10
15
α°
R = 20000
R = 30000
R = 45000
R = 60000
R = 75000
R = 250000
R = 3000000
NACA 4412
0
20
40
60
80
100
120
$C_x \cdot 10^3$

Limitations

- Low Reynolds Number
    - 121,987 vs. 300k - 500k

- % Error Measurements
    - Low Quality Force Gauge
    - Different Precision Tools
    - Slow Motion Movie

Acknowledgements

Christopher Soo & Prof. Garofalo, 3D printing of wing model

Richard Crook, Lab Director

Prof. Nigro, Department Head

Foundation Cousteau and Windship Propulsion 1980 - 1985 System Cousteau - Pechney, Journal of Wind Engineering and Industrial Aerodynamics, 20 (1985).

Contact Information

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(757)-818-1265

Thank You

Questions?

Preliminary Design Report for **Hydrogen Feeder Vessels** Transporting LH2 from Offshore Windfarms to Shore Reception Facilities

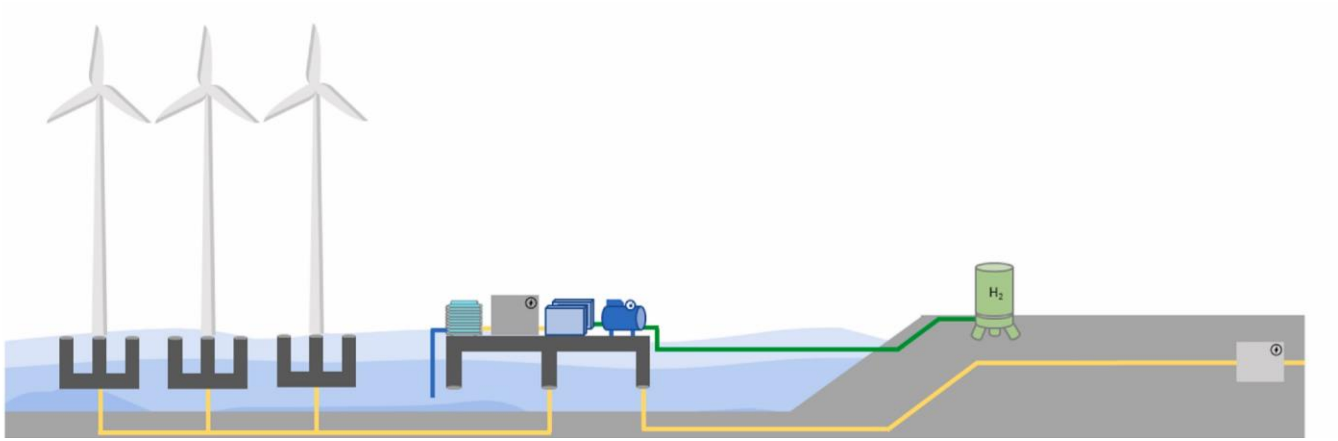
JOHN DONNELLY, SEAMUS O'NEIL, CHRISTOPHER CHU, BRIDGET DONOVAN, & KENNETH JONES

ASST. PROFESSOR HARIHARAN BALASUBARAMIAN

Department of Naval Architecture and Marine Engineering

MARITIME COLLEGE
STATE UNIVERSITY OF NEW YORK

The pipelines or cables typically used to transport power from wind farms to shore create limitations for deepwater wind farms



[3]

Undersea cables typically cost $2.5 million/km or more

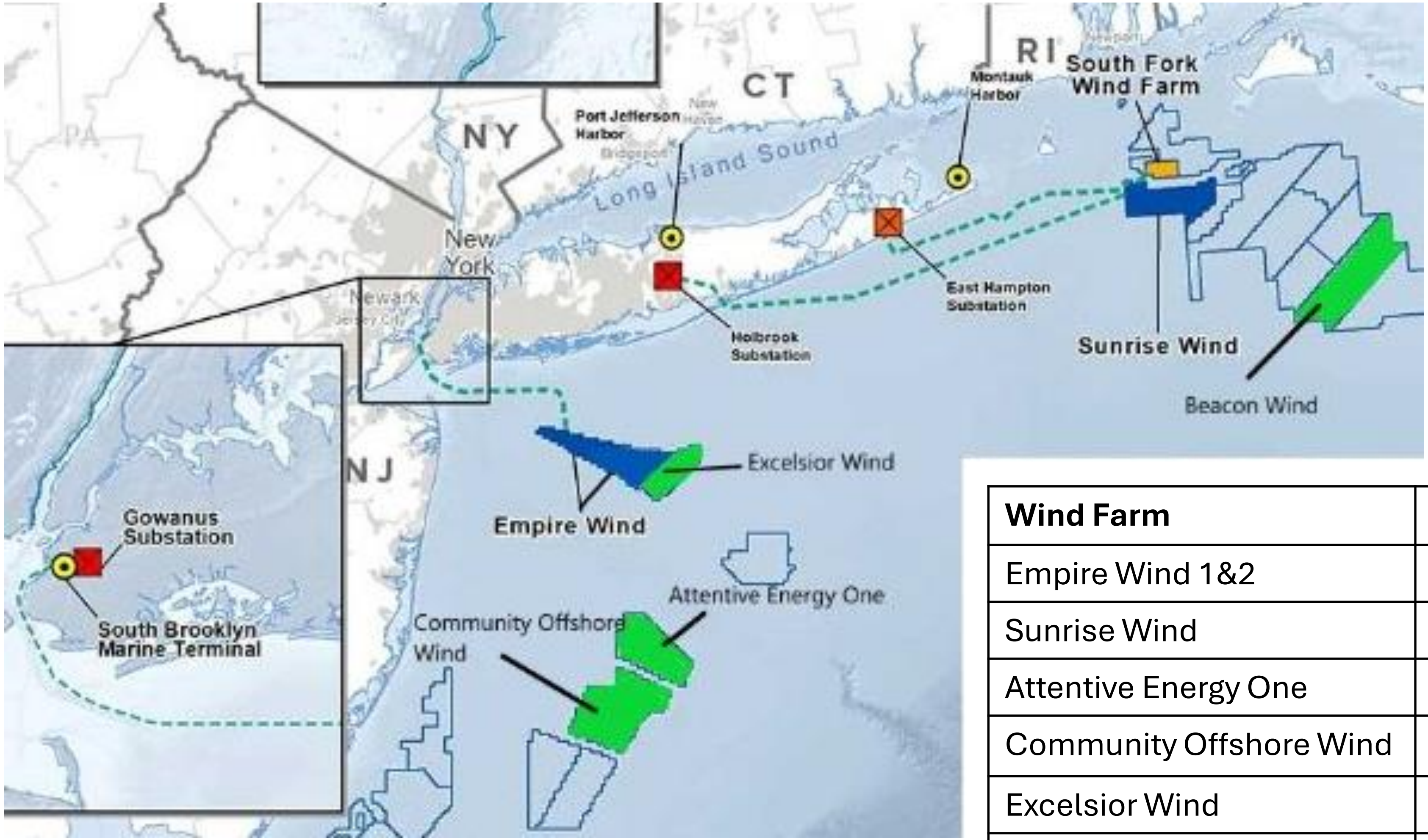
Undersea pipelines cost $4-7 million/km [2]

Despite the challenges of transporting and storing hydrogen, it can be immensely useful and a fuel source.

Power required to produce hydrogen: 42-60 kWh/kg

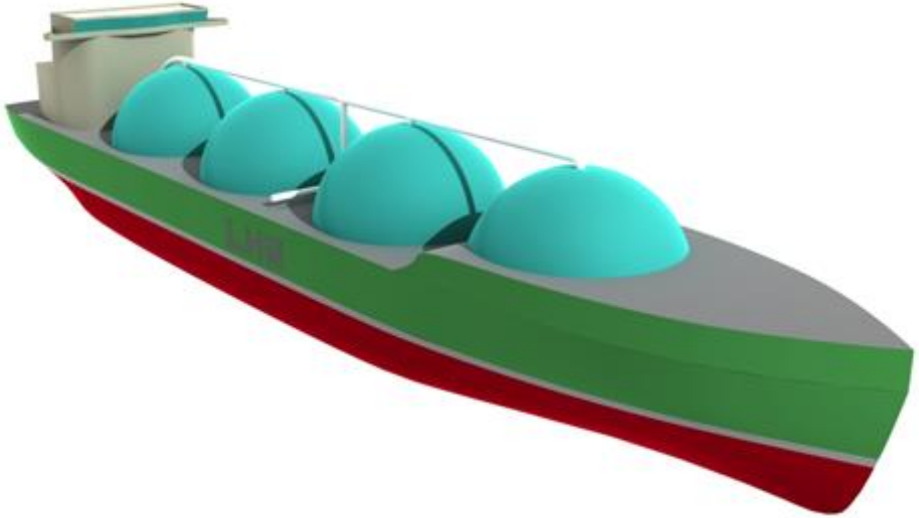
Power required to liquefy hydrogen: 11-15 kWh/kg

Density of hydrogen gas: 0.09 kg/m^3 [4,6]



[7,8,9,10]

Wind Farm	Capacity (MW)	LH2 Capacity (m^3/day)
Empire Wind 1&2	2100	6640-9490
Sunrise Wind	924	2920-4170
Attentive Energy One	1404	4440-6340
Community Offshore Wind	1314	4150-5940
Excelsior Wind	1314	4150-5940
Beacon Wind	1230	3890-5560



150,000m^3 vessel

Length on DWL: 271 m

Beam: 48 m

Draft: 8 m

Speed: 18 knots

Displacement: 71680 tons

50,000m^3 vessel

Length on DWL: 169 m

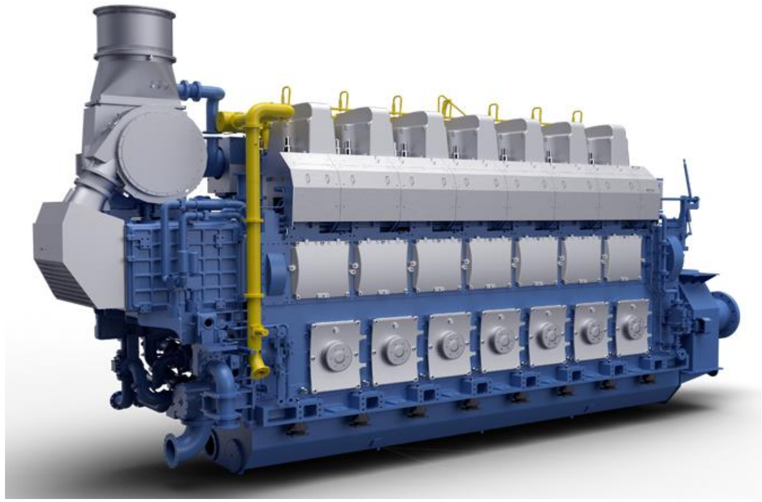
Beam: 30 m

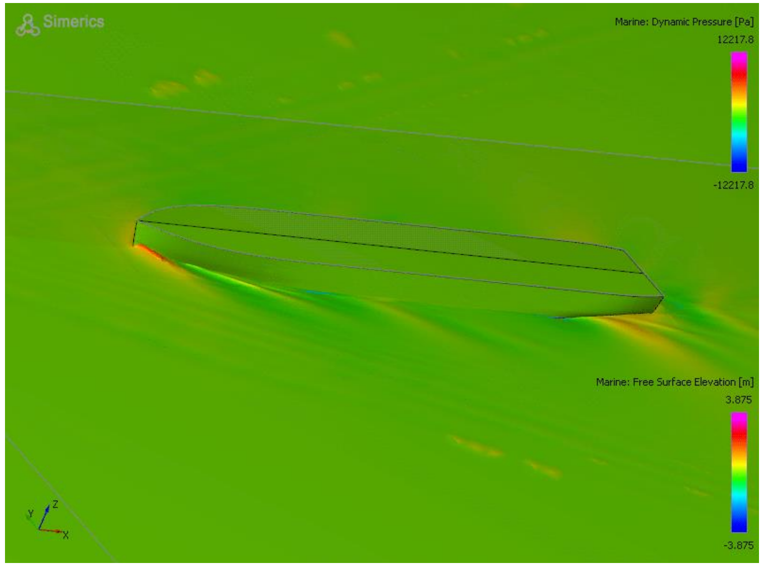
Draft: 6 m

Speed: 15 knots

Displacement: 21864 tons

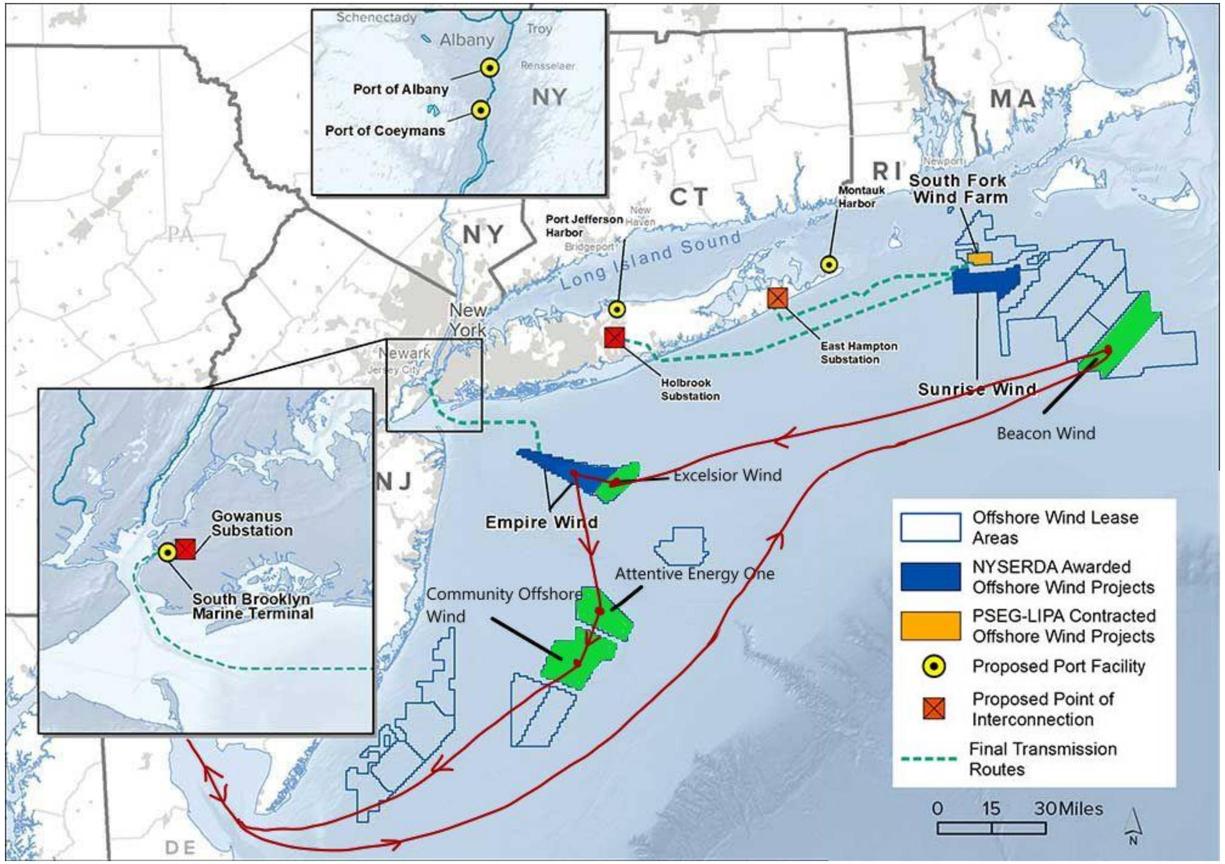
The ships utilize a dual-fuel-electric propulsion system





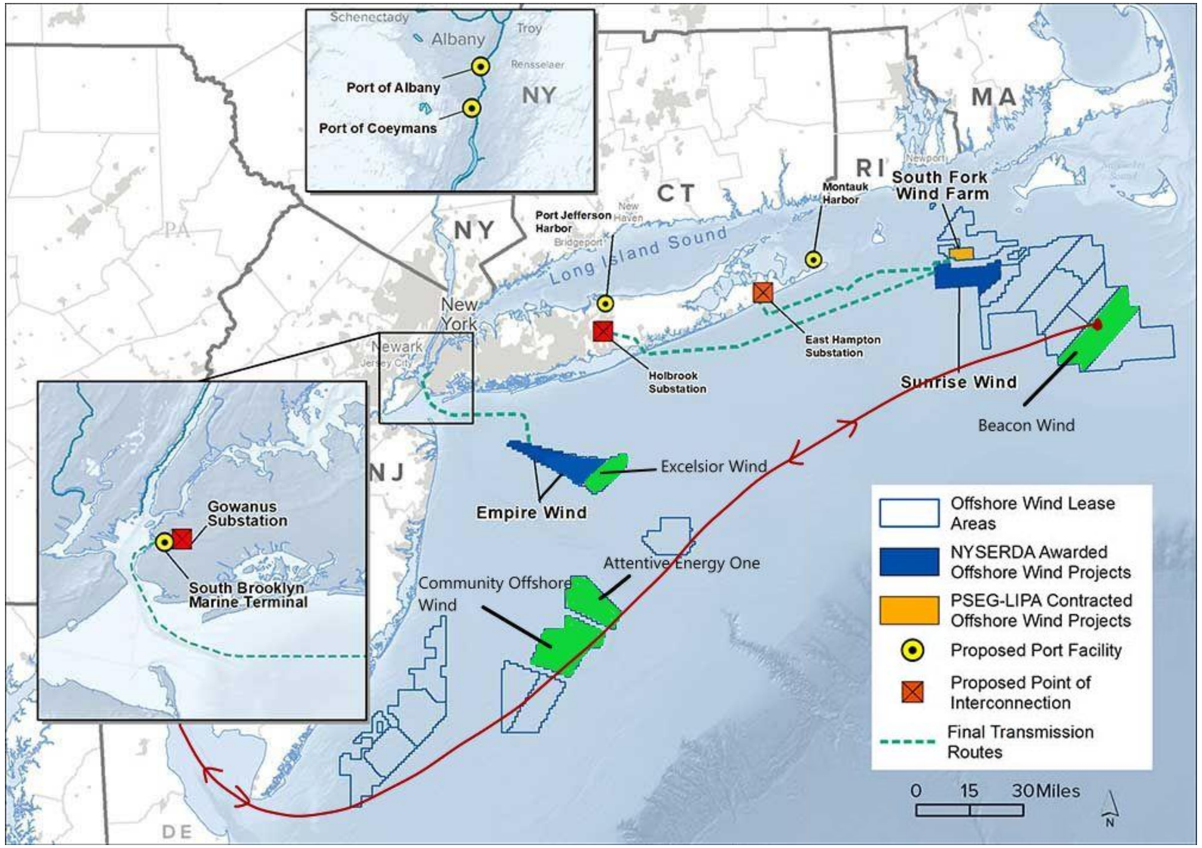
Ship	150,000 m^3 vessel	50,000 m^3 vessel
Required Power (approximate) [11]	25 MW	2 MW
Generators [12]	9H54DF (12.6 MW)	Wärtsilä 8V31SG
Installed Power	51 MW	17 MW
EEDI (approximate)	1.7	0

The 150,000m^3 vessel can complete a trip in 8 days



Evolution	Time to Complete (hours)	Hydrogen burnt (m^3)	Diesel Burnt (tons)
Travel	76	930	5.1
Loading at Farms	75	1900	7.4
Offloading	40	670	2.6
TOTAL	191	3050	15

The 50,000m^3 vessel can complete a trip in 6 days



Evolution	Time to Complete (hours)	Hydrogen burnt (m^3)
Travel	96	384
Loading at Farm	27	150
Offloading	27	152
TOTAL	150	687

Application	Multi-Farm Servicing			Single Farm Servicing		
Transport Method	150,000m3 vessel	Gas Pipeline	Electrical Cable	50,000m3 vessel	Gas Pipeline	Electrical Cable
Capital Cost	$258M	$2000M	$805M	$122M	$600M	$300M
Required Freight Rate	$3.04/kg to $4.34/kg	$0.60/kg to $0.86/kg	$5/MWh	$0.29/kg to $0.42/kg	$1.68/kg to $2.40/kg	$11/MWh

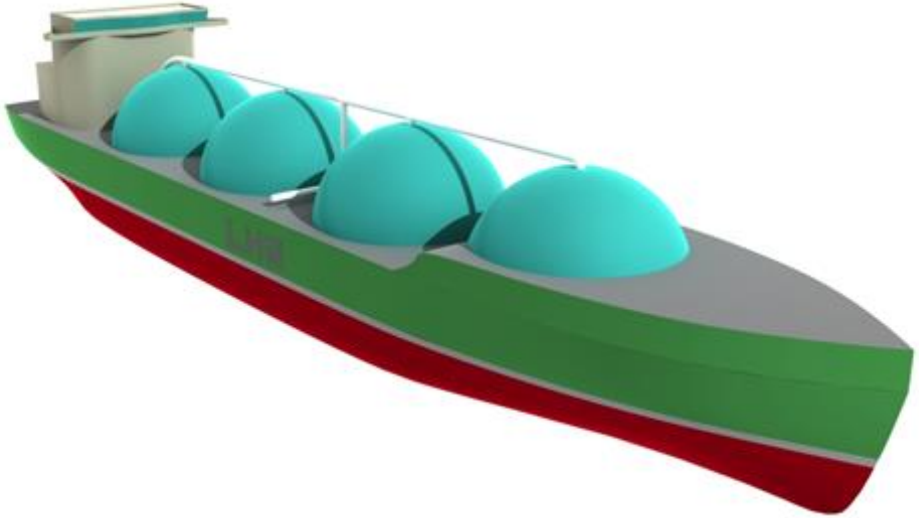
Future Works:

- Maneuvering study and characteristics, including additional power and regulatory requirements for dynamic positioning
- Detailed study on regulatory compliance
- Further Hydrostatics properties discussion
- Strength analysis
- Investigation into the potential of a dual-purpose LH2 carrier/ offshore supply vessel
- Investigation into the potential affects of single-point mooring systems on the feasibility of using feeder vessels to transport hydrogen from windfarms to shore.
- Selection of potential shipyards

Please direct questions to:

- Seamus O'Neil seamusone.21@sunymaritime.edu
- John Donnelly johndon.21@sunymaritime.edu
- Kenneth Jones kennethjon.21@sunymaritime.edu

Thank You



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Preliminary design of the "Mammoth Max"

Thomas Rooney, Logan Martinson, Connor Kemme, Erik Domorad

Prof. Hariharan Balasubramanian, Prof. Charles Munsch

Department of Naval Architecture and Marine Engineering

MARITIME COLLEGE
STATE UNIVERSITY OF NEW YORK

Owner Requirements

- Max DWT of 450,000 carrying iron ore.
- Must transport 1,000,000 MT of iron ore between Brazil and Japan within a year.
- Includes the use of wind assisted ship propulsion (WASP) to reduce emissions.

Principle Dimensions (Preliminary ship design)

Iron Ore Max Capacity	450,000	DWT
Length Overall	365	m
Length Between Perp.	360	m
Beam	68	m
Design Draft	23	m
Depth	30.6	m
L/B	5.47	-
B/T	2.82	-
B/D	2.14	-
L/D	11.8	-
Displacement @DWT 450000	515944	MT
Cb	0.895	-
Design Speed	14	Knots
Fn	0.121	-
S-L ratio @14 kt	0.737	-

Construction Costs

(Carreyette's method)

Steelwork labor coef., A'	4,160
Steelwork material coef., B'	624
Outfit labor coef., C'	46,795
Outfit material coef., D'	10,399
Machinery labor coef.	1,040
Machinery material coef.	4,160
Steelwork labor cost (million $)	44.8
Steelwork material cost (million $)	32.01
Outfit labor cost (million $)	8.91
Outfit material cost (million $)	18.42
Machinery labor cost (million $)	5.53
Machinery material cost (million $)	22.13
Total ship building cost (million $)	131.81

- **Carreyette method used to find coefficients/ costs.**
- **Valemax roughly 110 million dollars to build.**
- **Planning to build ship in South Korea at Daewoo Shipbuilding and Marine Engineering.**

Operating Costs

- Cost of lube oil – 1100 $/MT
- Port costs are rough estimate-Contact port authorities for exact information.
- Dockage due =.2$ * Gross tonnage
- Port due = L*2$*days
- Cargo handling= 6$ per MT (Use crane system)

Annual fuel oil cost (million $)	14.23
Annual lube oil cost (million $)	0.1456
Annual port cost (million $)	12.53
Annual running cost (million $)	7.500
Total operating cost (million $)	34.41
Annual capital charges (million $)	7.591
Total annual cost (million $)	42.001

Fuel costs breakdown

- 3 round trips a year @333333 DWT
- 4,742,118 dollars a round trip
- 14,226,353 dollars a year for fuel cost

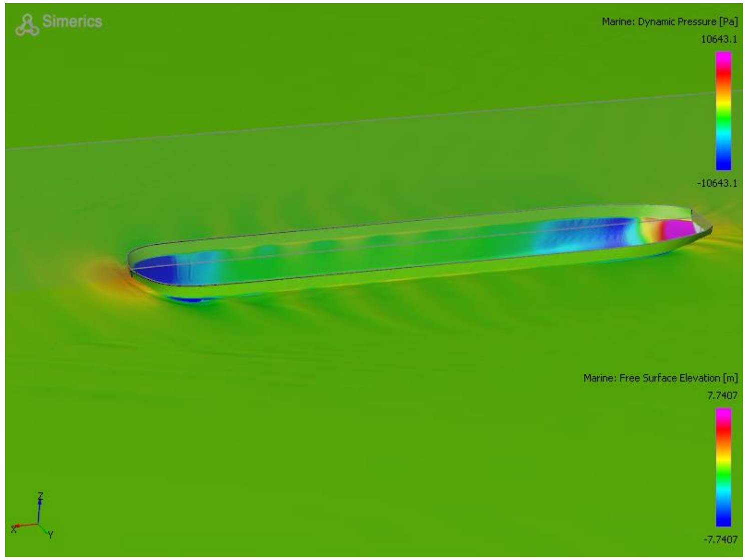
	Brazil to Japan	Japan to Brazil
Cost per tonne VLSFO	Brazil, 641 dollars	Japan, 653 dollars
Operating conditions	Loaded 162.1 g/kwh	Unloaded 155.2 g/kwh
One way consumption	3743.953 tonnes/trip	3586.897 tonnes/trip
Cost per trip	2,399,874 Dollars	2,342,244 Dollars

Operations

- Traveling from the ports of Ponta da Madeira, Brazil to Oita in Japan.
- Carrying 333,333 DWT to follow port restrictions. (Japan port Oita limiting DWT).
- Minimum operating days required to ensure 1 millions MT of iron ore delivered in a year.

Operational data	
Nautical miles per round trip	24060
Annual operating days	230
Proportion of miles in ballast (%)	50
Average loaded cargo / maximum (%)	0.7333
Load factor (%)	0.3666
Average speed (weighted average)	14.5
Steaming days per round trip	69.13
Port days per round trip	7
Total days per round trip	76.13
Round trips per year	3.020

Powering & Engine Selection



- Engine selected-WinGD X72-B 7 cylinder to satisfy results from CFD
- Engine is specifically designed for larger commercial vessels with EEDI regulations and operational flexibility in mind. Two stroke, low speed diesel engine.
- Designed for reliability and long periods of time without maintenance.

Engine Data	
Bore Diameter	720 mm
Piston Stroke	3 086 mm
Shaft Speed	66-89 rpm
Fuel Consumption rate	162.1 g/kWhr
Mean Effective Pressure	21 Bar
Weight Engine	642 MT
Power Output	15,000-27,440 kW
Specific Power	18.6 KW/MT

Weights and centers - Lightship

Category	Weight, MT	VCG, m above BL	Wt*VCG, MT-m
Light Ship Items:			
Hull Structure	49474.457	13.774	681441.382
Super Structures	0	17.5	0
Deck Houses	1150.288	43.396	49917.895
Structure Sum	50624.745	14.447	731359.276
Outfit	2663.424	32.1	85495.910
Special Outfit	0	0	0
Machinery:			
Propulsion	1478.891		
Remainder	882.507		
Machinery sum:	2361.398	12.7167	30029.155
Margin	1112.991	15.218	16937.687
Lightship Sum:	56762.558	15.218	863822.029

Weights (lightship items)

- The lightship weights are calculated using the methods outlined by Watson.
- The structural weight obtained by equipment number estimate.
- These weights represent a ship without deadweight items such as cargo, required fluids, crew and other items not present in lightship.

Weights continued (deadweight example)

Deadweight Items:	Weight, MT	VCG, m above BL	WT*VCG, MT-m
Cargo DWT	333333	16.321	6983184.091
Fuel Oil	8731.124	1.55	13533.242
Lube Oil	43.843	27.6	
Ballast Water	0	0	0
Fresh Water	379.464	22.95	8708.705
Crew and Effects	5.1	30.6	156.06
Provisions	22.321	30.6	683.0357
Deadweight sum:	342181.853	20.47526798	7006265.135
Total Ship weight:	399277.411	18.850	7870087.163

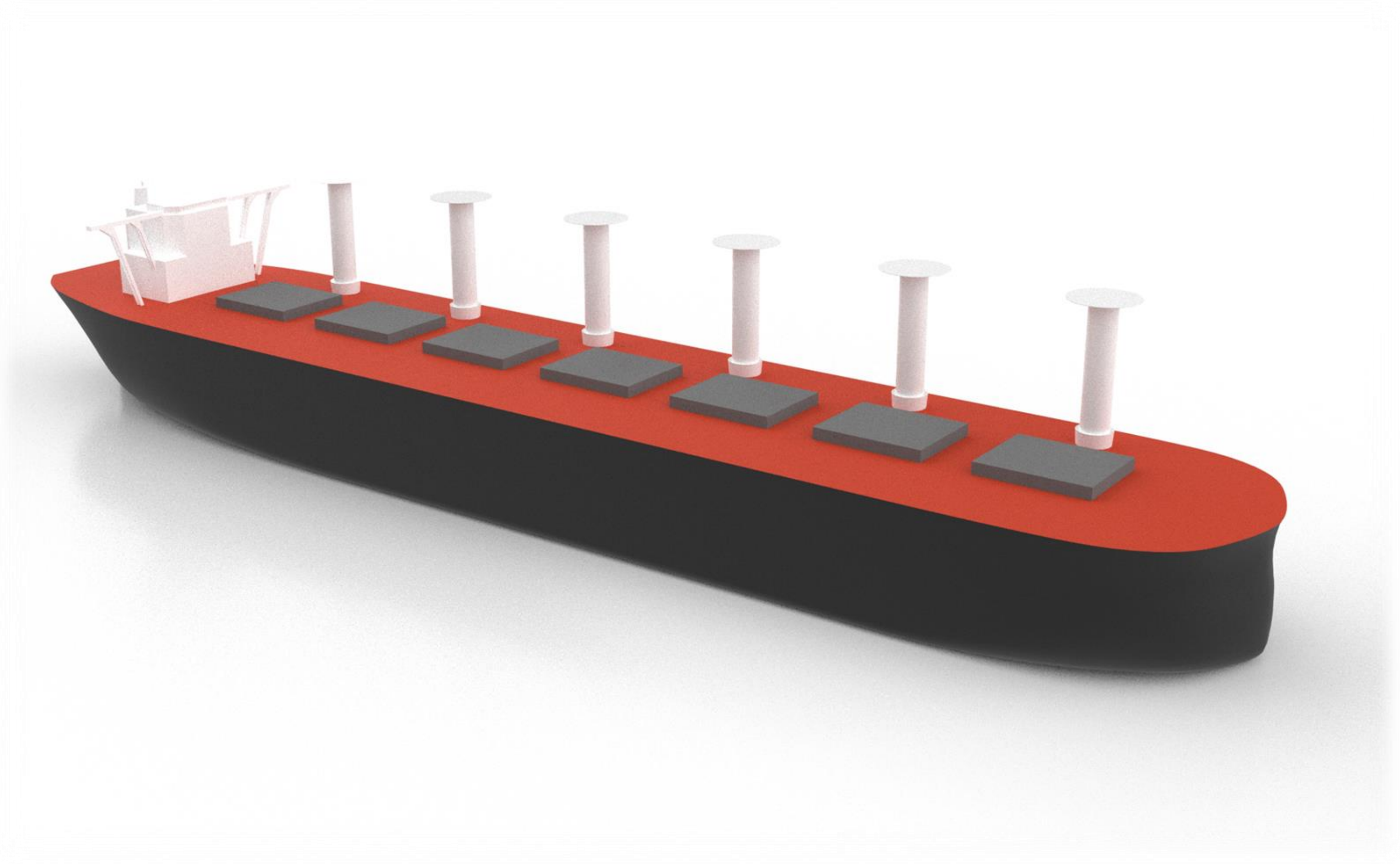
- The deadweight items are calculated including fuel oil, lube oil, fresh water, crew and effects, and provisions.
- Each items weight in MT multiplied by the VCG gives us the moments.
- These calculations represent a carrying capacity of 333,333 DWT.

EEDI

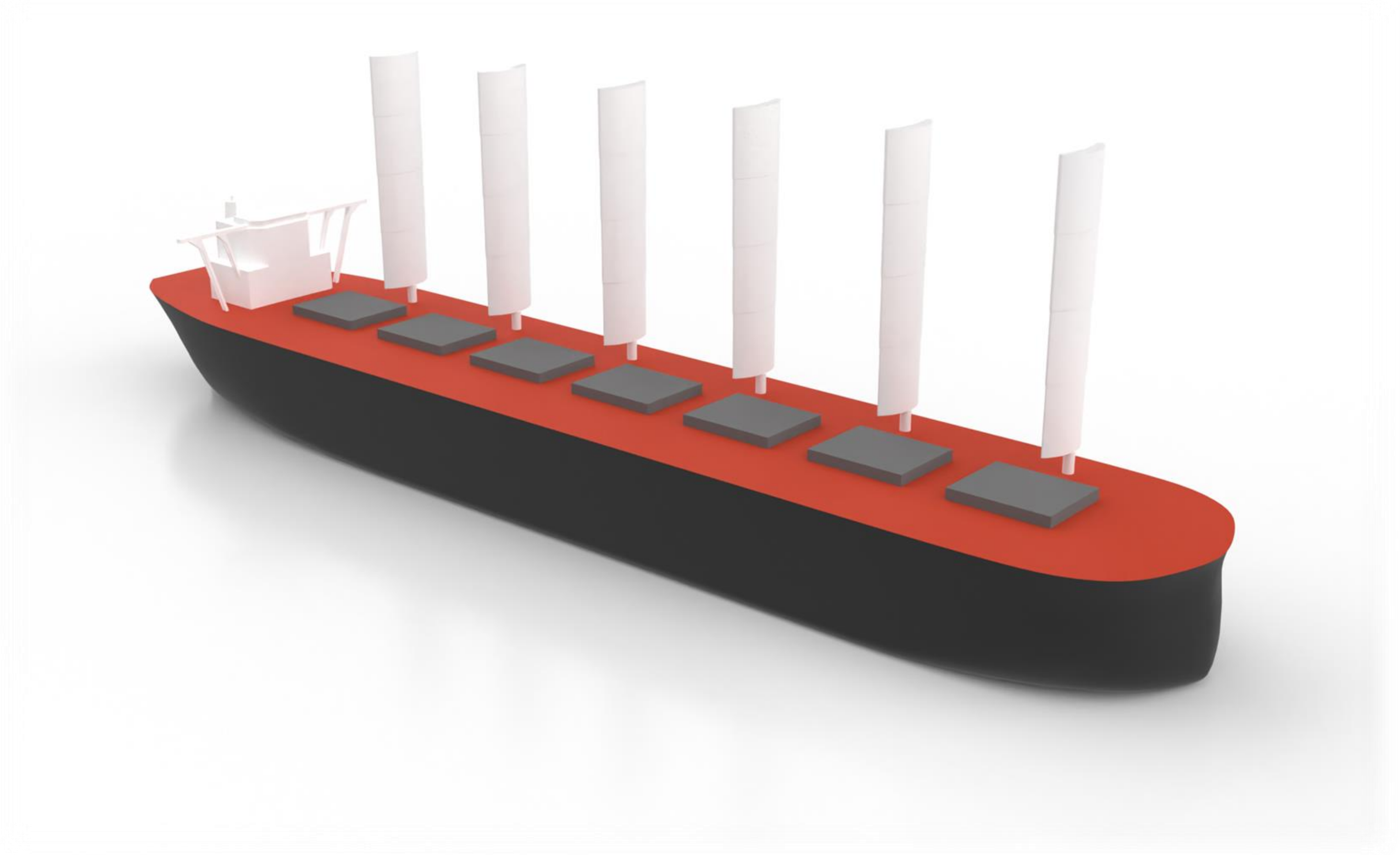
- As part of the owns requirement, the ship is intended to comply by use of WASP.
- IMO aims to reduce fuel consumption on ships and greenhouse gas emissions.
- To see which WASP arrangement is best, we analyze four arrangements, one without wasp.
- We are yet to Calculate an EEDI bespoke to each WASP arrangement.

Mammoth Max EEDI (g(CO2))/ton-mile	
Phase-1 DWT regression reference	1.934
Phase-3 Required EEDI	1.354
Phase-3 Ideal attained EEDI	1.286
EEDI calculated (prior to WASP installation)	1.948

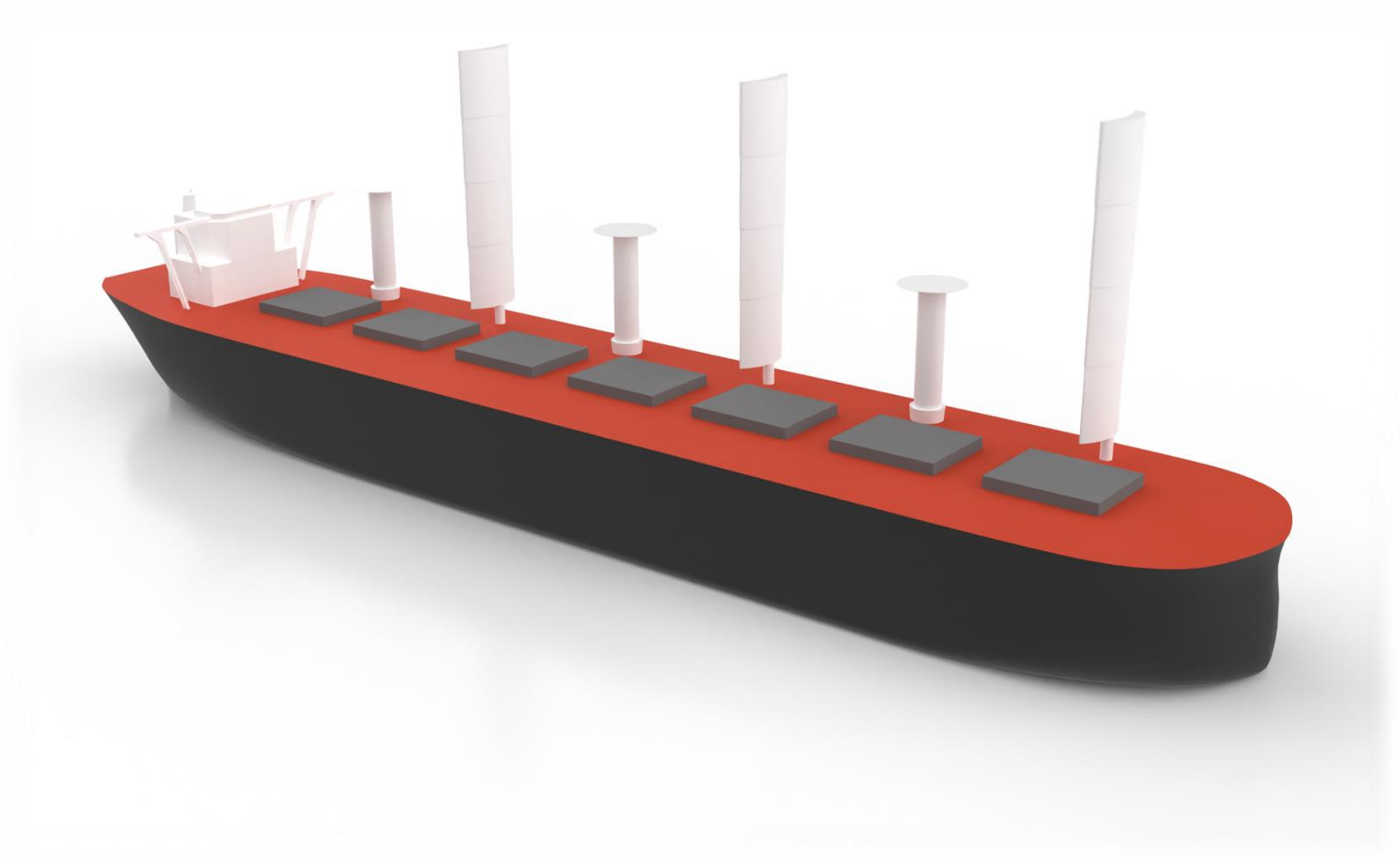
Flettner Rotors



Rigid Sails



Flettner Rotors & Rigid Sails

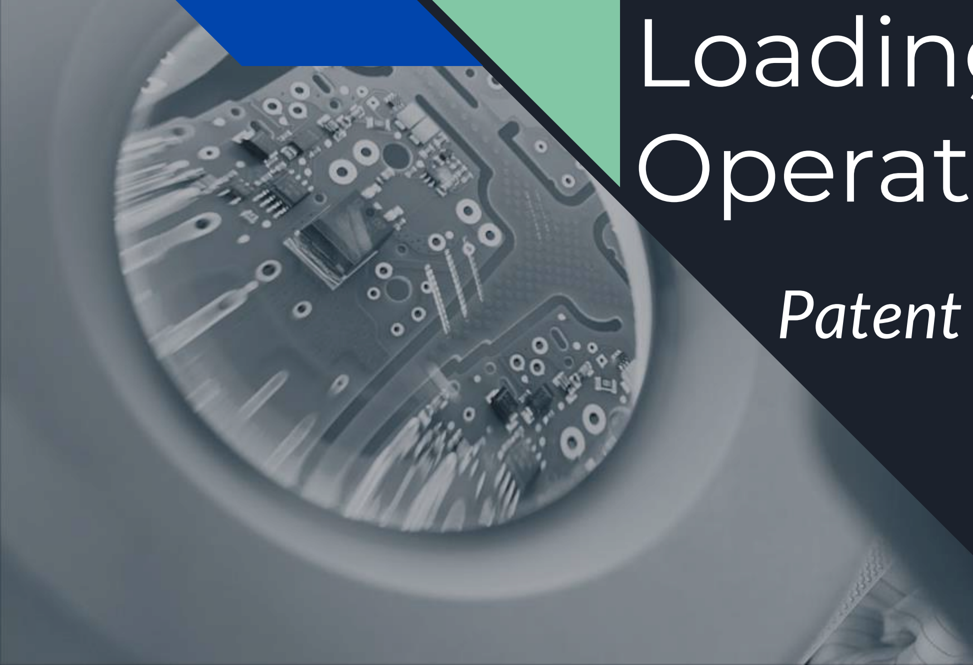


Future Requirements

- Produce and Prepare foam hull model to validate CFD results.
- Derive a method to account for wind speed and direction along various routes.
- Produce calculations of WASP performance.
- Calculate a refined a ROI calculation for each arrangement considering WASP performance.
- Strength and stress analysis on ship.
- Determining Maneuvering capabilities.
- Researching into additional green energies to further reduce EEDI come the occasion which WASP is not enough.

A Novel Application of AI for Liquid Cargo Loading and Discharge Operations

Patent Pending



Katherine Mattikow

Overview

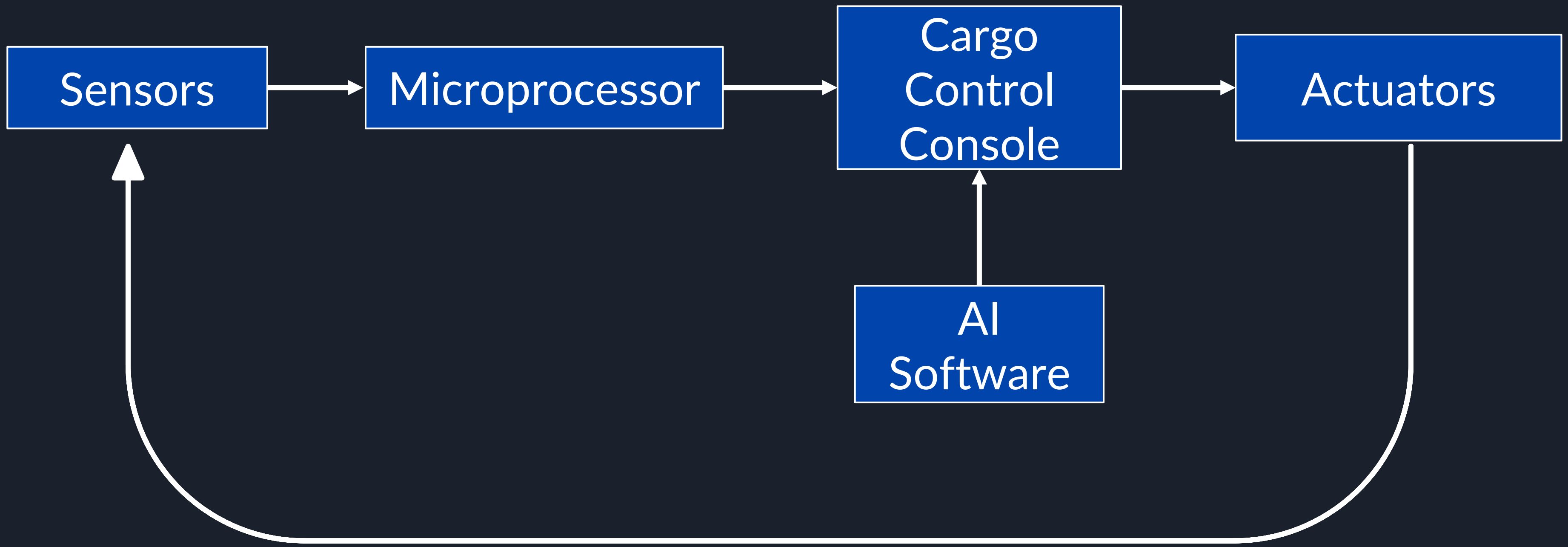
Using artificial intelligence and smart sensors to optimize marine liquid cargo transfer operations can improve efficiency, reduce the incidence of unintentional cargo discharge, and mitigate cargo losses.

Components of Liquid Cargo Transfer

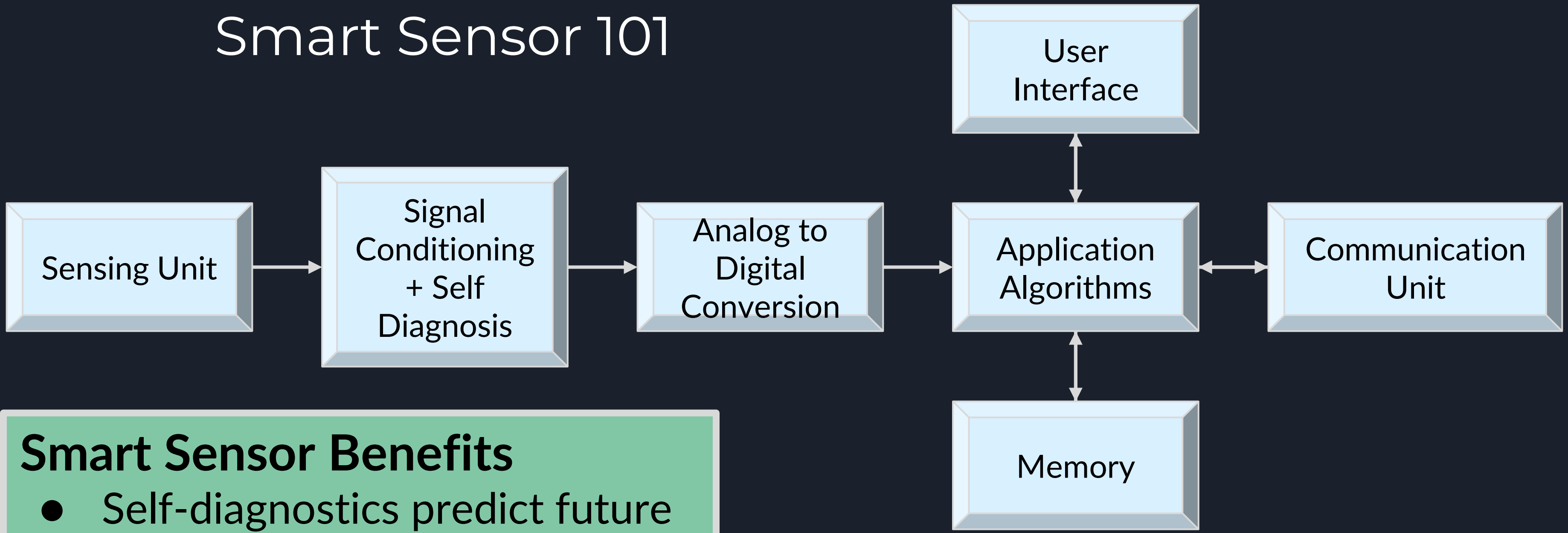
Ballast Water + **Liquid Cargo** + **Inert Gas**

This presentation focuses on the liquid cargo aspect of cargo management

System Schematic



Smart Sensor 101



Smart Sensor Benefits

- Self-diagnostics predict future performance of the sensor
- Simplified wiring
- Remote monitoring and troubleshooting

Data Flow

Smart Sensor Data	Input Variables	Algorithm	AI Decision Making	Actuation
integrated throughout the cargo handling system, providing continuous feedback on variables such as tank levels, temperature, pressure, flow rates, and valve statuses	• Drafts • Temperature • Gas Profile • Fill Percentage • Valve Status • Pump Status • Pressure	• Flow Calculations • Throughput Determination • Pressure Trends	Interprets algorithmic outputs, decides optimal method for achieving loading/discharge, sends action information to the actuators	Actuators implement the step-by-step plan by mechanically manipulating valves and pumps

Flow Calculation *(Simplified)*

$$Q = \frac{\pi P r^4}{8 \eta l}$$

Q = Flow Rate
P = Pressure
r = Pipe Radius
η = Fluid Viscosity
L = Pipe Length

Flow Rate	Q
Pressure	P
Pipe Radius	r
Fluid Viscosity	η
Pipe Length	l
Density	ρ
Specific Gravity	G
Pressure Drop	ΔP
Flow Coefficient	Cv
Temperature	T
Inlet Diameter	d
Stem Flow	m
Viscosity	Fv
Reynold's Number	Re or Nr
Kinematic Viscosity	Vcs

Applications

01 *Efficiency and Optimization of Cargo Operations*

02 *Environmental Harm Reduction*

03 *Enabling Full Vessel Automation*

04 *Cargo Shortage and Loss Mitigation*

1 Efficiency and Optimization of Cargo Operations

Current Lay Time

22.56 Hours

Lower Operational Expenses

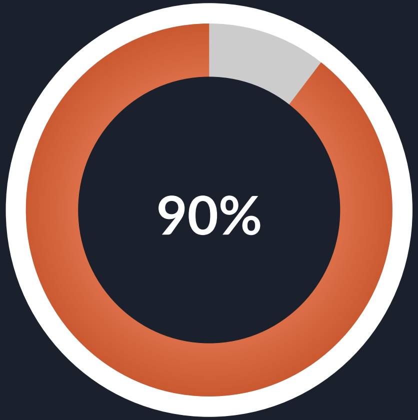
Uninterrupted Supply Chain

Lower Turnaround Times

More Voyages

Positive Relationships with Shippers

2 Environmental Harm Reduction



Human error accounts for 90% of oil spills in the marine environment

Causes of human error in marine pollution incidents during the loading/discharge of liquid cargo

- 01 **Miscommunication**
- 02 **Fatigue**
- 03 **Procedure Fault**
- 04 **Absence of Work Plan**
- 05 **Deficiency of Concentration**
- 06 **Deficiency of Situational Awareness**

Enabling Full Vessel Automation

3

Autonomous Steering Systems

Autonomous Docking

Autonomous Fueling

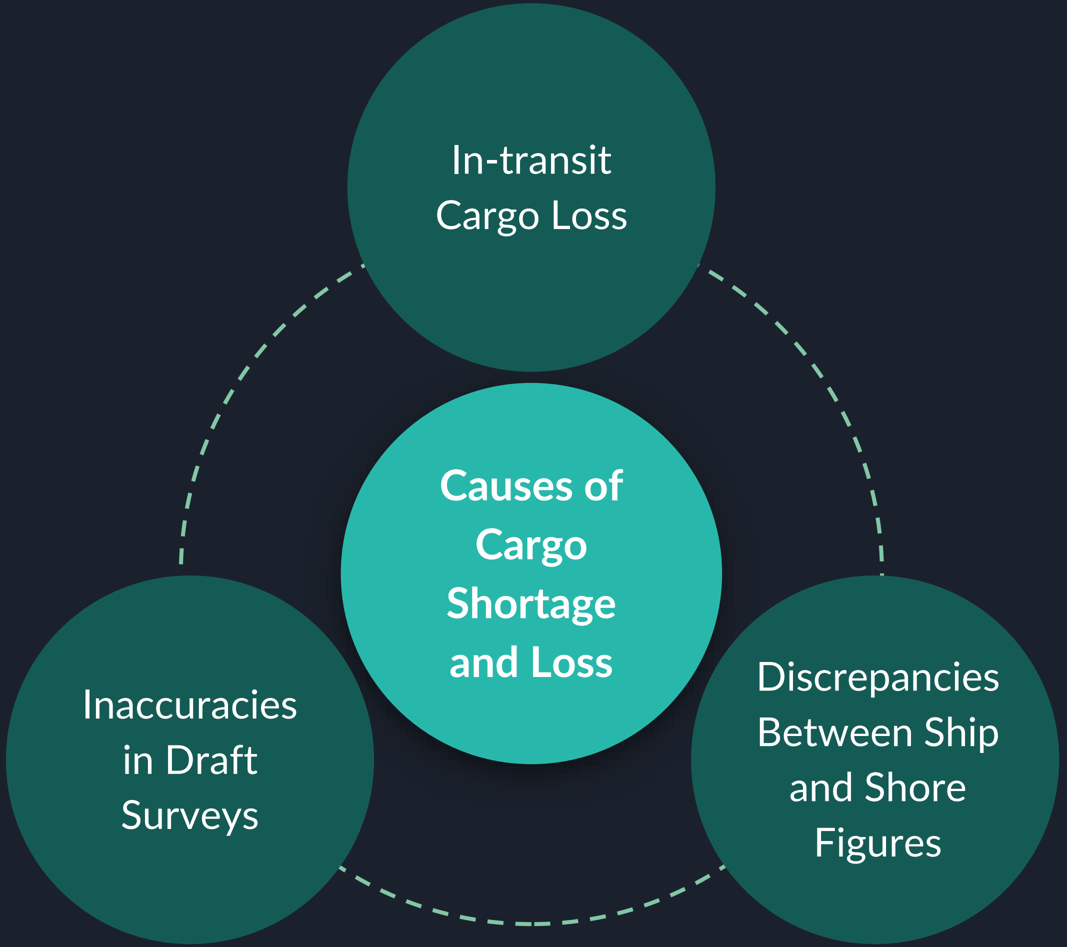
Autonomous Cargo Management

Necessary components of full vessel automation

No shipboard artificial intelligence augmented system may take the onus of watchstanding from the seafarer as it is mandated by law.

It is essential to note that while artificial intelligence can enhance marine transfer operations, human oversight and intervention should still be maintained, particularly for critical decision-making and handling unforeseen circumstances. The use of artificial intelligence in this context should aim to augment human capabilities and enhance safety rather than replace human roles entirely.

Cargo Shortage and Loss Mitigation



Cargo Shortage and Loss Mitigation

A discrepancy between ship and shore figures of **0.3%** or lower is within acceptable margins

A properly executed draft survey may have a **0.5%** inaccuracy

In the most severe scenario, the compounded miscalculation is **0.8%**

(75.19 x 3,000,000) x 0.008 =

$1,804,560

Saving per loading or discharge

Additional Future Applications

- Lightering
- Inter-tank Transfers
- Underway Ballasting
- Predictive Maintenance
- Alternative Fuel Management

Sustainability in Ship Design and Operations Conference 2024

FSRU CLOSED LOOP MODIFICATION

ENERGOS INFRASTRUCTURE

Jonathan Cullum
Technical Superintendent
ENERGOS INFRASTRUCTURE

Hariharan Balasubramanian
Assistant Professor, Department of Naval Architecture and Marine Engineering
SUNY Maritime College

Jonathan Cullum

USMMA 1991
Marine Engineering Systems

USCG Chief Engineer
Steam / Motor /GT
Unlimited HP

Over 30 years at sea
LNG Carrier / Oil Tanker / Container / RoRo

Technical Superintendent
Energos Infrastructure
2022(Nov) – present

Hariharan Balasubramanian

2005 – 2011
Motor / Steam LNG Carriers
as 3rd Assistant and 2nd Assistant Engineer

2011 – 2019
M.S & PhD in Ocean Engineering
(Florida Atlantic University)

2020 – 2022
Hydrodynamicist
(Ship – Bridge simulation models & Icebergs)

2022(Nov) – present
Assistant Professor
Department of Naval Architecture
and Marine Engineering
State University of New York Maritime College

Russia Attacks Ukraine

Putin's Forces Attack Ukraine

Ukraine's government said it faced "a full-scale attack from multiple directions." World leaders condemned President Vladimir Putin's actions.

Published Feb. 23, 2022 Updated Oct. 23, 2024

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Russia-Ukraine war Why are Ukrainian soldiers leaving the ranks? The patrols hunting for conscripts

News | Russia-Ukraine war

Timeline: After months of tensions, Russia attacks Ukraine

Russia launches a multipronged attack after months of diplomacy failing to resolve the crisis.

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BUSINESS | RUSSIAN FEDERATION

Could LNG boost energy security if Russia reduces exports?

Nik Martin

02/22/2022

Europe's gas reserves are at their lowest in years with winter demand not yet over. As the Ukraine crisis escalates, raising fears over Russian supply, could liquefied natural gas (LNG) fill the gap?

Reuters World US Election Business Markets Sustainability More

Energy

Germany freezes Nord Stream 2 gas project as Ukraine crisis deepens

By Sarah Marsh and Madeline Chambers

February 22, 2022 11:55 AM EST · Updated 3 years ago

Europe | LNG Terminals

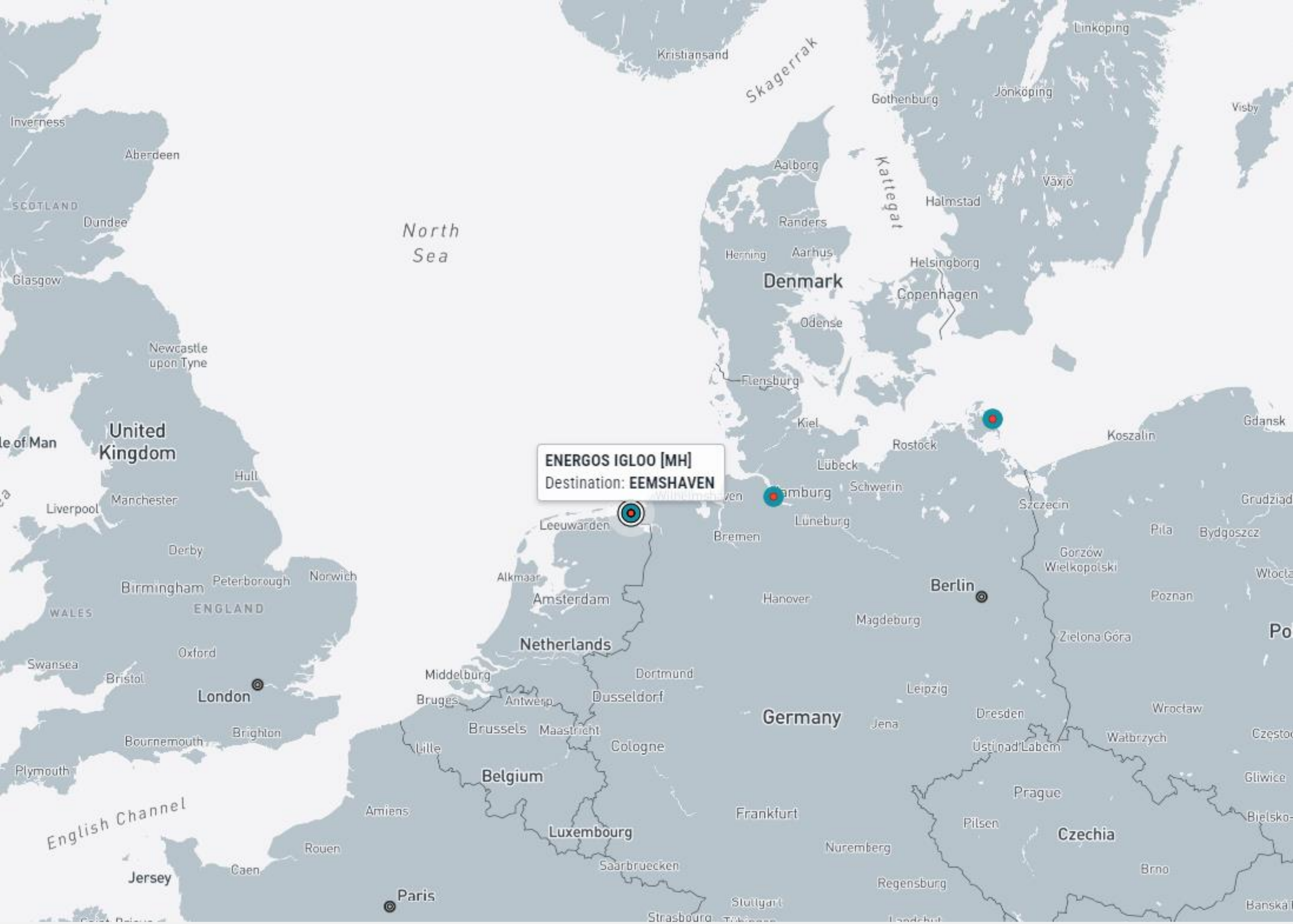
First FSRU arrives in Eemshaven to start serving Gasunie's LNG import hub

By **LNG Prime Staff**

September 4, 2022

The 170,000-cbm Golar Igloo in Eemshaven (Image: Gasunie)

The first out of two chartered floating storage and regasification units has arrived in the Dutch port of Eemshaven where it will soon start serving Gasunie's new LNG import hub.



ENERGOS IGLOO [MH]
Destination: EEMSHAVEN
North Sea
Skagerrak
Kattegat
English Channel
United Kingdom
SCOTLAND
ENGLAND
WALES
Denmark
Netherlands
Belgium
Luxembourg
Germany
Czechia
Inverness
Aberdeen
Dundee
Glasgow
Newcastle upon Tyne
Hull
Manchester
Liverpool
Derby
Birmingham
Peterborough
Norwich
Oxford
Swansea
Bristol
London
Brighton
Bournemouth
Plymouth
Jersey
Caen
Rouen
Amiens
Paris
Lille
Bruges
Brussels
Middelburg
Antwerp
Maastricht
Alkmaar
Amsterdam
Leeuwarden
Bremen
Hanover
Dortmund
Dusseldorf
Cologne
Frankfurt
Saarbruecken
Strasbourg
Stuttgart
Nuremberg
Regensburg
Jena
Leipzig
Dresden
Magdeburg
Berlin
Lüneburg
Schwerin
Lübeck
Kiel
Rostock
Flensburg
Odense
Copenhagen
Helsingborg
Herning
Aarhus
Randers
Aalborg
Kristiansand
Gothenburg
Halmstad
Växjö
Jönköping
Linköping
Visby
Gdansk
Koszalin
Szczecin
Grudziądz
Piła
Bydgoszcz
Gorzów Wielkopolski
Poznan
Zielona Góra
Wrocław
Wałbrzych
Ústí nad Labem
Prague
Pilsen
Brno
Gliwice

What is an FSRU?

F	Floating
S	Storage
R	Regasification
U	Unit

What is an FSRU?

Wikipedia
The Free Encyclopedia

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Regasification

5 languages

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From Wikipedia, the free encyclopedia

(Redirected from FSRU)

Regasification is a process of converting liquefied natural gas (LNG) at −162 °C (−260 °F) temperature back to natural gas at atmospheric temperature. LNG gasification plants can be located on land as well as on floating barges, i.e. a **Floating Storage and Regasification Unit** (FSRU). Floating barge mounted plants have the advantage that they can be towed to new offshore locations for better usage in response to changes in the business environment. In a conventional regasification plant, LNG is heated by sea water to convert it to natural gas / methane gas.

Regasification terminal of Tokyo Gas in Yokohama

Byproducts [edit]

ENERGOS INFRASTRUCTURE

Why use LNG ?

Environmental Benefits

LNG is considered one of the cleanest fossil fuels, with significant environmental advantages:

- **Lower emissions**: When burned, LNG produces fewer emissions of carbon dioxide, nitrogen oxides, and sulfur compared to other fossil fuels [1] [4]. It emits 40% less CO_2 than coal and 30% less than oil [4].
- **Reduced air pollution**: LNG emits significantly less soot, dust, particulates, and sulfur dioxide compared to coal and oil [4].
- **Noise reduction**: LNG-fueled engines tend to be quieter than diesel engines, reducing noise pollution [1].

Operational and Economic Benefits

- **High energy density**: LNG has a high energy density, allowing small amounts to generate large amounts of energy [1].
- **Efficiency in transport**: Due to its high energy density, LNG enables longer travel distances on less fuel, especially advantageous for maritime and long-distance land transport [1].

Regasification

OPEN	use SW for heating
CLOSED	use external heat
COMBINED	use SW and external heat together

SW Temps

Minimum SW inlet temp 14°C

ENERGOS
INFRASTRUCTURE

FSRU Development

First Gen	use Propane as intermediary fluid
Second Gen	use direct LNG/SW heat exchangers
Third Gen	use Glycol as intermediary fluid

Energos Igloo

OPEN LOOP

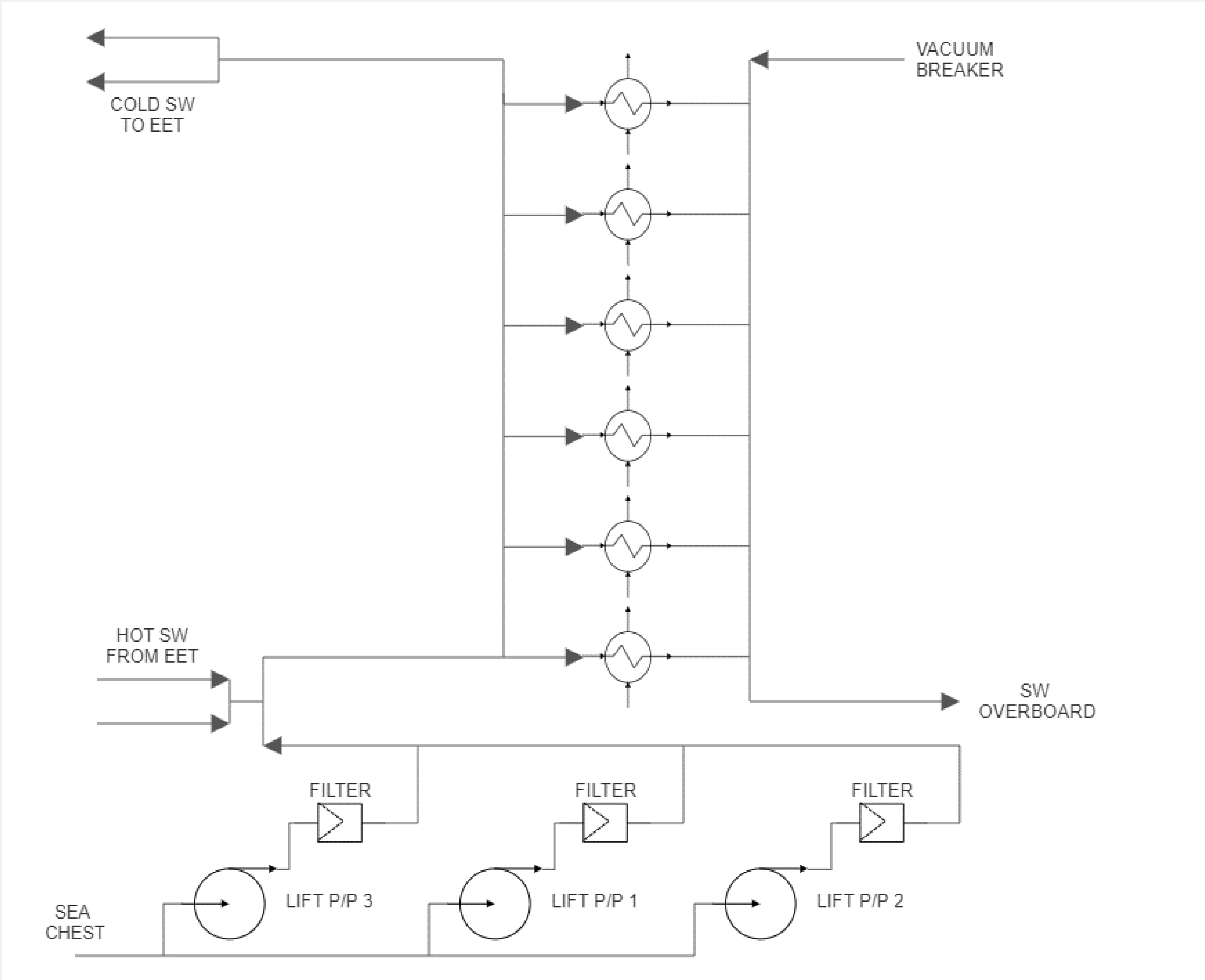
- 14°C minimum inlet SW temp (10.0°C is setting for PSD)
- 5°C minimum outlet SW temp (3.0°C is setting for PSD)

Chicago Power & Process, Inc. **Proprietary S&T LNG Vaporizers**

1	CUSTOMER SAMSUNG HEAVY INDUSTRIES				REFERENCE NO.	Golar
2	ADDRESS				CPP FILE NO.	CPP-11-104 (CH11-1234)
3	PLANT LOCATION				DATE	January 31, 2012
4	SERVICE OF UNIT Single Stage H.P. LNG Vaporizer (SI Units)				ITEM NO.	HA 1100/2100/3100/ A/B
5	SIZE 52648-1		TYPE Special NJN		HORIZONTAL	inclined 3 degrees
6	SURFACE (m2) (GROSS) 789.8		SHELLS/UNIT One		SURF/SHELL (m2) (EFF.)	770.3
7	PERFORMANCE OF ONE UNIT					
8			SHELL SIDE		TUBE SIDE	
9	FLUID CIRCULATED		Sea Water		LNG / Natural Gas	
10	TOTAL FLUID ENTERING		2632 m3/hr (Note 1)		104,276.10 kg/hr	
11			INLET	OUTLET	INLET	OUTLET
12	VAPOR	kg/hr	---	---	---	104,276.10
13	LIQUID	kg/hr	2,697,610	2,697,610	104,276.10	---
14	NON-CONDENSABLES	kg/hr	---	---	---	---
15	DENSITY	kg/m3	1026.51	1028.66	433.56	101.26
16	VISCOSITY	cP	1.013	1.418	0.1186	0.0149
17	SPECIFIC HEAT	kJ/kg-ºC	3.9289	3.9333	3.6001	3.5279
18	THERMAL CONDUCTIVITY	W/m-ºC	0.6127	0.6023	0.1997	0.0518
19	LATENT HEAT	kcal/kg				
20	MOLECULAR WEIGHT				16.72 (Note 4)	
21	TEMPERATURE IN	ºC	14.0		-152.9	
22	TEMPERATURE OUT	ºC	7.22 (Note 2)		8.0	
23	OPERATING PRESSURE	BarG			109.0	
24	NO. PASSES PER SHELL		ONE		ONE	
25	VELOCITY					
26	PRESSURE DROP	Bar	1.74 (Note 3)		0.43	
27	FOULING RESISTANCE	m²-C/W	Note 5		Note 5	
28	HEAT EXCHANGED 19,934.99	kW			MTD CORRECTED 44.8	ºC
29	TRANSFER RATE – SERVICE 664.4 / 577.7	W/ m2 C	(Clean / Design)			
30	CONSTRUCTION					
31	DESIGN PRESSURE	BarG	7.0		125	
32	TEST PRESSURE	BarG	Per Code		Per Code	
33	DESIGN TEMPERATURE (Max/Min)	ºC	65 / -170		65 / -195.5	
34	TUBES 254 SMO (Note 6) NO 802	OD 0.75	BWG 16		LENGTH 16.46 m	PITCH 33.3375 mm
35	SHELL AL6XN ID	OD 132.1 cm				
36	EXPANSION JOINT (BELLOWS) AL-6XN					
37	BONNET 316L SS				CHANNEL COVER	N/A
38	TUBESHEET-STATIONARY AL-6XN				TUBESHEET-FLOATING	N/A
39	BAFFLES - CROSS AL-6XN TYPE Seg.				FLOATING HEAD COVER	N/A
40	TUBE SUPPORTS AL-6XN				IMPINGEMENT PROTECTION	Yes
41	GASKETS N/A				PACKING	N/A
42	TUBE TO TUBESHEET JOINT Seal Welded & Rolled into Double Grooved Holes					
43	CONNECTIONS-SHELL SIDE IN QTY (2) 20" on 26" reducer		OUT 30"		RATING	16K JIS
44	CONNECTIONS-TUBE SIDE IN 8"		OUT 12"		RATING	900# RFWN
45	CORROSION ALLOWANCE – SHELL SIDE ---				TUBE SIDE ---	
46	CODE REQUIREMENTS ASME Sec. VIII, Div. 1				TEMA CLASS	"R"
47	OTHER DNV					
48	NOTES (1) 1316 m3/hr in "Cold" LNG section & 1316 m3/hr in "Warm" NG section at full load					
49	(2) SW bulk outlet temperature. SW flow of 1303 m3/hr in the "Cold" LNG section should be maintained at all times to guard against potential freeze problems.					
50	(3) SW pressure drop when operating at full load.					
51	(4) Standard LNG: 96.01% C1, 3.2% C2, 0.6% C3, 0.05% iC4, 0.05%nC4, 0.01%iC5, 0.08% N2 (mole %)					
52	(5) 15% excess surface area with no additional fouling applied					
53	(6) Helium leak tested tube to tubesheet joints					
54	(7) The hot circuit must be started first and shut down last.					
55	(8) Proprietary design features for tube side LNG distribution, performance, and venting.					

Chicago Power & Process, Inc. Phone: 847/870-7900
Arlington Heights, Illinois 60004 tlavalle@chicagopowerandprocess.com

Heating from Shore



First Year of Operation

Harbor temperature as low as 3.5°C

14°C minimum inlet SW temp

9°C outlet SW temp

5 – 6 °C ΔT

Close the Loop

Recirculate the vaporizer SW outlet to the lift pump suction

Capture the 5 – 6 °C ΔT

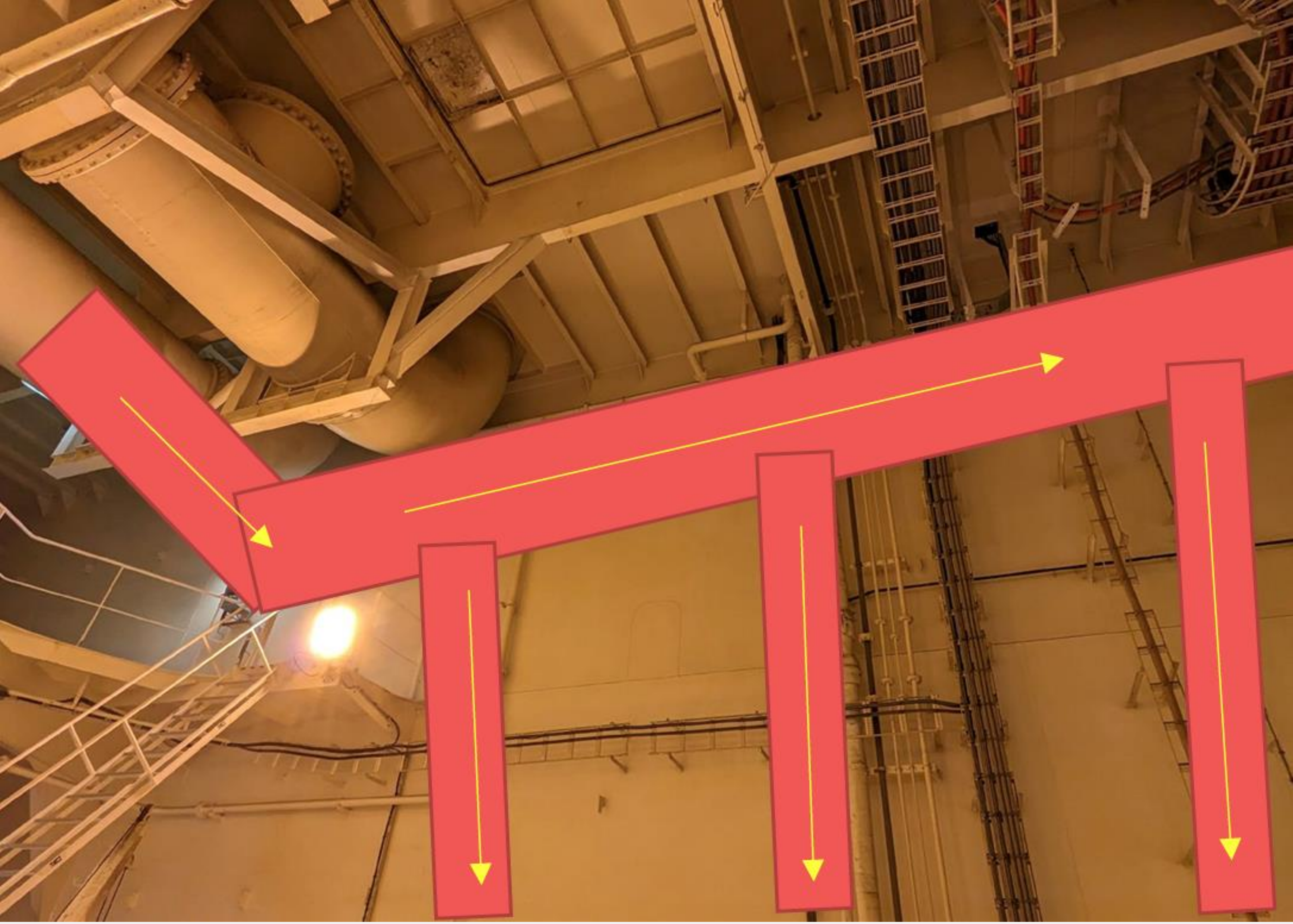
Obtain a higher capacity of the regas plant

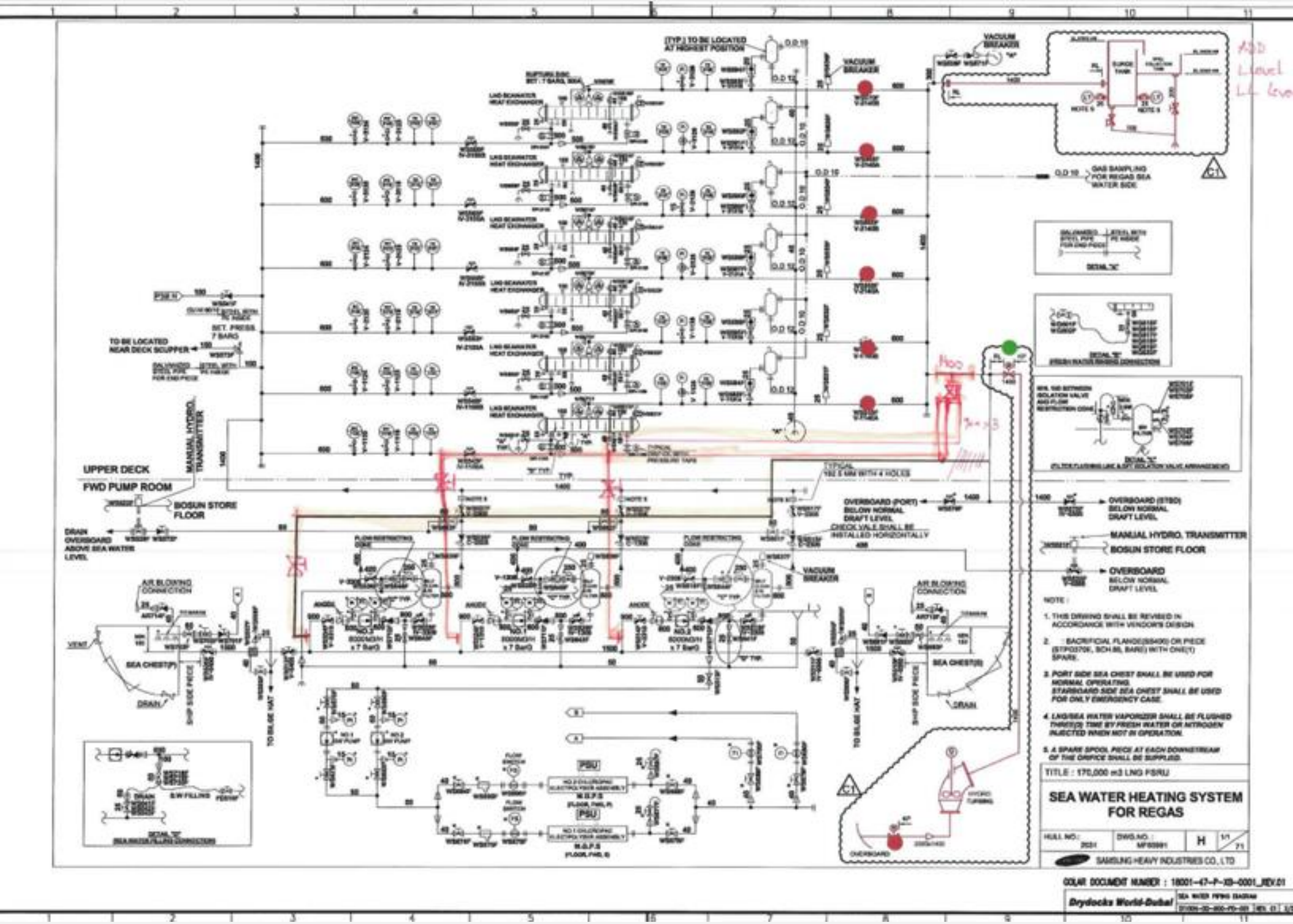
Can we do it ?

In 2018 a Hydroturbine Generator was installed to recapture some of the energy used to “lift” the SW to the regas plant

So we already had a header tank to use for a closed loop circuit


TO BE KEPT
CLOSED AT SEA




UPPER DECK
FWD PUMP ROOM
MANUAL HYDRO. TRANSMITTER
BOSUN STORE FLOOR
TO BE LOCATED NEAR DECK SCUPPER
SET. PRESS. 7 BARG
DRAIN OVERBOARD ABOVE SEA WATER LEVEL
AIR BLOWING CONNECTION
SEA CHEST(P)
SEA CHEST(S)
VENT
DRAIN
SHIP SIDE PIECE
TO BILGE HAT
LNG/SEAWATER HEAT EXCHANGER
VACUUM BREAKER
GAS SAMPLING FOR REGAS SEA WATER SIDE
OVERBOARD (PORT) BELOW NORMAL DRAFT LEVEL
CHECK VALVE SHALL BE INSTALLED HORIZONTALLY
OVERBOARD (STBD) BELOW NORMAL DRAFT LEVEL
MANUAL HYDRO. TRANSMITTER
BOSUN STORE FLOOR
OVERBOARD BELOW NORMAL DRAFT LEVEL
FLOW RESTRICTING ORIFICE
PSU
OVERBOARD
NOTE :
1. THIS DRAWING SHALL BE REVISED IN ACCORDANCE WITH VENDOR'S DESIGN.
3. PORT SIDE SEA CHEST SHALL BE USED FOR NORMAL OPERATING. STARBOARD SIDE SEA CHEST SHALL BE USED FOR ONLY EMERGENCY CASE.
4. LNG/SEA WATER VAPORIZER SHALL BE FLUSHED THREE(3) TIME BY FRESH WATER OR NITROGEN INJECTED WHEN NOT IN OPERATION.
5. A SPARE SPOOL PIECE AT EACH DOWNSTREAM OF THE ORIFICE SHALL BE SUPPLIED.
TITLE : 170,000 m3 LNG FSRU
SEA WATER HEATING SYSTEM FOR REGAS
SAMSUNG HEAVY INDUSTRIES CO., LTD
GOLAR DOCUMENT NUMBER : 18001-47-P-XB-0001_REV.01
Drydocks World-Dubai

Do the Math

TRITEC MARINE

ENERGOS

Modification of the LNG SW heating system to be capable of operation in closed loop mode

Desktop Feasibility Study Report

Document No. 11551-101-GEN-REP-001-C02

Date: 03 July 2023

This study has focussed on two areas. Firstly, an overview of the current heating arrangements, the heating requirement for operation of two skids at full design capacity and the required heat supply to meet these heating requirements. Secondly, the effects on the sea water system and pump operation when converted from open loop to closed loop operation.

The study has looked at the technical feasibility of modifying the sea water regasification system to operate in closed loop mode in the winter months in order to maintain operation of two regassification skids at full design capacity.

It has been found, within the limits of the stated assumptions, a shore heat supply of approx. 100 MW would be capable of providing sufficient heat to maintain this operation with closed loop operation of the sea water system.

The study in considering pump operation has found that within the limits of the assumptions and uncertainties, operation of the sea water lift pumps in closed loop mode can be controlled by regulation of newly installed pump suction side and discharge side throttling valves to operate the pump on its performance curve while minimising the deviation of the new operating point from the original design operating point and remaining within pump manufacturers recommended maximum operating pressure.

It is recommended to confirm the correct SW flow in the system when currently in operation and review additional operating data in order to provide better model validation.

The system operation under abnormal conditions was considered. This was to evaluate the resultant pressures around the system under the condition of pump operation with all vaporiser sea water

Increased Sustainability

Increased efficiency

Less fuel used for regas

Less emissions

Less warm water to harbor

Design Considerations

How to do it while on station

How to get the pipes into place

Increased suction head pressure

Stagnant water in the loop

Participants

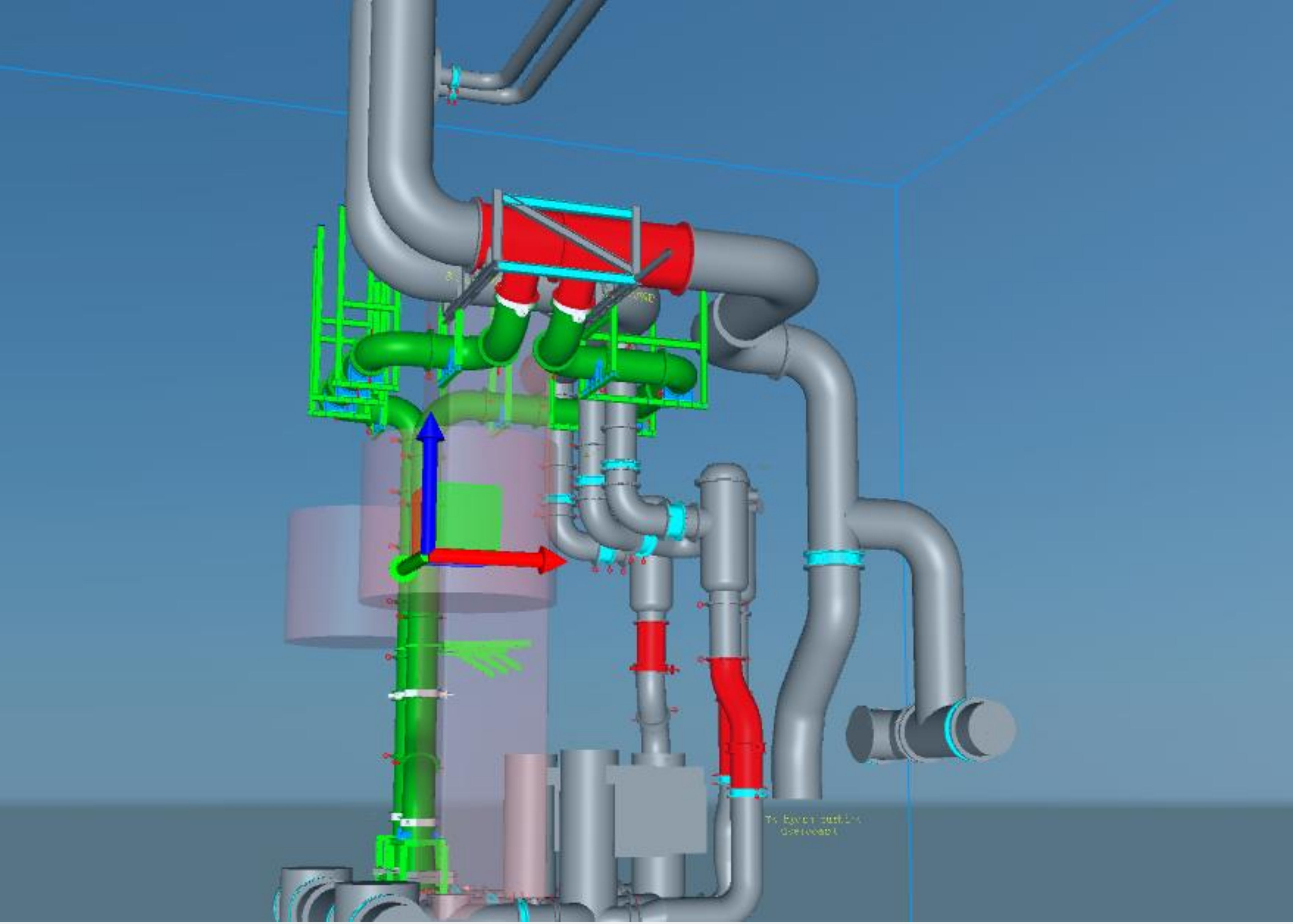
Preliminary Design

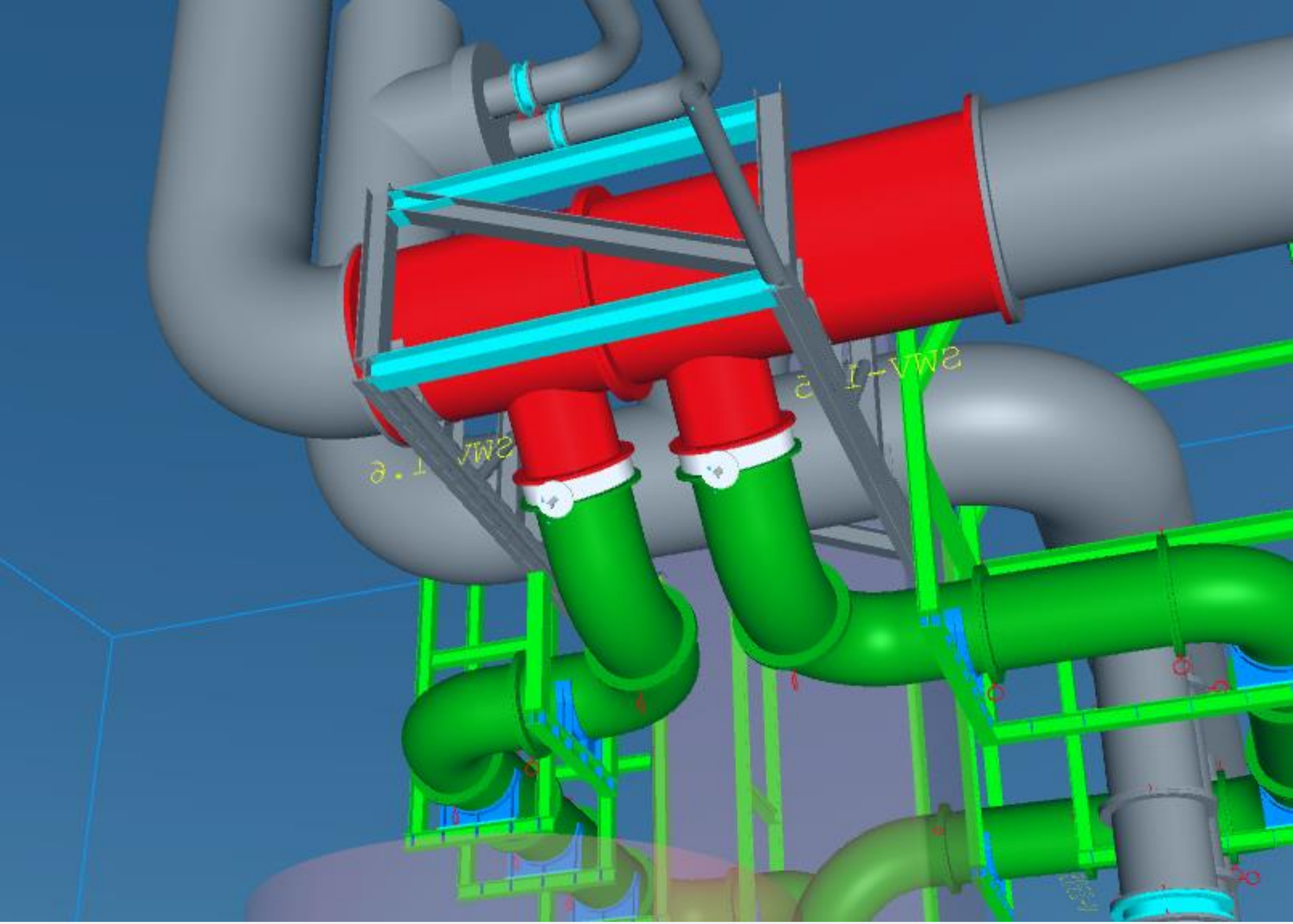
Steel pipe with Glass Flake for tie-in

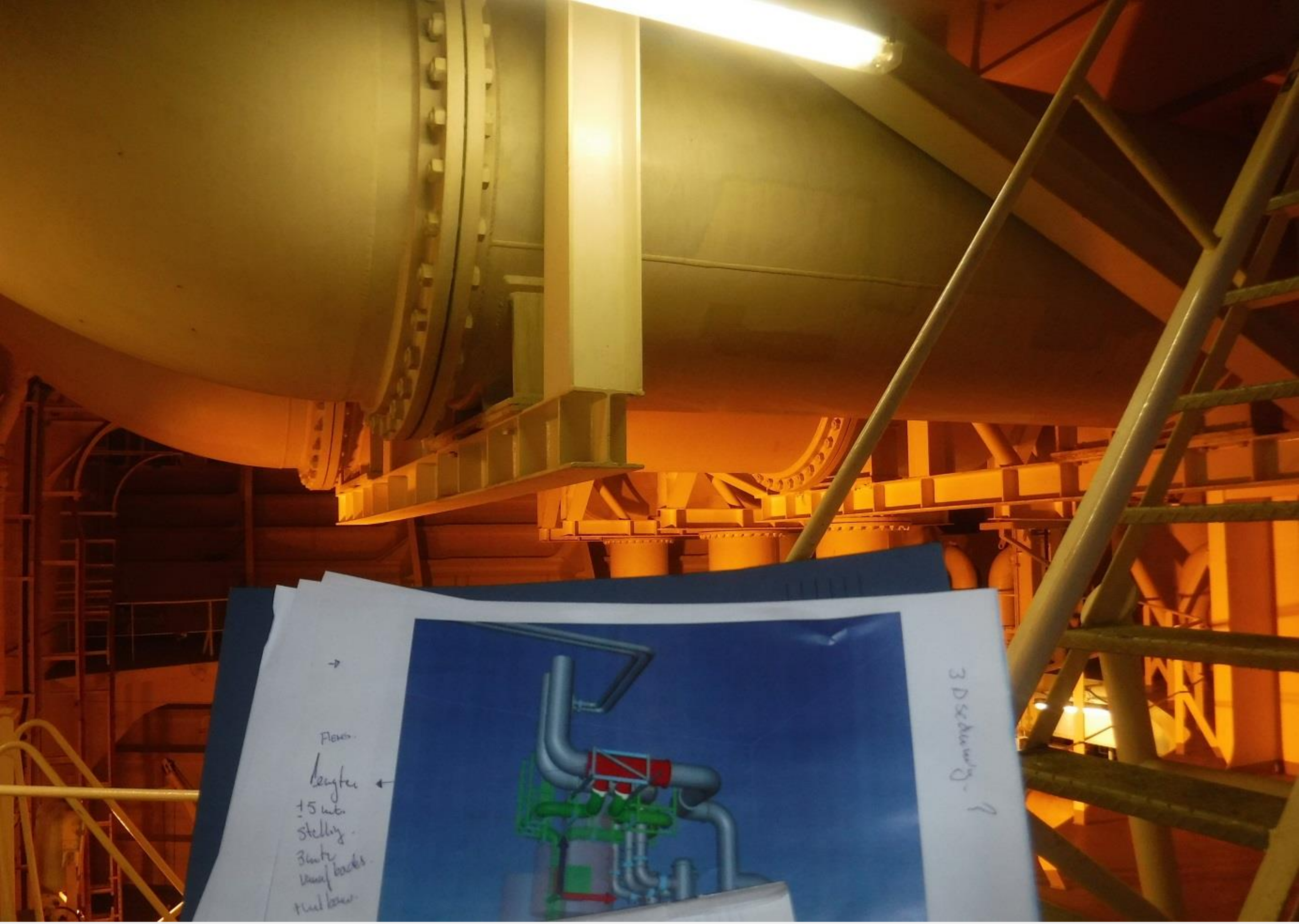
GRE pipes for recirculation

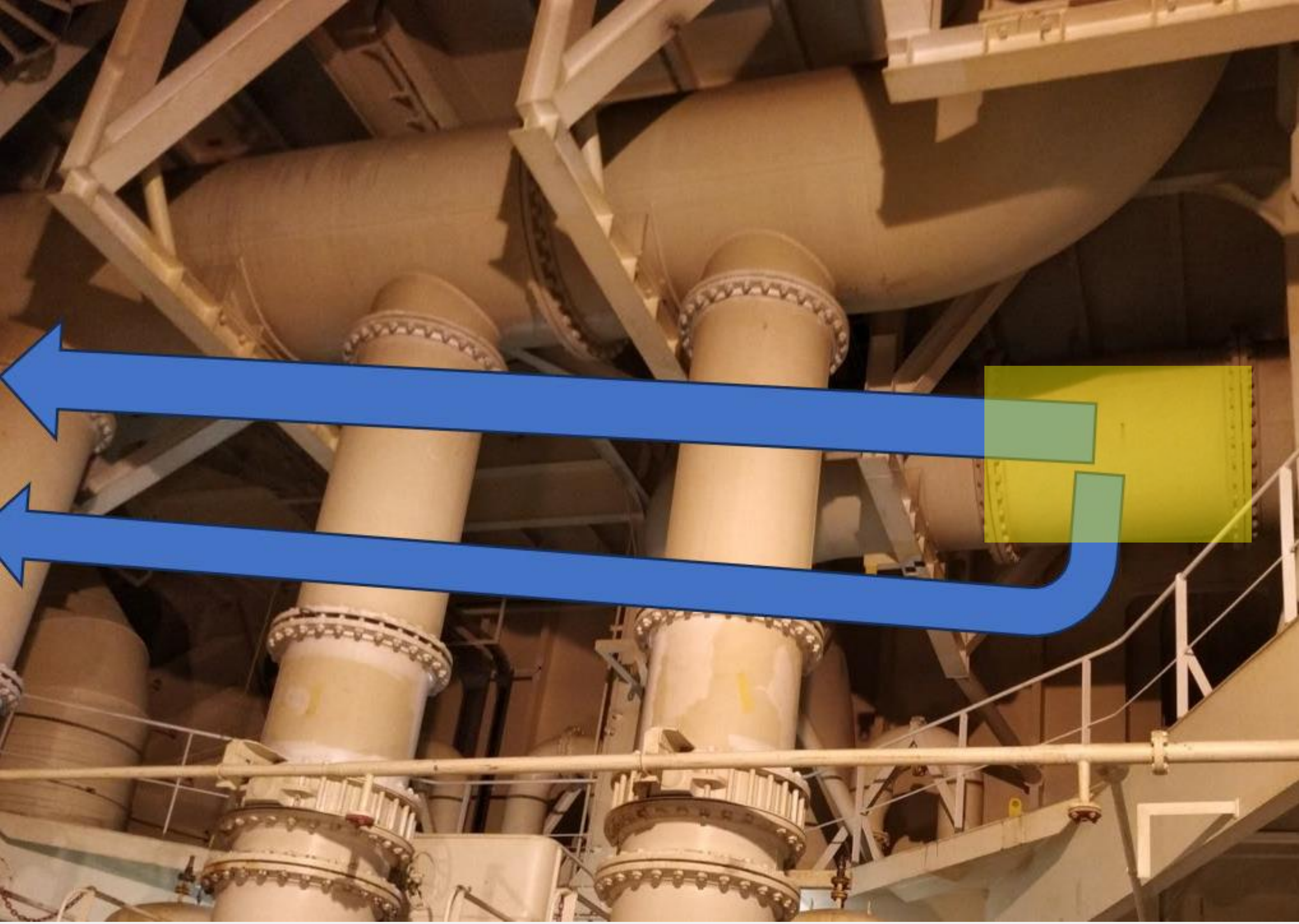
Additional Pressure Switches

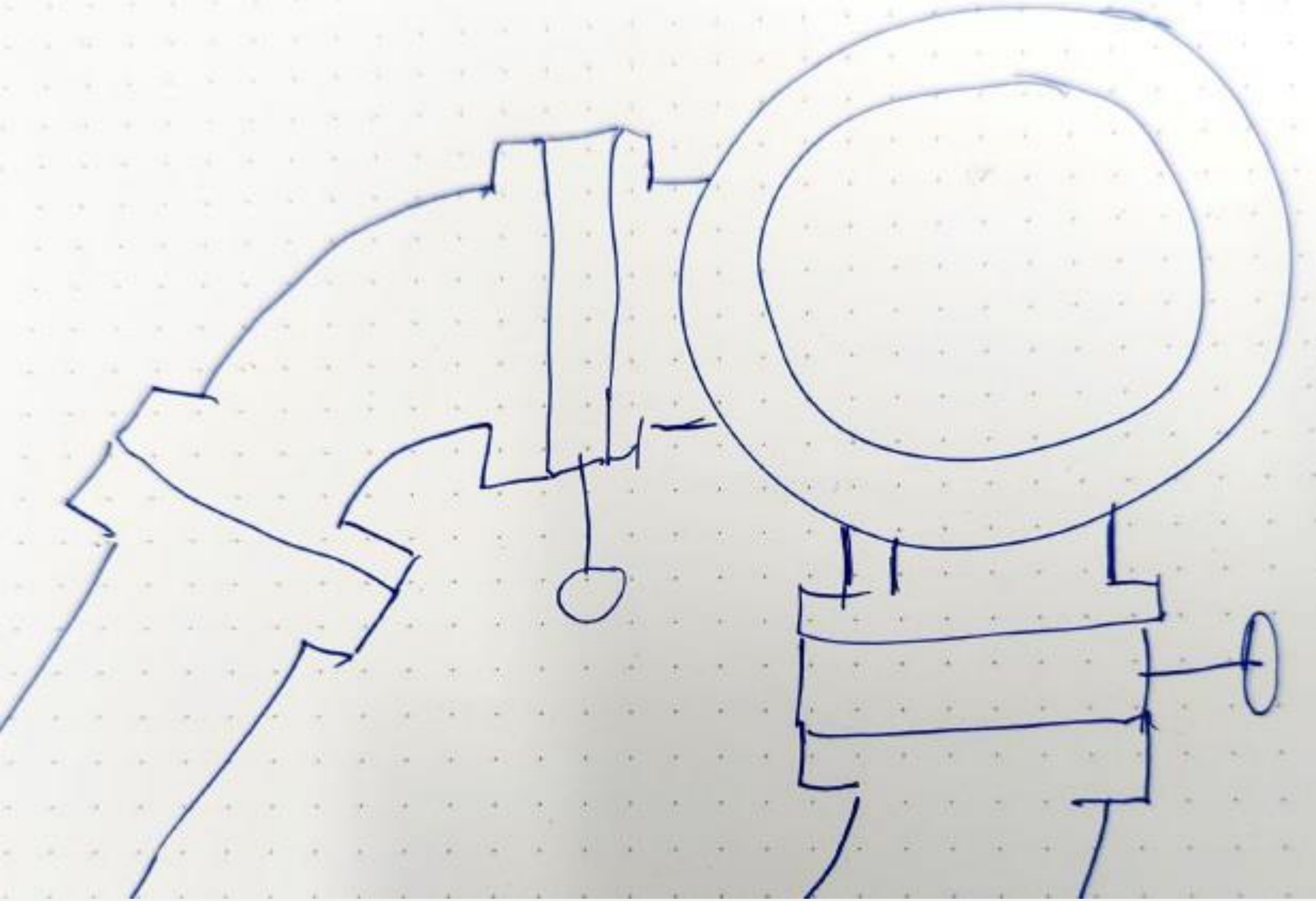
What could go wrong?

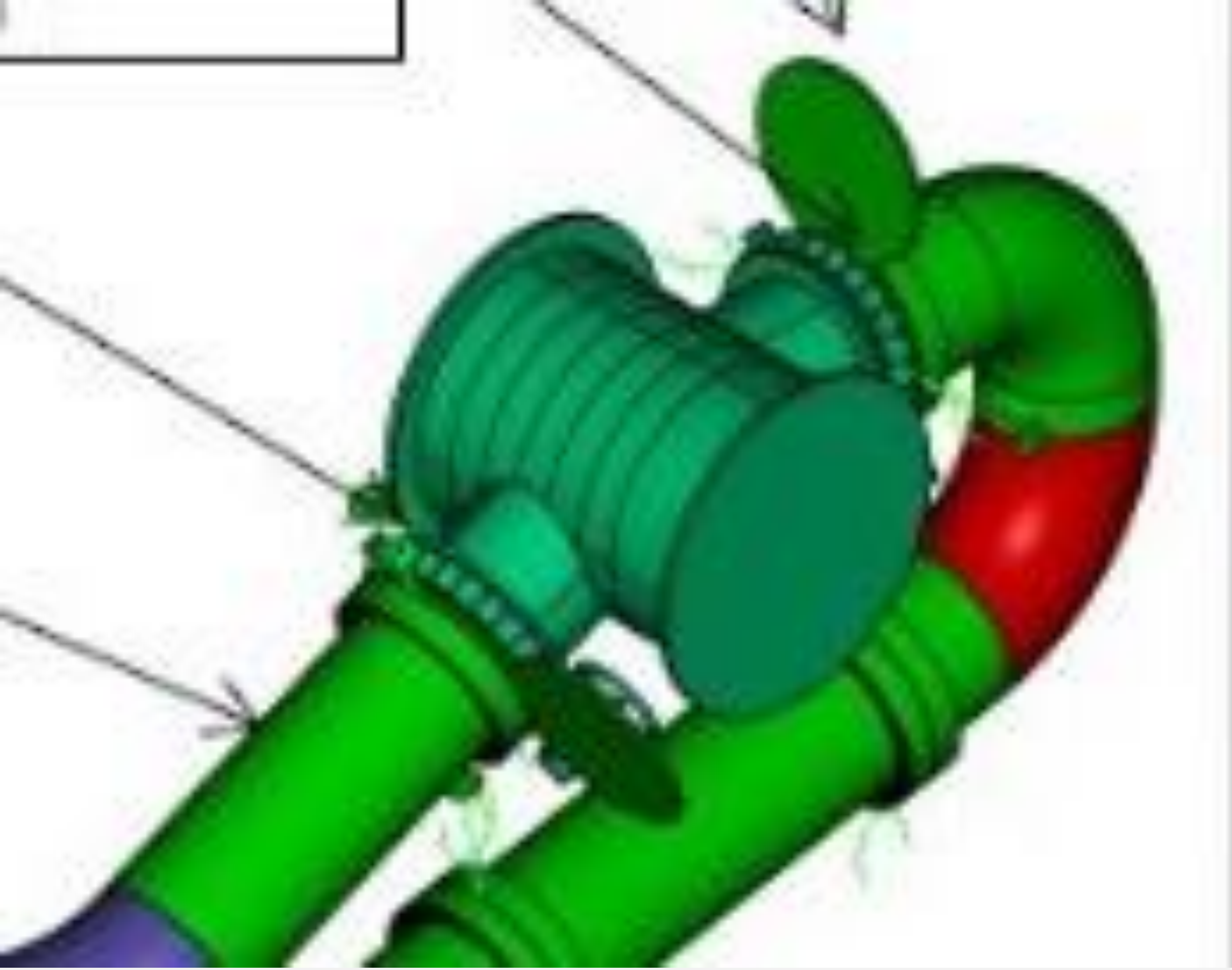


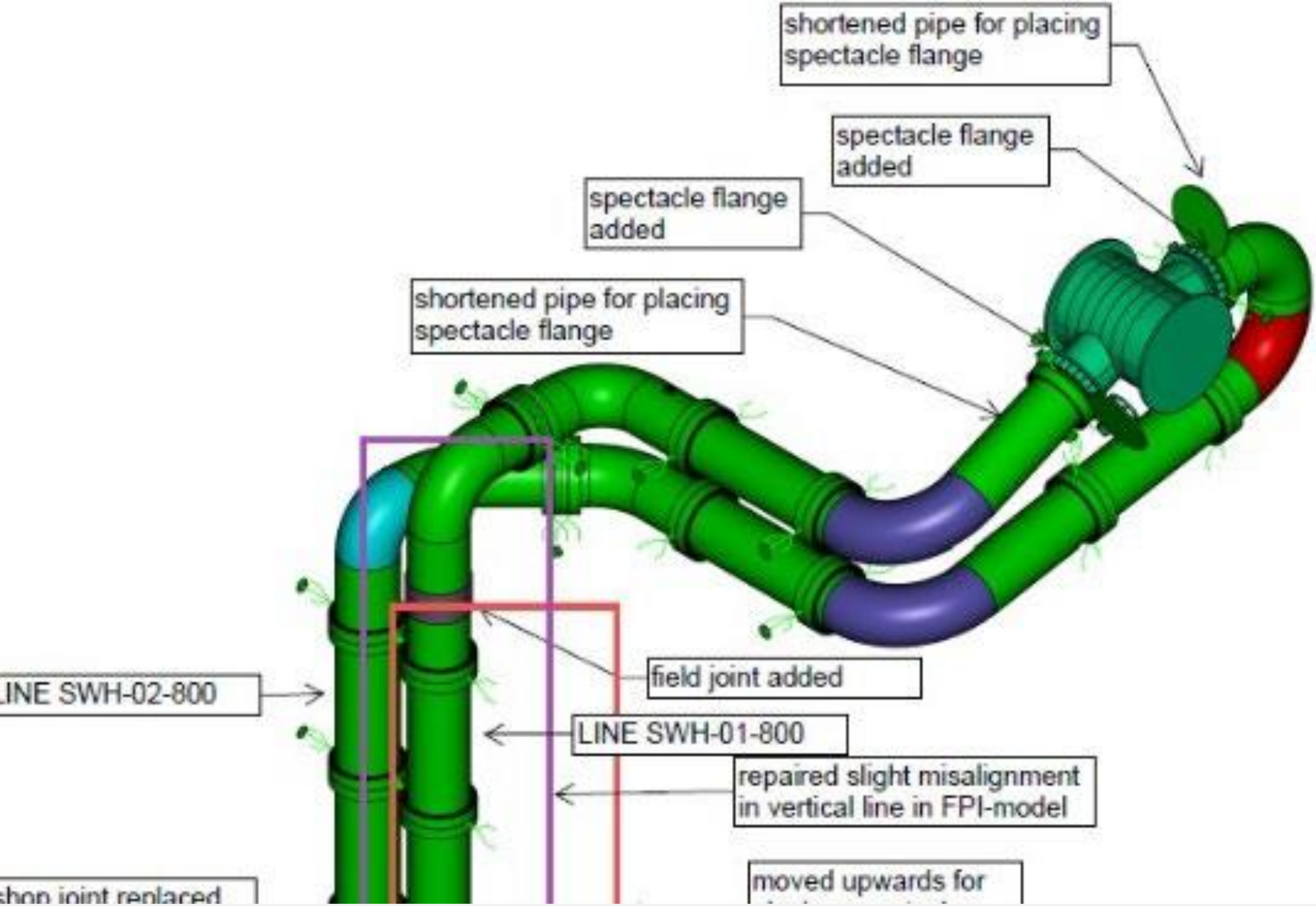


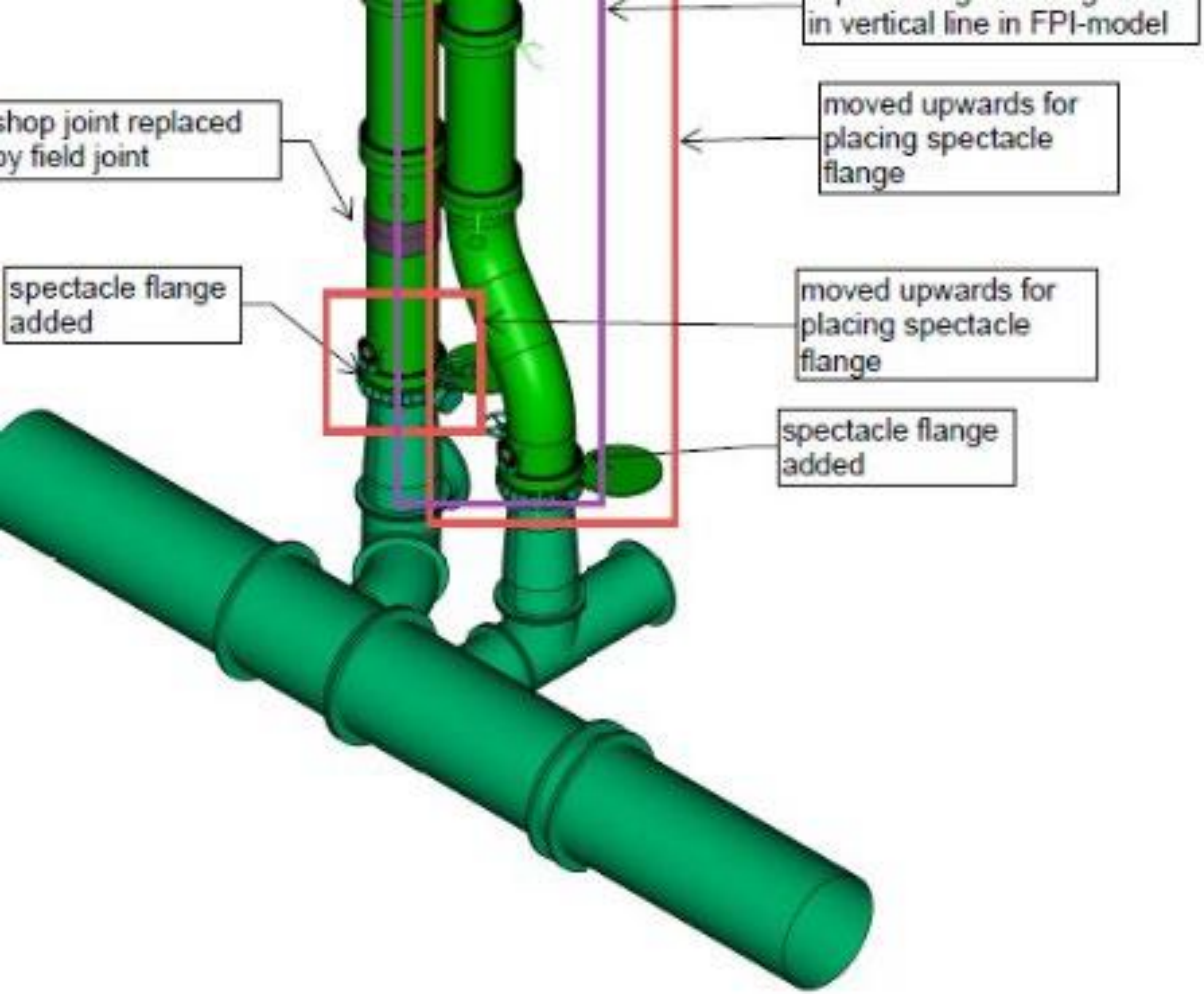

Flens.
lengte
3D tekening ?



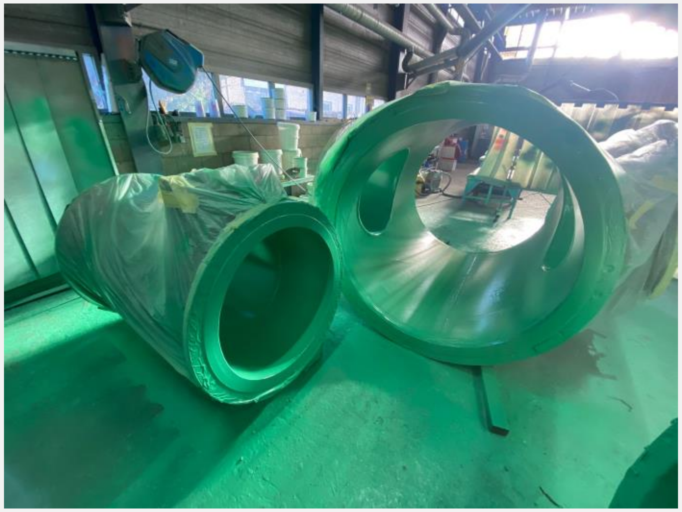





shortened pipe for placing spectacle flange
spectacle flange added
spectacle flange added
shortened pipe for placing spectacle flange
field joint added
LINE SWH-02-800
LINE SWH-01-800
repaired slight misalignment in vertical line in FPI-model
moved upwards for
shop joint replaced


in vertical line in FPI-model
shop joint replaced
y field joint
moved upwards for placing spectacle flange
spectacle flange added
moved upwards for placing spectacle flange
spectacle flange added

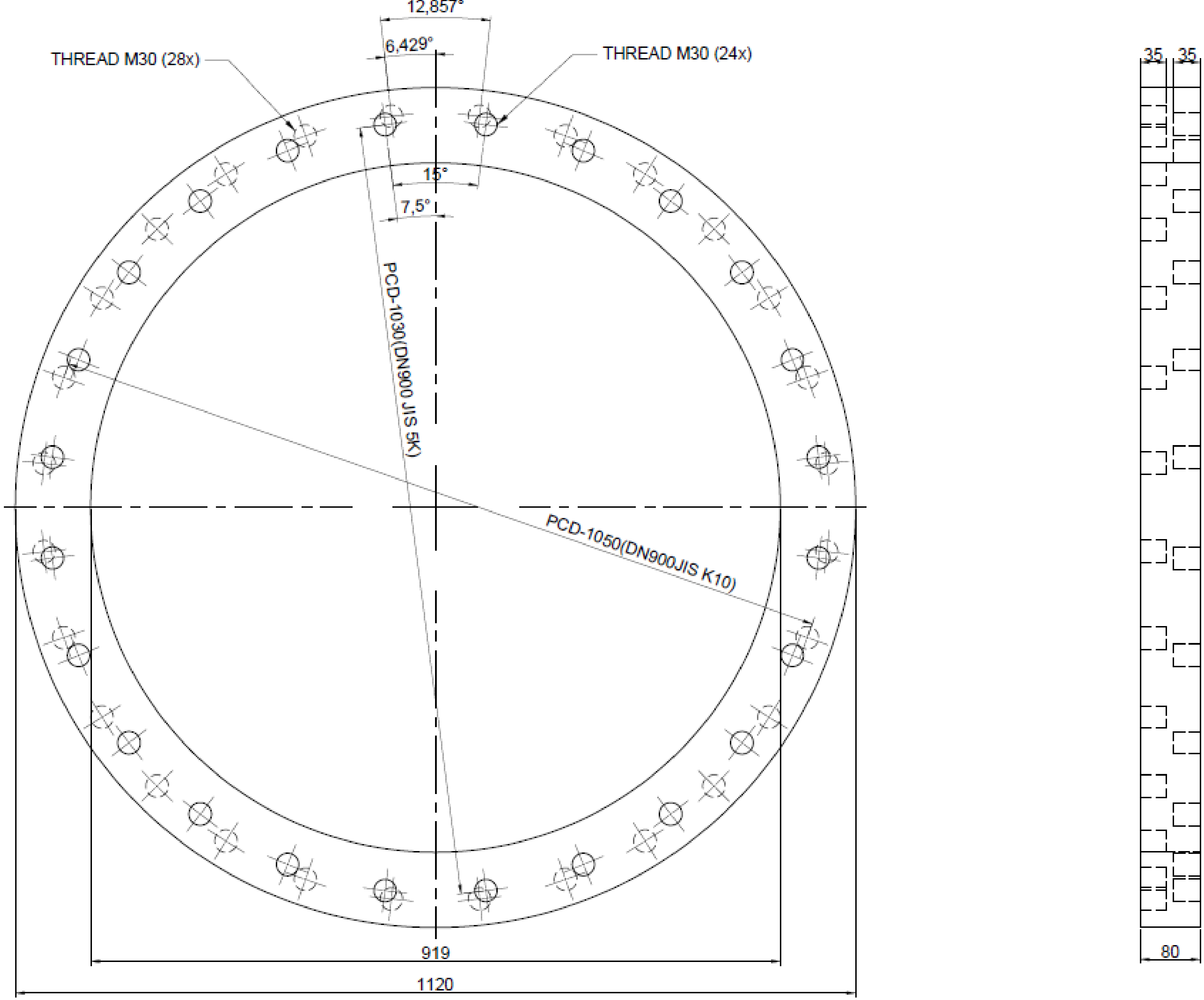
Prefabrication



ENERGOS INFRASTRUCTURE

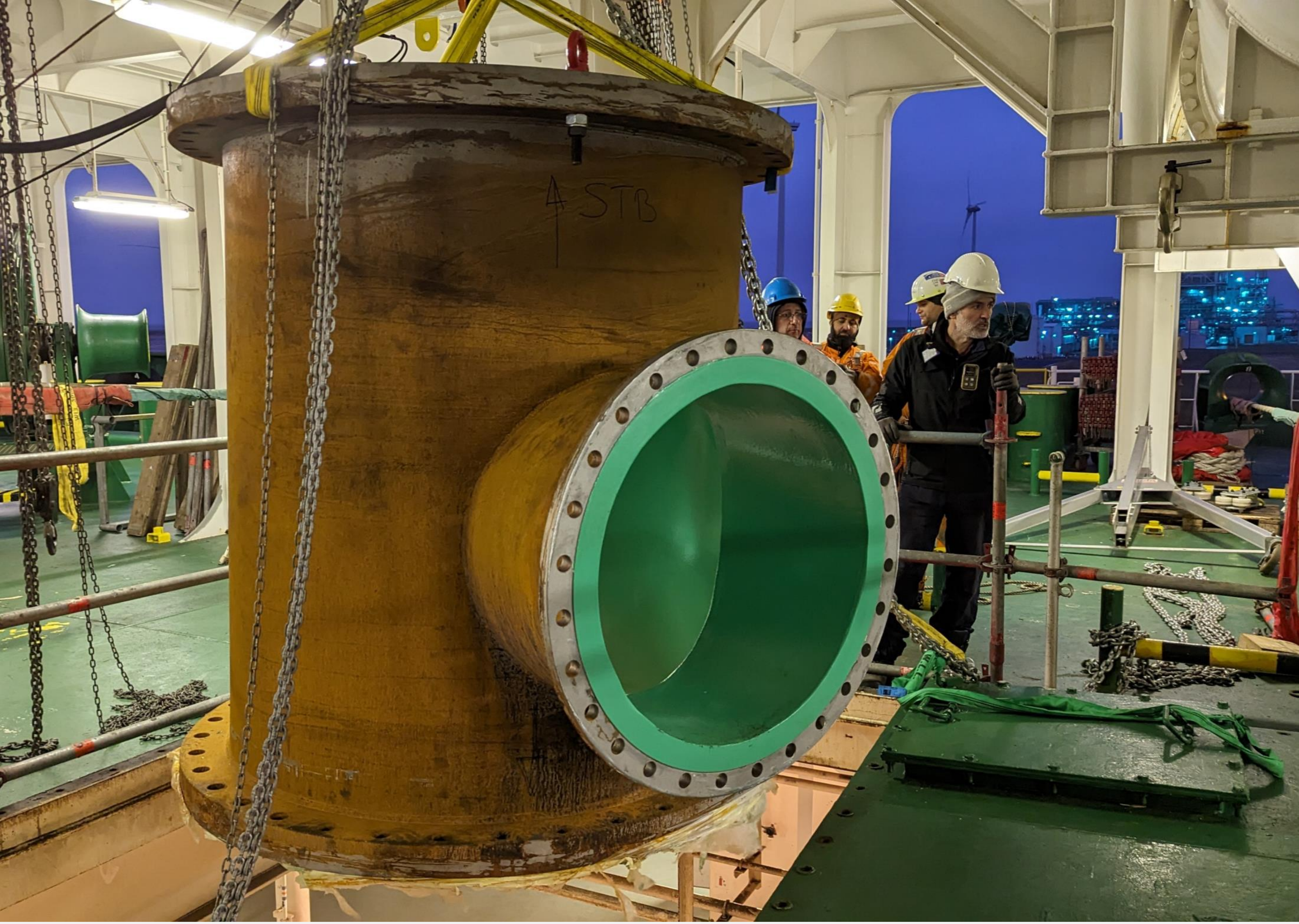
Delivery

Shutdown and Start

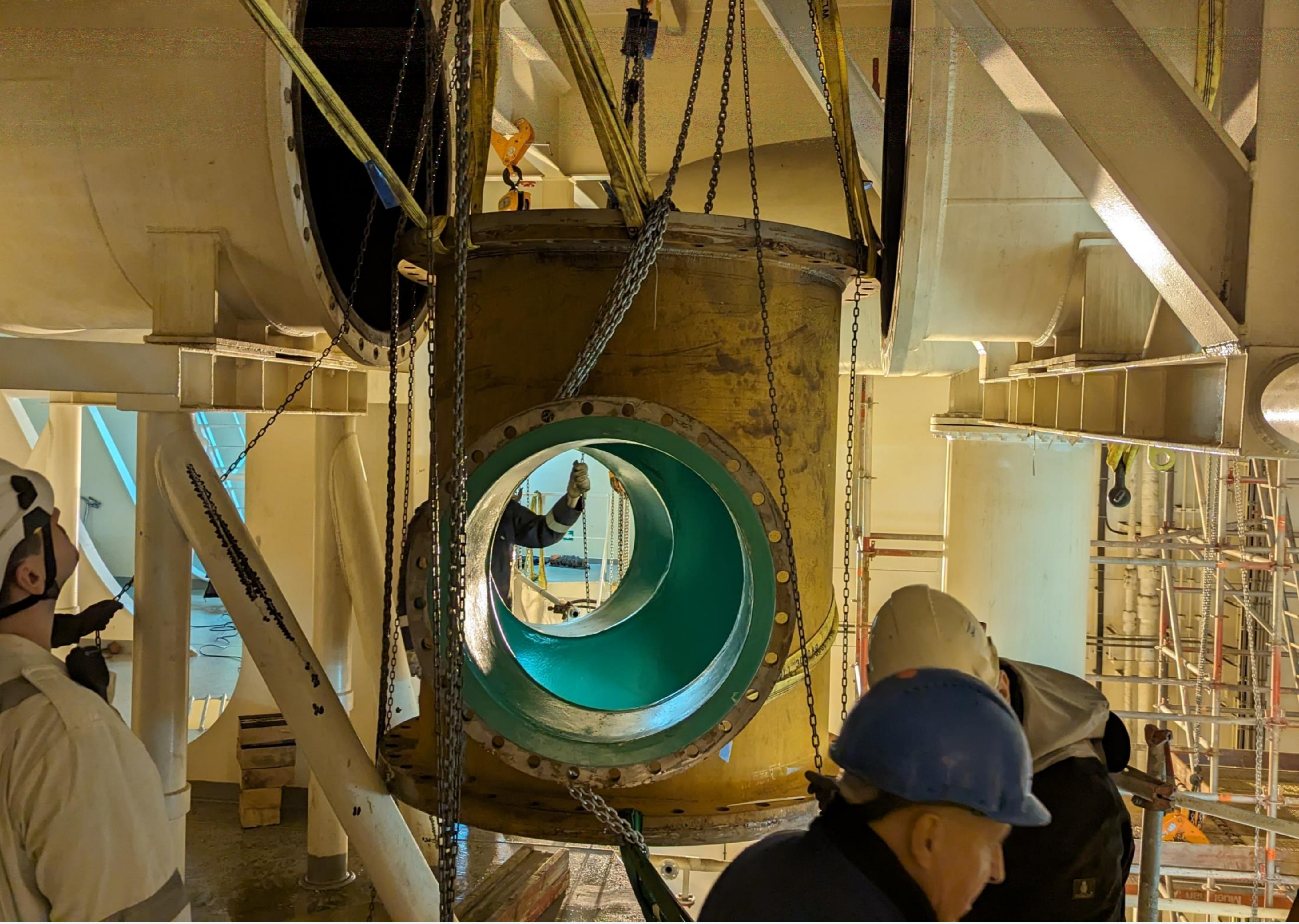


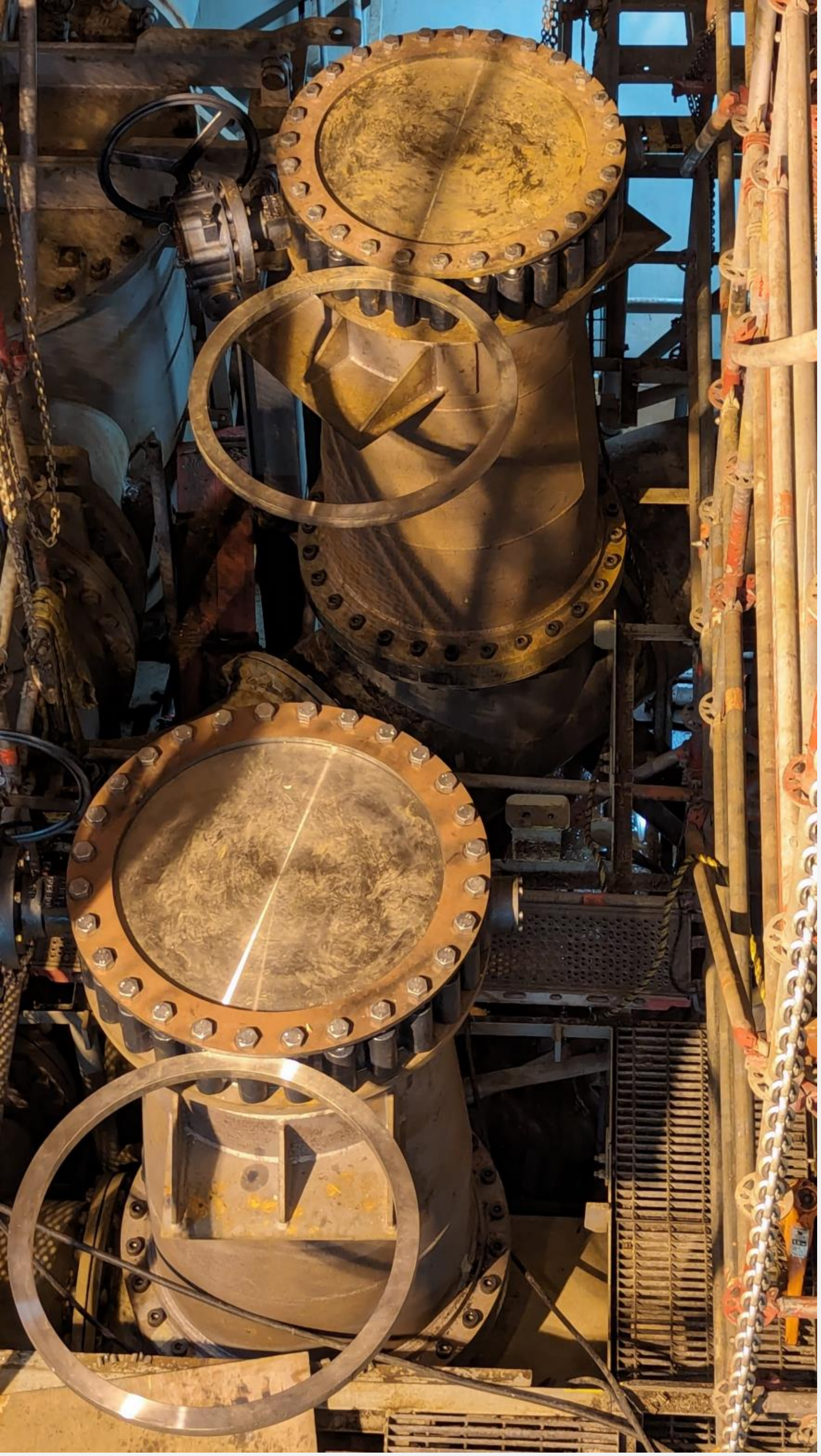
NOTE: PCD- Pitch Circle Diameter

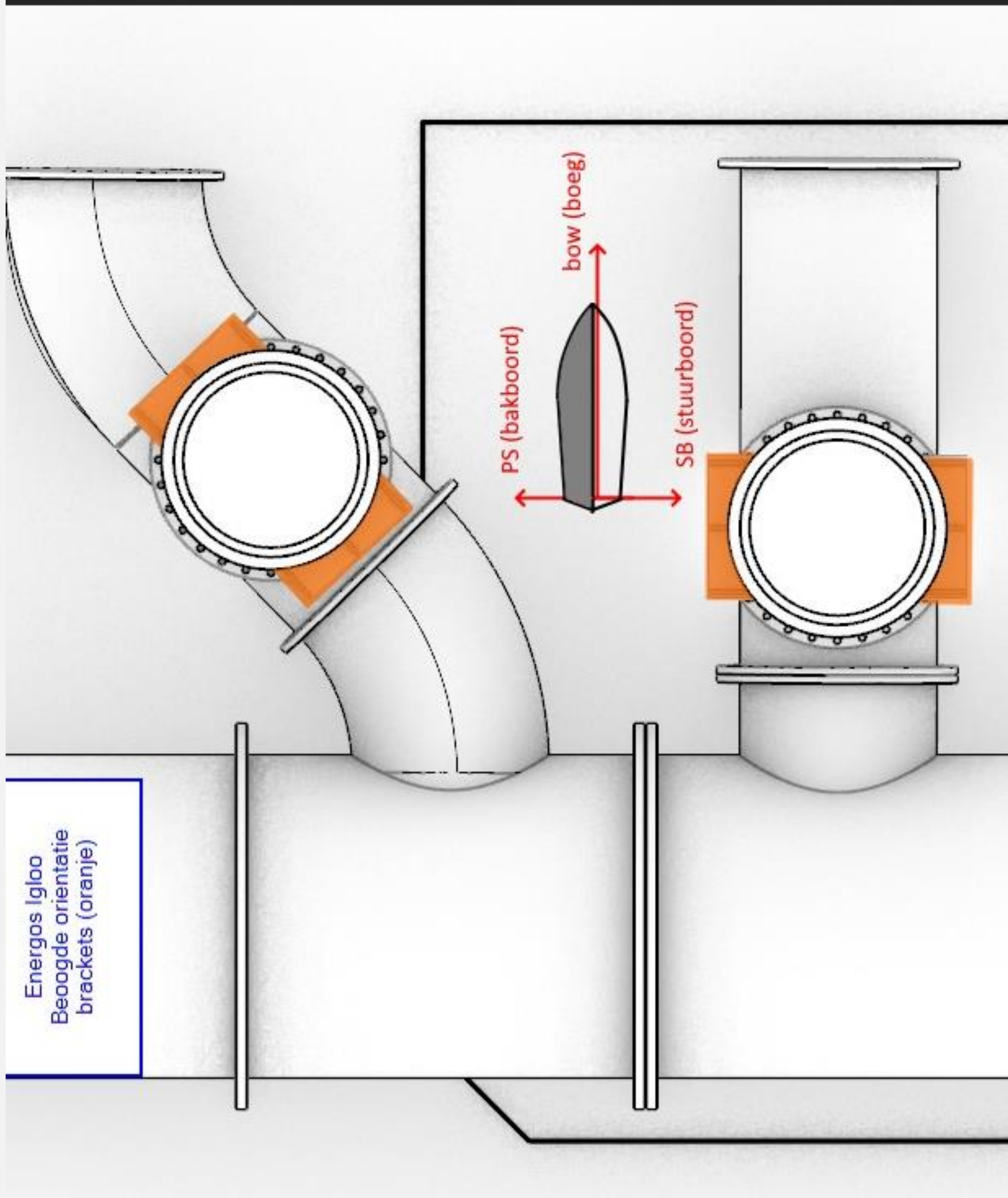
ENERGOS INFRASTRUCTURE

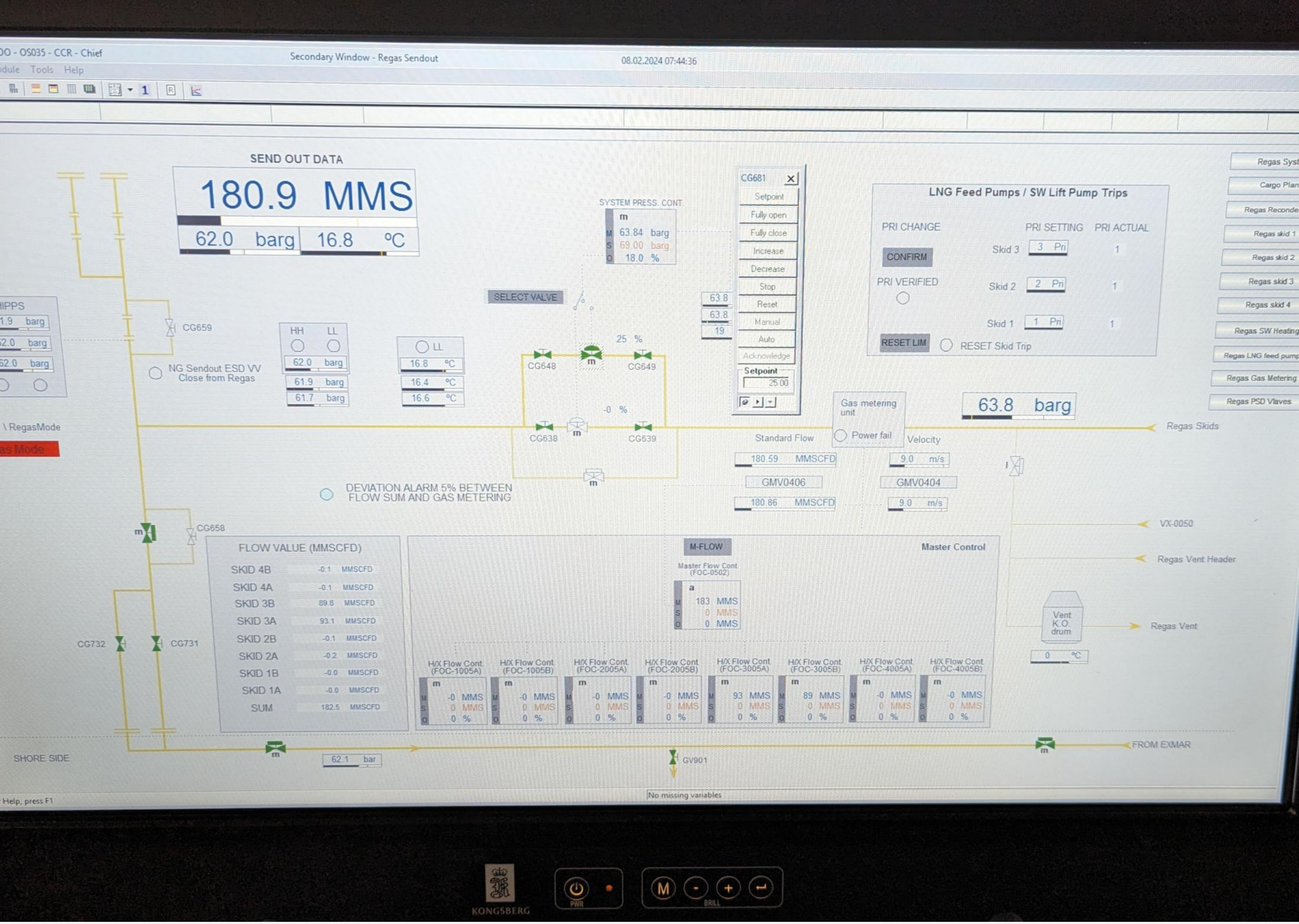

4 STB


2
3000 kg



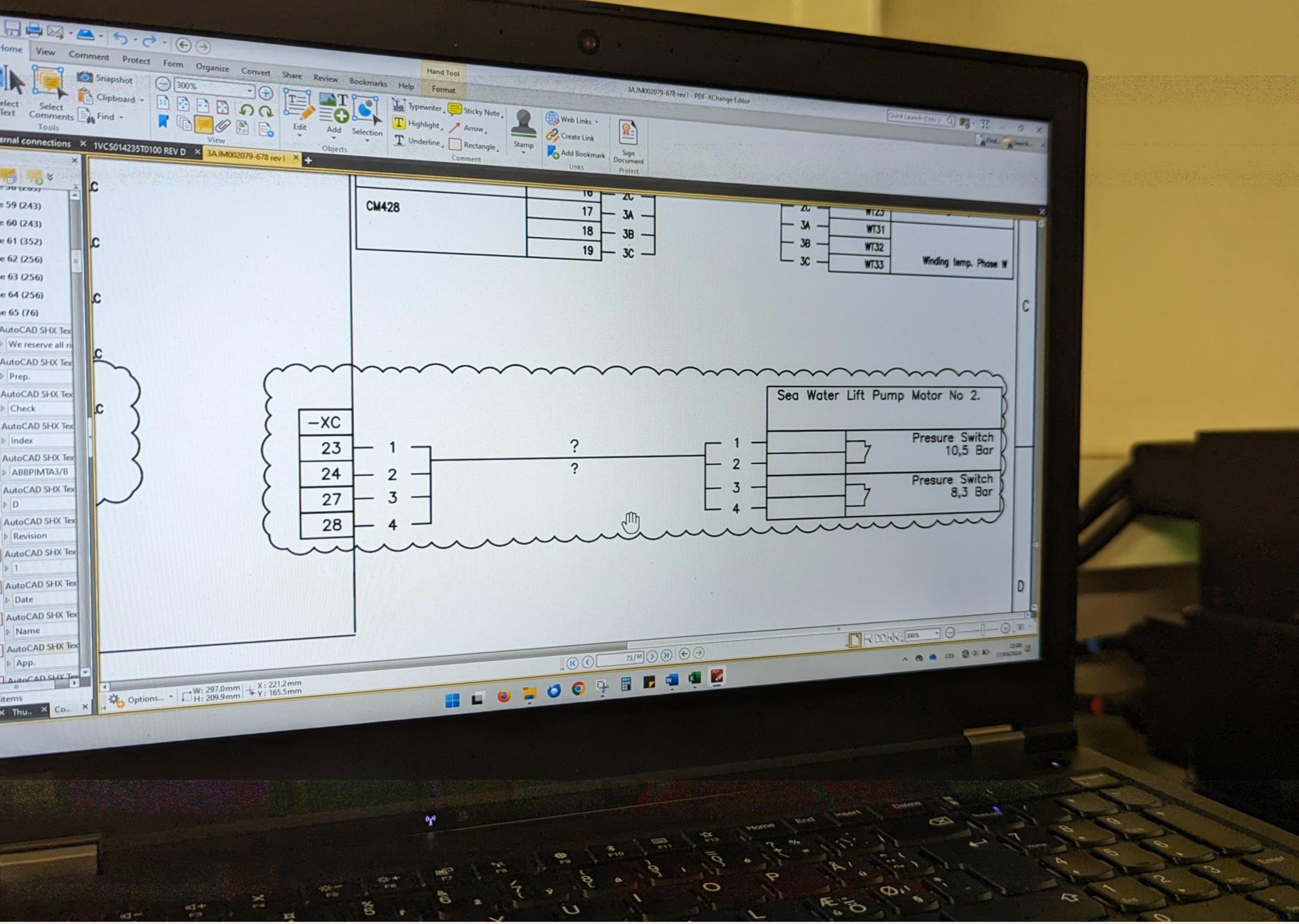



bow (boeg)
PS (bakboord)
SB (stuurboord)
Energos Igloo
Beoogde orientatie
brackets (oranje)



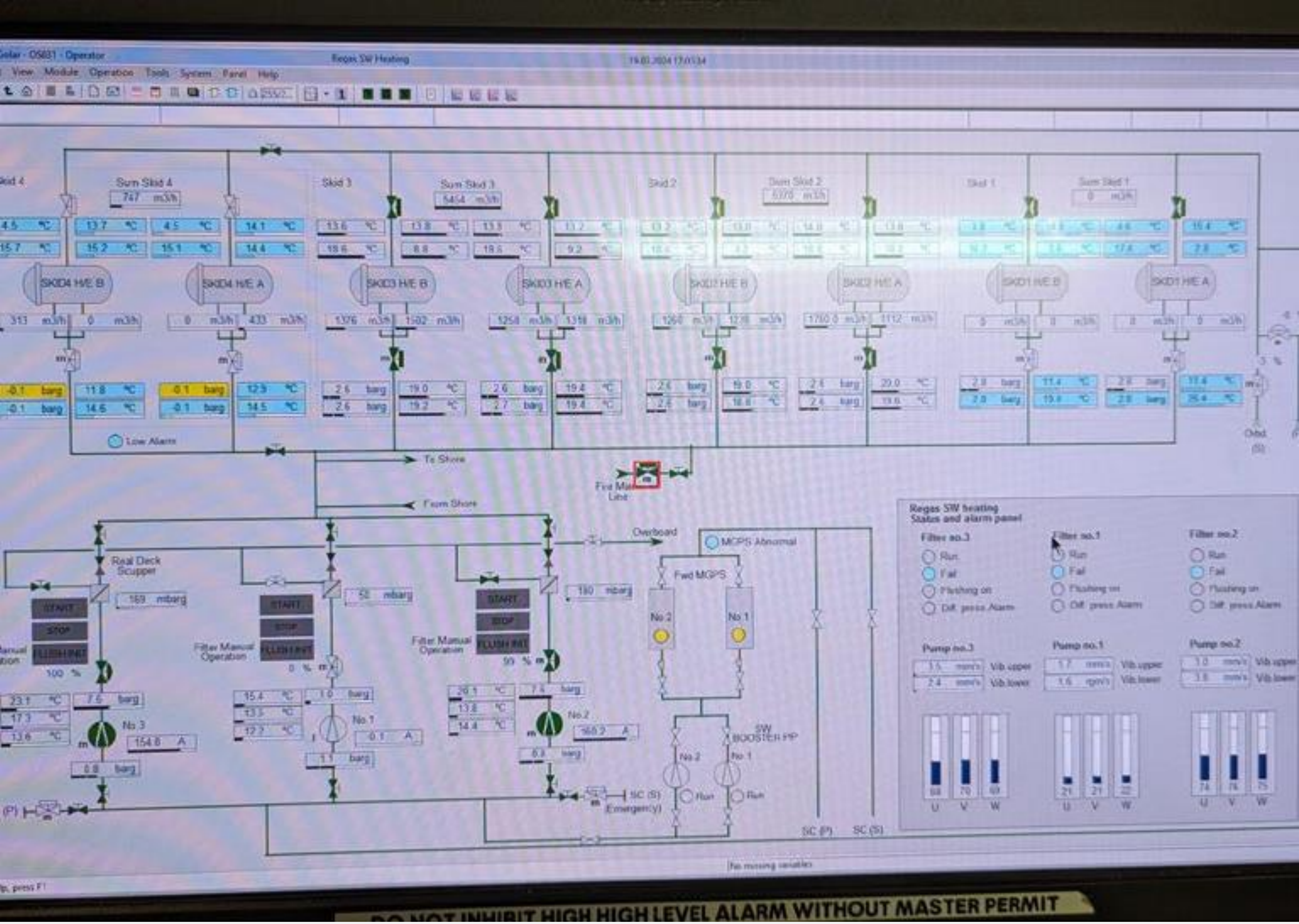
Secondary Window - Regas Sendout
08.02.2024 07:44:36
SEND OUT DATA
180.9 MMS
62.0 barg
16.8 °C
SYSTEM PRESS. CONT.
63.84 barg
69.00 barg
18.0 %
CG681
Setpoint
Fully open
Fully close
Increase
Decrease
Stop
Reset
Manual
Auto
Acknowledge
LNG Feed Pumps / SW Lift Pump Trips
PRI CHANGE
PRI SETTING
PRI ACTUAL
CONFIRM
PRI VERIFIED
Skid 3
Skid 2
Skid 1
RESET LIM
RESET Skid Trip
SELECT VALVE
NG Sendout ESD VV Close from Regas
DEVIATION ALARM 5% BETWEEN FLOW SUM AND GAS METERING
Gas metering unit
Power fail
Standard Flow
Velocity
180.59 MMSCFD
GMV0406
180.86 MMSCFD
GMV0404
63.8 barg
Regas Skids
VX-0050
Regas Vent Header
Regas Vent
Vent K.O. drum
FLOW VALUE (MMSCFD)
SKID 4B -0.1 MMSCFD
SKID 4A -0.1 MMSCFD
SKID 3B 89.8 MMSCFD
SKID 3A 93.1 MMSCFD
SKID 2B -0.1 MMSCFD
SKID 2A -0.2 MMSCFD
SKID 1B -0.0 MMSCFD
SKID 1A -0.0 MMSCFD
SUM 182.5 MMSCFD
M-FLOW
Master Control
Master Flow Cont. (FOC-0502)
183 MMS
SHORE SIDE
FROM EXMAR
GV901
No missing variables
KONGSBERG

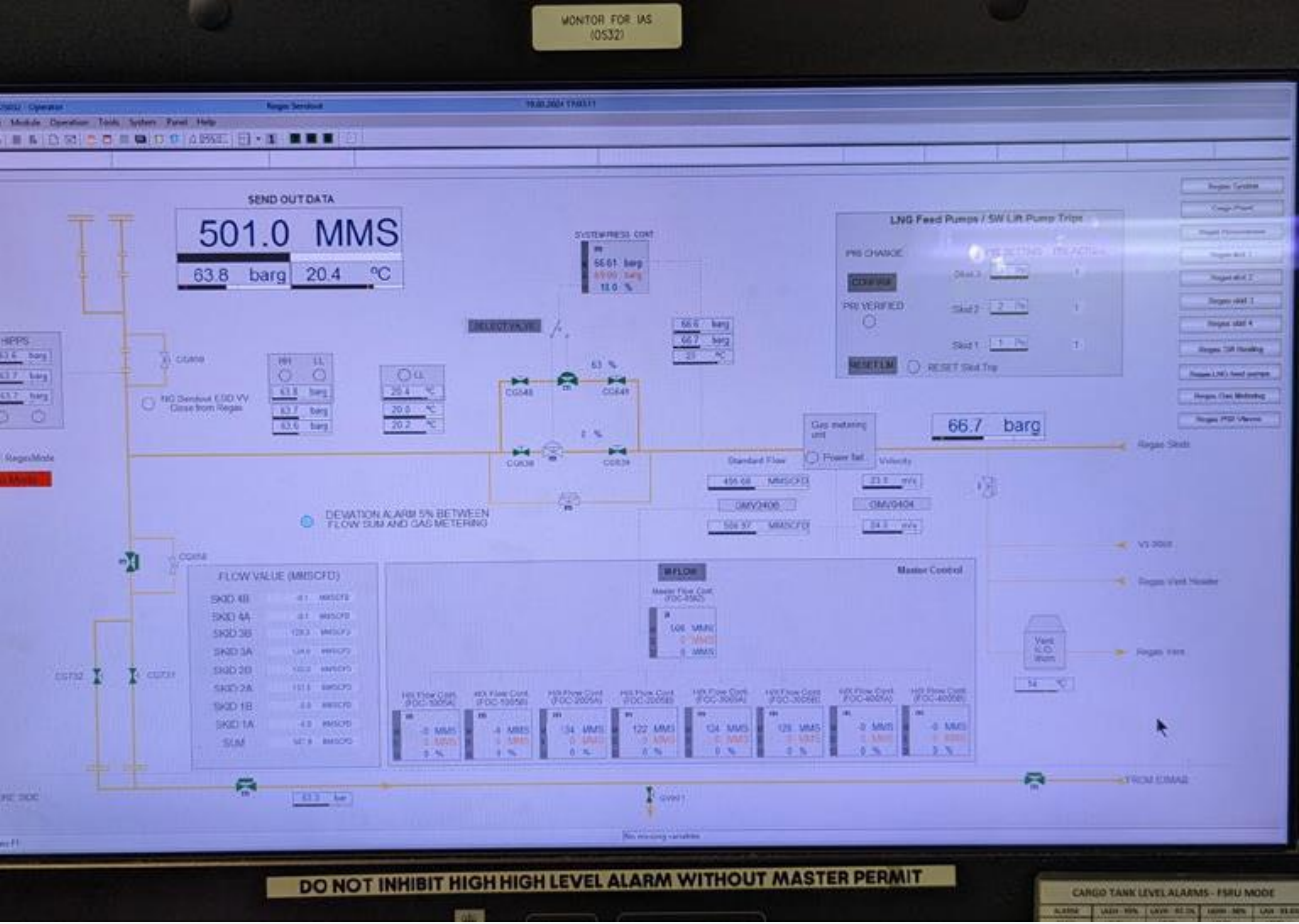

Layher
Muehlhan


CM428
Sea Water Lift Pump Motor No 2.
Presure Switch 10,5 Bar
Presure Switch 8,3 Bar
-XC
Winding temp. Phase W

PRE-COMMISSIONING CHECKS

Responsible	Description	Expected Result
Igloo C/E	Leak check of GRE piping before starting commissioning Fill GRE piping with FW hose Leak check Correct any leaks before full system test	No leaks, piping full
ABB	Uploaded software to Lift Pump REM	no alarms, no errors
	Can do stby lift pumps 1 by 1, with regas in operation	
Igloo ETO	Extract HV breaker and earth	
Igloo ETO	Return breaker to position after update	
ABB	Confirm functionality of Lift Pump REM 1 by 1	no alarms, no errors
ABB Igloo C/E	Test Pressure switch functionality for Lift Pump REM using external pressure calibration pump. Lift pump does not need to be running. Coordinate with CCR to test Stbdy lift pumps	
	Lift pump 1 discharge	REM command stop
	Lift pump 1 filter outlet	REM command stop
	Lift pump 2 discharge	REM command stop
	Lift pump 2 filter outlet	REM command stop


Regas SW Heating
View Module Operation Tools System Panel Help
Sum Skid 4
Skid 3
Sum Skid 3
SKID4 H/E B
SKID4 H/E A
SKID3 H/E B
SKID3 H/E A
Low Alarm
To Shore
From Shore
Fire Main Line
Overboard
MGPS Abnormal
Fwd MGPS
No 2
No 1
Rail Deck Scupper
START
STOP
FLUSH INIT
Filter Manual Operation
No 3
SW BOOSTER PP
Run
SC (S)
Emergency
SC (P)
SC (S)
Regas SW heating
Status and alarm panel
Filter no.3
Filter no.1
Filter no.2
Run
Fail
Flushing on
Diff. press Alarm
Pump no.3
Pump no.1
Pump no.2
Vib upper
Vib lower
U
V
W
DO NOT INHIBIT HIGH HIGH LEVEL ALARM WITHOUT MASTER PERMIT


MONITOR FOR IAS (OS32)
Module Operation Tools System Panel Help
SEND OUT DATA
501.0 MMS
63.8 barg
20.4 °C
LNG Feed Pumps / SW Lift Pump Trips
PRI CHANGE
PRI VERIFIED
RESET Skid Trip
NG Sendout ESD VV Close from Regas
66.7 barg
Regas Skids
DEVIATION ALARM 5% BETWEEN FLOW SUM AND GAS METERING
FLOW VALUE (MMSCFD)
SKID 4B
SKID 4A
SKID 3B
SKID 3A
SKID 2B
SKID 2A
SKID 1B
SKID 1A
SUM
Master Control
DO NOT INHIBIT HIGH HIGH LEVEL ALARM WITHOUT MASTER PERMIT
CARGO TANK LEVEL ALARMS - FSRU MODE

19-Mar-24

07:51 3A booster pump stopped
08:00 3B booster pump stopped, Regas stopped
08:46 SW lift pump stopped
08:40 Sea chest closed
08:56 Start SW lift pump on closed loop mode, Commence closed loop tests
11:12 Commence unmooring with LNG/C "***Gaslog Houston***"
11:18 All lines cast off with LNG/C "***Gaslog Houston***"
11:37 Booster pump started 3A
11:42 Booster pump started 3B
12:00 250MMS online on closed loop mode
14:21 Booster pump started 2B
14:36 Booster pump started 2A
14:50 410 MMS online
15:00 440 MMS online
15:15 390 MMS online
16:18 450 MMS online
16:20 470 MMS online
16:23 410 MMS online
17:05 500 MMS online
17:10 Commence ramp down
17:26 3B booster pump stopped
17:29 3A booster pump stopped
17:40 Closed loop tests completed, switched to Open loop configuration
18:00 230 MMS online

Conclusions

Project met expectations

Project completed
on time and within budget

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