Wind Assisted Ship Propulsion "WASP"

Educational/ Teaching Material

WASP is co-funded by the Interreg North Sea Region Programme 2014-2020
Total budget € 5.393.222 - ERDF contribution € 2.613.458
Priority 2: Eco-innovation: Stimulating the green economy

https://northsearegion.eu/wasp

Deliverable data

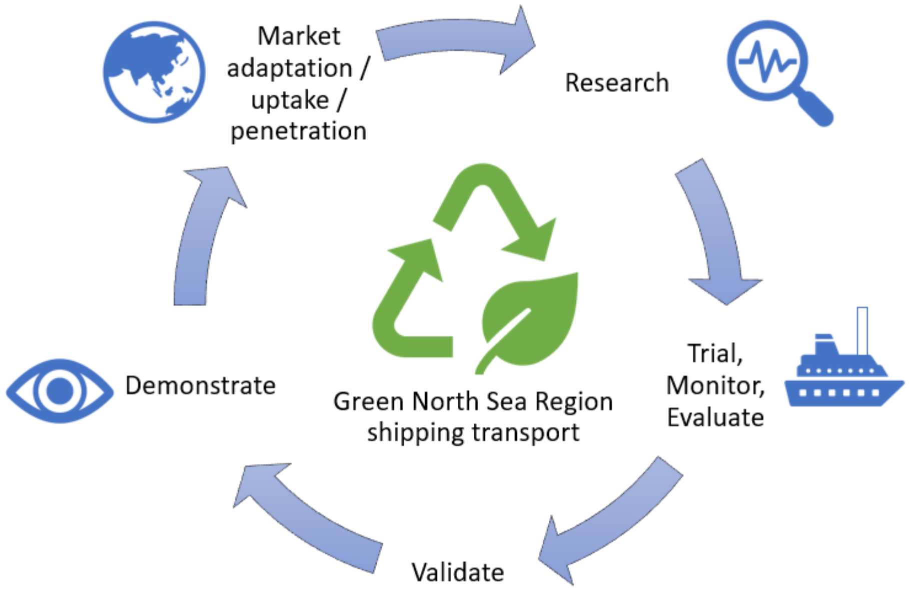
Deliverable No.	2.B.
Deliverable Title	Development of educational and training materials
Work Package No: title	WP 4: Policy and viable business
Deliverable type	New services
Lead beneficiary	KLU
Responsible author	Lara Pomaska
Co-authors	WASP project consortium
Date of delivery	20-06-2023

Content

- WASP Project overview
- Work packages overview
- The business landscape for wind propulsion in shipping
- Characterizing WPT fuel savings in the maritime sector
- Digital twins
- Future considerations

WASP Project overview

Key objectives and project cycle



- Wind Propulsion Technology proven concepts lead to greening of NSR sea transport
- Identify the viable business cases for (hybrid) wind propulsion technologies
- Facilitate a level playing field for WPT with policy instruments

Project structure

WP1: Project Management	Work Package Leader: NMTF
WP2: Communication Activities	Work Package Leader: IWSA
WP3: Engineering of Wind Propulsion Technologies	Work Package Leader: KUL
WP4: Policy & viable business	Work Package Leader: KLU
WP5: Operating of WPT and performance	Work Package Leader: SSPA

Shipowners, their installations and technology providers

Scheepvaartbedrijf van Dam

2 Ventifoils (eConowind)

BOOMSMA

2 Flatrack Ventifoils (eConowind)

Flettner Rotor (Norsepower)

Flettner Rotor (ECO Flettner)

Wing sail (eConowind)

Ships and installations

Shipowner	Van Dam Shipping	Boomsma Shipping	Scandlines	Rörd Braren	Tharsis Sea-River Shipping
Country	The Netherlands	The Netherlands	Denmark	Germany	The Netherlands
Vessel	Ankie	Frisian Sea	Copenhagen	Annika Braren	Tharsis
Ship type	General cargo	General cargo	RoPax	Minibulker	General cargo
DWT	3,638 t	6,445 t	5,000 t	5,035 t	2,300 t
WPT	2 retrofit front-placed suction wings of 16 m	2 Flatrack suction wings of 11 m	Flettner rotor	Flettner rotor	2 flexible wing sails
WPT Provider	eConowind	eConowind	Norsepower	ECO Flettner	eConowind
WPT installation	March 2020	November 2020	September 2020	Q1 2021	Q1 2021
Trials planned	Q1 2021	Q1 2021	Q4 2020	2021	2021

WP4: Overcome business and regulatory barriers

Objectives

- Investigate the **economic implications** of WASP technologies
- Identify regulatory and business **barriers** and find **strategies** to overcome these
- Develop innovative financial **solutions** and provide business decision **support** for shipowners

- Economic implications of WASP technologies
- Viable business case
- Socio-economic benefits
- Policy awareness
- Strategies to overcome the barriers
- Innovative financing solutions
- Potential WPT market uptake

WP3: Engineering of Wind Propulsion Technologies

Ship owners, their installations and (technology providers)

2 Ventifoils
(eConowind)

2 Flatrack Ventifoils
(eConowind)

Flettner Rotor
(Norsepower)

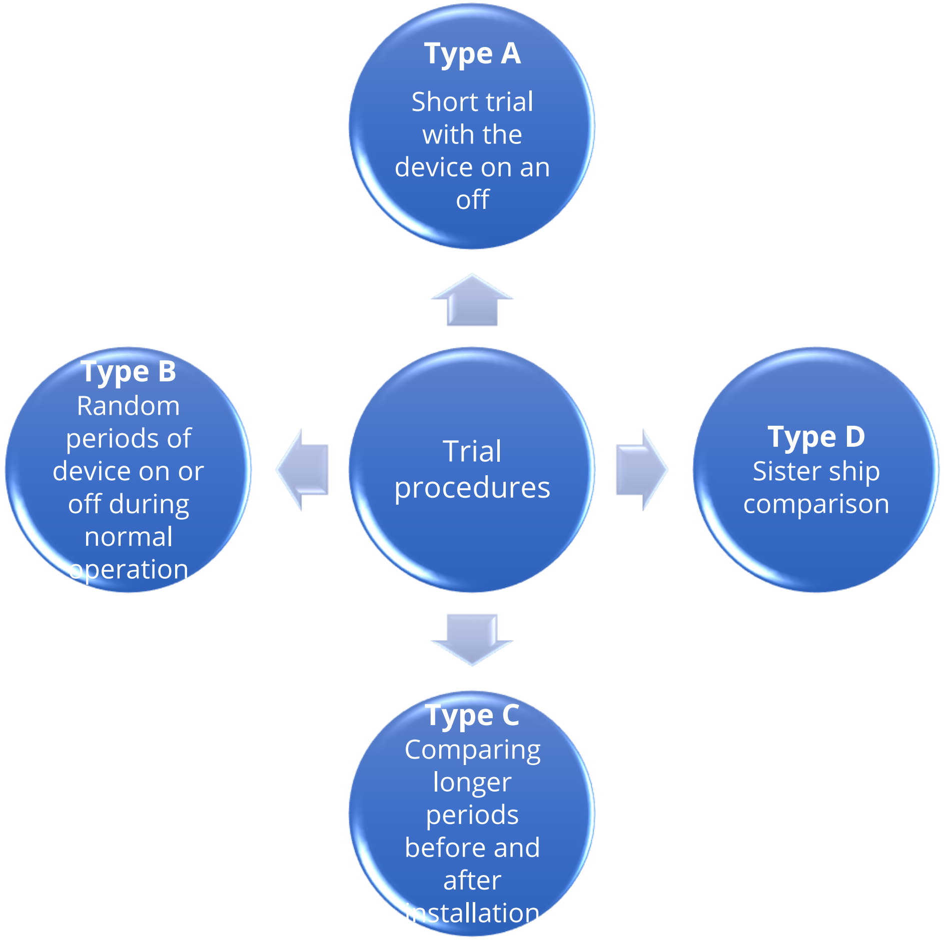
Flettner Rotor
(ECO Flettner)

Wing sail
(eConowind)

Objectives

- WP3 will prepare ship owners for the installation and operation of WPTs
- Objectives
  - Preparation of WASP participating vessels for operation with WPTs
  - Investigate the implications of using WPTs with simulation studies
  - Use the acquired knowledge to inform ship owners and maximize WPT potential
- WP3 is intended to present ship owners with a sufficient understanding of WPT operation and the possible savings that could be realized

WP5: Operating of Wind Propulsion Technologies and performance



Objectives

- Demonstrate the usability of WPT on vessels
- Develop methods and third-party validated performance indicators for independent evaluation of WPTs in general and assessing the performance of a number of WPTs with these indicators
- The real-life trials will be on existing shipping lanes with ships carrying freight; the only way to really measure cost, fuel and emission reductions
- By testing and assessing several WPTs in real life, on different vessel types and on various routes, knowledge and experience is expected to be gathered from the demonstrations as a base to understand under what conditions and in which circumstances WPT can be beneficial or non-beneficial
- These will provide credible data of WPT performances for new launching customers that will be included in decision support tools

Work Package Results

Predictions

WP 3
Engineering of Wind Propulsion Technologies

WP 4
Policy and viable business

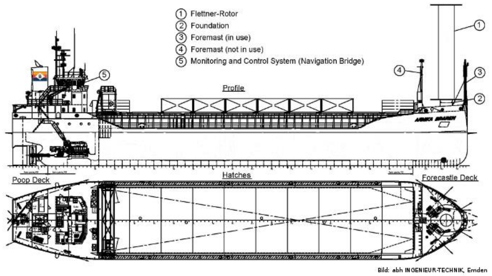
Trials

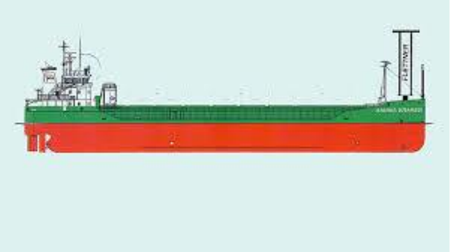
WP 5

- Trial procedures Type A,B,C,D
- Demonstrate the usability of WPT on 5 vessels
- Validate evaluation tools developed in WP3 & 4

Support further market uptake

- Develop methods and performance indicators for 3rd party evaluation
- Demonstrate under what conditions WPT can be beneficial





The business landscape for wind propulsion in shipping

Overcome business and regulatory barriers

Interreg North Sea Region WASP
European Regional Development Fund
EUROPEAN UNION
wasp Wind Assisted Ship Propulsion

- Economic implications of WASP technologies
- Viable business case
- Socio-economic benefits
- Policy awareness
- Strategies to overcome the barriers
- Innovative financing solutions
- Potential WPT market uptake

Viable business case

Key investment drivers

- Bunker savings
- Brand value enhancement
- Green agenda

Incentivization for WASP investments

- Policy makers
- Customers

Risks

- Technical, operational, financial risks vary according to technology
- Further exploration is required

Other considerations

- Fast & effective decision making process
- Communication between technical experts & top management

Other important stakeholders

- Crew
- Insurance companies
- Classification societies

Barriers of WASP technology

- Uncertainty
  - Fuel prices
  - Shipping market cycle
  - Actual results
- Policy
  - Lack of incentives
  - Lack of guidance
- Different operation profiles
  - Optimal route
  - Time charterer
  - Voyage charterer
- Applicability
  - Safety
  - Reliability
  - Compatibility
- Operational risks
  - Technical uncertainty
  - Counterparts
  - Port operations
- Capital investment
  - Limited access
  - Payback period

Cost & access to capital | **Split incentives** | **Trusted information**

Source: https://vb.northsearegion.eu/public/files/repository/20220111103132_WASPWP4.D5B_BarriersandovercomingstrategiesforacceleratingtheuptakeofWASP.pdf

Strategies to overcome barriers

Interreg North Sea Region WASP European Regional Development Fund | EUROPEAN UNION | wasp Wind Assisted Ship Propulsion

Cost and access to captial

- Company growth
- Cooperation
- Governmental support
- Market growth

Split incentives

- Promoting sustainability practices
- Development of green IP competences
- Incentives with economic-based strategies

Information trust

- Consistency
- Transparency
- Platforms
- Supervision

Source: https://vb.northsearegion.eu/public/files/repository/20220111103132_WASPWP4.D5B_Barriersandovercomingstrategiesforacceleratingtheuptakeof WASP.pdf

Considerations for WASP

Operational factors affecting the performance of the WASP technology

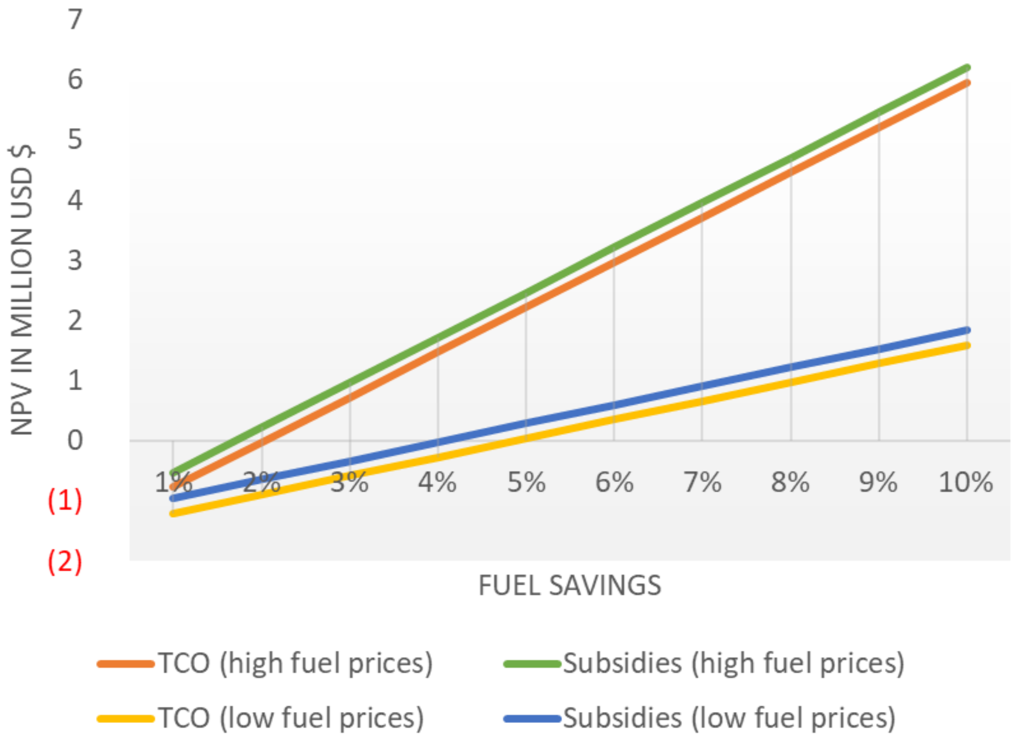
- Environmental factors
  - Wind speed
  - Wave height
  - Seasonal pattern
- On-board factors
  - Route optimization
  - Master’s decision making
  - Crew training
- Commercial factors
  - Trade pattern
  - Trip duration
  - Trip irregularity
  - Port calls

Operational comparison between Rotors and Kites

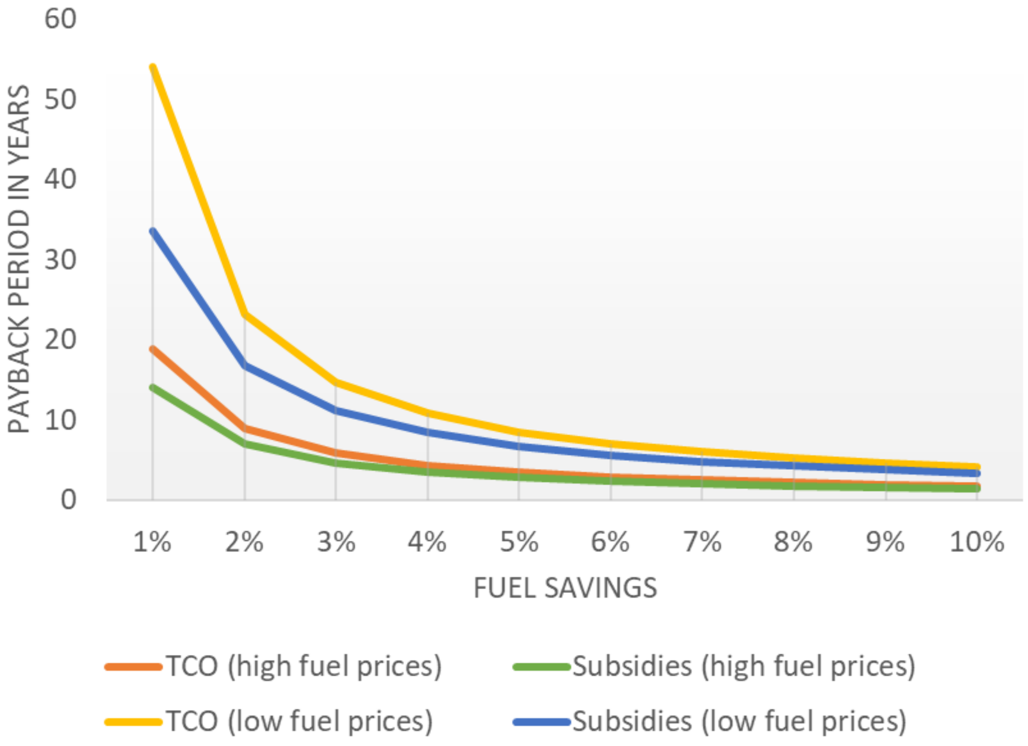
	Kites	Flettner Rotors
Absolute Power	Stronger winds at higher altitude	Slower winds on lower altitudes
Volatility of Power	Most effective with wind aligning with navigation direction	Wider range of wind directions
Scalability	Less scalability compared with rotors	Power output increases linearly with number of installations
Wind direction	Most effective with tailwinds	Most effective with winds from side
Comptability with ship operation	Less deck space needed	Fundamental deck construction

Financial analysis

Net present value



Payback period



Business decision support

Accelerate the uptake of Wind Assisted Ship Propoulsion Technologies

Design a decision support tool for shipowners that are interested in WASP

Determine the best wind-assisted technology for each individual vessel of their fleet

How can shipowners be supported with their decision-making process?

Source: https://northsearegion.eu/wasp/wasp-tools/

Financial model inputs

Cost of equipment
- Includes acquisition & installation
- 1.8 mio USD

Advance payment
- Payment when signing the contract
- 15%

Duration of agreement
- Financial relation between tech provider and owner
- 48 months

Cost of financing
- Agreed interest for acquisition
- 12%

Split of savings
- Owner will receive 75% of savings (e.g. CO_2 savings)
- 75% owner-side

WACC of owner
- Weight cost of capital by shipowner
- 6%

WACC of tech provider
- Weight cost of capital by tech provider
- 8%

Source: https://northsearegion.eu/wasp/wasp-tools/

Key technical data input

Installed power	Total installed power of main engine	7,500 kW
SFOC	Specific fuel oil consumption (average)	195 gr/kWh
At sea	Estimated days at sea	200 days
At port	Estimated days at port	160 days
Consumption at sea	Estimation in **Maximum Continuous Rating (MCR)**	90%
Consumption at port	As above when ship is at port	20%

Cost of fuel	Estimation in USD per ton	750 USD/ton
Tons p.a.	Estimation of the model	7,441 tons
Cost of fuel p.a.	Estimation of the model	5,580,900 USD
CO2 tons p.a.	Estimation of the model **(1t FO is 3.11t CO2)**	23,142 tons
CO2 cost	Provide estimation of 1 ton of CO2	190 USD/ton
Savings	Expected energy savings from the technology	15%
Fuel savings	Estimation of the model; from technology	837,135 USD
Carbon savings	Estimation of the model; from technology	485,985 USD

Source: https://northsearegion.eu/wasp/wasp-tools/

Results

	Shipowner	Tech. Provider
WACC	6%	8%
Initial Payment	-270,000	270,000
NPV	336,162	1,092,114

It seems like a fair deal for both parties

Sensitivity analysis

The percentage is the ratio of the NPV of the owner over the NPV of the Technology provider

advance payment (columns) / carbon price (rows)

carbon price	5%	10%	15%	20%	25%	30%	35%	40%
0	7%	-8%	-19%	-28%	-35%	-40%	-45%	-49%
20	17%	1%	-12%	-21%	-29%	-35%	-40%	-45%
40	26%	9%	-4%	-15%	-23%	-30%	-35%	-40%
60	36%	17%	3%	-8%	-17%	-24%	-30%	-35%
80	45%	25%	10%	-2%	-11%	-19%	-25%	-31%
100	54%	33%	17%	5%	-5%	-14%	-21%	-26%
120	63%	41%	24%	11%	0%	-8%	-16%	-22%
140	72%	48%	31%	17%	6%	-3%	-11%	-17%
160	80%	56%	38%	23%	11%	2%	-6%	-13%

Any ratio below 100% favors the Tech. Provider. The closer to 100% the more balanced the deal therefore colored with green

Source: https://northsearegion.eu/wasp/wasp-tools/

Characterizing WPT fuel savings in the maritime sector

With the “Sea Trial“ methodology

WASP Sea Trial methodology

- Main objective is to confirm fuel savings
- Test methodology: Compare with and without WPT
- All tested devices can be turned off/on or be tilted

Sea trial analysis

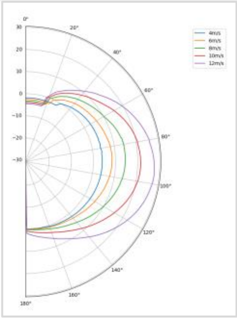
1. Speed trial

2. Analyse speed trial

Power saving 1 wind speed

3. Calibrate virtual ship model

Power saving at any wind condition



4. Voyage analysis

Average fuel saving

1.1 Speed trial
m/v Copenhagen *with Norsepower rotor*

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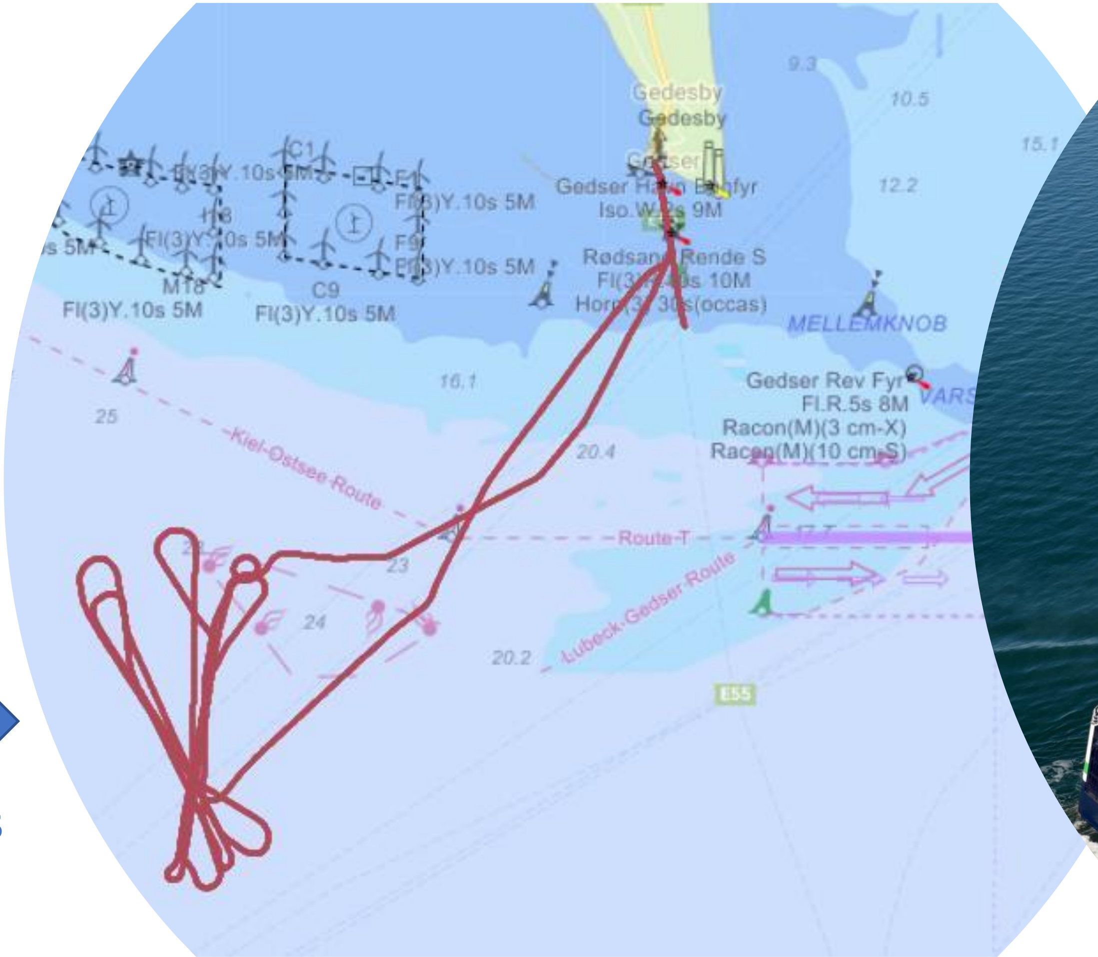
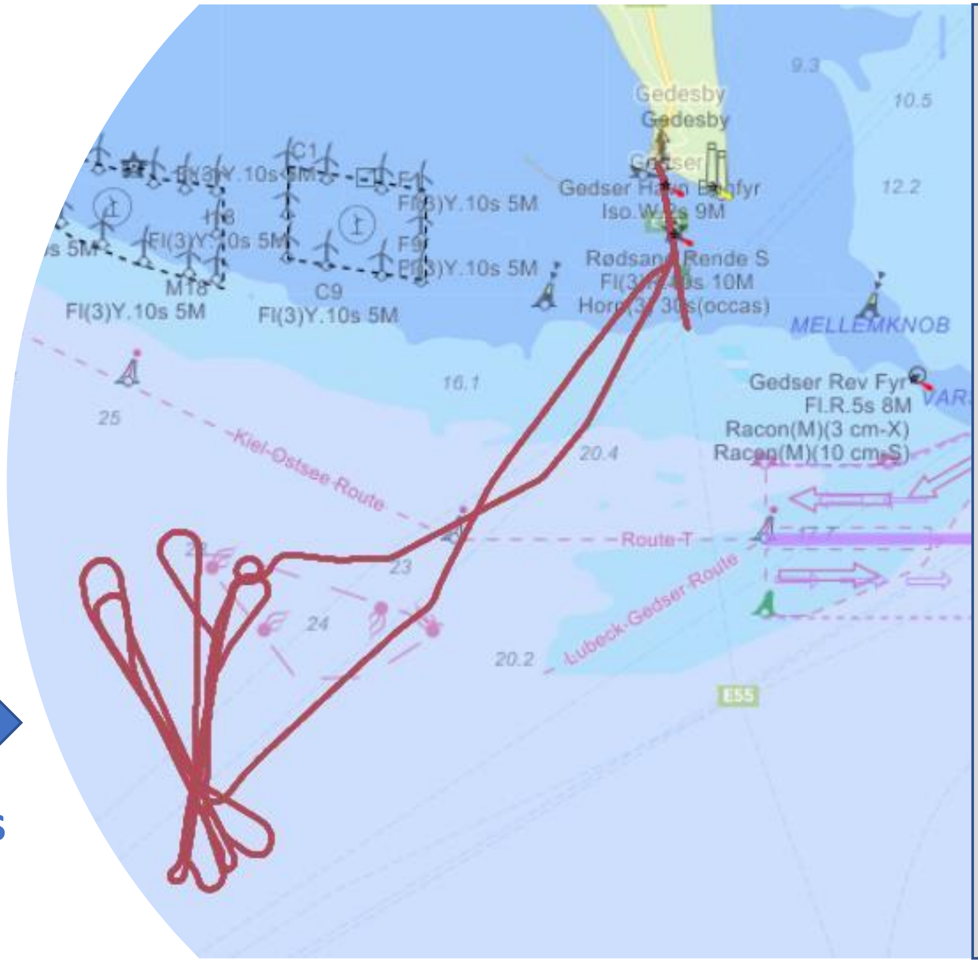
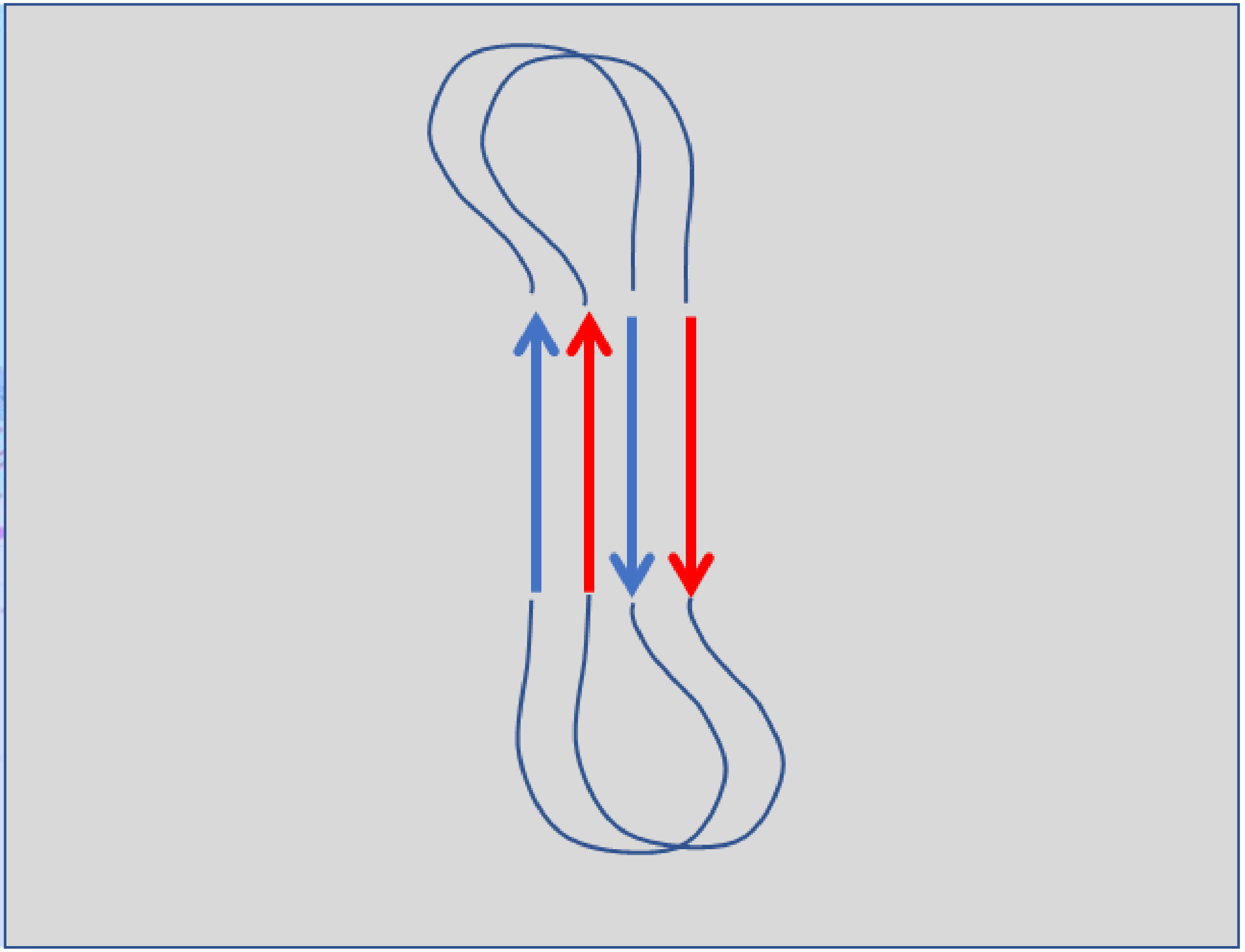


WIND

8-10 m/s

1.1 Speed trial
m/v Copenhagen *with Norsepower rotor*

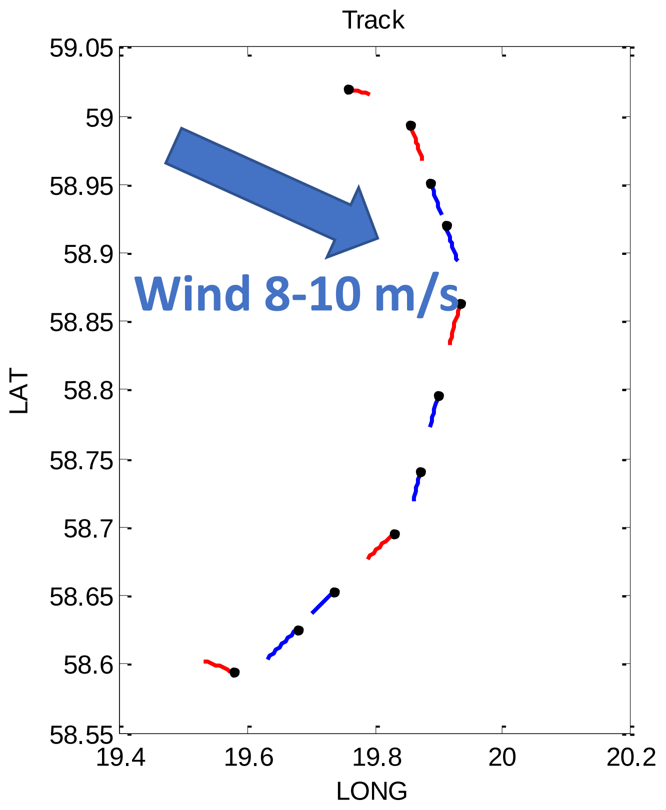


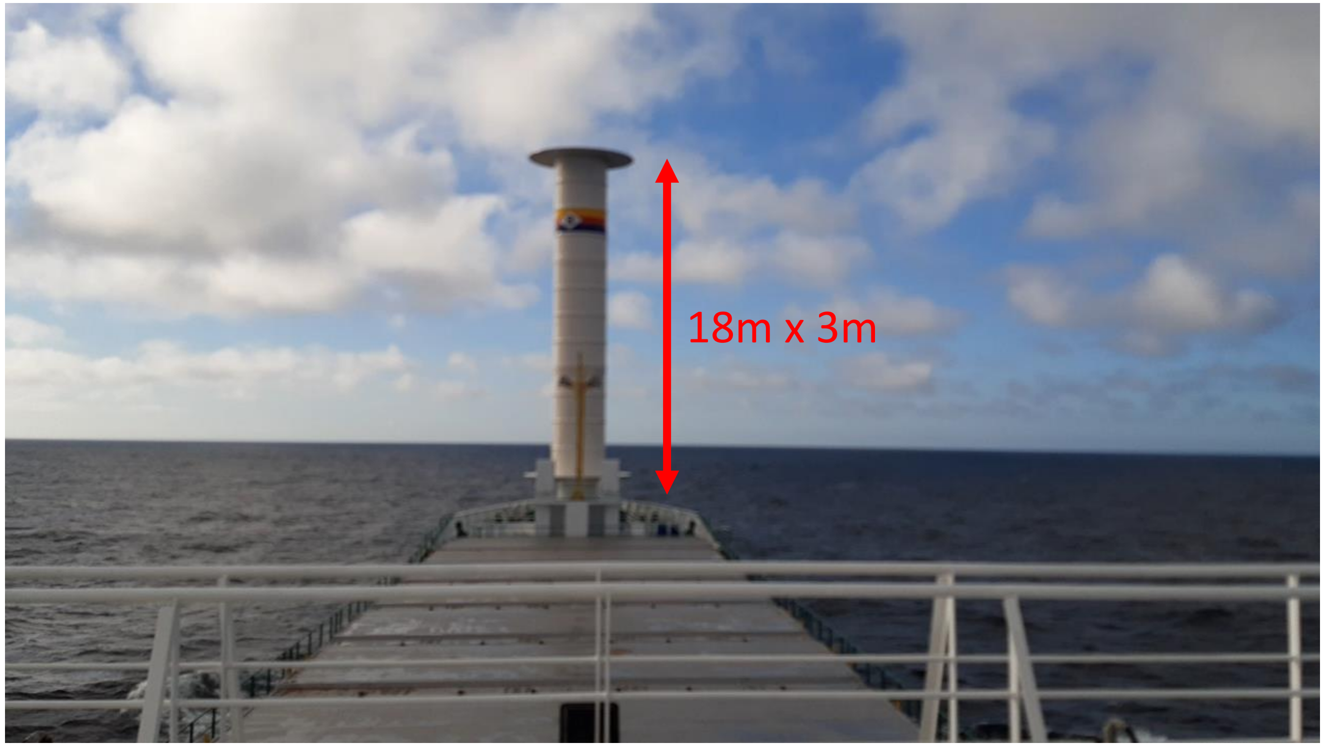


WIND

8-10 m/s

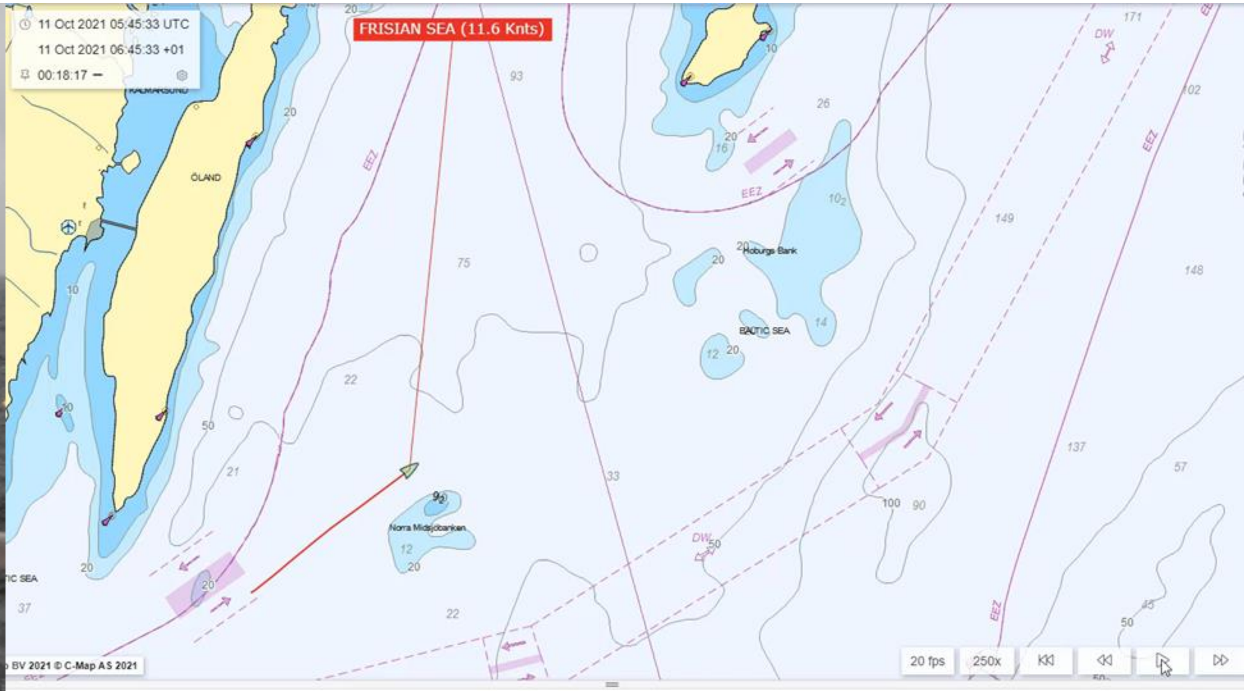
1.2 Speed trial
Annika Braren *with EcoFlettner rotor*





1.3 Speed trial

Frisian Sea *with Econowind Ventifoils*

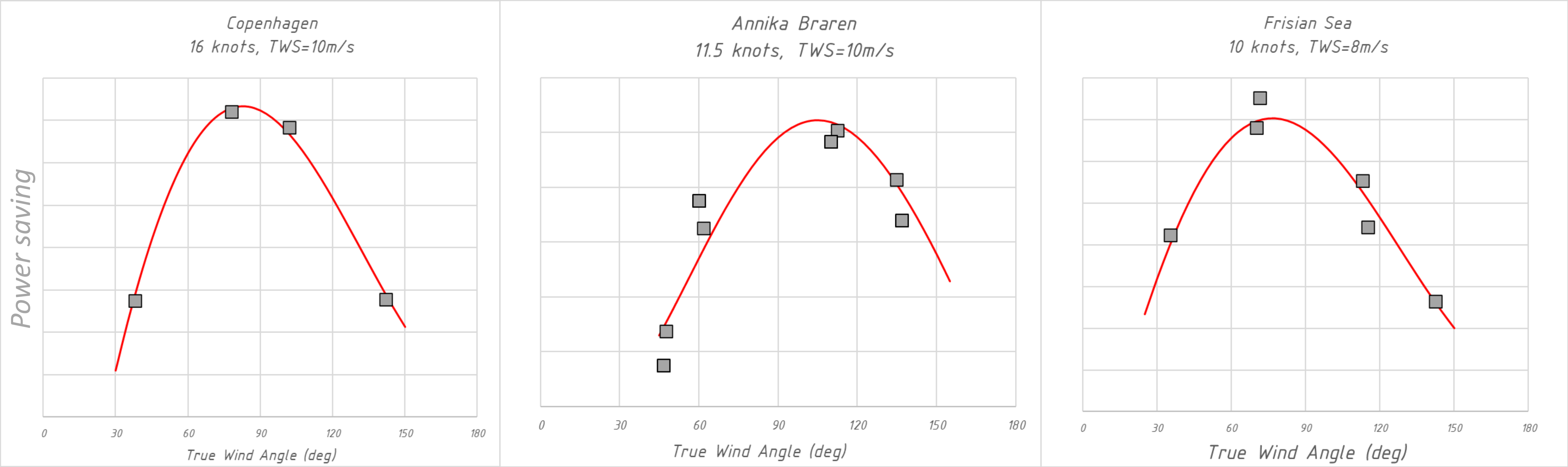


Wind 7-9 m/s

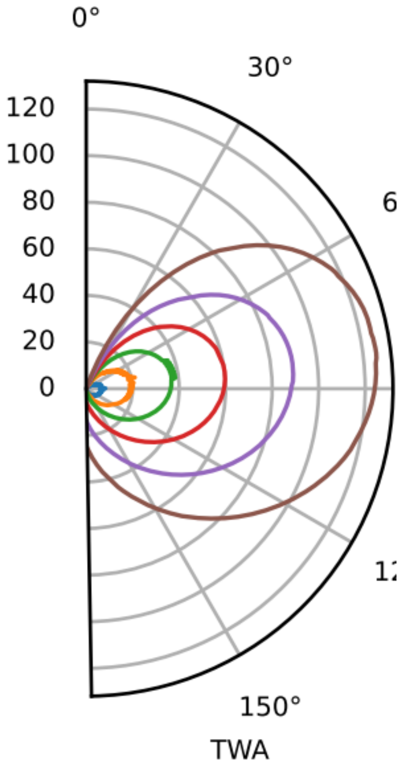
WASP sea trial details

- 6-8 hours
- In-service
- Bf 5-7
- No additional Instruments needed

2. Sea trial results



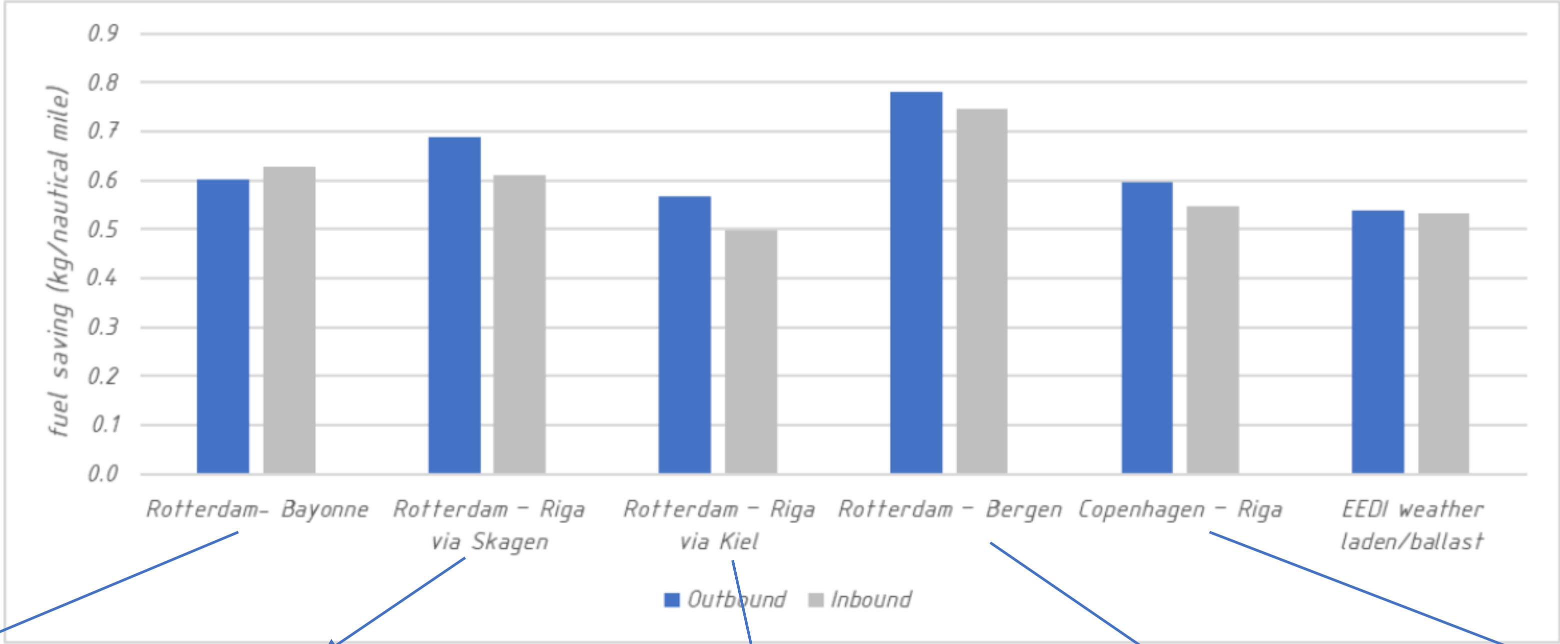
3. Sea trial results



- ✓Confirm prediction results
- ➢Extrapolate to average saving on a route

4. Power saving potential (kW)

Frisian Sea



Rotterdam- Bayonne

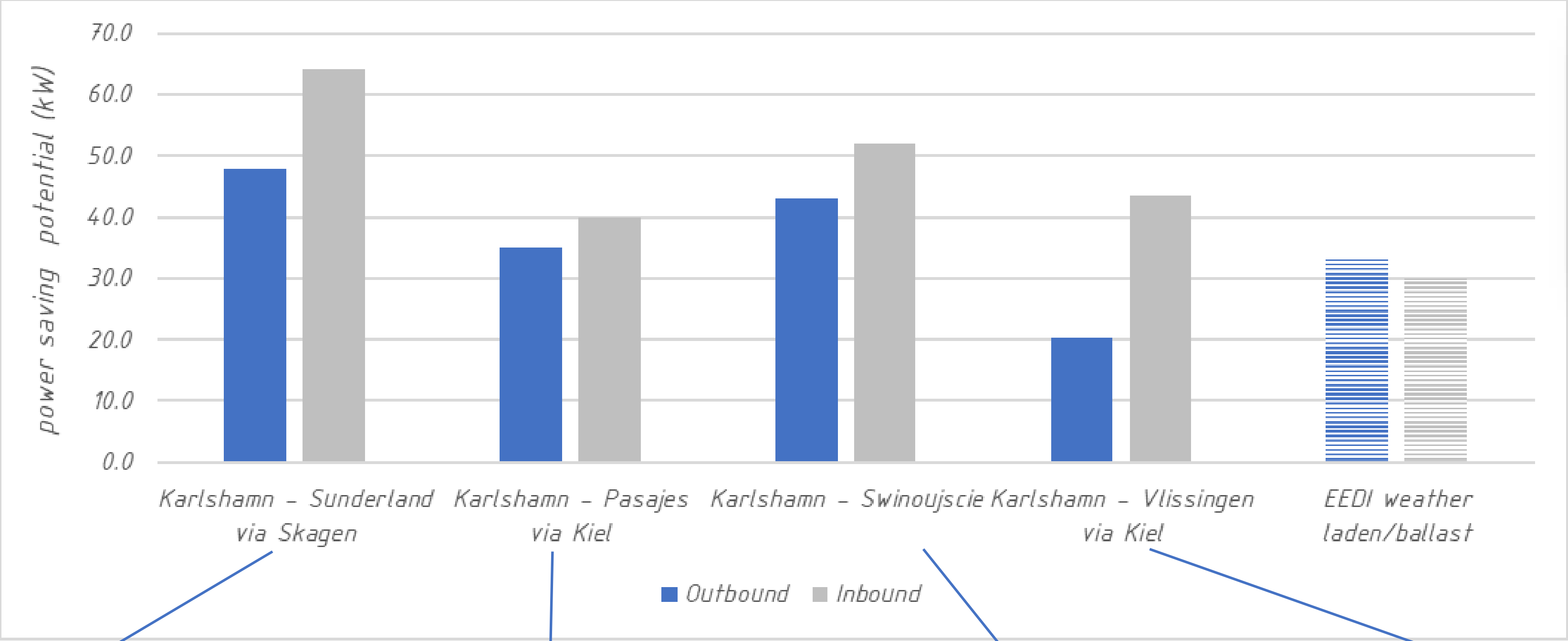
Rotterdam – Riga via Skagen

Rotterdam – Riga via Keil

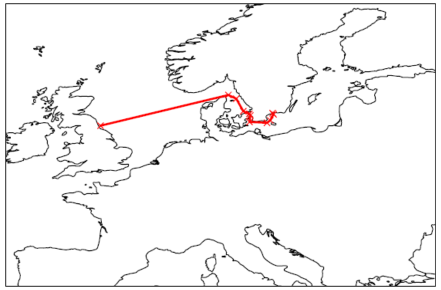
Rotterdam – Bergen

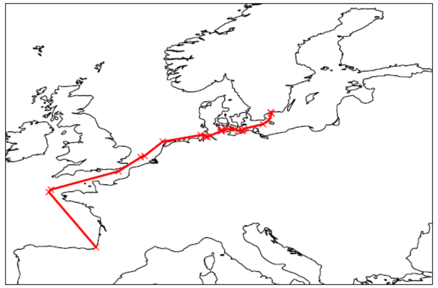
Copenhagen - Riga

4. Power saving potential (kW)



Annika Braren





Sea trial results

Extrapolated results

Vessel	Power Saving Potential (kW)
Copenhagen	~ 375 kW
Annika Braren	~ 35 kW
Frisian Sea	~ 30 kW

- Comparing sea legs only
- Considering only propulsion power and power required by WPT
- Including sea margin (wave added resistance and service condition of hull.)

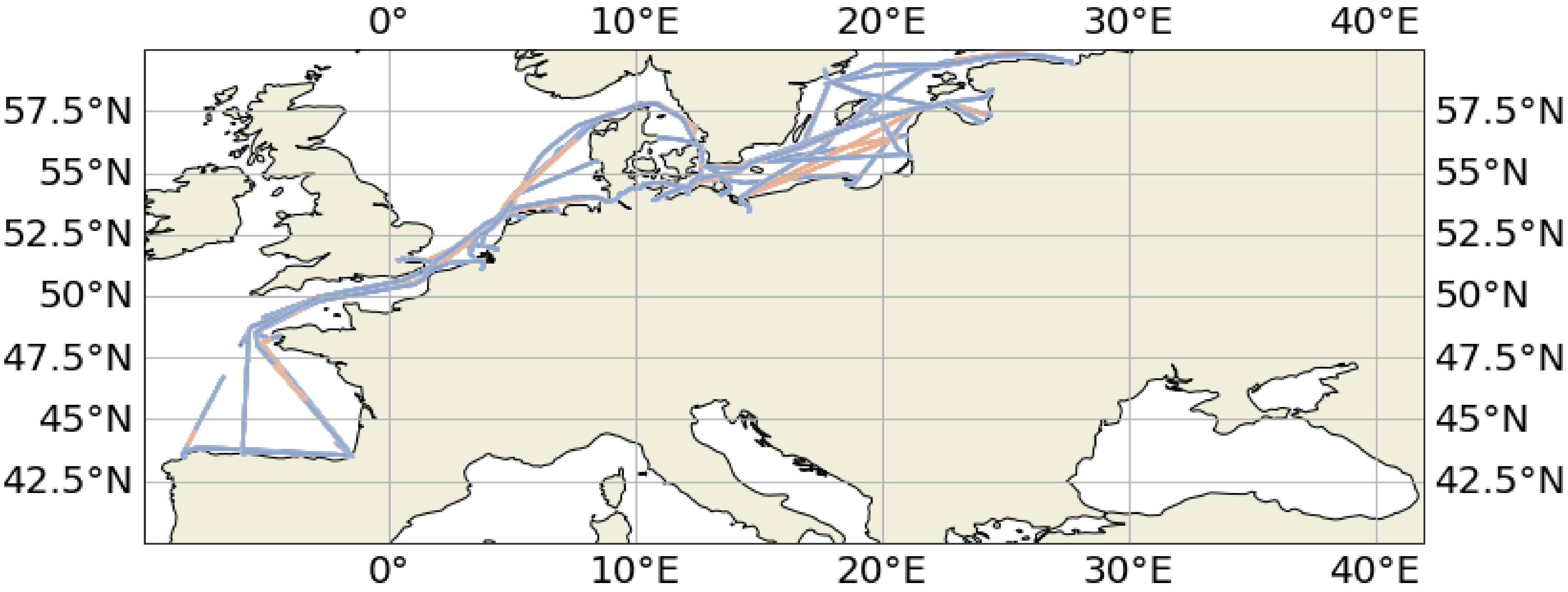
Utilizing the sea trial results

- The measurements are directly used as an input to verify the numerical models
- Determine the resistance curve of the ship (propulsive power needed to maintain a given speed)
- Extend the models additional insight into WPT operation and potential for fuel savings

Digital twins

Use cases with WASP technologies

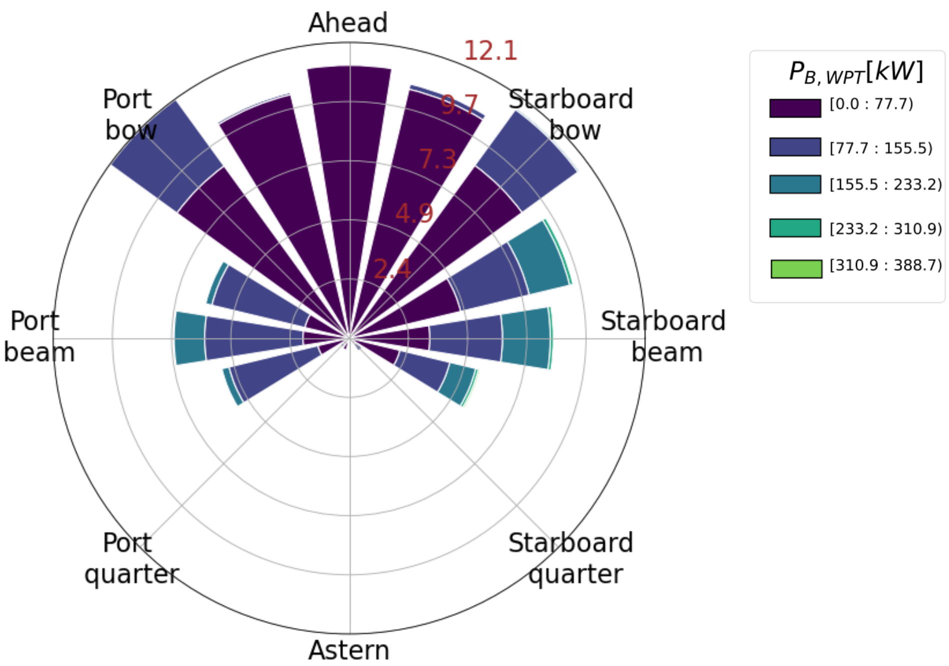
Use case – Frisian Sea

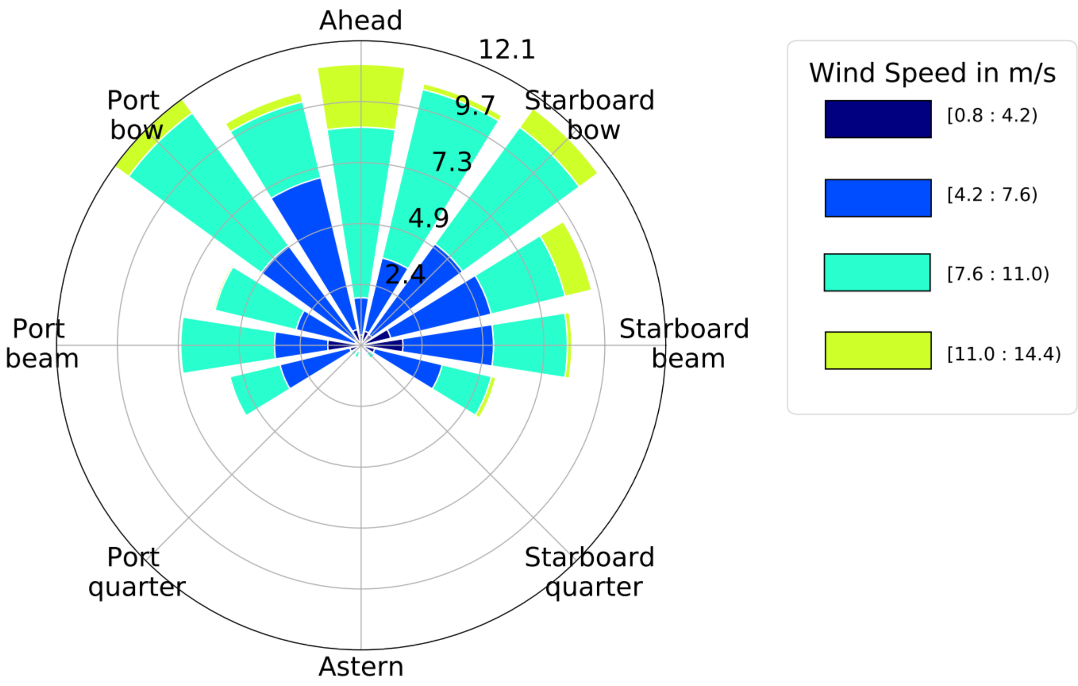


Orange dots denote the hybrid mode
(~15% of the total operational time from July 2021-July 2022)

Power savings at specific conditions

- The power savings assuming optimal control of the WPTs



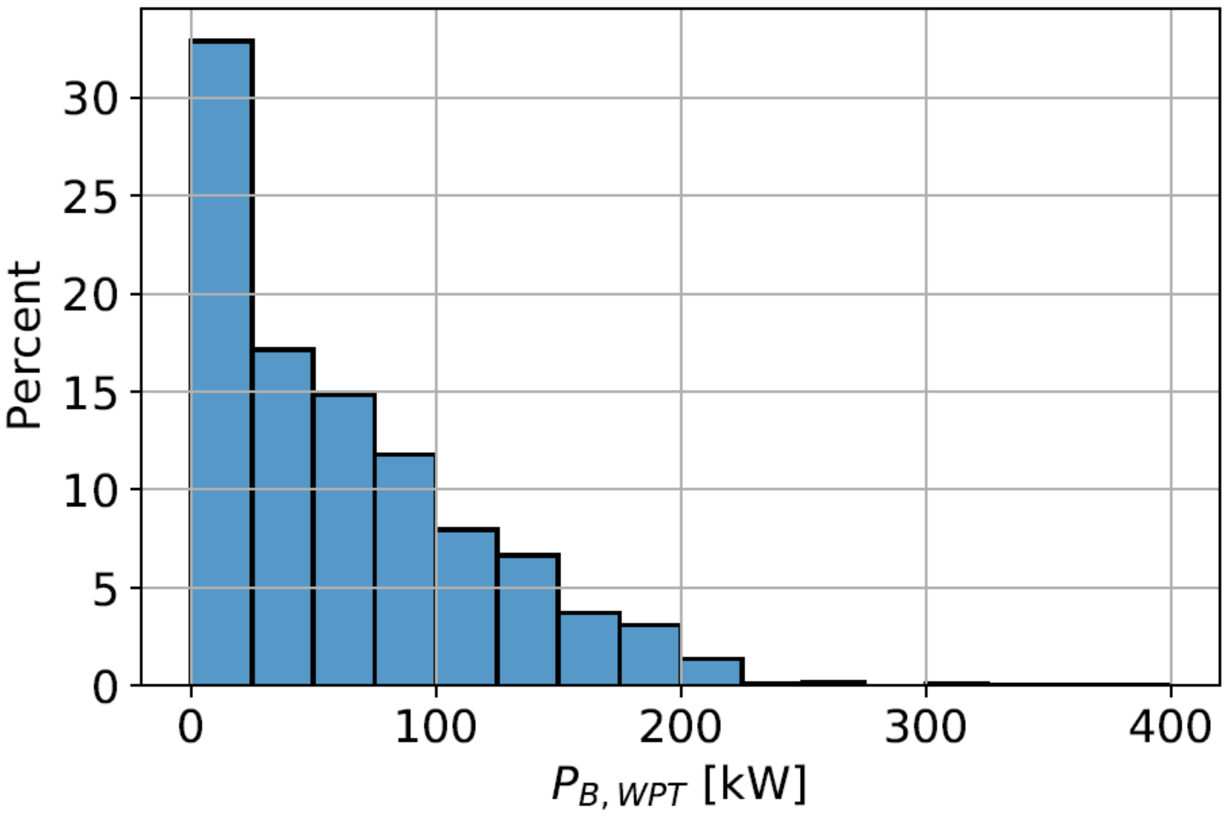


Power saving w.r.t to ship bow

Wind speed w.r.t ship bow

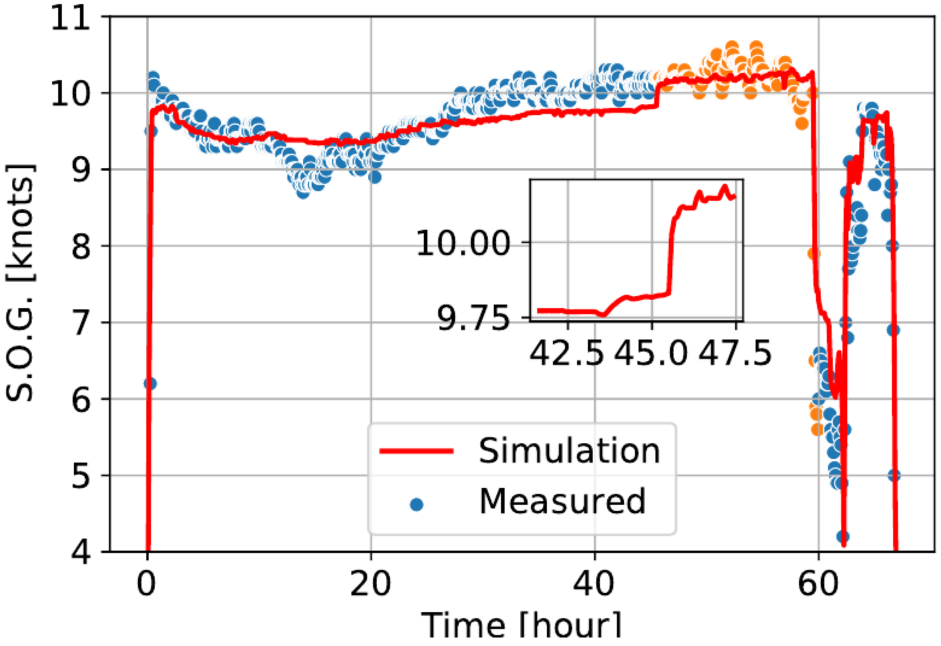
Statistical analysis of savings

- We can also generate statistical representations of savings over a single route or in the long-term
- This shows the power savings by wind energy capture as a percent of total time (over the course of a year)

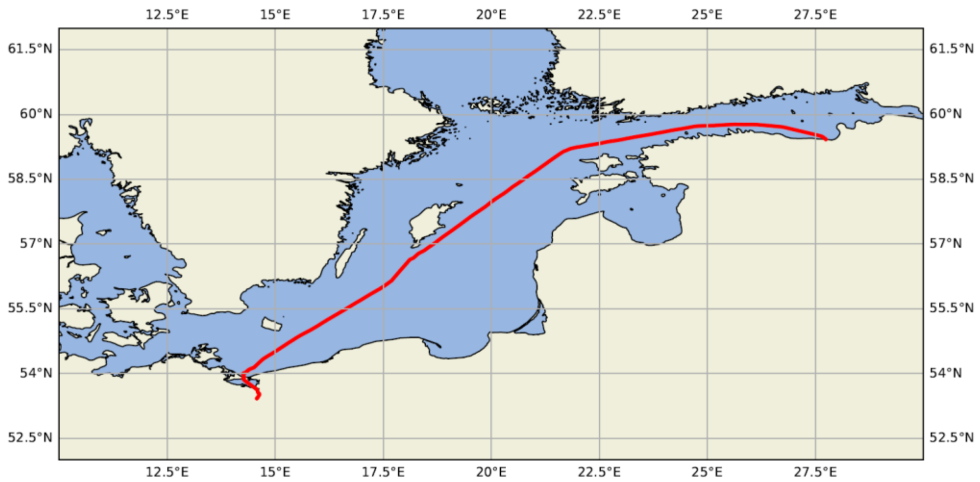


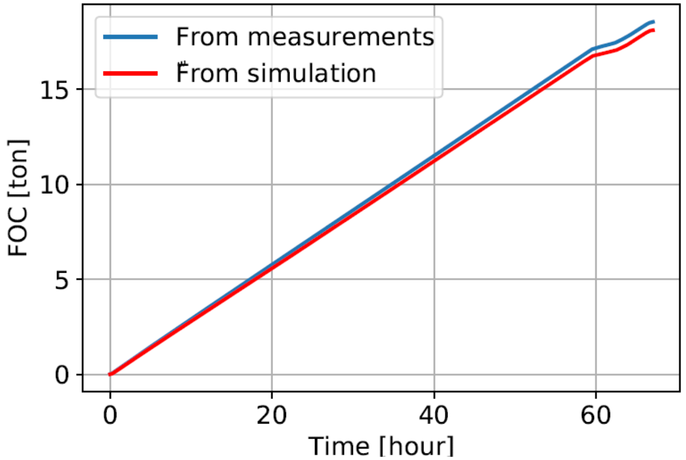
Performance over a specific route

This route features a ‘step change’ when the suction sails were activated



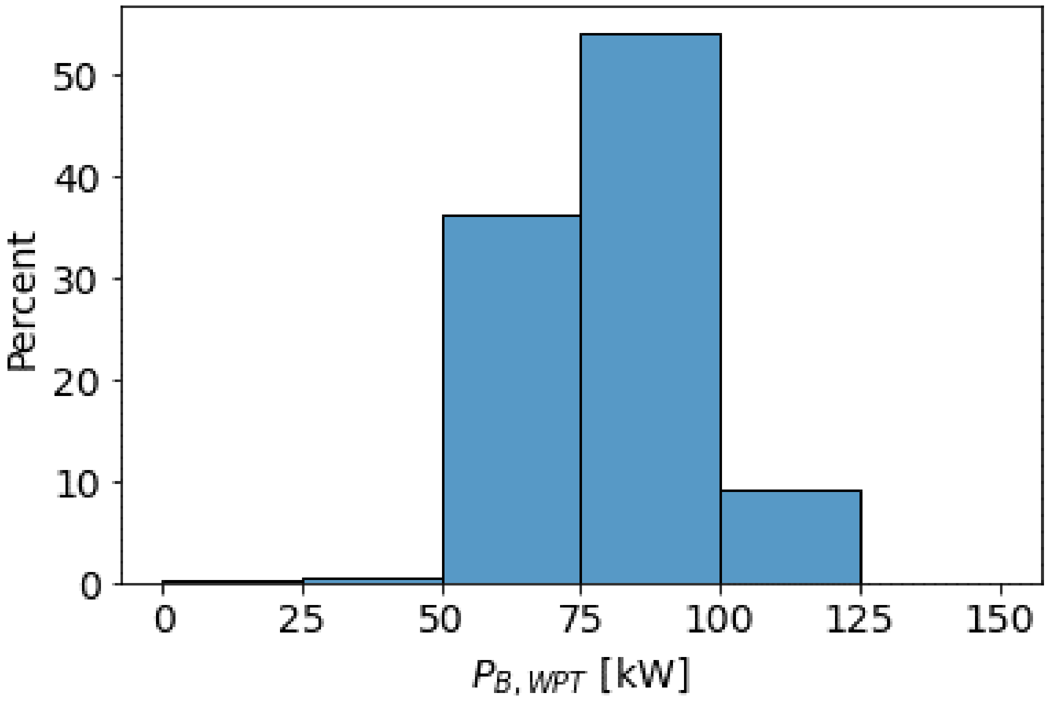
Blue – no WPT
Orange – WPT activated





Savings from wind energy capture

- Total fuel consumed with active WPTs = 4.08 ton
- ~245 kg fuel saved (~6% of total FC during WPT operation and 1.3% fuel saving from WPT for the whole route)
- The average WPT generated power is ~78 kW



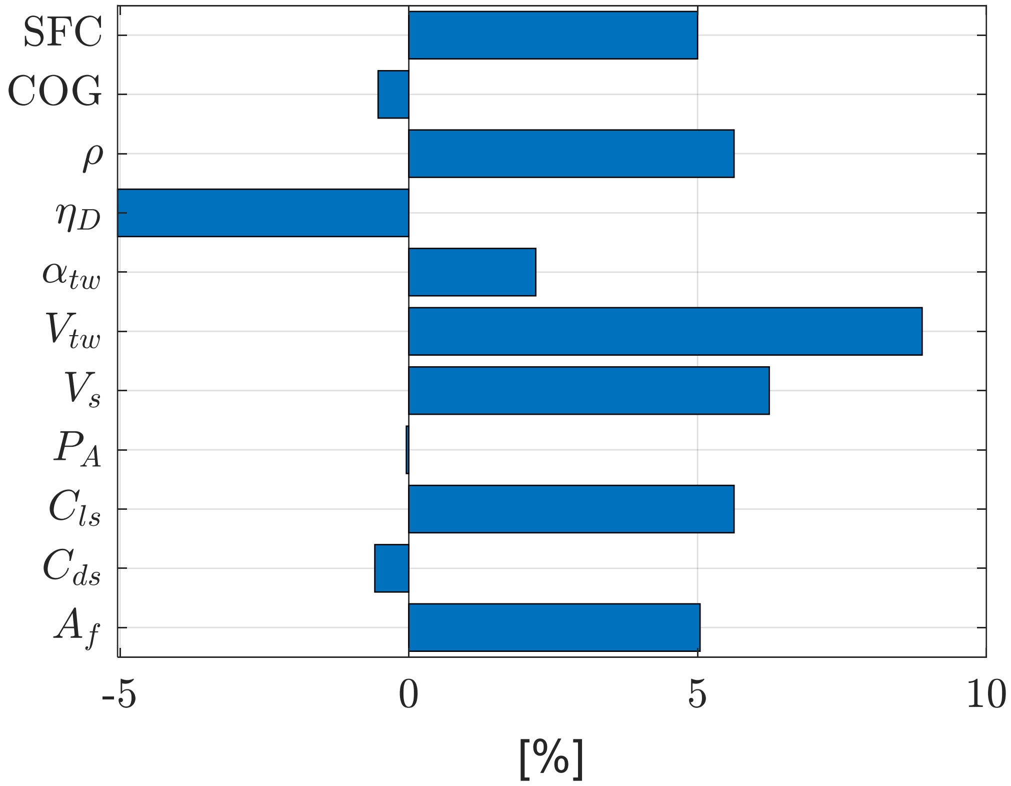
Challenges due to uncertainties

- Assumptions regarding suction sail performance (i.e. value of C_L) – difficult to verify without force measurements (challenging to capture at industrial scale)

- Source of wind data (onboard anemometer versus wind database, e.g. Copernicus)

Sensitivity of fuel savings estimations to parameter variations

- Sensitivity to increasing various parameters by 5% from a reference condition (with WPT)
- FC savings due to WPT increases almost linearly with coefficient of lift (C_L), ship speed (V_s) and decreases with propulsion system efficiency (η_D)
- The most significant parameter on FC is the true wind speed



Anemometer measurements versus wind database

- We observed significant differences between sea trial anemometer measurements and online wind data for the same time

TWS [sea trial] [m/s]	TWS [CDS] [m/s]	TWS diff. [%]	TWA [sea trial] [°]	TWA [CDS] [°]	TWA diff. [%}
6.3	9.15	45.2	265.6	240	-9.6
7.7	9.53	23.8	255.3	236	-7.6
7.2	9.53	32.4	261.0	237	-9.2
9.8	9.34	-4.7	237.5	246.0	3.6
7.3	9.34	27.9	241.6	246.0	1.8
6.9	9.65	39.9	237.7	239.0	0.5
7.6	8.82	16.1	237.0	255.0	7.6
8.0	8.86	10.8	258.0	257.13	-0.3
7.8	8.86	13.6	247.4	257.0	3.9
7.8	7.34	-5.9	250.1	255.0	2.0
8.0	7.38	-7.8	263.5	258.0	-2.1
8.6	7.04	-18.1	257.5	258.0	0.2
9.7	7.04	-27.4	262.5	258.0	-1.7
9.3	7.39	-20.5	264.5	245	-7.4
9.3	7.39	-20.5	256.1	245	-4.3

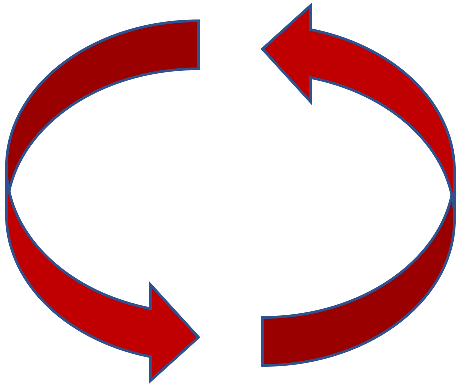
- This has obvious implications for fuel savings calculations

Moving towards wide-scale uptake of WPTs

- One of the barriers is general lack of knowledge/measurements (little before WASP)…more is needed!

- Reluctance to test/adopt immature technologies

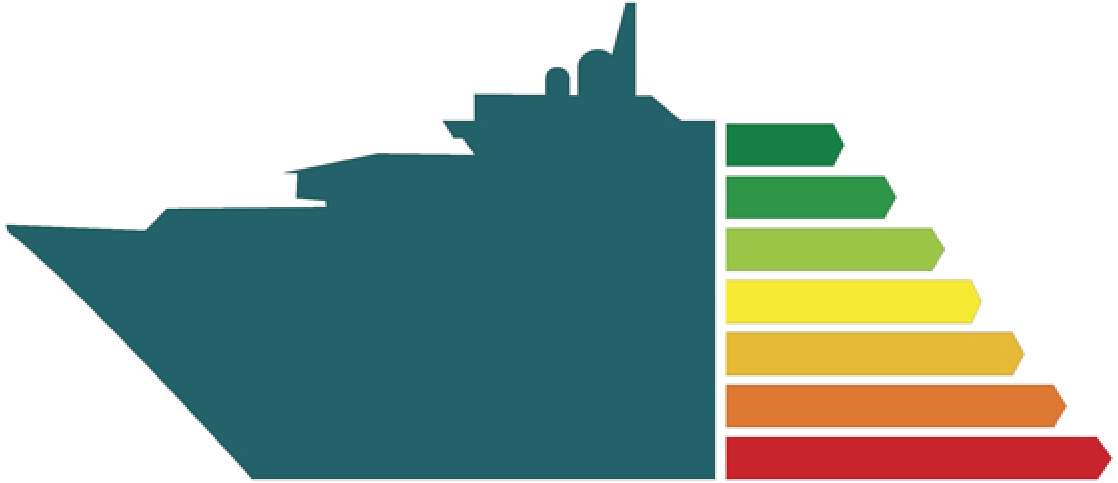
- Investment for specialized test rigs/technology demonstrators that avoid interrupting the operations of a commercial vessel?



Overcoming hurdles to WPT adoption

- WPTs need assistance to compete with conventional propulsion systems

- Impact from policy
  - EEDI or SEEMP – more stringent measures could aid WPT uptake for new builds and existing vessels
  - Market based mechanisms (MBM) – essentially a carbon price
  - Emissions trading system (ETS)



Future considerations

- Candidate vessels with fixed route versus wide area of operation

- Choosing an ‘optimal’ route/weather routing

- Potential for integrated wind-hybrid propulsion system (main engine(s) output changing based on wind capture)

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wasp
Wind Assisted Ship Propulsion

Thank you for your attention!

https://northsearegion.eu/wasp/

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