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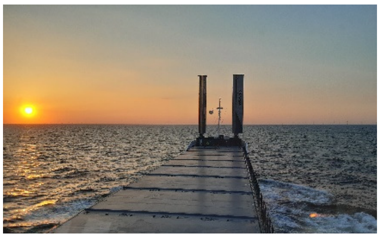
Speed trial and route analysis of m/v Ankie with suction wings



wasp Wind Assisted Ship Propulsion

Interreg North Sea Region WASP European Regional Development Fund

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Sofia Werner

Author

Sofia Werner

Reference:

WASP – Wind Assisted Ship Propulsion

Speed trial and route analysis of m/v Ankie with suction wings

Several speed trials were performed with m/v Ankie during 2022-2023. The purpose of the tests was to verify the power saving of the suction wings. This report describes the tests conditions, measurements, analysis, and results.

The work is a part of the Interreg North Sea Region project WASP - Wind Assisted Ship Propulsion.

SSPA Sweden AB

Christian Finnsgård

Vice President

Research Department

SSPA Sweden AB

Sofia Werner

Lead Researcher – Wind Powered Ships

Research Department

Revision History

Rev.	Publish Date	Description of changes	Signature
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Summary and recommendations

Speed trials was performed on m/v Ankie with the purpose of verifying the power saving of the wings.

At true wind speed 10 m/s and ship's speed 9.5 knots, the wings give a net power saving for apparent wind angles larger than around 20 degrees and the saving reaches up to 15% at the most favourable wind angle.

The speed trial result is scaled up to give a prediction of the in-service fuel reduction using a ship simulation model correlated to the actual speed trial measurements, a voyage prediction tool and statistical weather distribution.

It is estimated that the power reduction on typical routes is between 3.5% corresponding to a power saving of 40 kW.

The mayor uncertainties of the trial result include the wind speed, ship speed and power measurements. The disturbance of hull to the wind measurement onboard the vessel may disturb the relation between the trial result, which is based on the on-board measurements, and the route analysis that scale up the result to yearly fuel savings, which is based on the natural undisturbed wind on the ocean.

The result should be interpreted large uncertainty margins.

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Figure 1	Trial recorded data
Figure 2	Speed trial evaluation according to ISO 15016
Figure 3	Route analysis results

Symbols and abbreviations

ξ_p	Load variation factor, for power correction according to ITTC (2017)	-
AWS	Apparent wind speed	m/s
AWA	Apparent wind angle	deg
AWS_x	Apparent wind speed in ship longitudinal direction	m/s
AP	Aft perpendicular	
A_T	Transversal wind area	m^2
A_W	Total projected wing area	m^2
B	Beam of hull	m
BL	Baseline	
CL	Center line	
FP	Fore perpendicular	
FS	Full scale	
GWA	Global wind angle	deg
H	Wings height	m
IMO	International Maritime Organization	
ITTC	International Towing Tank Conference	
T	Draught	m
T_F	Draught at fore perpendicular	m
TWA	True wind angle	deg
TWS	True wind speed	m/s
V	Volume displacement	M3
V_s	Ship speed	knots
SOG	Speed over ground	knots
COG	Course over ground	deg
STW	Speed through water	knots

1 Introduction

Ship owner van Dam installed wind assistance solution from Econowind on m/v Ankie in 2020. Several speed trials have been performed with the purpose of evaluating the performance of the wings.

The first trial, conducted April 23, 2022, was supervised onboard by Sofia Werner, SSPA Sweden AB. The following trials were conducted by the crew based on instructions from SSPA. Data was recorded automatically and transmitted to onshore database, where it was downloaded by SSPA.

The speed trial result is scaled up to a predicted power saving potential using a voyage analysis and statistical weather data. All data processing, analysis and route evaluation is carried out independently by SSPA.

This work is a part of Work Package 5 in the Interreg North Sea Region project WASP. The scope of Work Package 5 is to demonstrate the performance of Wind Propulsion Technologies on five vessels.

The aim is *not* to compare and rank different wind propulsion technologies. The fuel savings of each installation depend on the ship, speed and route, and therefore the tested cases cannot be compared with each other.

Figure A. Sea trial on April 23, 2022 on m/v Ankie (84.95m x 12.5m) with two suction wings from Econowind.

2 Speed trial data

2.1 Conventions and definitions

The following coordinate systems are used in this report:

- Used when referring to locations or distances on the ship:
    - Body-fixed, Cartesian, right-handed system “XYZ” with the origin in intersection of AP, CL and BL.
    - X-axis positive forward
    - Y-axis positive to port
    - Z-axis positive upwards

The following definitions of directions and angles are used in this report.

- Global wind angle (GWA): defined in the geographical system
    - GWA=0° means wind coming from north
- True wind angle (TWA): the angle between the wind direction and the course of the ship
    - TWA=0° means head wind
    - TWA=90° means beam wind (starboard side)

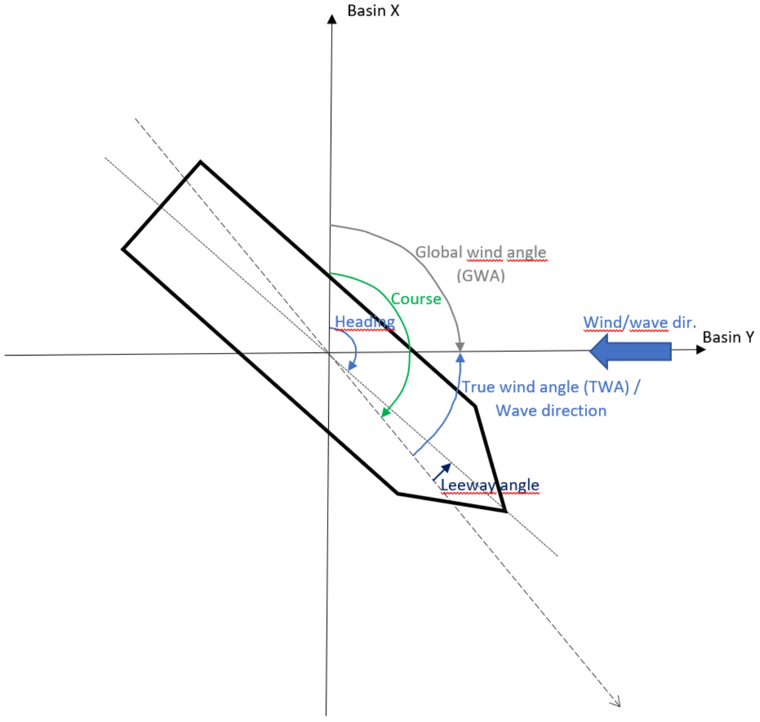


Figure B Definitions of directions and angles

2.2 Ship

The general cargo vessel m/v Ankie (IMO 9331359) operates mainly in the North Sea region and Baltic sea.

The ship data used for the sea trial analysis is listed in Table 1. The ship has a ducted, controllable pitch propeller. The engine is a 4-stroke direct coupled, and with a shaft generator. The ship loading condition during trial is given in Table 2.

Table 1. Ship data at trial

Name	Symbol	Magnitude	Comment
Length over all	Loa	84.95 m	
Beam over all	B	12.5 m	
Load variation factor for power	ξ_p	-0.15	Based on similar ships in SSPA's database
Hight of anemometer	h	21 m	from waterline at trial
Transversal wind area	A_T	167 m^2	

Table 2. Ship loading condition during trial

Name	Symbol	Magnitude	Comment
Draft forward	Tf	2.7 m	
Draft aft	Ta	3.4 m	
Displacement	Δ	2600 ton	

2.3 Wind propulsion system

The ship is equipped with two suction wings from Econowind with dimensions according to Table 3. The wings are tiltable aft wards. Air suction is created with fans driven by electric motors. Rotation angle is set automatically based on the apparent wind measured in the mast.

Table 3 Wind propulsion system particulars

Name	Magnitude	Comment
Span	13 m	
Chord	2.1 m	
Area	2x27.3= 54.6m^2	projected
Position wing 1	77 m / 4m	From AP / from CL
Position wing 2	77 m / -4m	From AP/ from CL

2.4 Trial location and environmental conditions

The first trial was conducted in the North sea off the Netherland cost. An external weather source (SMHI) reported conditions as stated in Table 4. Environmental conditions registered onboard are given in Table 5.

Table 4. Observed weather

Wind	NE	10-11 m/s
Wave hights (observed)	NE	1.0 m

Table 5. Environmental conditions, registered onboard

Name	Symbol	Magnitude	Comment
Temperature air	t_a	10°	
Air pressure	p	1013 mbar	Was not measured
Density air	ρ_a	1.24 kg/m^3	Derived from temperature

2.5 Data acquisition

All recorded data is listed in Appendix 1, Figure 1. Data acquisition was performed using the systems given in Table 6.

2.5.1 Power consumption of wings

The suction wing fans were supplied from the ship's shaft generator. PTO was registered in the data logging system. No other mayor consumers were active during the trial.

Table 6. Data acquisition sources

Variable	Instrument	Recording system	Frequency
Shaft power Propeller shaft rate	Eefting torque meter	Eefting data log	5 min running average
Shaft generator	Generator PTO	Eefting data log	5 min running average
SOG, COG	GPS	Eefting data log	5 min running average
STW	Doppler log	Eefting data log	5 min running average
Heading (gyro) Rudder angle		Manual reading of displays on the bridge during trial runs	
Relative wind at mast top	Ships Anemometer	Eefting data log	5 min running average

2.6 Trial procedure

The trial was conducted according to the principles in ISO 15016/ITTC 7.5-04-01-01.1, with some deviations.

The trial program included 30 single runs. Each run was 10 minutes long. Constant heading was kept during the runs using the ships autopilot.

The following sequence was followed for each heading:

1) Wings were folded down on the deck
2) Steady heading and speed were checked with external GPS by plotting over time.
3) Measurements conducted for 10 minutes
4) While keeping heading, rpm and pitch constant, wings were raised and set in operation mode.
5) Steady heading and speed were checked with external GPS by plotting over time.
6) Measurements conducted for 10 minutes

For some headings, the order was opposite (wings first, without wings second). All runs were performed at a constant shaft rate and propeller pitch. The rpm of the wings was set automatically by the wings control system.

Additionally, four runs were conducted without the wings, straight into the wind with varying ship speed to

3 Trial analysis and results

3.1 Current

Speed differences is derived based on STW. Therefore, no current correction is needed since in the WASP trials.

3.2 Wind

The wind was not completely constant during the trial. This could potentially disturb the trial evaluation process, when runs with and without wings are compared. To minimise the disturbance this may have on the comparison, the ship's wind resistance is subtracted from each individual run, according to the ISO 15016 procedure.

According to ISO 15016, the measured wind should be averages between two runs in opposite directions, to reduce the disturbance of the ship's superstructure on the anemometer. In this trial, the runs were however not conducted as reciprocal double-runs and therefore this procedure cannot be followed.

3.3 Water temperature, displacement and superstructure resistance

The measured power for each single run is corrected for the wind resistance of the superstructure based on ISO/ITTC standard procedure. The wind resistance coefficient is from SSPA's database.

Correction for water temperature and a correction of displacement to baseline displacement are done according to the procedures.

3.4 Power correction

The correction of propulsive efficiency due to the added resistance corrections is derived using the Direct Power Method according to the ISO standard using the assumed load variation factor stated in Table 1. (See the ISO 15016 standard for a detailed description of the Direct Power Method.)

The corrected power is listed in Appendix 1, Figure 2-7.

3.5 Baseline

There were no model test curves available for the ship. Instead, the baseline curve was derived by a series of runs at different power settings, Figure C.

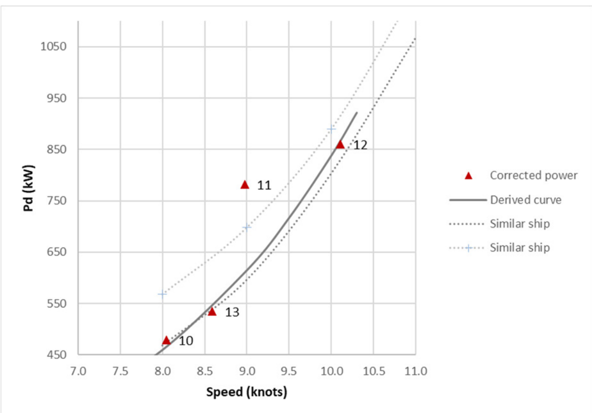


Figure C. Power at sea trial – speed test without wings. Power corrected according to ISO 15016.

3.6 Wing evaluation

The principle of the wing evaluation is to compare single runs *with and without* wings at the *same wind angle*. Table 7 give a comparison of the speed and corrected power between the runs with and without wings. At most of the measured wind angles, the speed increases when the wings are employed. Normally, an increased speed due to additional wind thrust gives a slightly reduction of power due to higher efficiency when the propeller is off-loaded. However, this is not observed in all runs. This could be due to measurement uncertainty of the power. In the following wing performance analysis, the speed difference is the dominating factor and the possible errors in the power measurement has less influence, but it adds to the uncertainty of the results.

Th numbers in Table 7 are the direct results from the trial, but they are hard to interpret. In Chapter 4, the result is normalised to give representative power savings for a given speed.

Table 7 Speed and corrected power from speed trial.

Date	**Runs**	**Δ STW (knots)**	**Δ Ps (%)**
2022-06-05	Run 2&1	0.16	0.1%
2022-06-05	Run 4&3	0.10	1.6%
2022-06-09	Run 8&9	0.01	-1.5%
2022-06-18	Run 10&11	0.13	-0.7%
2022-06-18	Run 12&11	0.08	2.7%
2022-07-13	Run 13&14	0.12	0.2%
2023-03-24	Run 4&5	0.83	-1.9%
2023-03-24	Run 6&7	0.10	-2.5%
2022-04-23	Run 16&17	0.02	0.2%
2022-04-23	Run 18&17	-0.03	-0.3%
2022-04-23	Run 20&19	0.18	2.6%
2022-04-23	Run 20&21	0.19	-0.6%
2022-04-23	Run 23&22	0.23	-0.5%
2022-04-23	Run 23&24	0.22	-2.8%
2022-04-23	Run 26&25	0.00	-6.8%

4 Wing performance analysis

The result of the trial presented in the previous chapter showed that the wings are able to increase the speed. In this chapter, the trial result is normalised such that a power reduction for a given ship speed can be presented. Two alternative normalisation methods are used.

4.1 Power saving at sea trial conditions

Consider two runs, with and without WPT:

	Ship speed **V (m/s)**	**Delivered Power** **P (W)**
Without WPT	V_0	P_0
With WPT	V_1	P_1

1) Fit a polynomial P= *f(V)* to the baseline speed-power curve, or part of the baseline curve that covers range of speeds measured in the trial. Normally a 3rd order works well. Extract the polynomial coefficients.
2) The power saving ΔP at V_1 is derived as

$$\Delta P_1 = f(V_0) - f(V_1) + P_0 - P_1 \quad (1)$$

Note that ΔP_1 at is only valid at V_1 and at the sea trial wind condition.

The Baseline curve can either be taken from the conventional speed trial performed earlier, model test results, or a speed variation test carried out in conjunction with the WASP sea trial.

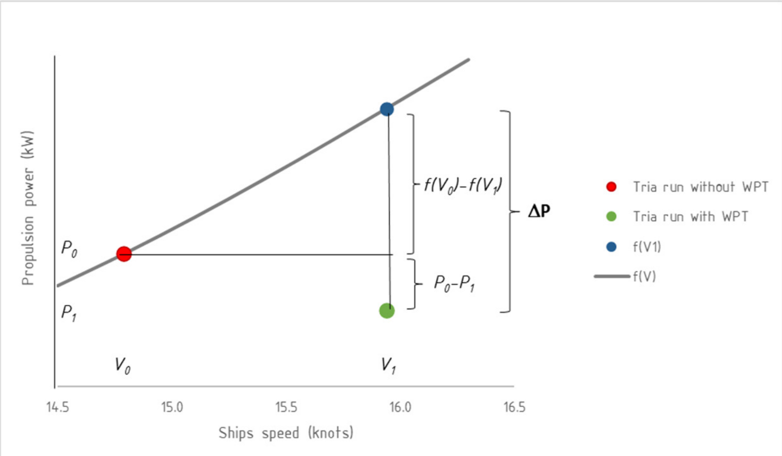


Figure D. Extracting sea trial power difference due to WPT using the ship's speed-power curve f(V)

4.2 Normalisation to reference condition, Method 1

The power savings derived in previous step are only valid for the ships speed and wind as measured during the sea trial runs. To translate these power differences to a reference condition, the following steps are carried out. The reference condition is supposed to be given as a ship speed V_{ref} and a true wind at 10m hight over water $TWS_{ref,10}$.

The apparent wind measured at the anemometer (AWS_a , AWA_a) is translated to the corresponding hight of the mid-point of the WPT using the 1/7 power law (→ AWS_a , AWA_a). (See for example ISO 15016).

The apparent wind corresponding to the reference condition is computed for the true wind angles at the sea trial, and at a hight at the midpoint of the WPT (→ $AWS_{ref,m}$, $AWA_{ref,m}$).

From equation (1) we have ΔP_1 valid at ship speed V_1 and apparent wind $AWS_{1,m}$, $AWA_{1,m}$.

A pseudo WPT thrust coefficient is computed as

$$\tilde{C}_{t1} = \frac{\Delta P_1 \cdot \eta_D}{V_1} \cdot \frac{1}{0.5 \cdot \rho_{st} \cdot A_{\mathrm{WPT}} \cdot {AWS_{1,m}}^2} \tag{2}$$

In ideal condition, the thrust coefficients vary with AWA according to

$$C_{t\ ideal} = C_L \sin(AWA) - C_D \cos(AWA) \tag{3}$$

C_{t1} can be corrected to the reference AWA using the slope of eq(3) in the following way:

$$C_{t1\ corr} = \left[C_L \cos\left(AWA_{1,m}\right) - C_D \sin\left(AWA_{1,m}\right)\right] \cdot \left(AWA_{1,m} - AWA_{ref,m}\right) \tag{4}$$

The power difference at the reference condition and at $TWA_{1,m}$ is then estimated as

$$\Delta P_{1,ref} = \frac{\left(\tilde{C}_{t1} - C_{t1\ corr}\right) \cdot 0.5 \cdot \rho_{ref} \cdot A_{\mathrm{WPT}} \cdot {AWS_{ref,m}}^2 \cdot V_{ref}}{\eta_D} \tag{5}$$

Note that $\tilde{C}_t$ is a pseudo coefficient and its magnitude cannot be compared with theoretical performance of the WPT.

C_L, C_D and η_D are assumed values for the specific case. It can be shown that the derived power difference is not very sensitive to these values, if the reference condition is close to that of the sea trial.

The method should only be used to normalise the sea trial result to a reference condition close to the sea trial condition. That means in practice that the reference condition will be selected to be the average true wind speed during the sea trial, rounded to integer, and similar for the ship speed.

Table 8. Power reduction derived from speed trial and normalized to reference ship's speed 9.5 knots and reference wind 10m/s. Power saving without considering power consumption from wings.

		Reference conditions 10 m/s at 10m		
	runs	AWA	TWA	∆P
		deg	deg	kW
2022-06-05	Run 2&1	58	82	148.1
2022-06-05	Run 4&3	77	105	92.7
2022-06-09	Run 8&9	73	101	101.9
2022-06-18	Run 10&11	123	147	60.7
2022-06-18	Run 12&11	138	157	2.6
2022-07-13	Run 13&14	150	164	72.5
2023-03-24	Run 4&5	65	91	217.3
2023-03-24	Run 6&7	117	143	33.1
2022-04-23	Run 16&17	22	32	8.4
2022-04-23	Run 18&17	26	38	-4.2
2022-04-23	Run 20&19	26	39	29.3
2022-04-23	Run 20&21	26	39	57.2
2022-04-23	Run 23&22	60	85	126.4
2022-04-23	Run 23&24	60	85	151.5
2022-04-23	Run 26&25	29	42	42.2

4.3 Normalisation Method 2

In Method 1, the translation of a speed increase to a power decrease is done by shifting the power curves. This does not fully account for the changed propulsive efficiency when the propeller is unloaded due to the wind propulsion. A second simplification in Method 1 is that the changed apparent wind due to a changed ship speed is accounted for. In order to include these effects, a second normalisation method is introduced. It makes use of a 1DOF speed-power prediction program, which can model the relation between speed, power and the change in propeller efficiency due to changed speed or propeller load. The propeller characteristics of Wagening C 4.40 is used to model the propeller. The process follows the present steps:

1. Ensure that the output of the speed-power prediction program is equal to the Baseline curve (the ship's calm water speed-power curve at the actual loading condition, without wings)

2. Use the speed-power program to find the additional force in the longitudinal direction that matches the change in speed AND corrected power between two runs *with* and *without* wings. That force was the wings thrust, *T* in the run with wings.

3. The thrust coefficient is derived by

$$C_t = \frac{T}{\frac{1}{2}\rho_a \cdot A_W \cdot AWS^2} \tag{5}$$

with AWS measured at the trial and translated to mid-hight of the wings and using 1/7 power law.

4. Ct is regressed against AWA by adapting a theoretical Ct curve of a generic suction wing derived by CFD.

5. For the nominal condition (ship's speed 9.5 knots, TWS_{10m}=10m/s, air temperature 15 deg), the apparent wind is computed for a range of wind directions, and the wings thrust *T* is computed using the C_t-polynomial.

6. The speed power prediction program is executed both with and without the wings thrust (entered as a reduction of resistance) and at the nominal speed. The difference in the resulting power is denoted Gross Power Saving. This represents the hydrodynamic power saving.

7. The wings power consumption, as measured during the trial, is subtracted from the Gross Power Saving to give the Net Power Saving. It is assumed that this number include transmission efficiency.

4.4 Results

The resulting gross saving (power saving without considering the wings power consumption) from Method 1 and Method 2 are compared in Figure E.

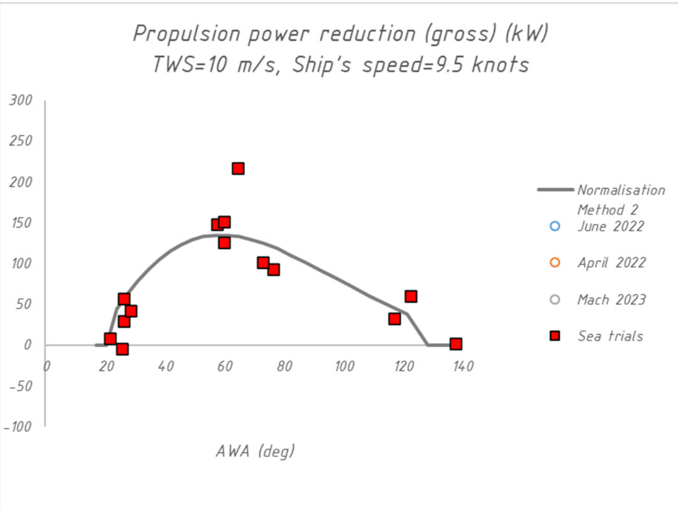


Figure E. Hydrodynamic power savings derived with normalization method 1 and 2 at nominal conditions. Not accounting for power consumption from suction fans. Reference wind speed 8m/s at 10m above sea.

5 In-service fuel saving

The following sections describe the methodology applied to estimate the power saving due to the wings for the given routes.

In short, the procedure is outlined as follows:

- Calibrate digital models of the ship, propeller and wings against sea trial.
- Predict the required power to reach the intended speed for a matrix of environmental conditions, using an in-house Velocity Power Prediction (VPP) program. The VPP model is presented in section 5.1.
- Assembly statistics of the environmental conditions that the vessel will encounter along the route over time.
- Perform route simulations using Monte Carlo technique over combinations of environmental conditions along the route to estimate statistical properties of route energy requirement.

5.1 Power prediction

5.1.1 Ship and propeller models

For each unique environmental condition encountered by the vessel it is necessary to predict the power requirement to reach the intended speed. A quasi-static force equilibrium is found at the intended speed, at which the propulsive and rudder forces are in equilibrium with hydrodynamic and aerodynamic forces. This equilibrium equation is set up in 4 DOF (Degrees of Freedom) including surge, sway, roll and yaw as follows:

$$[Fx, Fy, Mx, Mz] = f(n, \delta, \varphi, \psi)$$

Where $[Fx, Fy, Mx, Mz]$ are total force and moment residuals on the vessel in surge, sway, roll, and yaw respectively, n is the propeller rpm, δ is the rudder angle, φ is the heel angle and ψ is the leeway angle. The problem is a multi-dimensional root-finding problem and is solved iteratively, ultimately finding the required input parameters to generate a zero vector as output.

The function f consists of a set of force calculation routines, each one responsible for calculating a subset of the total force acting on the vessel given the current input parameters. The following force calculation routines has been used in this report:

- **Calm water resistance**

The speed-power curve in the actual service condition was first derived as described in Section 3.5 Resistance curves were derived using the propulsive efficiency η_D from the model test of similar ships.

- **Added resistance in waves**

Spectral superposition of R_{AW} (found from model tests in regular waves from SSPA database) and wave spectrum (ITTC) to find mean added resistance in an irregular sea state.

- **Manoeuvring and rudder forces**

Manoeuvring forces based on bis system model in Norrbin (1970). The forces on the hull and rudder due to drift and rudder angles are introduced in the ship simulation tool in terms of manoeuvring coefficients. The manoeuvring coefficients used is extracted from SSPAs database of manoeuvring model tests.

- **Propulsive forces**

The propulsive factors are taken from the model test of similar ships from SSPA's database. The propeller is modelled as a Wagening C 4.40 with constant pitch. This simplification is assumed not to have any impact on the result, since the propeller model only needs to predict the slope of the propeller efficiency correctly. The chosen propeller model is supposed to represent the actual propeller well in this respect.

The propulsive set-up is checked by comparing the predicted power and shaft rate with the sea trial base line runs.

- **Superstructure aerodynamic forces**
  The wind resistance coefficient is from SSPA's database.

- **Wind propulsor model**

A quasi-static force model of a generic wing sail is used for the route simulations in this report

- Apparent wind is calculated, including effects from the Atmospheric Boundary Layer (ABL) in accordance with ITTC recommended profile (ITTC 1984).
- Wind propulsor force coefficients are derived as detailed in Section 5.1.2.
- Force contribution in vessel coordinate system is calculated based on apparent wind, aerodynamic coefficients and geometry.

5.1.2 Wing model

The wings model is derived with the following process:

A generic suction wing is modelled by RANS CFD simulations with the wing standing on a symmetry plane, i.e without any ship hull. The interaction effect between the two wings is modelled using a lifting line based code (Malmek 2020). The ideal wings model is calibrated to the measured speed trial results, which accounts for the interaction between the ship hull and the wings.

The same correction is applied to the side force, assuming that the ideal wings Cl/Cd is preserved. This is an assumption, but since side forces is not measured at the speed trial, it is the best possible assumption. However, the magnitude of the side force has only a marginal effect on the power gain for the current case.

The suction wing fan rpm is set with respect to apparent wind speed according to a function provided by the wing maker. The power required to operate the wings is a function of the fan rpm, also provided by the maker.

The wings are assumed to be lowered and stored on deck when they do not provide a net saving.

5.1.3 Power saving

The speed power predictions are executed both with and without the wings thrust at the nominal speed. The difference in the resulting power is denoted Gross Power Saving. This represents the hydrodynamic power saving. Including the power consumption from wing fans gives the net power saving.

5.2 Route analysis method

The route simulation tool uses a Monte Carlo technique over combinations of environmental conditions along the route to estimate statistical properties of route energy requirement. The method is described in by Olsson et.al (Olsson 2020).

The methodology entails the following limitations and assumptions:

- No route optimisation with respect to weather or current.
- The wings will be in use whenever wind condition allows.
- When wings are used, main engine power will be reduced to keep the prescribed ship speed.
- The main engine is assumed to always deliver enough power and torque to reach the intended speed, i.e. no involuntary speed reductions.
- Voluntary speed reductions are not accounted for.

The routes are divided into legs, as shown in Figure F. For each leg on the route, a discrete joint weather distribution (True wind speeds and True wind angles) is derived from wind statistics obtained from the ERA5 reanalysis dataset available in the Copernicus Climate Data Store (https://cds.climate.copernicus.eu). Each leg is treated independently, and leg-wise distributions are assumed to be uncorrelated.

5.2.1 Operational conditions for route simulation

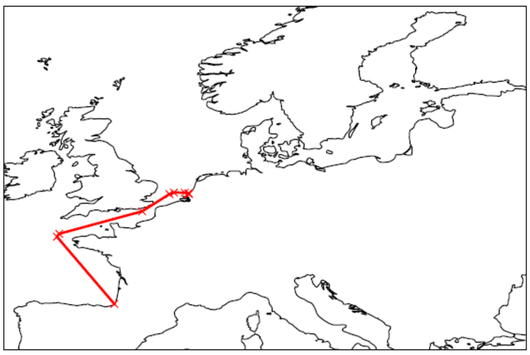
The route analysis is carried out for the following conditions:

- Ship's speed 9.5 knots
- Laden draught: 5m e.k.
- Ballast draught: 3 m e.k.
- Density air 1.24 kg/m^3
- SFOC 186 g/kWh

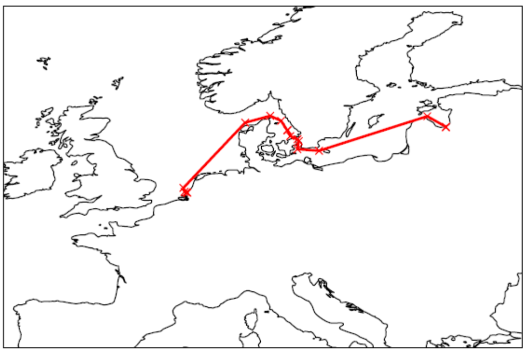
The ship does *not* operate on a fixed trade. To be able to estimate a yearly average fuel saving in this study, the route analysis is carried out for six typical routes (Table 9). Route 6 is a generic setting based on the EEDI weather matrix (IMO 2021).

Table 9. Routes for analysis and their relative frequency of occurrence.

	Outbound	**Inbound**
Route 1	Rotterdam- Bayonne	Bayonne-Rotterdam
Route 2	Rotterdam – Riga via Skagen	Riga- Rotterdam via Skagen
Route 3	Route 2 but via Kiel	
Route 4	Rotterdam – Bergen	Bergen- Rotterdam
Route 5	Copenhagen - Riga	Riga – Copenhagen
Route 6	EEDI weather matrix	



Rotterdam- Bayonne



Rotterdam – Riga via Skagen

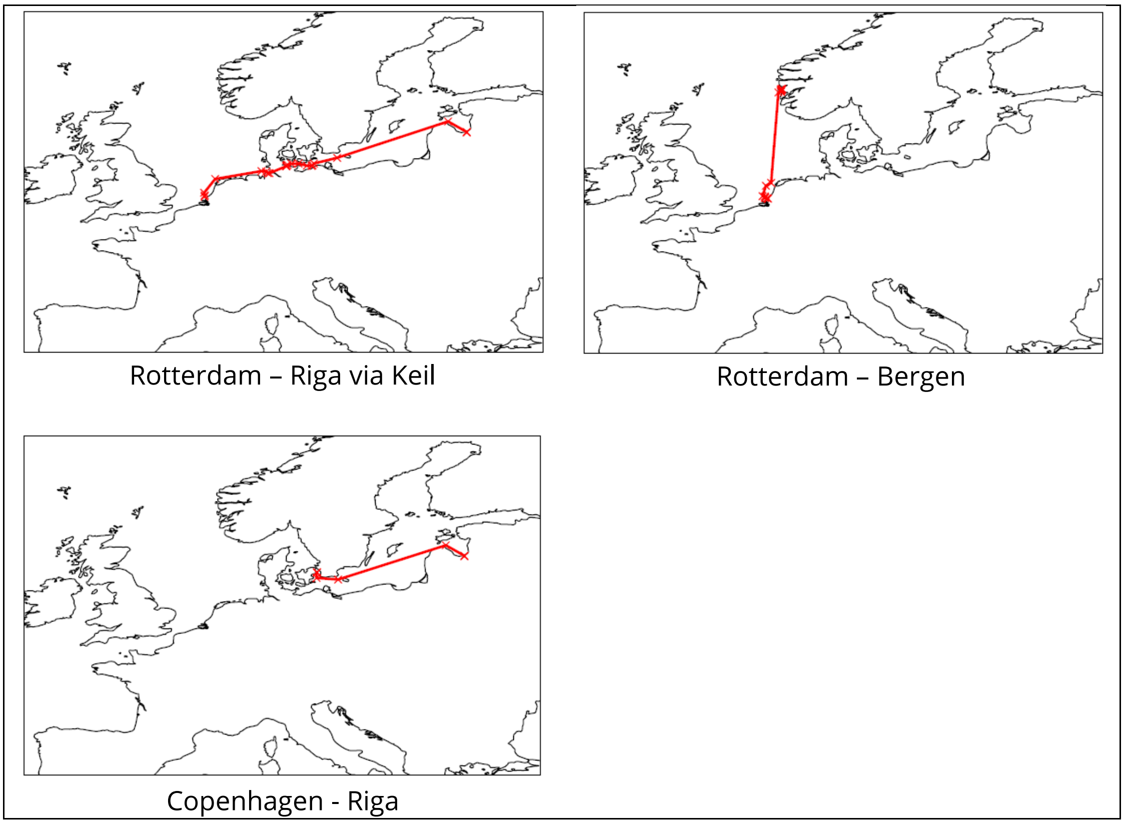


Figure F. Routes

The wind statistics for these routes are presented in Figure G and Figure H.

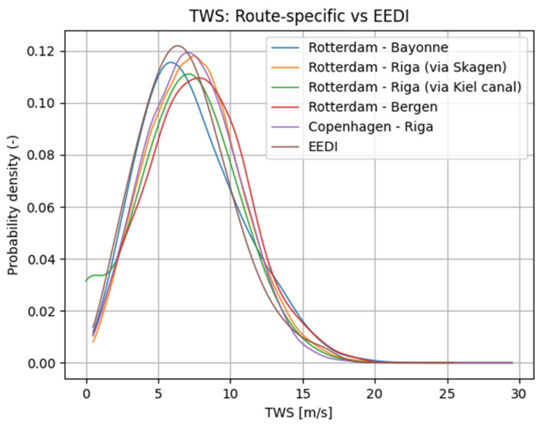


Figure G. The probability of true wind speed on the routes from external weather source.

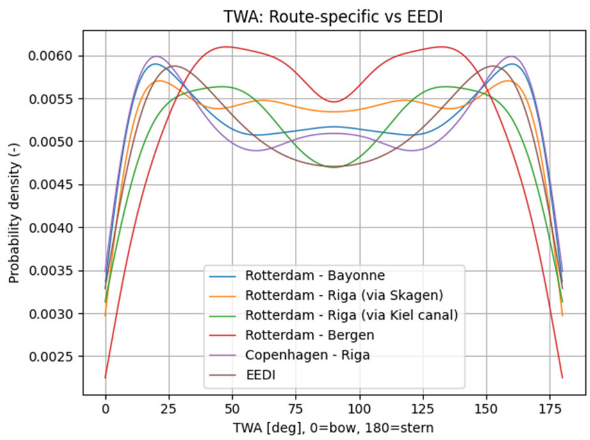


Figure H The probability of true wind angle relative to ship heading, from external weather source.

5.3 Results

5.3.1 Power saving at all wind conditions

The power prediction model is used to derive the power saving at all wind conditions, as presented in Figure I.

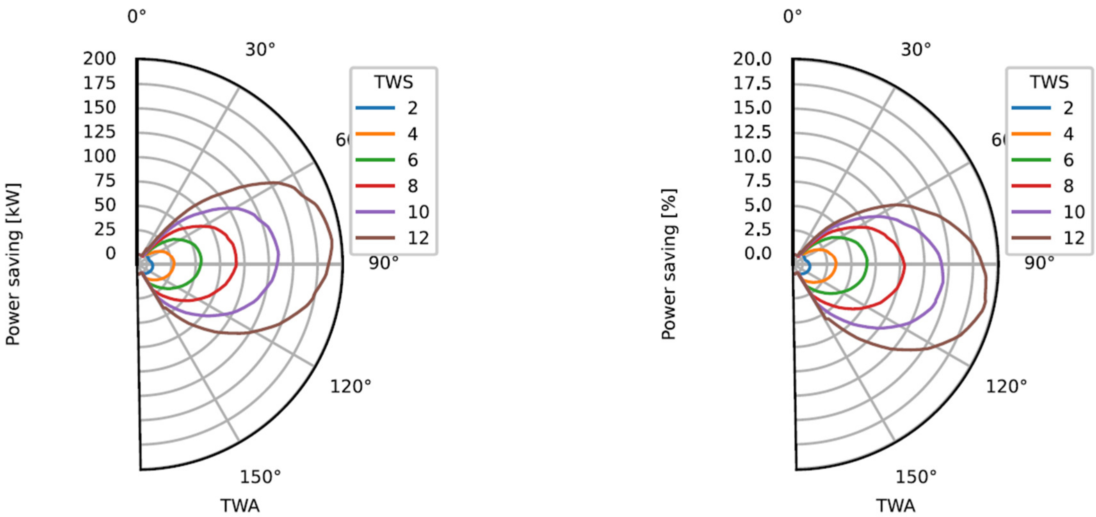


Figure I. Net power saving at various wind speeds.

5.3.2 Power saving on the route

The average power and fuel savings are given in Table 10 and Figure J. This represents the average value of letting the ship sail the route 100 000 times in randomly chosen weather conditions based on weather statistics from the full year of 2019. Some days the weather will be favourable with large power savings, some days it will be adverse. The probability distribution curves are shown in Appendix 1.

Largest power saving per mile is achieved on route Bergen-Rotterdam. On this route the prevailing wind directions are further towards the beam then for the other routes and with generally stronger winds speeds.

The route Copenhagen – Riga is east-west bound and the prevailing winds are either head or stern winds. The power savings are therefore smaller.

Table 10 Average power and fuel saving predicted for routes

	Route	power saving (%)	power saving (kW)	energy saving (MWh/trip)	fuel saving (ton/trip)	fuel saving (kg/nm)
1	Rotterdam- Bayonne	3	41.4	3.5	0.65	0.81
	Bayonne – Rotterdam	3.8	35.8	3.0	0.56	0.69
2	Rotterdam – Riga via Skagen	3.6	45.5	5.1	0.95	0.89
	Riga – Rotterdam via Skagen	3.8	38.2	4.2	0.79	0.74
3	Rotterdam – Riga via Kiel	2.9	35.6	3.2	0.60	0.70
	Riga – Rotterdam via Kiel	3	30.1	2.7	0.50	0.58
4	Rotterdam – Bergen	3.7	48.2	2.7	0.50	0.95
	Bergen – Rotterdam	4.2	42.0	2.3	0.44	0.82
5	Copenhagen – Riga	2.8	35.2	1.8	0.33	0.69
	Riga – Copenhagen	3.0	29.8	1.5	0.28	0.58
6	EEDI weather laden	2.7	35.38		0.00	0.69
	EEDI weather ballast	3.3	30.57		0.00	0.60

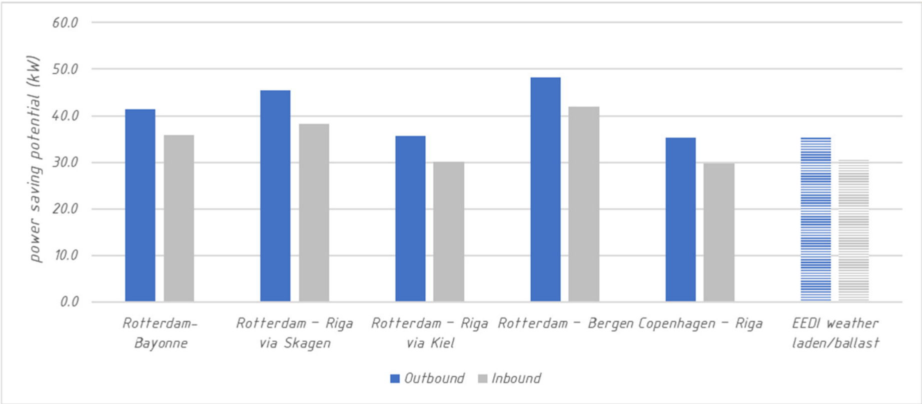


Figure J. Average power saving potential per route

5.4 Yearly average saving

Based on an assumed evenly distribution of the voyages given in Table 9, the average fuel saving is 40 kW, around 3.5%.

6 Conclusions

6.1 Result

A speed trial was performed on m/v Ankie with the purpose of verifying the power saving of the wings.

At true wind speed 10 m/s and ship's speed 9.5 knots, the wings give a net power saving for apparent wind angles larger than around 20 degrees and the saving reaches up to 15% at the most favourable wind angle.

The speed trial result is scaled up to give a prediction of the in-service fuel reduction using a ship simulation model correlated to the actual speed trial measurements, a voyage prediction tool and statistical weather distribution.

It is estimated that the power reduction on typical routes is between 3.5% corresponding to a power saving of 40 kW.

The mayor uncertainties of the trial result include the wind speed, ship speed and power measurements. The disturbance of hull to the wind measurement onboard the vessel may disturb the relation between the trial result, which is based on the on-board measurements, and the route analysis that scale up the result to yearly fuel savings, which is based on the natural undisturbed wind on the ocean.

The result should be interpreted large uncertainty margins.

7 References

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			from datalog 5 min averaged data							
Date	**Run**	**Wings**	**STW (knots)**	**SOG (knots)**	**Power (kW)**	**COG**	**AWA**	**AWS**	**ME rpm**	**ME pitch %**
2022-06-05	1	down	10.9	10.9	1026	52	44.3	8.7	187	82
2022-06-05	2	up	11.1	11.2	1029	52	43.0	9.0	187	82
2022-06-05	3	down	10.9	11.1	1029	52	44.2	9.1	187	82
2022-06-05	4	up	11.0	11.2	1027	57	48.5	6.6	187	82
2022-06-09	8	up	9.5	9.5	542	312	41.3	5.5	187	60
2022-06-09	9	dows	9.5	9.5	546	313	44.5	4.7	187	60
2022-06-18	10	up	10.1	12.1	725	233	117.5	5.6	187	69
2022-06-18	11	dows	10.0	12.1	730	234	105.0	8.0	187	69
2022-06-18	12	up	10.1	11.9	727	232	144.3	8.8	187	69
2022-07-13	13	up	9.9	9.6	527	136	142.9	4.0	187	60
2022-07-13	14	down	9.8	9.6	530	136	137.8	2.5	187	60
2023-03-24	10	down	8.3	7.4	636	71	13.9	19.7	170	70
2023-03-24	11	down	9.0	8.7	943	71	15.5	20.2	170	85
2023-03-24	12	down	10.0	9.4	1059	72	14.2	21.3	170	90
2023-03-24	13	down	9.0	8.2	739	71	15.6	21.6	170	77
2023-03-24	4	up	8.7	10.3	532	320	64.3	9.8	170	70
2023-03-24	5	down	7.8	9.6	546	319	64.2	11.0	170	70
2023-03-24	6	up	9.5	11.3	501	279	121.6	7.9	170	70
2023-03-24	7	down	9.5	10.3	517	282	97.7	7.5	170	70
2022-04-23	16	up	9.2	9.5	698	253	21.8	13.7	172	77
2022-04-23	17	down	9.2	9.5	693	253	24.3	13.4	172	77
2022-04-23	18	up	9.1	9.4	701	254	26.2	14.4	172	77
2022-04-23	19	down	9.3	9.3	757	233	25.6	15.6	187	70
2022-04-23	20	up	9.5	9.7	759	233	26.1	14.1	187	70
2022-04-23	21	down	9.3	9.5	760	233	31.0	14.2	187	70
2022-04-23	22	down	9.5	9.5	761	252	46.0	8.4	187	70
2022-04-23	23	up	9.7	9.7	755	264	52.9	9.3	187	70
2022-04-23	24	down	9.5	9.6	761	263	63.7	6.7	187	70
2022-04-23	25	down	9.3	9.3	768	222	42.5	10.8	187	70
2022-04-23	26	up	9.3	9.1	780	226	30.2	15.8	187	70

0 degrees = head wind

Wind at the height of anemomenter					
Run no.	AWS [m/s]	AWA [deg]	TWS [m/s]	TWA [deg]	GWA [deg]
1	8.66	44	6.08	84	136
3	9.07	44	6.38	82	134
6	4.46	63	5.47	133	170
6	4.46	63	5.47	133	170
9	4.73	44	3.63	114	67
11	8.02	105	10.59	133	7
11	8.02	105	10.59	133	7
14	2.53	138	7.12	166	302

Wind at the height of anemomenter - averaged over double runs					
Run no.	AWS [m/s]	AWA [deg]	TWS [m/s]	TWA [deg]	GWA [deg]

Wind at reference height					
Run no.	AWS [m/s]	AWA [deg]	TWS [m/s]	TWA [deg]	GWA [deg]
1	8.21	42	5.47	84	136
3	8.57	42	5.74	82	134
6	4.30	56	4.92	133	170
6	4.30	56	4.92	133	170
9	4.61	40	3.27	114	67
11	7.09	101	9.52	133	7
11	7.09	101	9.52	133	7
14	1.93	128	6.40	166	302

Corrections						
Run no.	Wind [kN]	Waves [kN]	Depth [knots]	Temp/Dens [kN]	Idling WPU [kN]	Current [knots]
1	1.4	0.0	0.00	0.0	0.0	-0.0
3	1.7	0.0	0.00	0.0	0.0	0.0
6	-1.5	0.0	0.00	0.0	0.0	0.0
6	-1.5	0.0	0.00	0.0	0.0	0.0
9	-0.4	0.0	0.00	0.0	0.0	0.3
11	-1.7	0.0	0.00	0.0	0.0	-0.3
11	-1.7	0.0	0.00	0.0	0.0	-0.1
14	-1.7	0.0	0.00	0.0	0.0	0.1

Corrections in percent of total resistance							
Run no.	Wind [%]	Waves [%]	Depth [%]	Temp/dens [%]	Idling WPU [%]	Displ. [%]	Eff. [%]
1	1.2	0.0	0.0	0.0	0.0	0.0	-0.3
3	1.4	0.0	0.0	0.0	0.0	0.0	-0.3
6	-1.2	0.0	0.0	0.0	0.0	0.0	0.3
6	-1.2	0.0	0.0	0.0	0.0	0.0	0.3
9	-0.5	0.0	0.0	0.0	0.0	0.0	-0.2
11	-1.8	0.0	0.0	0.0	0.0	0.0	-0.2
11	-1.8	0.0	0.0	0.0	0.0	0.0	-0.2
14	-2.3	0.0	0.0	0.0	0.0	0.0	-0.2

Corrected power		
Run no.	Pdt (ST) [kW]	
1	1002	
3	1003	
6	1022	
6	1022	
9	543	
11	738	
11	738	
14	539	

Wind at the height of anemomenter					
Run no.	AWS [m/s]	AWA [deg]	TWS [m/s]	TWA [deg]	GWA [deg]
2	8.99	43	6.20	82	134
4	6.61	49	5.12	105	162
5	1.94	45	4.65	163	200
7	3.22	58	4.93	146	184
8	5.54	41	3.73	101	53
10	5.61	118	9.25	147	21
12	8.82	144	13.38	157	30
13	4.04	143	8.68	164	300

Wind at the height of anemomenter - averaged over double runs					
Run no.	AWS [m/s]	AWA [deg]	TWS [m/s]	TWA [deg]	GWA [deg]

Wind at reference height					
Run no.	AWS [m/s]	AWA [deg]	TWS [m/s]	TWA [deg]	GWA [deg]
2	8.52	40	5.58	82	134
4	6.34	45	4.61	105	162
5	2.20	34	4.18	163	200
7	3.25	49	4.44	146	184
8	5.36	38	3.35	101	53
10	4.82	112	8.32	147	21
12	7.52	142	12.03	157	30
13	3.24	137	7.81	164	300

Corrections						
Run no.	Wind [kN]	Waves [kN]	Depth [knots]	Temp/Dens [kN]	Idling WPU [kN]	Current [knots]
2	1.7	0.0	0.00	0.0	0.0	0.0
4	-0.2	0.0	0.00	0.0	0.0	-0.0
5	-1.8	0.0	0.00	0.0	0.0	-0.0
7	-1.7	0.0	0.00	0.0	0.0	0.0
8	0.1	0.0	0.00	0.0	0.0	0.3
10	-1.8	0.0	0.00	0.0	0.0	-0.3
12	-4.4	0.0	0.00	0.0	0.0	-0.1
13	-2.0	0.0	0.00	0.0	0.0	0.1

Corrections in percent of total resistance							
Run no.	Wind [%]	Waves [%]	Depth [%]	Temp/dens [%]	Idling WPU [%]	Displ. [%]	Eff. [%]
2	1.4	0.0	0.0	0.0	0.0	0.0	-0.1
4	-0.1	0.0	0.0	0.0	0.0	0.0	-0.1
5	-1.5	0.0	0.0	0.0	0.0	0.0	0.5
7	-1.4	0.0	0.0	0.0	0.0	0.0	0.5
8	0.1	0.0	0.0	0.0	0.0	0.0	-0.3
10	-1.8	0.0	0.0	0.0	0.0	0.0	-0.3
12	-4.4	0.0	0.0	0.0	0.0	0.0	-0.2
13	-2.9	0.0	0.0	0.0	0.0	0.0	-0.2

Corrected power		
Run no.	Pdt (ST) [kW]	
2	1003	
4	1019	
5	1023	
7	1020	
8	535	
10	733	
12	758	
13	540	

Wind at the height of anemomenter					
Run no.	AWS [m/s]	AWA [deg]	TWS [m/s]	TWA [deg]	GWA [deg]
15	15.50	15	11.02	21	274
17	13.45	24	9.35	36	289
19	15.58	26	11.46	36	269
21	14.16	31	10.36	45	277
22	8.38	46	6.10	81	334
24	6.71	64	6.32	108	11
25	10.81	43	7.97	66	289
28	21.02	9	16.71	11	241

Wind at the height of anemomenter - averaged over double runs					
Run no.	AWS [m/s]	AWA [deg]	TWS [m/s]	TWA [deg]	GWA [deg]

Wind at reference height					
Run no.	AWS [m/s]	AWA [deg]	TWS [m/s]	TWA [deg]	GWA [deg]
15	14.40	14	9.91	21	274
17	12.53	23	8.41	36	289
19	14.45	25	10.30	36	269
21	13.15	30	9.32	45	277
22	7.89	43	5.49	81	334
24	6.27	60	5.68	108	11
25	10.09	41	7.17	66	289
28	19.34	9	15.03	11	241

Corrections						
Run no.	Wind [kN]	Waves [kN]	Depth [knots]	Temp/Dens [kN]	Idling WPU [kN]	Current [knots]
15	11.7	0.0	0.00	0.0	0.0	-0.0
17	7.8	0.0	0.00	0.0	0.0	0.0
19	10.7	0.0	0.00	0.0	0.0	-0.0
21	8.5	0.0	0.00	0.0	0.0	0.0
22	1.5	0.0	0.00	0.0	0.0	-0.0
24	-0.6	0.0	0.00	0.0	0.0	0.0
25	3.8	0.0	0.00	0.0	0.0	-0.4
28	23.2	0.0	0.00	0.0	0.0	0.4

Corrections in percent of total resistance							
Run no.	Wind [%]	Waves [%]	Depth [%]	Temp/dens [%]	Idling WPU [%]	Displ. [%]	Eff. [%]
15	14.5	0.0	0.0	0.0	0.0	0.0	1.7
17	8.7	0.0	0.0	0.0	0.0	0.0	1.7
19	11.6	0.0	0.0	0.0	0.0	0.0	1.7
21	8.9	0.0	0.0	0.0	0.0	0.0	1.7
22	1.5	0.0	0.0	0.0	0.0	0.0	1.6
24	-0.6	0.0	0.0	0.0	0.0	0.0	1.6
25	3.6	0.0	0.0	0.0	0.0	0.0	1.7
28	25.8	0.0	0.0	0.0	0.0	0.0	1.7

Corrected power		
Run no.	Pdt (ST) [kW]	
15	566	
17	624	
19	662	
21	683	
22	741	
24	758	
25	731	
28	615	

Wind at the height of anemomenter					
Run no.	AWS [m/s]	AWA [deg]	TWS [m/s]	TWA [deg]	GWA [deg]
16	13.72	22	9.49	32	286
18	14.37	26	10.36	38	292
20	14.14	26	10.00	39	272
23	9.33	53	7.47	85	349
23	9.33	53	7.47	85	349
26	15.79	30	11.90	42	267
27	18.37	15	14.03	19	250
27	18.37	15	14.03	19	250

Wind at the height of anemomenter - averaged over double runs					
Run no.	AWS [m/s]	AWA [deg]	TWS [m/s]	TWA [deg]	GWA [deg]

Wind at reference height					
Run no.	AWS [m/s]	AWA [deg]	TWS [m/s]	TWA [deg]	GWA [deg]
16	12.78	21	8.54	32	286
18	13.35	25	9.32	38	292
20	13.16	25	8.99	39	272
23	8.70	50	6.72	85	349
23	8.70	50	6.72	85	349
26	14.62	29	10.70	42	267
27	16.96	14	12.62	19	250
27	16.96	14	12.62	19	250

Corrections						
Run no.	Wind [kN]	Waves [kN]	Depth [knots]	Temp/Dens [kN]	Idling WPU [kN]	Current [knots]
16	8.2	0.0	0.00	0.0	0.0	0.0
18	9.0	0.0	0.00	0.0	0.0	-0.0
20	8.6	0.0	0.00	0.0	0.0	0.1
23	1.3	0.0	0.00	0.0	0.0	0.1
23	1.3	0.0	0.00	0.0	0.0	0.2
26	10.9	0.0	0.00	0.0	0.0	0.2
27	16.8	0.0	0.00	0.0	0.0	0.0
27	16.8	0.0	0.00	0.0	0.0	0.0

Corrections in percent of total resistance							
Run no.	Wind [%]	Waves [%]	Depth [%]	Temp/dens [%]	Idling WPU [%]	Displ. [%]	Eff. [%]
16	9.2	0.0	0.0	0.0	0.0	0.0	1.9
18	10.2	0.0	0.0	0.0	0.0	0.0	1.9
20	9.4	0.0	0.0	0.0	0.0	0.0	1.7
23	1.3	0.0	0.0	0.0	0.0	0.0	1.7
23	1.3	0.0	0.0	0.0	0.0	0.0	1.8
26	11.7	0.0	0.0	0.0	0.0	0.0	1.8
27	17.1	0.0	0.0	0.0	0.0	0.0	1.8
27	17.1	0.0	0.0	0.0	0.0	0.0	1.8

Corrected power		
Run no.	Pdt (ST) [kW]	
16	625	
18	622	
20	679	
23	737	
23	737	
26	681	
27	663	
27	663	

Wind at the height of anemomenter					
Run no.	AWS [m/s]	AWA [deg]	TWS [m/s]	TWA [deg]	GWA [deg]
10	19.74	14	15.75	18	88
11	20.20	16	15.80	20	91
12	21.26	14	16.27	19	91
13	21.57	16	17.35	20	90
2	7.55	88	8.90	122	49
5	11.03	64	9.97	86	44
7	7.51	98	9.45	128	50
9	7.69	86	8.65	118	47

Wind at the height of anemomenter - averaged over double runs					
Run no.	AWS [m/s]	AWA [deg]	TWS [m/s]	TWA [deg]	GWA [deg]

Wind at reference height					
Run no.	AWS [m/s]	AWA [deg]	TWS [m/s]	TWA [deg]	GWA [deg]
10	18.16	14	14.17	18	88
11	18.62	15	14.21	20	91
12	19.63	14	14.63	19	91
13	19.83	15	15.61	20	90
2	6.83	84	8.00	122	49
5	10.11	62	8.96	86	44
7	6.71	94	8.50	128	50
9	6.96	83	7.78	118	47

Corrections						
Run no.	Wind [kN]	Waves [kN]	Depth [knots]	Temp/Dens [kN]	Idling WPU [kN]	Current [knots]
10	19.8	0.0	0.00	0.0	0.0	-0.5
11	20.2	0.0	0.00	0.0	0.0	0.5
12	22.6	0.0	0.00	0.0	0.0	0.8
13	23.2	0.0	0.00	0.0	0.0	-0.8
2	-1.5	0.0	0.00	0.0	0.0	-0.9
5	0.9	0.0	0.00	0.0	0.0	0.9
7	-1.5	0.0	0.00	0.0	0.0	-0.3
9	-1.3	0.0	0.00	0.0	0.0	0.3

Corrections in percent of total resistance							
Run no.	Wind [%]	Waves [%]	Depth [%]	Temp/dens [%]	Idling WPU [%]	Displ. [%]	Eff. [%]
10	27.0	0.0	0.0	0.0	0.0	0.0	2.2
11	16.9	0.0	0.0	0.0	0.0	0.0	2.2
12	19.0	0.0	0.0	0.0	0.0	0.0	2.2
13	31.3	0.0	0.0	0.0	0.0	0.0	2.2
2	-2.0	0.0	0.0	0.0	0.0	0.0	2.2
5	1.1	0.0	0.0	0.0	0.0	0.0	2.2
7	-1.9	0.0	0.0	0.0	0.0	0.0	2.2
9	-1.7	0.0	0.0	0.0	0.0	0.0	2.2

Corrected power		
Run no.	Pdt (ST) [kW]	
10	479	
11	782	
12	860	
13	535	
2	532	
5	534	
7	523	
9	524	

Wind at the height of anemomenter					
Run no.	AWS [m/s]	AWA [deg]	TWS [m/s]	TWA [deg]	GWA [deg]
1	5.68	76	6.80	126	50
3	9.72	95	11.30	121	48
4	9.84	64	8.87	91	51
6	7.86	122	11.20	143	62
8	7.69	86	8.83	120	46
8	7.69	86	8.83	120	46

Wind at reference height					
Run no.	AWS [m/s]	AWA [deg]	TWS [m/s]	TWA [deg]	GWA [deg]
1	5.26	71	6.12	126	50
3	8.71	91	10.16	121	48
4	9.05	62	7.97	91	51
6	6.82	118	10.07	143	62
8	6.97	82	7.94	120	46
8	6.97	82	7.94	120	46

Corrections						
Run no.	Wind [kN]	Waves [kN]	Depth [knots]	Temp/Dens [kN]	Idling WPU [kN]	Current [knots]
1	-1.6	0.0	0.00	0.0	0.0	0.3
3	-1.6	0.0	0.00	0.0	0.0	-0.3
4	0.3	0.0	0.00	0.0	0.0	0.4
6	-1.8	0.0	0.00	0.0	0.0	0.4
8	-1.5	0.0	0.00	0.0	0.0	0.0
8	-1.5	0.0	0.00	0.0	0.0	0.0

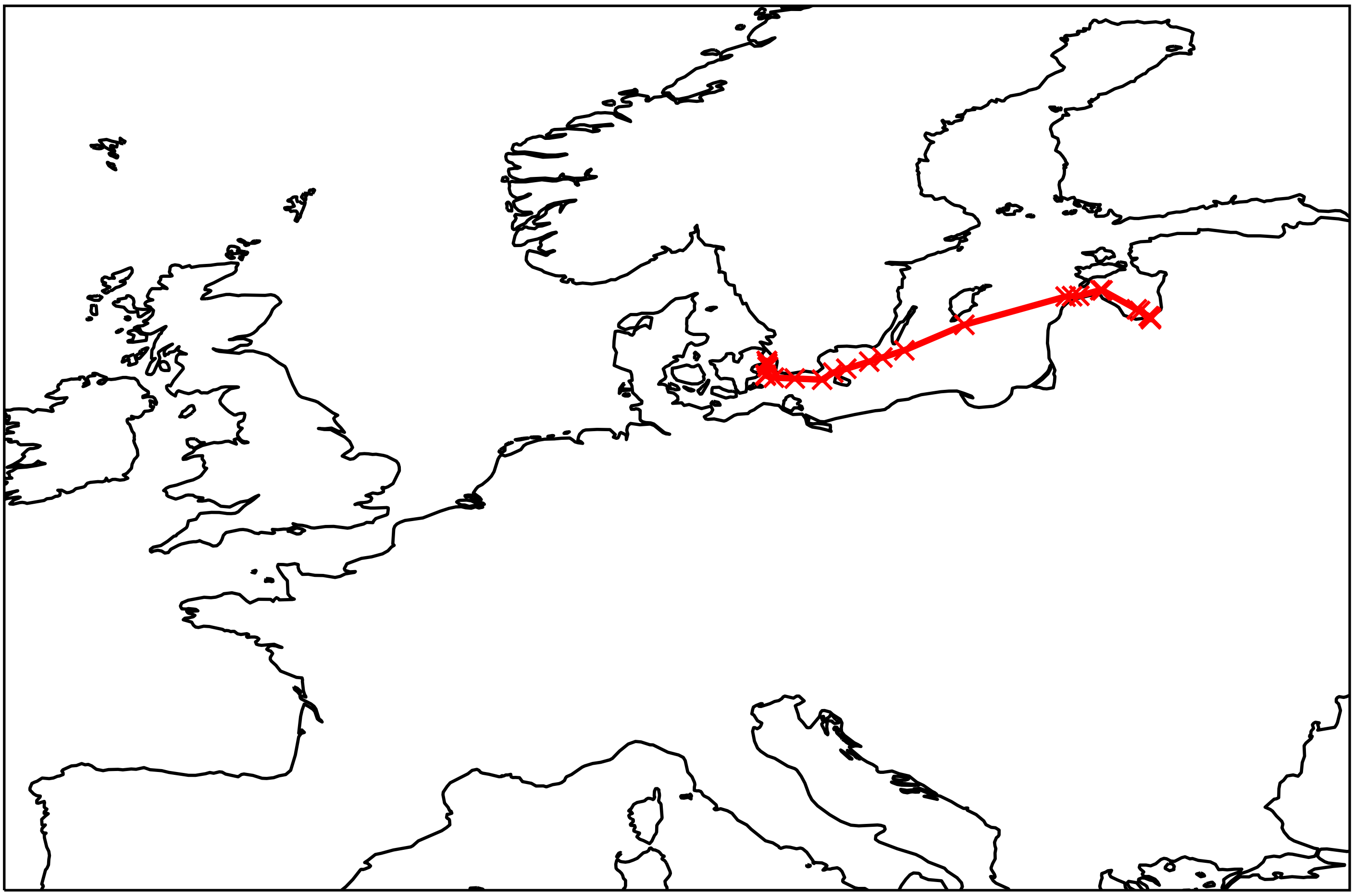
Corrections in percent of total resistance							
Run no.	Wind [%]	Waves [%]	Depth [%]	Temp/dens [%]	Idling WPU [%]	Displ. [%]	Eff. [%]
1	-2.3	0.0	0.0	0.0	0.0	0.0	-0.3
3	-2.3	0.0	0.0	0.0	0.0	0.0	-0.3
4	0.4	0.0	0.0	0.0	0.0	0.0	-0.2
6	-2.5	0.0	0.0	0.0	0.0	0.0	-0.2
8	-2.1	0.0	0.0	0.0	0.0	0.0	-0.3
8	-2.1	0.0	0.0	0.0	0.0	0.0	-0.3

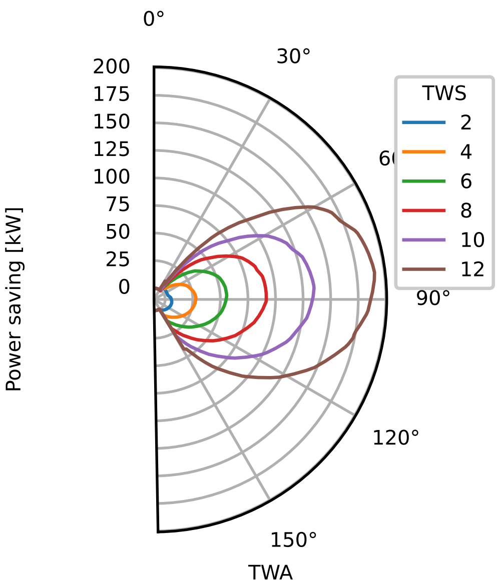
Corrected power		
Run no.	Pdt (ST) [kW]	
1	523	
3	524	
4	524	
6	510	
8	513	
8	513	

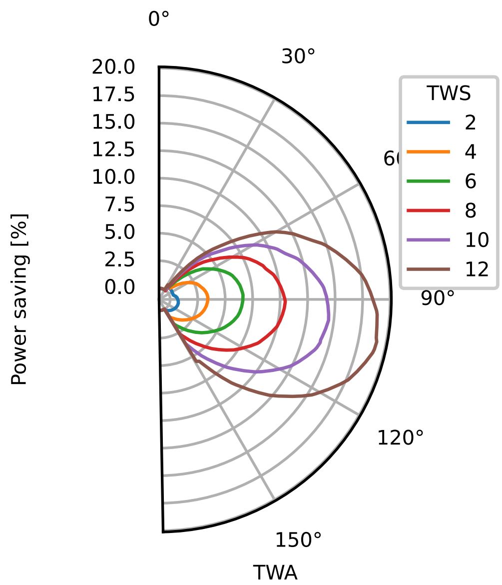
Route analysis report: WPS evaluation

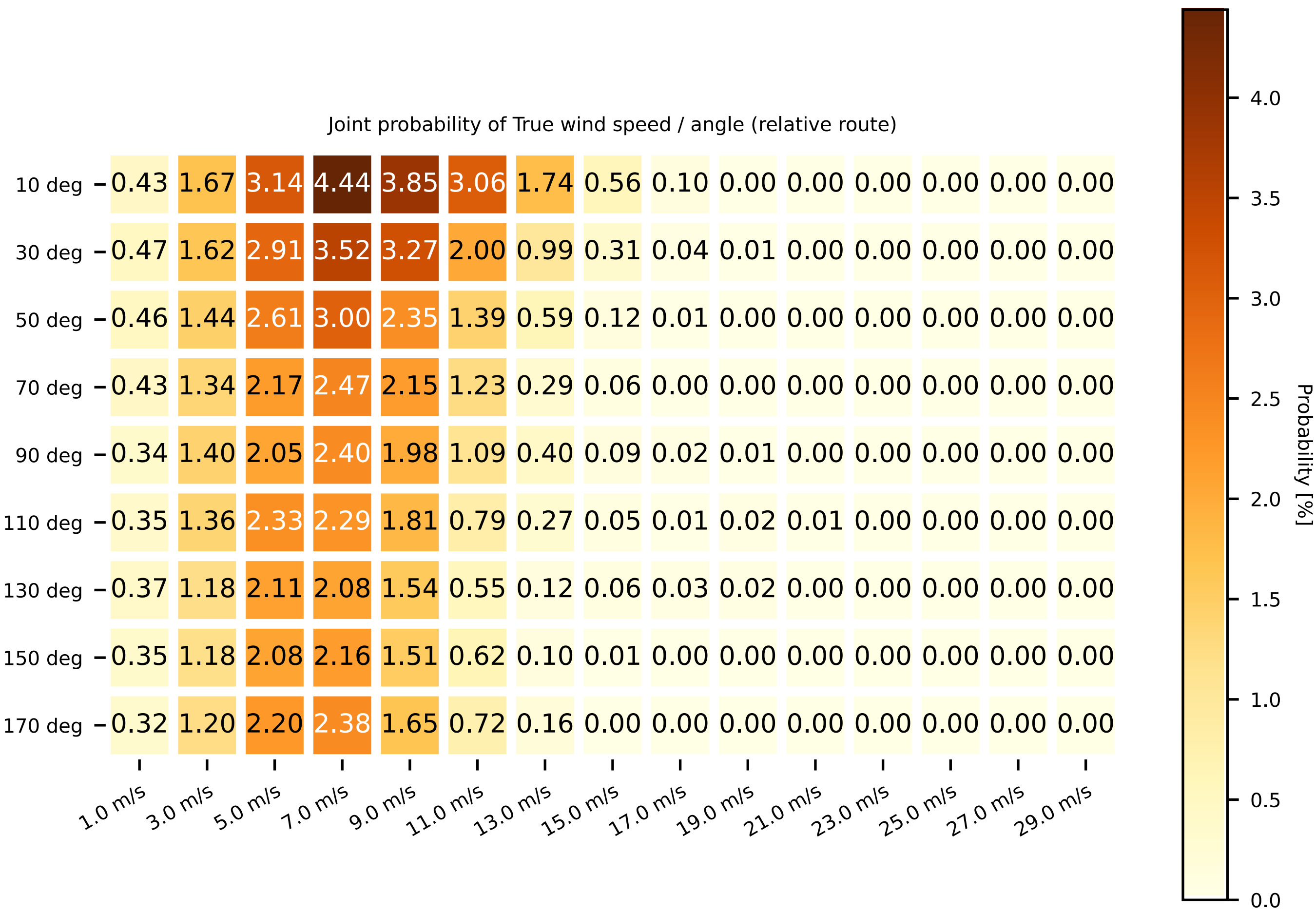
Results for a route analysis for ship: Ankie (ballast) on route: Copenhagen – Riga (inbound) with total distance: 477.3 nm

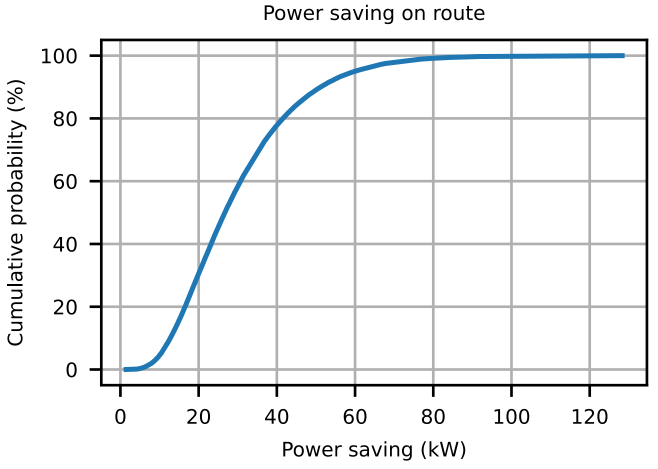
	Average	Min (2.5%)	Max (97.5%)
Power saving (kW)	29.81	8.47	67.79
Energy saving on route (MWh)	1.48	0.41	3.37
Energy saving on route (%)	3.0	0.8	6.9

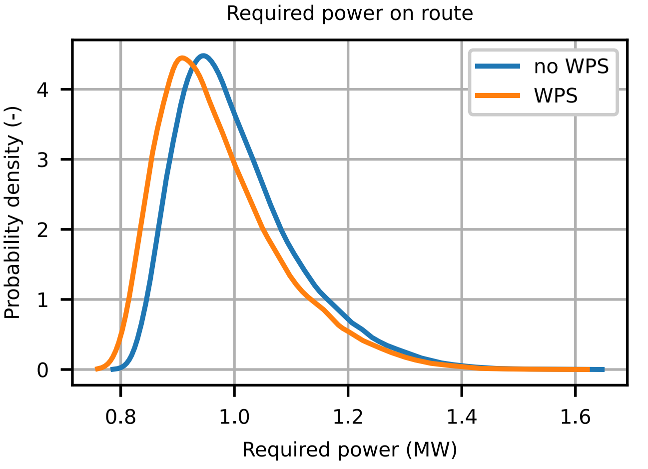



0°
30°
60°
90°
120°
150°
200
175
150
125
100
75
50
25
0
Power saving [kW]
TWA
TWS
2
4
6
8
10
12


0°
30°
60°
90°
120°
150°
20.0
17.5
15.0
12.5
10.0
7.5
5.0
2.5
0.0
Power saving [%]
TWA
TWS
2
4
6
8
10
12


Joint probability of True wind speed / angle (relative route)
10 deg 0.43 1.67 3.14 4.44 3.85 3.06 1.74 0.56 0.10 0.00 0.00 0.00 0.00 0.00 0.00
30 deg 0.47 1.62 2.91 3.52 3.27 2.00 0.99 0.31 0.04 0.01 0.00 0.00 0.00 0.00 0.00
50 deg 0.46 1.44 2.61 3.00 2.35 1.39 0.59 0.12 0.01 0.00 0.00 0.00 0.00 0.00 0.00
70 deg 0.43 1.34 2.17 2.47 2.15 1.23 0.29 0.06 0.00 0.00 0.00 0.00 0.00 0.00 0.00
90 deg 0.34 1.40 2.05 2.40 1.98 1.09 0.40 0.09 0.02 0.01 0.00 0.00 0.00 0.00 0.00
110 deg 0.35 1.36 2.33 2.29 1.81 0.79 0.27 0.05 0.01 0.02 0.01 0.00 0.00 0.00 0.00
130 deg 0.37 1.18 2.11 2.08 1.54 0.55 0.12 0.06 0.03 0.02 0.00 0.00 0.00 0.00 0.00
150 deg 0.35 1.18 2.08 2.16 1.51 0.62 0.10 0.01 0.00 0.00 0.00 0.00 0.00 0.00 0.00
170 deg 0.32 1.20 2.20 2.38 1.65 0.72 0.16 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
1.0 m/s
3.0 m/s
5.0 m/s
7.0 m/s
9.0 m/s
11.0 m/s
13.0 m/s
15.0 m/s
17.0 m/s
19.0 m/s
21.0 m/s
23.0 m/s
25.0 m/s
27.0 m/s
29.0 m/s
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Probability [%]

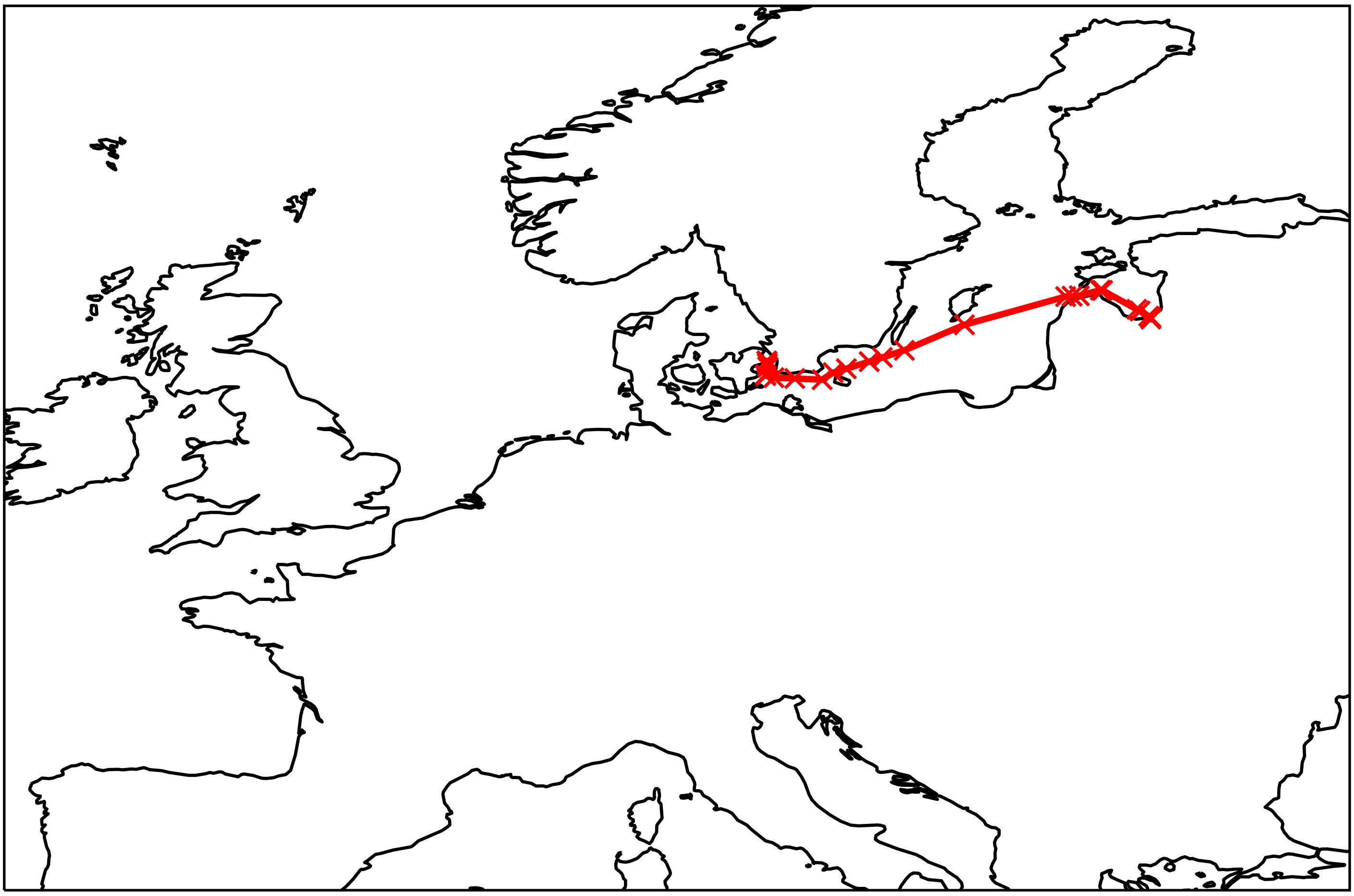

Power saving on route
Cumulative probability (%)
0
20
40
60
80
100
0
20
40
60
80
100
120
Power saving (kW)

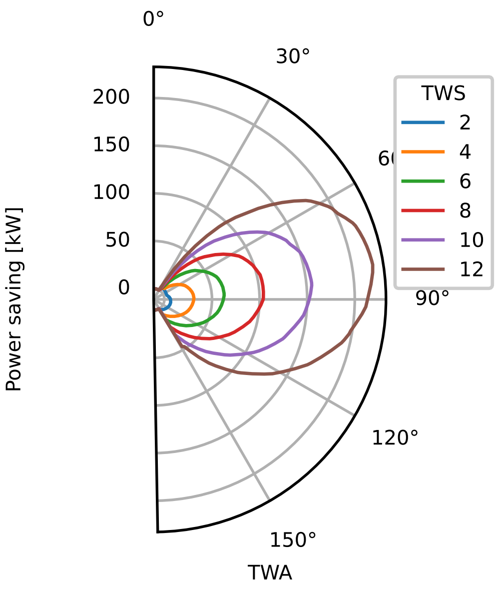

Required power on route
Probability density (-)
0
1
2
3
4
0.8
1.0
1.2
1.4
1.6
Required power (MW)
no WPS
WPS

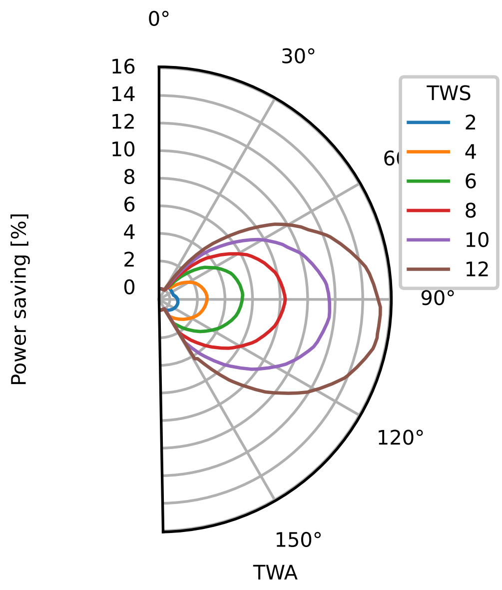
Route analysis report: WPS evaluation

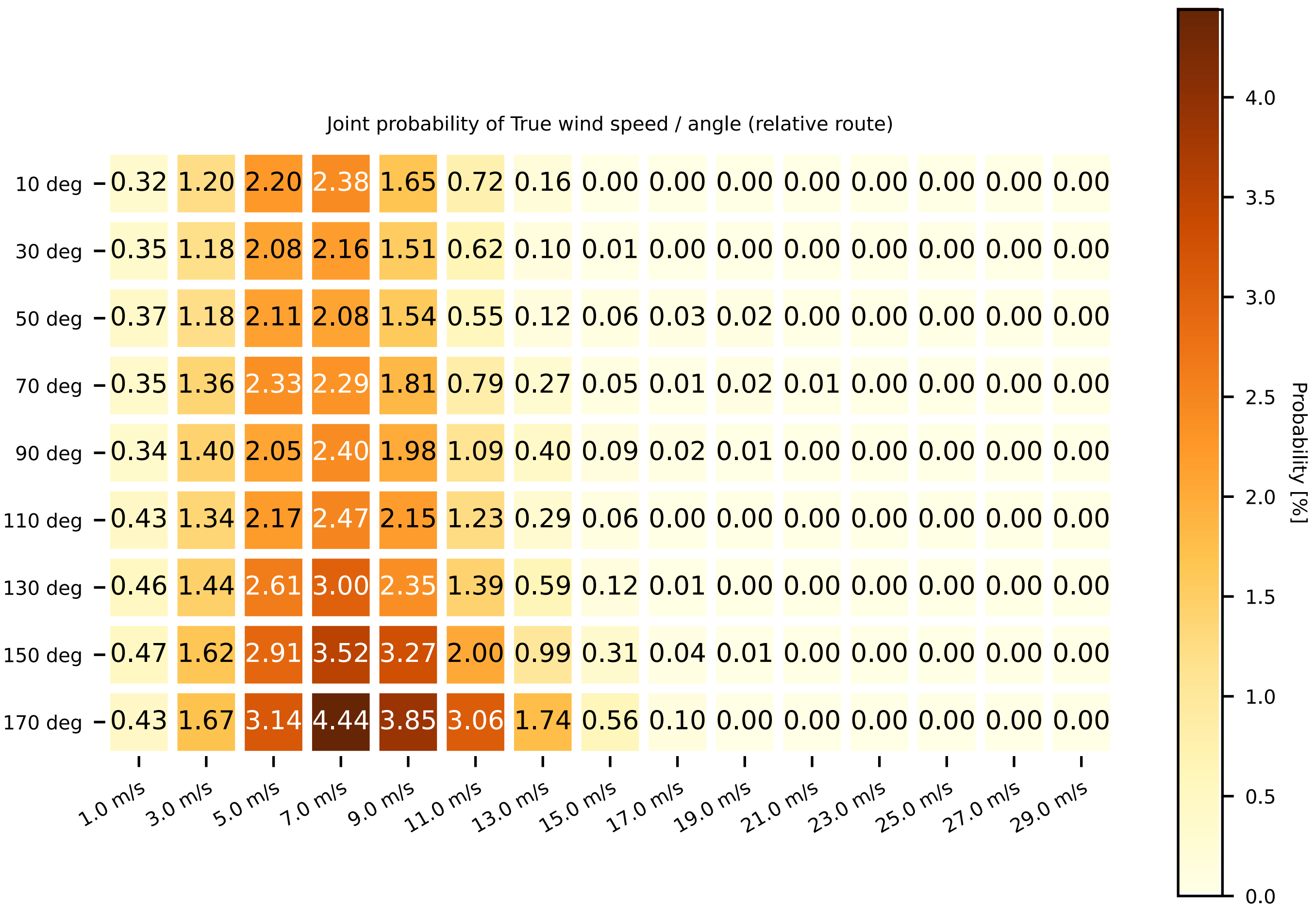
Results for a route analysis for ship: Ankie (laden) on route: Copenhagen – Riga (outbound) with total distance: 477.3 nm

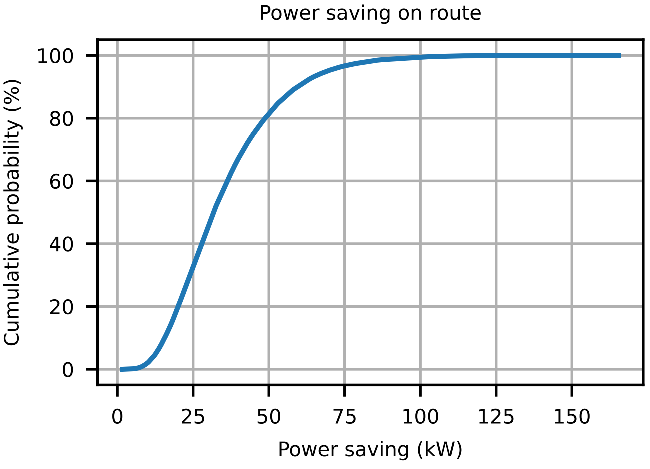
	Average	Min (2.5%)	Max (97.5%)
Power saving (kW)	35.21	10.52	79.14
Energy saving on route (MWh)	1.76	0.53	3.96
Energy saving on route (%)	2.8	0.9	6.1

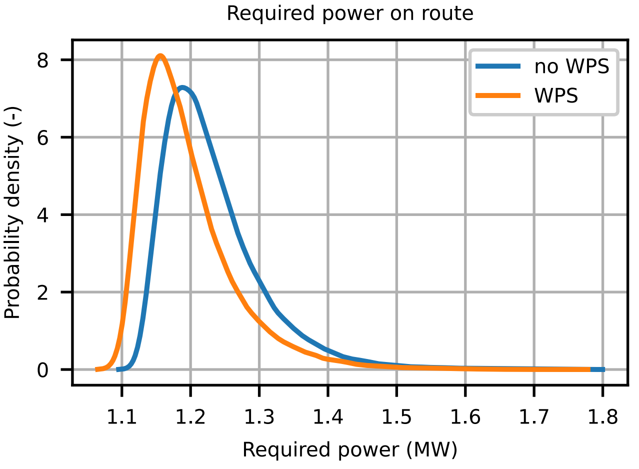



0°
30°
60°
90°
120°
150°
200
150
100
50
0
Power saving [kW]
TWA
TWS
2
4
6
8
10
12


0°
30°
60°
90°
120°
150°
16
14
12
10
8
6
4
2
0
Power saving [%]
TWA
TWS
2
4
6
8
10
12


Joint probability of True wind speed / angle (relative route)
10 deg 0.32 1.20 2.20 2.38 1.65 0.72 0.16 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
30 deg 0.35 1.18 2.08 2.16 1.51 0.62 0.10 0.01 0.00 0.00 0.00 0.00 0.00 0.00 0.00
50 deg 0.37 1.18 2.11 2.08 1.54 0.55 0.12 0.06 0.03 0.02 0.00 0.00 0.00 0.00 0.00
70 deg 0.35 1.36 2.33 2.29 1.81 0.79 0.27 0.05 0.01 0.02 0.01 0.00 0.00 0.00 0.00
90 deg 0.34 1.40 2.05 2.40 1.98 1.09 0.40 0.09 0.02 0.01 0.00 0.00 0.00 0.00 0.00
110 deg 0.43 1.34 2.17 2.47 2.15 1.23 0.29 0.06 0.00 0.00 0.00 0.00 0.00 0.00 0.00
130 deg 0.46 1.44 2.61 3.00 2.35 1.39 0.59 0.12 0.01 0.00 0.00 0.00 0.00 0.00 0.00
150 deg 0.47 1.62 2.91 3.52 3.27 2.00 0.99 0.31 0.04 0.01 0.00 0.00 0.00 0.00 0.00
170 deg 0.43 1.67 3.14 4.44 3.85 3.06 1.74 0.56 0.10 0.00 0.00 0.00 0.00 0.00 0.00
1.0 m/s 3.0 m/s 5.0 m/s 7.0 m/s 9.0 m/s 11.0 m/s 13.0 m/s 15.0 m/s 17.0 m/s 19.0 m/s 21.0 m/s 23.0 m/s 25.0 m/s 27.0 m/s 29.0 m/s
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Probability [%]

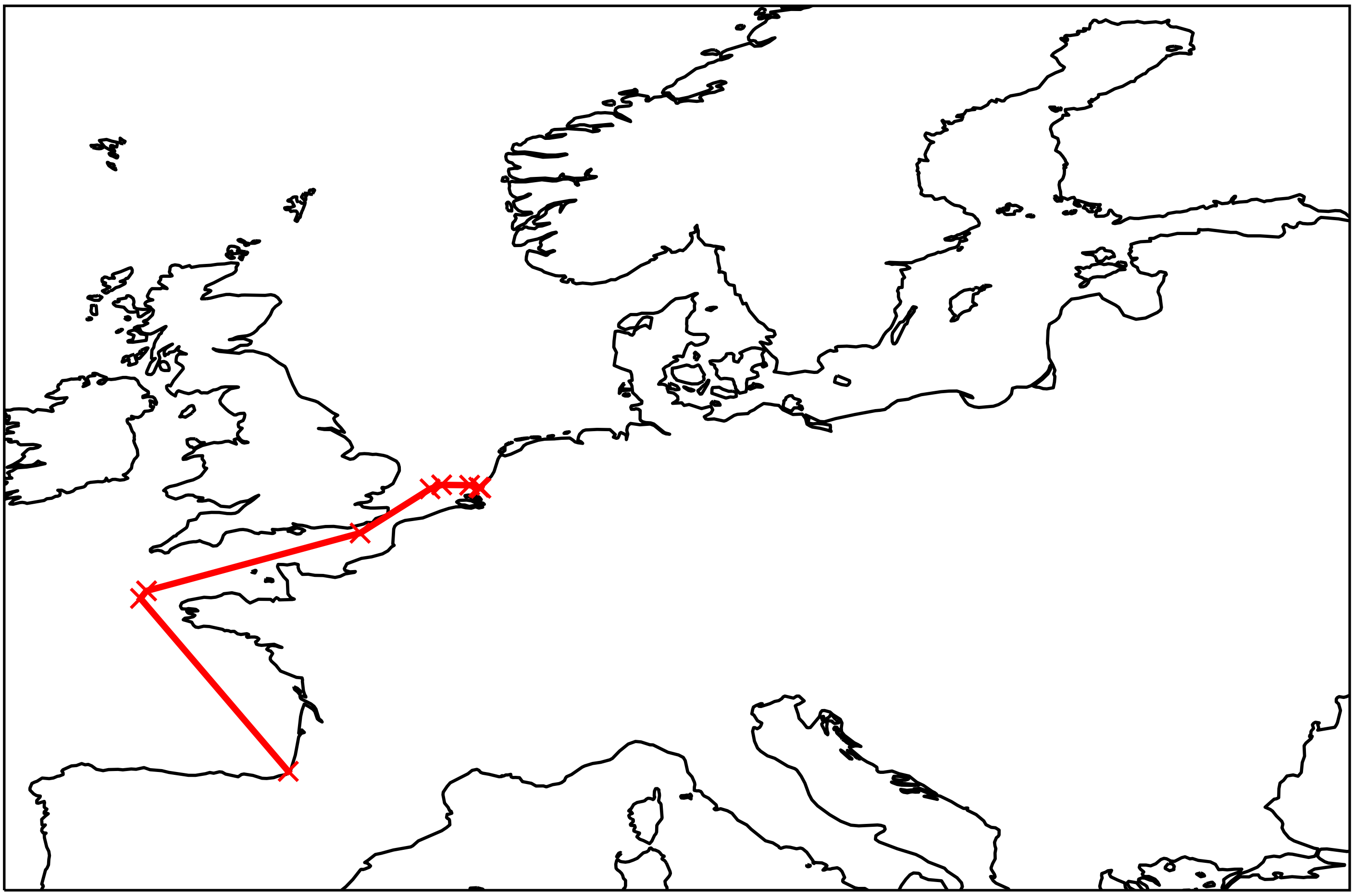

Power saving on route
Cumulative probability (%)
100
80
60
40
20
0
0
25
50
75
100
125
150
Power saving (kW)

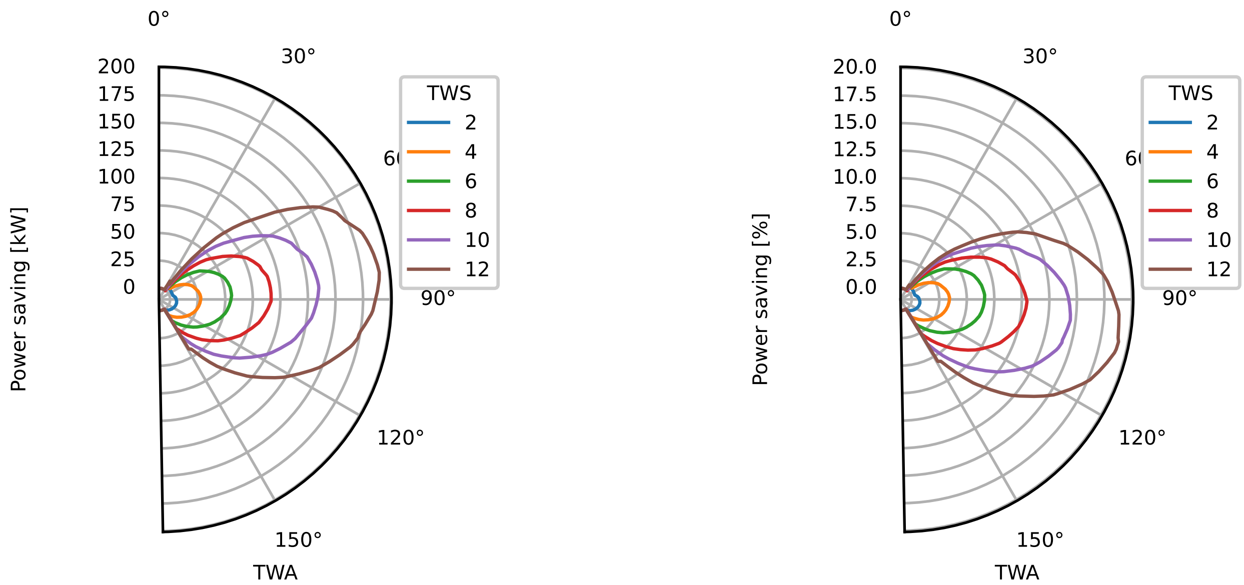

Required power on route
Probability density (-)
8
6
4
2
0
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
Required power (MW)
no WPS
WPS

Route analysis report: WPS evaluation

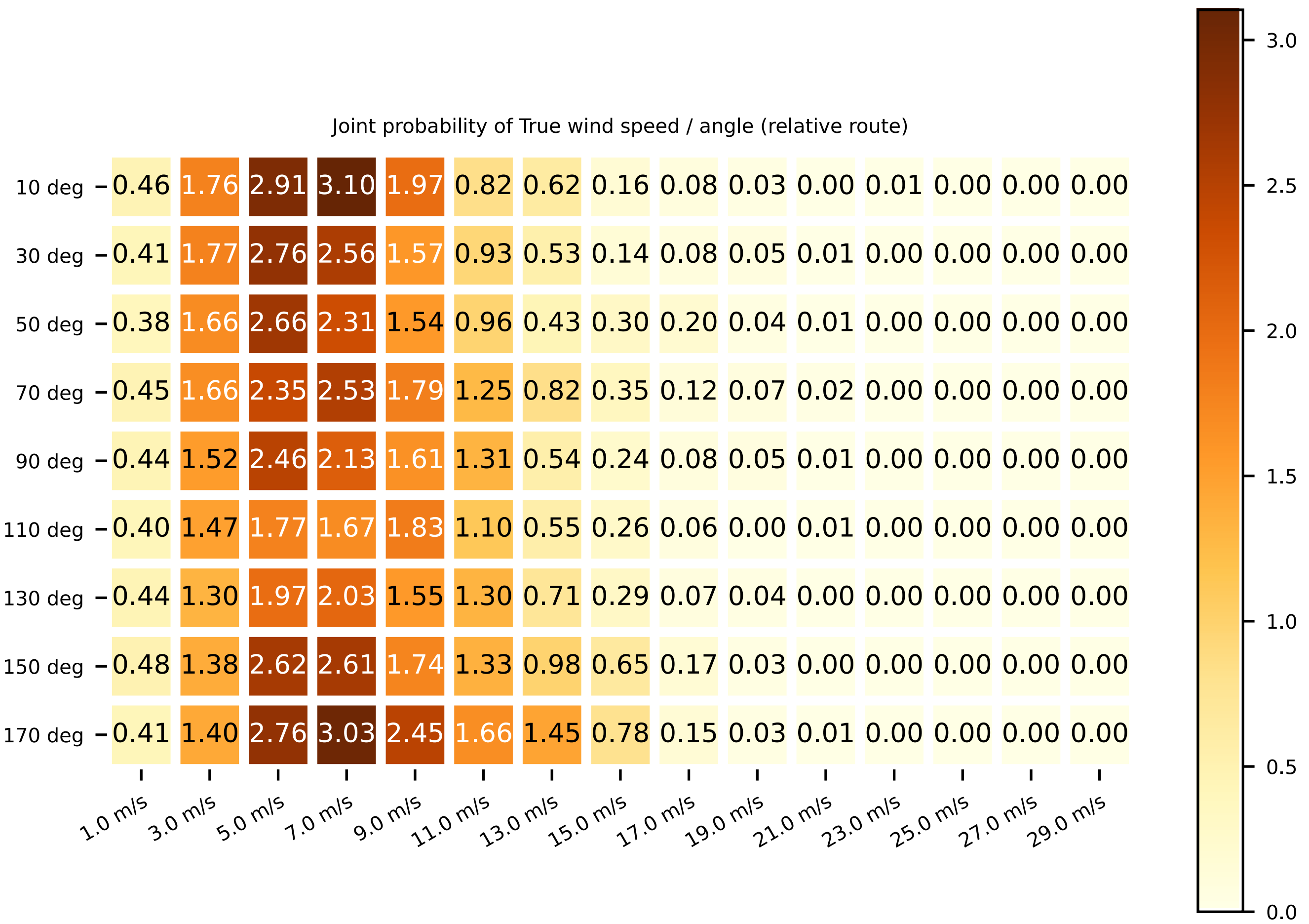
Results for a route analysis for ship: Ankie (ballast) on route: Rotterdam - Bayonne (inbound) with total distance: 811.8 nm

	Average	Min (2.5%)	Max (97.5%)
Power saving (kW)	35.77	1.70	120.39
Energy saving on route (MWh)	3.02	0.14	10.17
Energy saving on route (%)	3.8	0.2	11.9

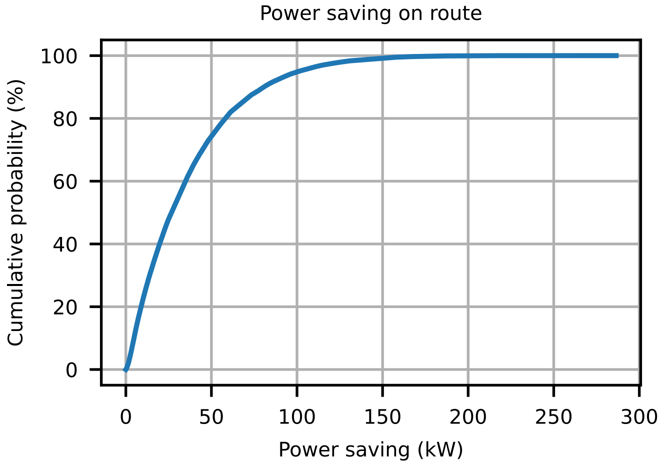


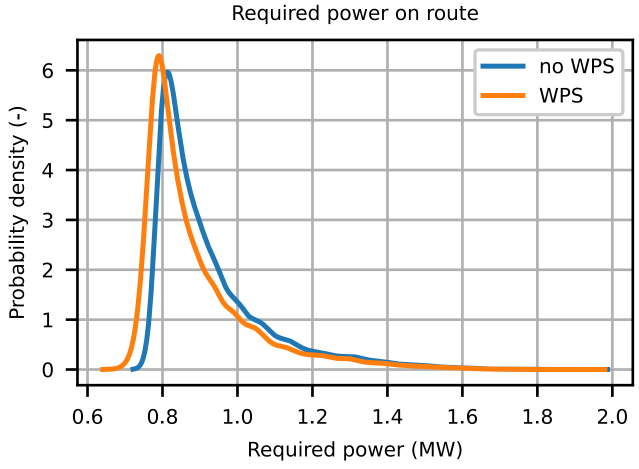


0°
30°
60°
90°
120°
150°
200
175
150
125
100
75
50
25
0
Power saving [kW]
TWA
TWS
2
4
6
8
10
12
20.0
17.5
15.0
12.5
10.0
7.5
5.0
2.5
0.0
Power saving [%]



Joint probability of True wind speed / angle (relative route)
10 deg 0.46 1.76 2.91 3.10 1.97 0.82 0.62 0.16 0.08 0.03 0.00 0.01 0.00 0.00 0.00
30 deg 0.41 1.77 2.76 2.56 1.57 0.93 0.53 0.14 0.08 0.05 0.01 0.00 0.00 0.00 0.00
50 deg 0.38 1.66 2.66 2.31 1.54 0.96 0.43 0.30 0.20 0.04 0.01 0.00 0.00 0.00 0.00
70 deg 0.45 1.66 2.35 2.53 1.79 1.25 0.82 0.35 0.12 0.07 0.02 0.00 0.00 0.00 0.00
90 deg 0.44 1.52 2.46 2.13 1.61 1.31 0.54 0.24 0.08 0.05 0.01 0.00 0.00 0.00 0.00
110 deg 0.40 1.47 1.77 1.67 1.83 1.10 0.55 0.26 0.06 0.00 0.01 0.00 0.00 0.00 0.00
130 deg 0.44 1.30 1.97 2.03 1.55 1.30 0.71 0.29 0.07 0.04 0.00 0.00 0.00 0.00 0.00
150 deg 0.48 1.38 2.62 2.61 1.74 1.33 0.98 0.65 0.17 0.03 0.00 0.00 0.00 0.00 0.00
170 deg 0.41 1.40 2.76 3.03 2.45 1.66 1.45 0.78 0.15 0.03 0.01 0.00 0.00 0.00 0.00
1.0 m/s 3.0 m/s 5.0 m/s 7.0 m/s 9.0 m/s 11.0 m/s 13.0 m/s 15.0 m/s 17.0 m/s 19.0 m/s 21.0 m/s 23.0 m/s 25.0 m/s 27.0 m/s 29.0 m/s
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Probability [%]

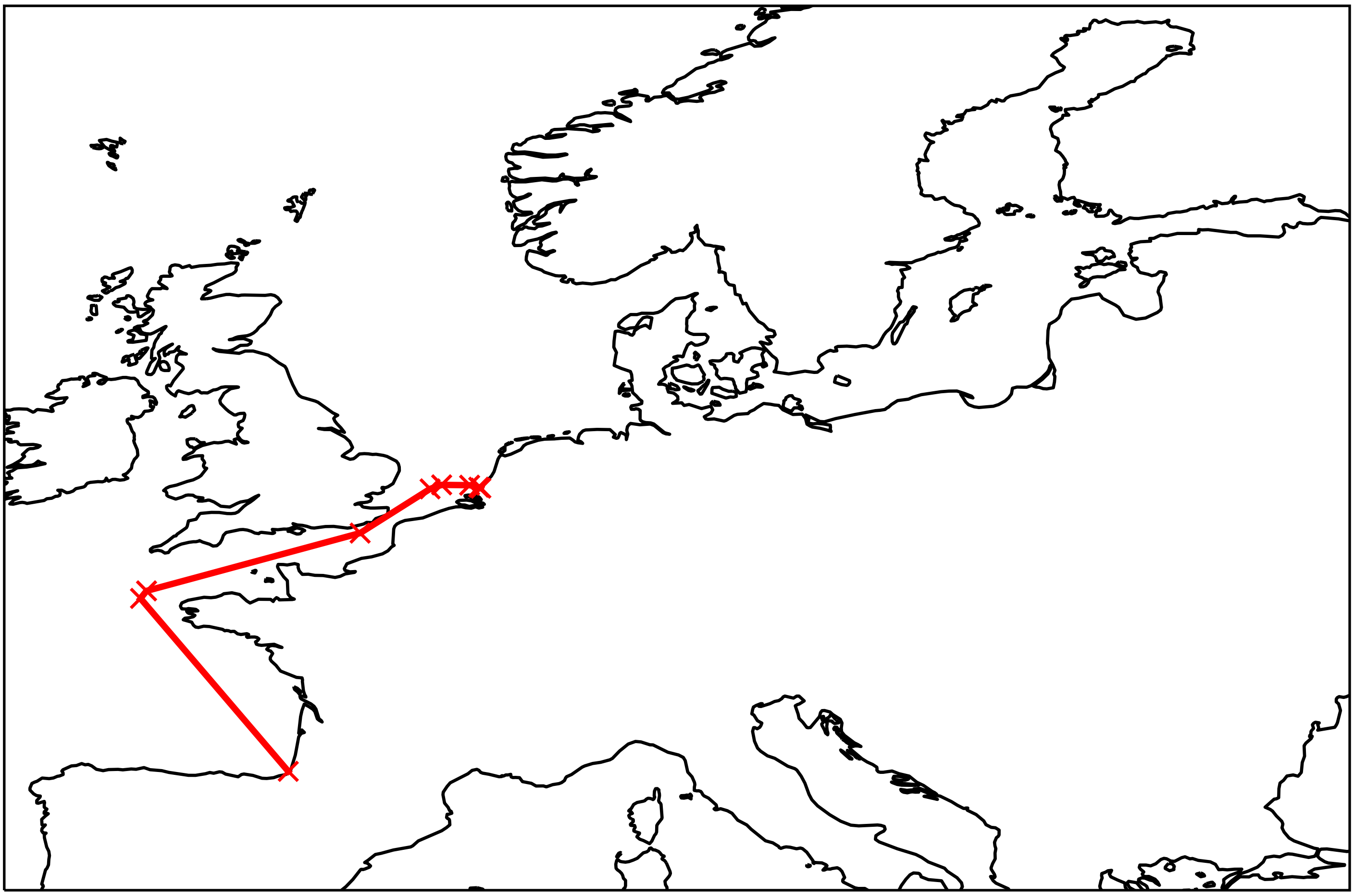

Power saving on route
Cumulative probability (%)
Power saving (kW)
0
20
40
60
80
100
0
50
100
150
200
250
300

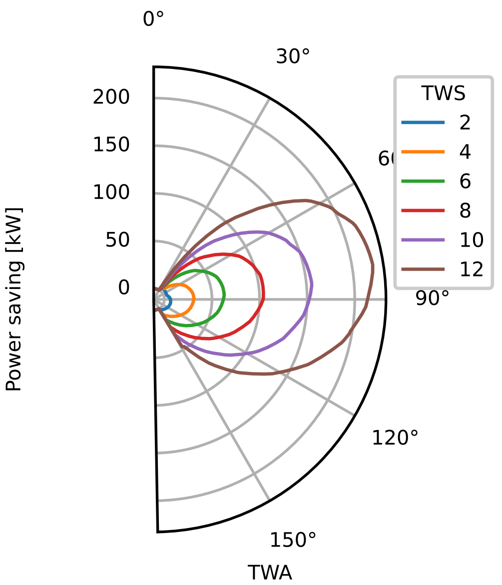

Required power on route
Probability density (-)
Required power (MW)
no WPS
WPS
0
1
2
3
4
5
6
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0

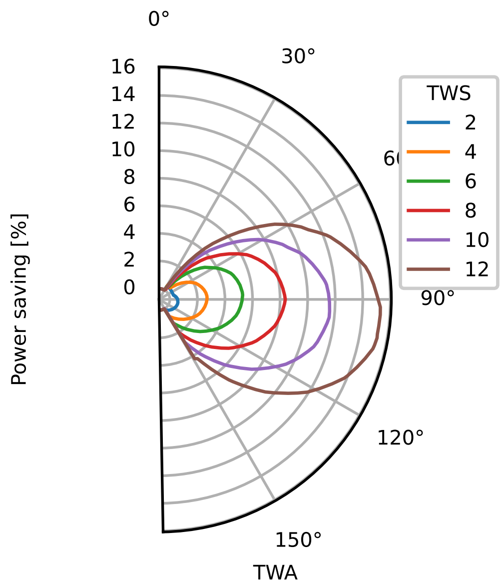
Route analysis report: WPS evaluation

Results for a route analysis for ship: Ankie (laden) on route: Rotterdam - Bayonne (outbound) with total distance: 811.8 nm

	Average	Min (2.5%)	Max (97.5%)
Power saving (kW)	41.39	2.01	133.93
Energy saving on route (MWh)	3.52	0.17	11.41
Energy saving on route (%)	3.0	0.1	9.5



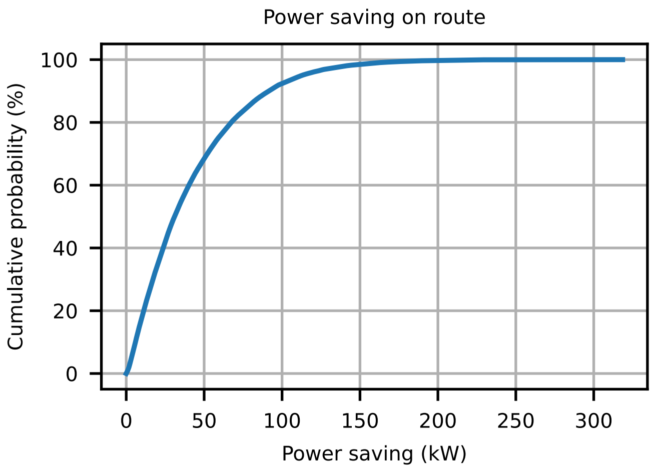


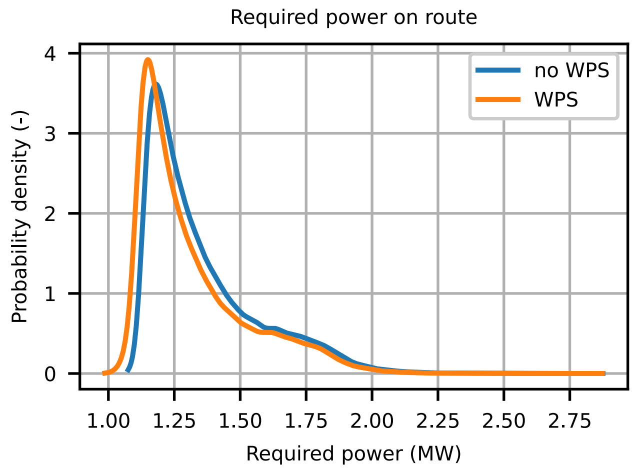


Joint probability of True wind speed / angle (relative route)

	1.0 m/s	3.0 m/s	5.0 m/s	7.0 m/s	9.0 m/s	11.0 m/s	13.0 m/s	15.0 m/s	17.0 m/s	19.0 m/s	21.0 m/s	23.0 m/s	25.0 m/s	27.0 m/s	29.0 m/s
10 deg	0.41	1.40	2.76	3.03	2.45	1.66	1.45	0.78	0.15	0.03	0.01	0.00	0.00	0.00	0.00
30 deg	0.48	1.38	2.62	2.61	1.74	1.33	0.98	0.65	0.17	0.03	0.00	0.00	0.00	0.00	0.00
50 deg	0.44	1.30	1.97	2.03	1.55	1.30	0.71	0.29	0.07	0.04	0.00	0.00	0.00	0.00	0.00
70 deg	0.40	1.47	1.77	1.67	1.83	1.10	0.55	0.26	0.06	0.00	0.01	0.00	0.00	0.00	0.00
90 deg	0.44	1.52	2.46	2.13	1.61	1.31	0.54	0.24	0.08	0.05	0.01	0.00	0.00	0.00	0.00
110 deg	0.45	1.66	2.35	2.53	1.79	1.25	0.82	0.35	0.12	0.07	0.02	0.00	0.00	0.00	0.00
130 deg	0.38	1.66	2.66	2.31	1.54	0.96	0.43	0.30	0.20	0.04	0.01	0.00	0.00	0.00	0.00
150 deg	0.41	1.77	2.76	2.56	1.57	0.93	0.53	0.14	0.08	0.05	0.01	0.00	0.00	0.00	0.00
170 deg	0.46	1.76	2.91	3.10	1.97	0.82	0.62	0.16	0.08	0.03	0.00	0.01	0.00	0.00	0.00

Probability [%]: 0.0 – 3.0

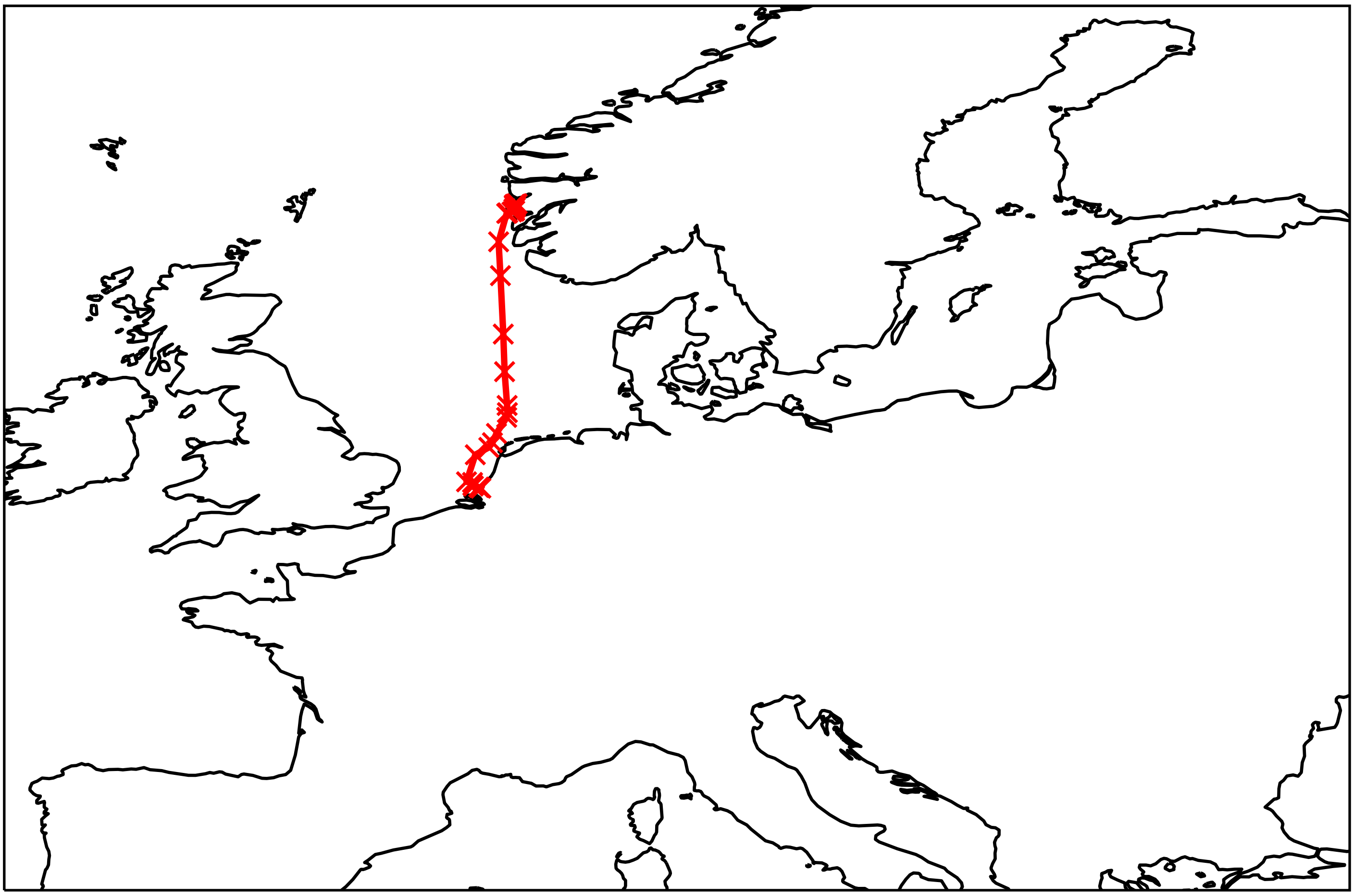

Power saving on route
Cumulative probability (%)
100
80
60
40
20
0
0
50
100
150
200
250
300
Power saving (kW)

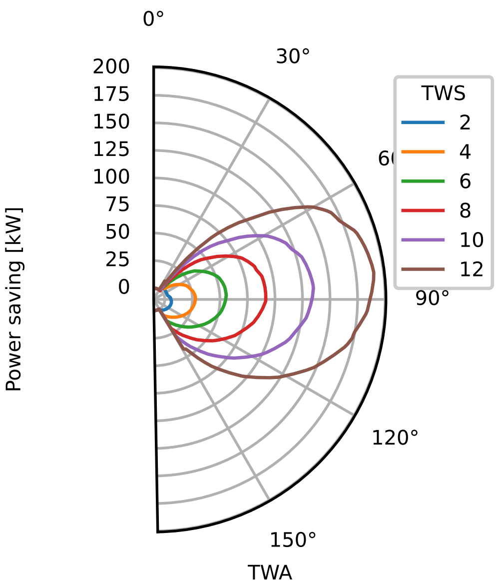

Required power on route
Probability density (-)
4
3
2
1
0
1.00
1.25
1.50
1.75
2.00
2.25
2.50
2.75
Required power (MW)
no WPS
WPS

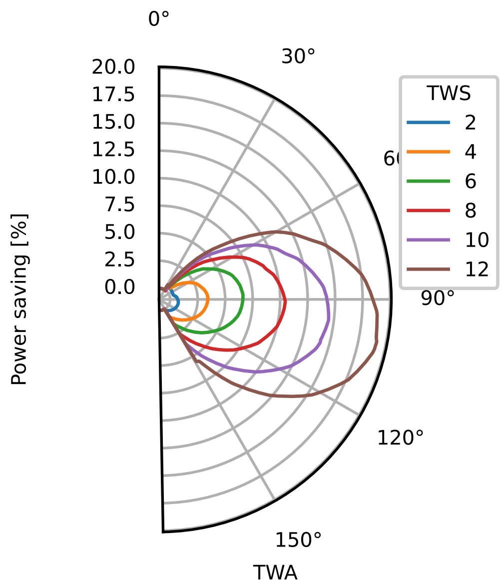
Route analysis report: WPS evaluation

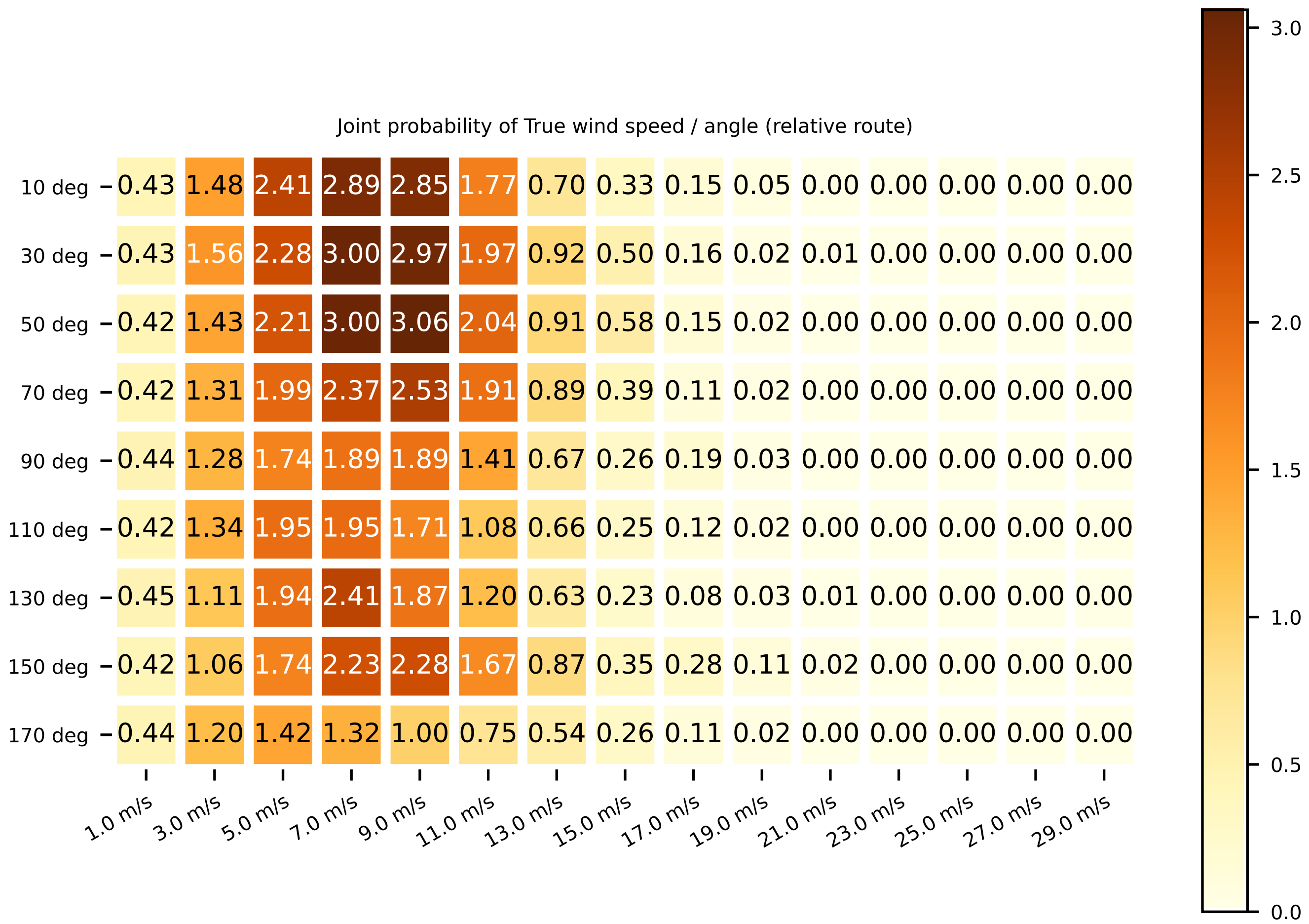
Results for a route analysis for ship: Ankie (ballast) on route: Rotterdam – Bergen (inbound) with total distance: 536.7 nm

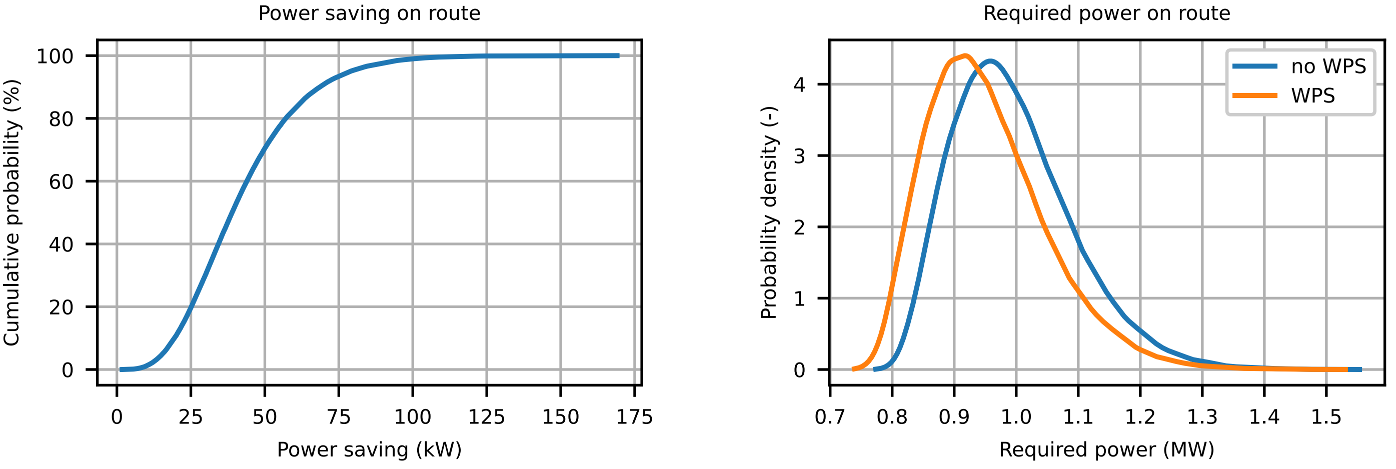
	Average	Min (2.5%)	Max (97.5%)
Power saving (kW)	41.95	12.49	88.69
Energy saving on route (MWh)	2.34	0.68	4.95
Energy saving on route (%)	4.2	1.2	8.7




0°
30°
60°
90°
120°
150°
200
175
150
125
100
75
50
25
0
Power saving [kW]
TWA
TWS
2
4
6
8
10
12


0°
30°
60°
90°
120°
150°
20.0
17.5
15.0
12.5
10.0
7.5
5.0
2.5
0.0
Power saving [%]
TWA
TWS
2
4
6
8
10
12

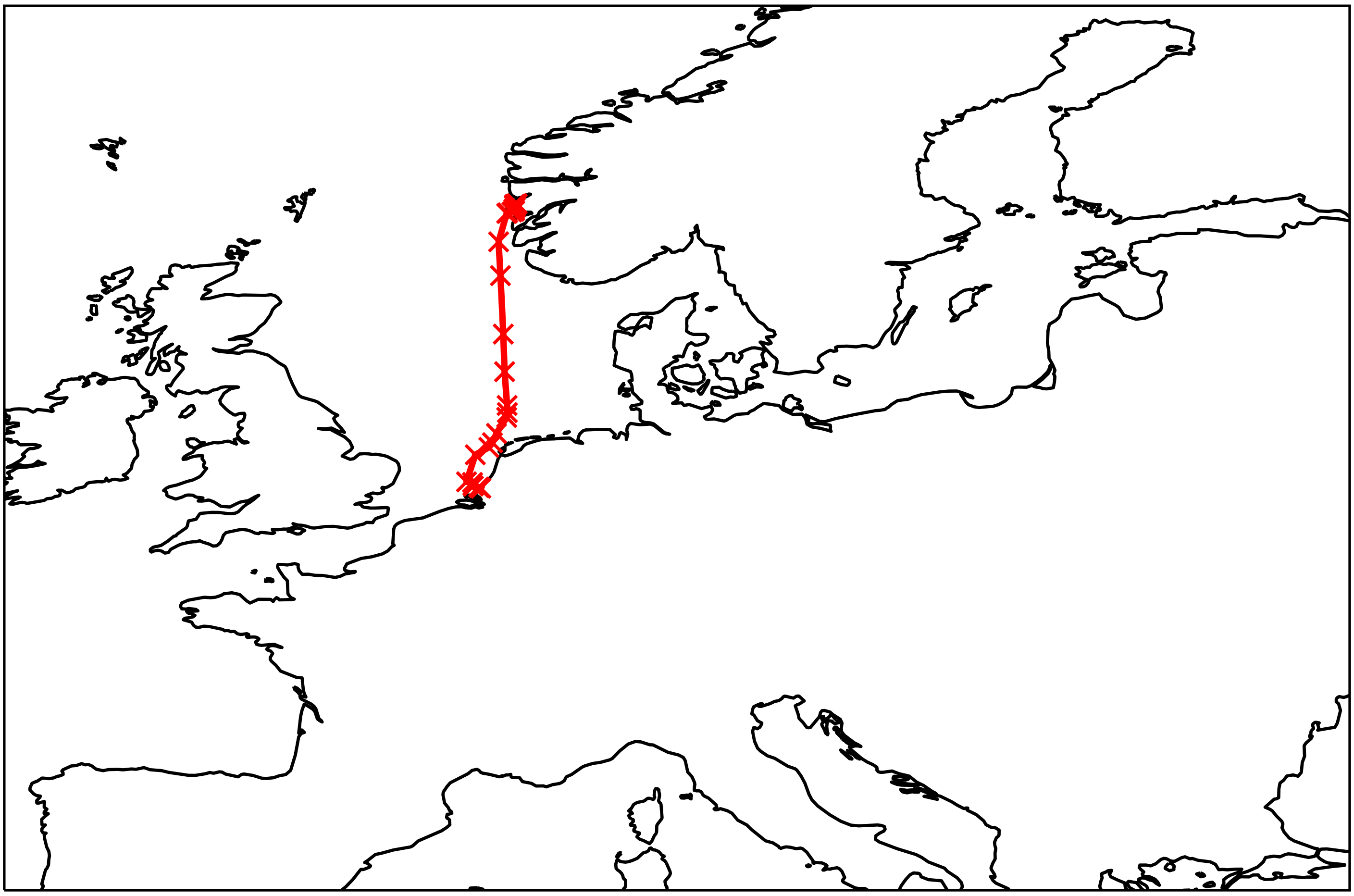

Joint probability of True wind speed / angle (relative route)
10 deg 0.43 1.48 2.41 2.89 2.85 1.77 0.70 0.33 0.15 0.05 0.00 0.00 0.00 0.00 0.00
30 deg 0.43 1.56 2.28 3.00 2.97 1.97 0.92 0.50 0.16 0.02 0.01 0.00 0.00 0.00 0.00
50 deg 0.42 1.43 2.21 3.00 3.06 2.04 0.91 0.58 0.15 0.02 0.00 0.00 0.00 0.00 0.00
70 deg 0.42 1.31 1.99 2.37 2.53 1.91 0.89 0.39 0.11 0.02 0.00 0.00 0.00 0.00 0.00
90 deg 0.44 1.28 1.74 1.89 1.89 1.41 0.67 0.26 0.19 0.03 0.00 0.00 0.00 0.00 0.00
110 deg 0.42 1.34 1.95 1.95 1.71 1.08 0.66 0.25 0.12 0.02 0.00 0.00 0.00 0.00 0.00
130 deg 0.45 1.11 1.94 2.41 1.87 1.20 0.63 0.23 0.08 0.03 0.01 0.00 0.00 0.00 0.00
150 deg 0.42 1.06 1.74 2.23 2.28 1.67 0.87 0.35 0.28 0.11 0.02 0.00 0.00 0.00 0.00
170 deg 0.44 1.20 1.42 1.32 1.00 0.75 0.54 0.26 0.11 0.02 0.00 0.00 0.00 0.00 0.00
1.0 m/s
3.0 m/s
5.0 m/s
7.0 m/s
9.0 m/s
11.0 m/s
13.0 m/s
15.0 m/s
17.0 m/s
19.0 m/s
21.0 m/s
23.0 m/s
25.0 m/s
27.0 m/s
29.0 m/s
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Probability [%]

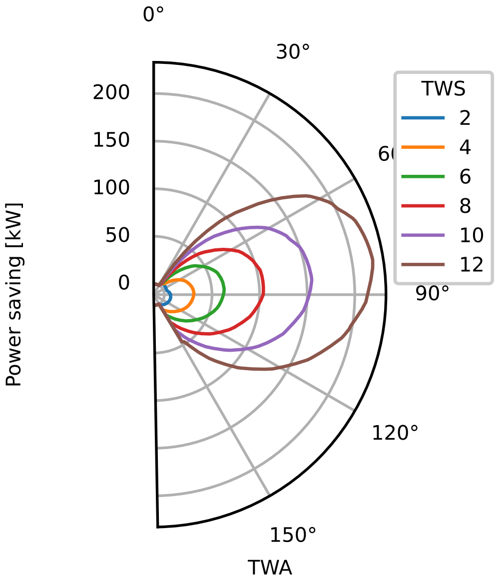

Power saving on route
Cumulative probability (%)
100
80
60
40
20
0
0
25
50
75
100
125
150
175
Power saving (kW)
Required power on route
Probability density (-)
4
3
2
1
0
0.7
0.8
0.9
1.0
1.1
1.2
1.3
1.4
1.5
Required power (MW)
no WPS
WPS

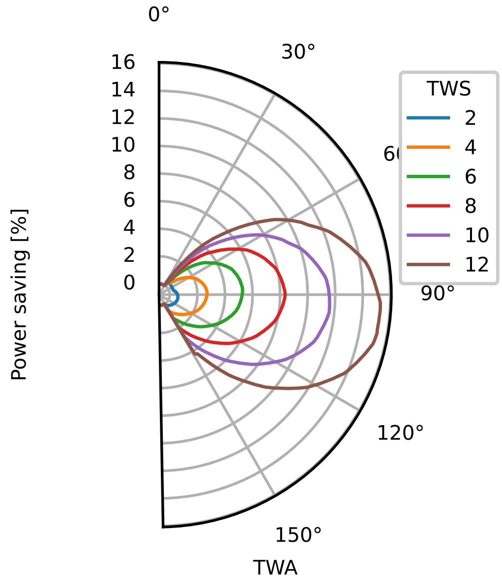
Route analysis report: WPS evaluation

Results for a route analysis for ship: Ankie (laden) on route: Rotterdam – Bergen (outbound) with total distance: 536.7 nm

	Average	Min (2.5%)	Max (97.5%)
Power saving (kW)	48.15	14.92	101.64
Energy saving on route (MWh)	2.71	0.84	5.72
Energy saving on route (%)	3.7	1.1	7.6



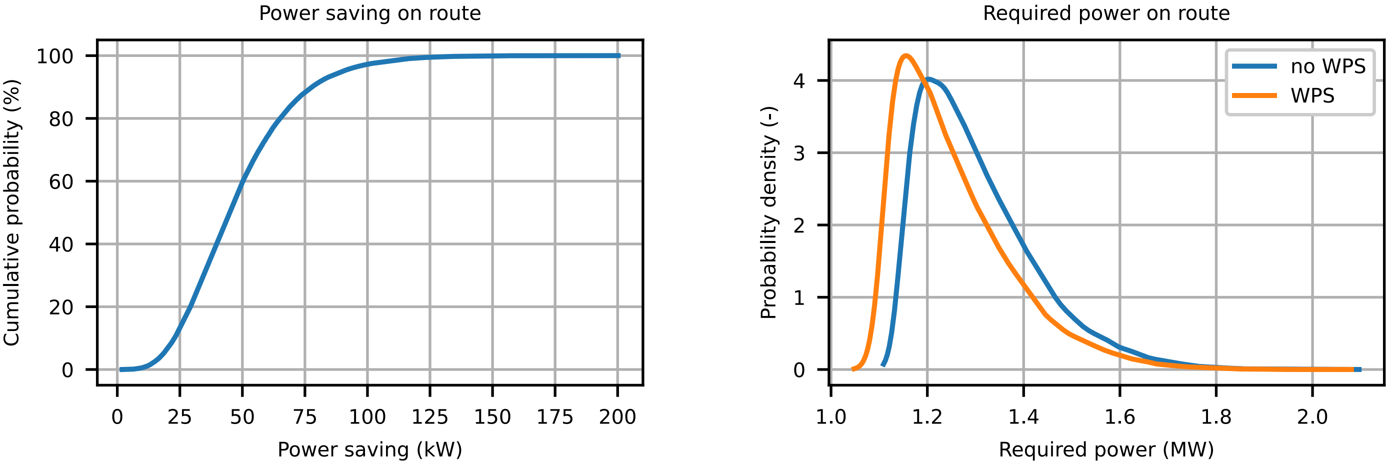




Joint probability of True wind speed / angle (relative route)

	1.0 m/s	3.0 m/s	5.0 m/s	7.0 m/s	9.0 m/s	11.0 m/s	13.0 m/s	15.0 m/s	17.0 m/s	19.0 m/s	21.0 m/s	23.0 m/s	25.0 m/s	27.0 m/s	29.0 m/s
10 deg	0.44	1.20	1.42	1.32	1.00	0.75	0.54	0.26	0.11	0.02	0.00	0.00	0.00	0.00	0.00
30 deg	0.42	1.06	1.74	2.23	2.28	1.67	0.87	0.35	0.28	0.11	0.02	0.00	0.00	0.00	0.00
50 deg	0.45	1.11	1.94	2.41	1.87	1.20	0.63	0.23	0.08	0.03	0.01	0.00	0.00	0.00	0.00
70 deg	0.42	1.34	1.95	1.95	1.71	1.08	0.66	0.25	0.12	0.02	0.00	0.00	0.00	0.00	0.00
90 deg	0.44	1.28	1.74	1.89	1.89	1.41	0.67	0.26	0.19	0.03	0.00	0.00	0.00	0.00	0.00
110 deg	0.42	1.31	1.99	2.37	2.53	1.91	0.89	0.39	0.11	0.02	0.00	0.00	0.00	0.00	0.00
130 deg	0.42	1.43	2.21	3.00	3.06	2.04	0.91	0.58	0.15	0.02	0.00	0.00	0.00	0.00	0.00
150 deg	0.43	1.56	2.28	3.00	2.97	1.97	0.92	0.50	0.16	0.02	0.01	0.00	0.00	0.00	0.00
170 deg	0.43	1.48	2.41	2.89	2.85	1.77	0.70	0.33	0.15	0.05	0.00	0.00	0.00	0.00	0.00

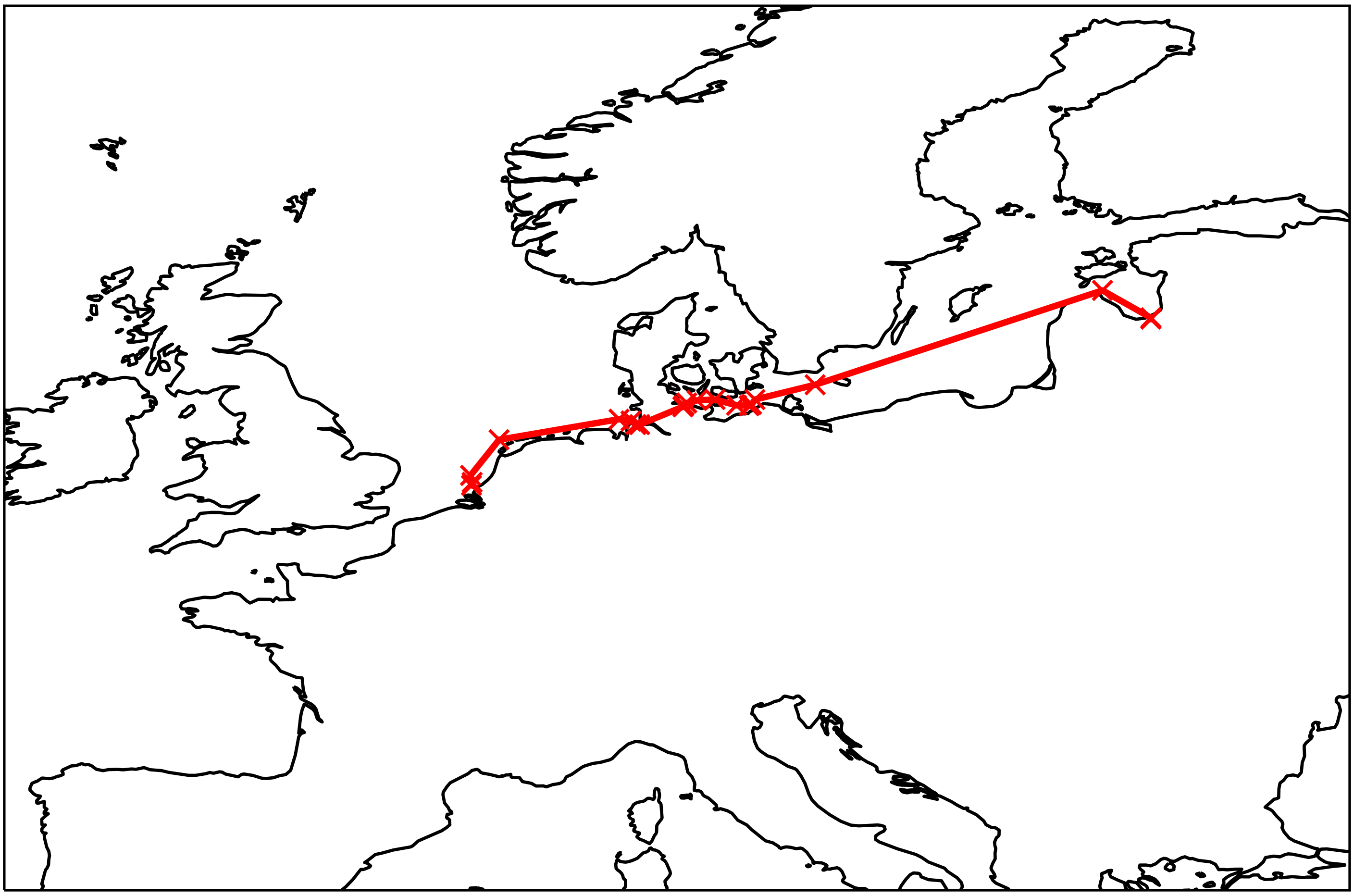
Probability [%]: 0.0 – 0.5 – 1.0 – 1.5 – 2.0 – 2.5 – 3.0

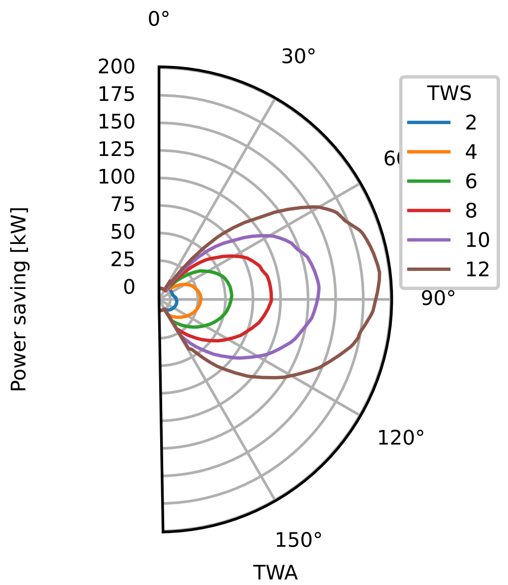

Power saving on route
Cumulative probability (%)
0
20
40
60
80
100
0
25
50
75
100
125
150
175
200
Power saving (kW)
Required power on route
Probability density (-)
0
1
2
3
4
1.0
1.2
1.4
1.6
1.8
2.0
Required power (MW)
no WPS
WPS

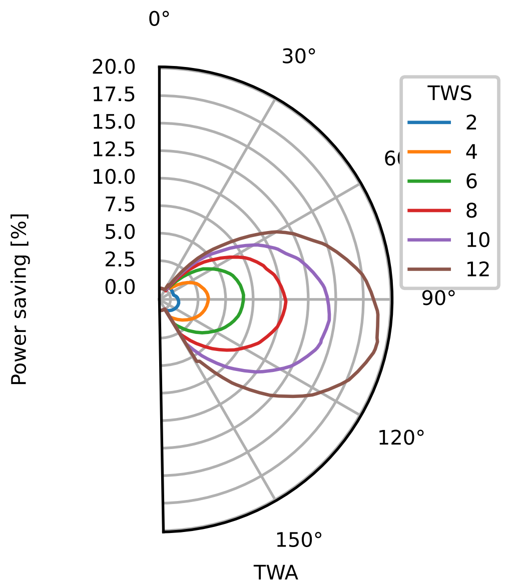
Route analysis report: WPS evaluation

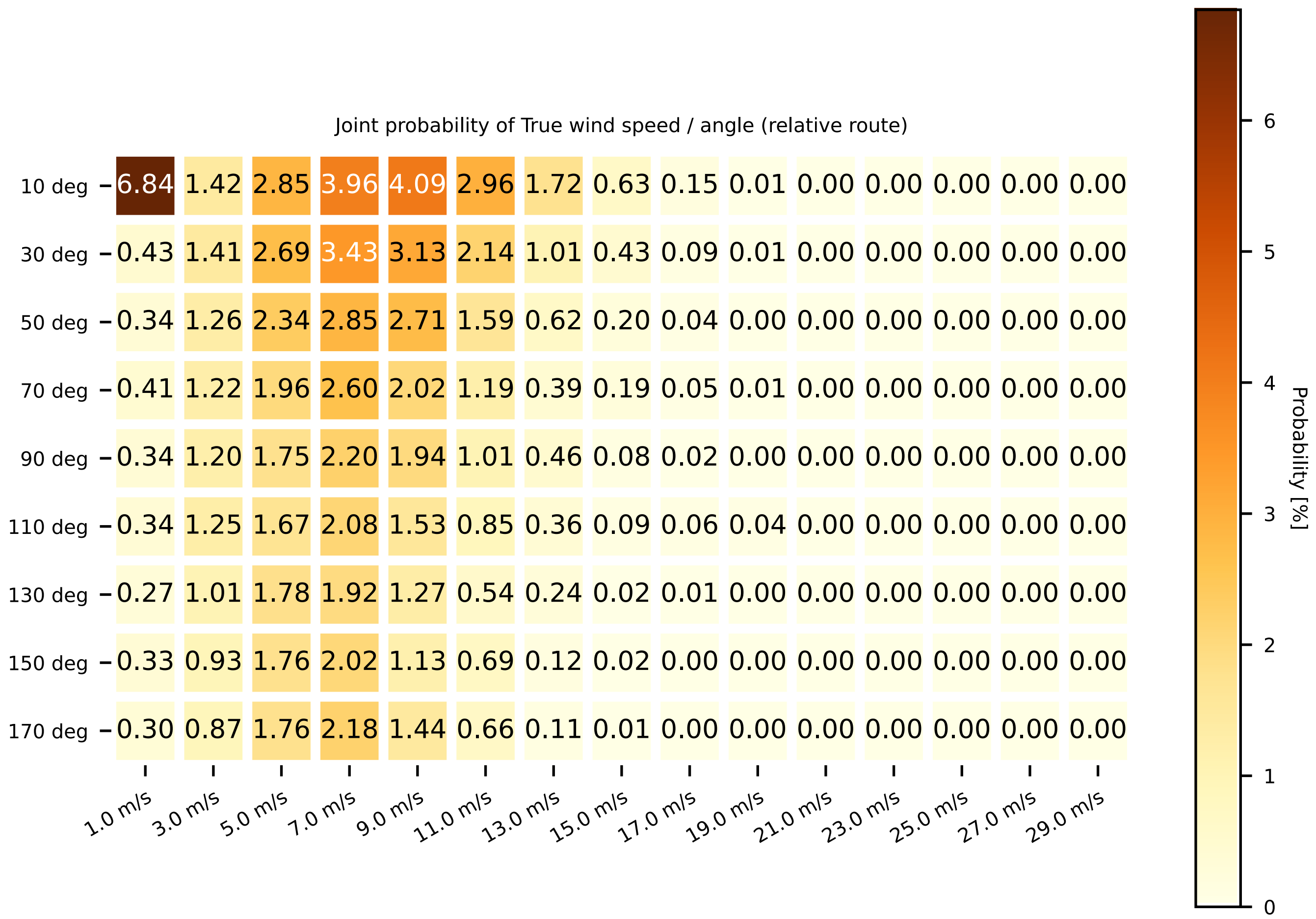
Results for a route analysis for ship: Ankie (ballast) on route: Rotterdam – Riga via Kiel (inbound) with total distance: 858.8 nm

	Average	Min (2.5%)	Max (97.5%)
Power saving (kW)	30.14	4.49	85.65
Energy saving on route (MWh)	2.68	0.38	7.67
Energy saving on route (%)	3.0	0.4	8.7

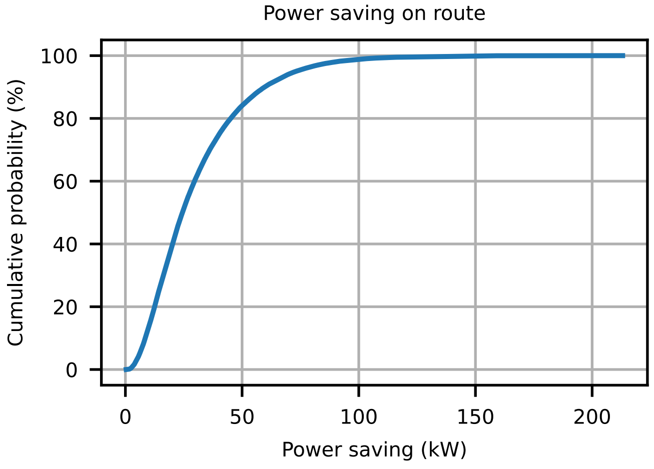


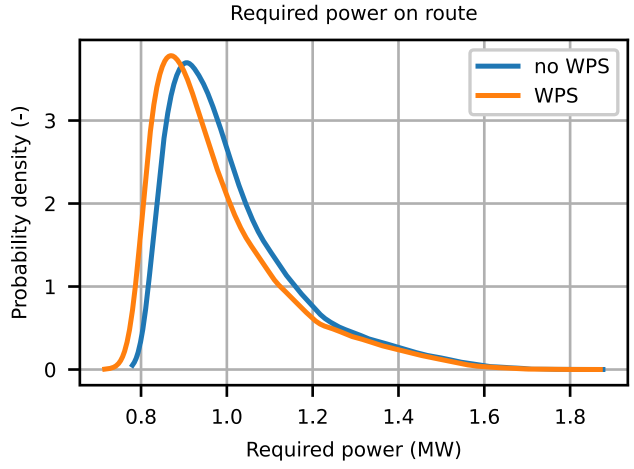






	1.0 m/s	3.0 m/s	5.0 m/s	7.0 m/s	9.0 m/s	11.0 m/s	13.0 m/s	15.0 m/s	17.0 m/s	19.0 m/s	21.0 m/s	23.0 m/s	25.0 m/s	27.0 m/s	29.0 m/s
10 deg	6.84	1.42	2.85	3.96	4.09	2.96	1.72	0.63	0.15	0.01	0.00	0.00	0.00	0.00	0.00
30 deg	0.43	1.41	2.69	3.43	3.13	2.14	1.01	0.43	0.09	0.01	0.00	0.00	0.00	0.00	0.00
50 deg	0.34	1.26	2.34	2.85	2.71	1.59	0.62	0.20	0.04	0.00	0.00	0.00	0.00	0.00	0.00
70 deg	0.41	1.22	1.96	2.60	2.02	1.19	0.39	0.19	0.05	0.01	0.00	0.00	0.00	0.00	0.00
90 deg	0.34	1.20	1.75	2.20	1.94	1.01	0.46	0.08	0.02	0.00	0.00	0.00	0.00	0.00	0.00
110 deg	0.34	1.25	1.67	2.08	1.53	0.85	0.36	0.09	0.06	0.04	0.00	0.00	0.00	0.00	0.00
130 deg	0.27	1.01	1.78	1.92	1.27	0.54	0.24	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00
150 deg	0.33	0.93	1.76	2.02	1.13	0.69	0.12	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
170 deg	0.30	0.87	1.76	2.18	1.44	0.66	0.11	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00

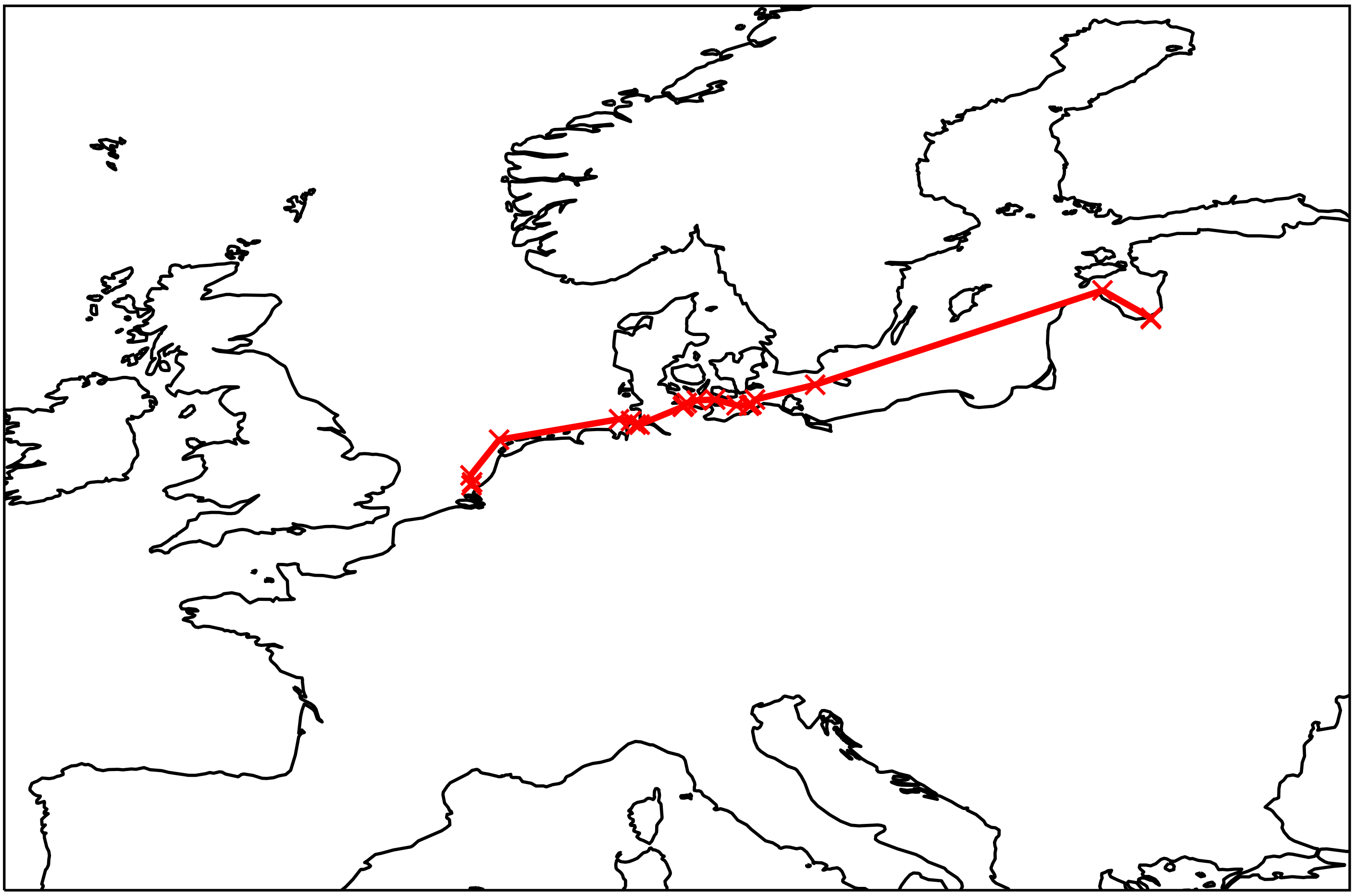

Power saving on route
Cumulative probability (%)
100
80
60
40
20
0
0
50
100
150
200
Power saving (kW)

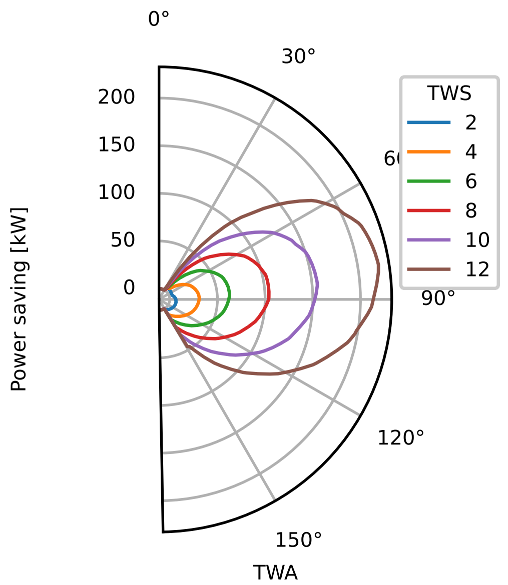

Required power on route
Probability density (-)
3
2
1
0
0.8
1.0
1.2
1.4
1.6
1.8
Required power (MW)
no WPS
WPS

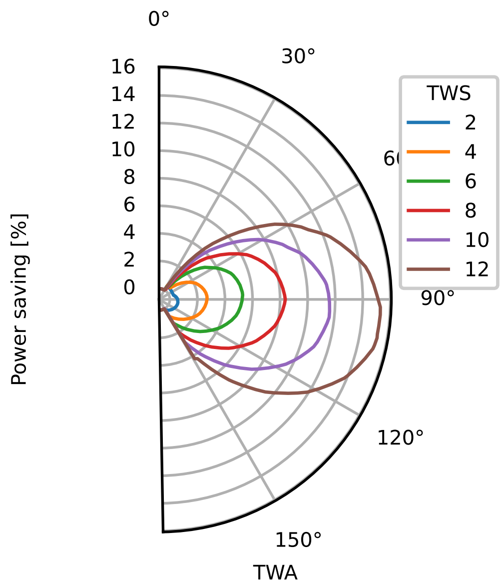
Route analysis report: WPS evaluation

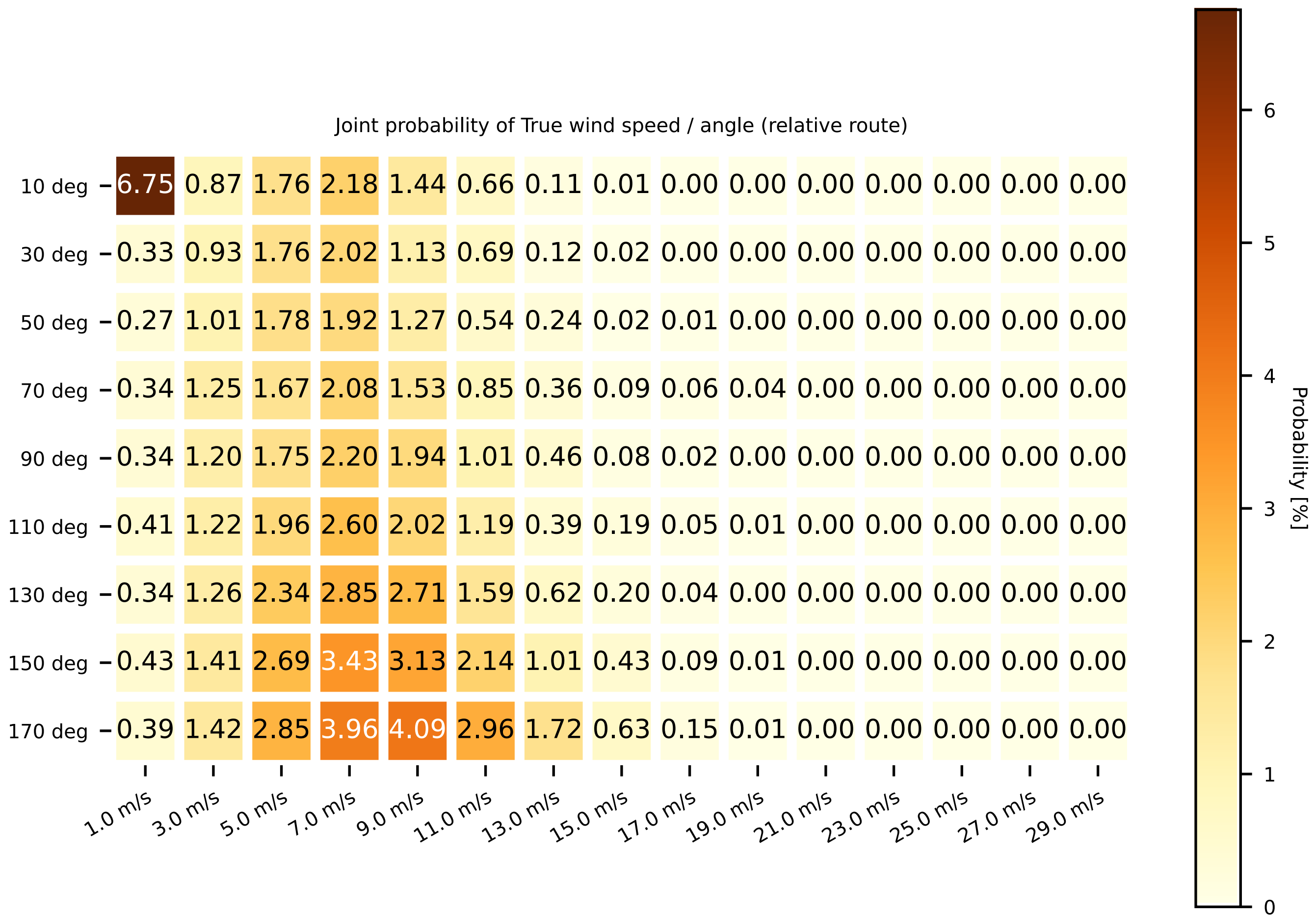
Results for a route analysis for ship: Ankie (laden) on route: Rotterdam – Riga via Kiel (outbound) with total distance: 858.8 nm

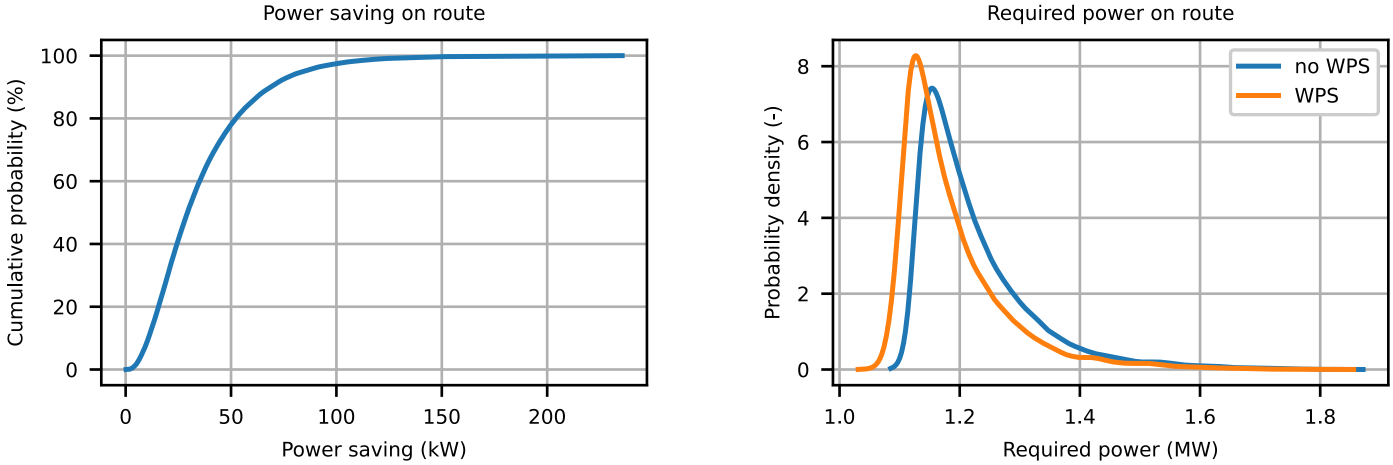
	Average	Min (2.5%)	Max (97.5%)
Power saving (kW)	35.63	5.80	100.62
Energy saving on route (MWh)	3.21	0.52	9.08
Energy saving on route (%)	2.9	0.5	7.6




0°
30°
60°
90°
120°
150°
200
150
100
50
0
Power saving [kW]
TWA
TWS
2
4
6
8
10
12


0°
30°
60°
90°
120°
150°
16
14
12
10
8
6
4
2
0
Power saving [%]
TWA
TWS
2
4
6
8
10
12

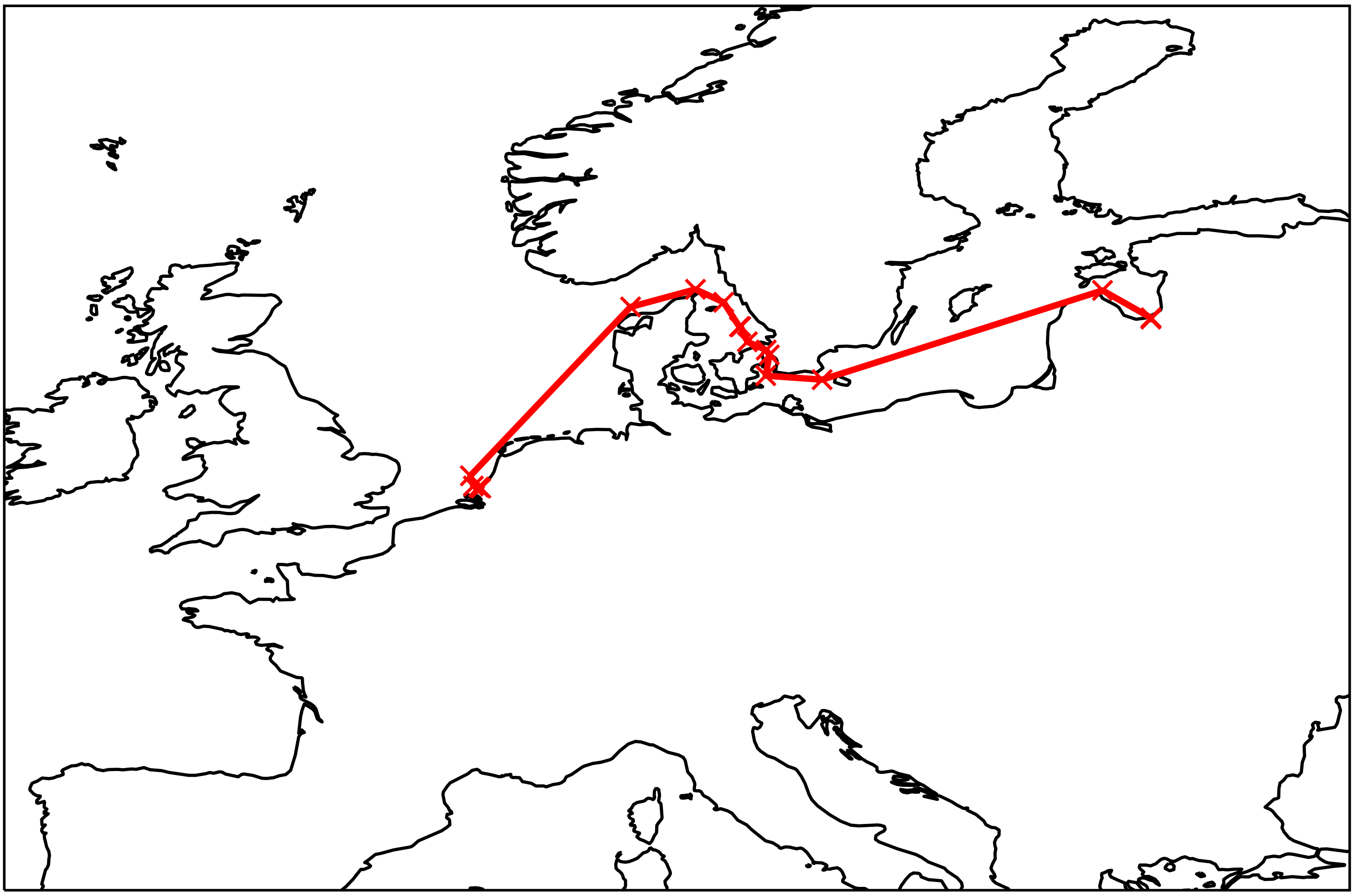

Joint probability of True wind speed / angle (relative route)
10 deg 6.75 0.87 1.76 2.18 1.44 0.66 0.11 0.01 0.00 0.00 0.00 0.00 0.00 0.00 0.00
30 deg 0.33 0.93 1.76 2.02 1.13 0.69 0.12 0.02 0.00 0.00 0.00 0.00 0.00 0.00 0.00
50 deg 0.27 1.01 1.78 1.92 1.27 0.54 0.24 0.02 0.01 0.00 0.00 0.00 0.00 0.00 0.00
70 deg 0.34 1.25 1.67 2.08 1.53 0.85 0.36 0.09 0.06 0.04 0.00 0.00 0.00 0.00 0.00
90 deg 0.34 1.20 1.75 2.20 1.94 1.01 0.46 0.08 0.02 0.00 0.00 0.00 0.00 0.00 0.00
110 deg 0.41 1.22 1.96 2.60 2.02 1.19 0.39 0.19 0.05 0.01 0.00 0.00 0.00 0.00 0.00
130 deg 0.34 1.26 2.34 2.85 2.71 1.59 0.62 0.20 0.04 0.00 0.00 0.00 0.00 0.00 0.00
150 deg 0.43 1.41 2.69 3.43 3.13 2.14 1.01 0.43 0.09 0.01 0.00 0.00 0.00 0.00 0.00
170 deg 0.39 1.42 2.85 3.96 4.09 2.96 1.72 0.63 0.15 0.01 0.00 0.00 0.00 0.00 0.00
1.0 m/s
3.0 m/s
5.0 m/s
7.0 m/s
9.0 m/s
11.0 m/s
13.0 m/s
15.0 m/s
17.0 m/s
19.0 m/s
21.0 m/s
23.0 m/s
25.0 m/s
27.0 m/s
29.0 m/s
Probability [%]
6
5
4
3
2
1
0

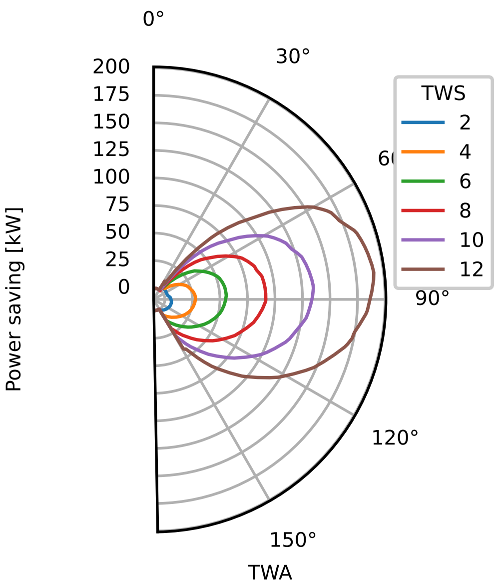

Power saving on route
Cumulative probability (%)
100
80
60
40
20
0
0
50
100
150
200
Power saving (kW)
Required power on route
Probability density (-)
8
6
4
2
0
1.0
1.2
1.4
1.6
1.8
Required power (MW)
no WPS
WPS

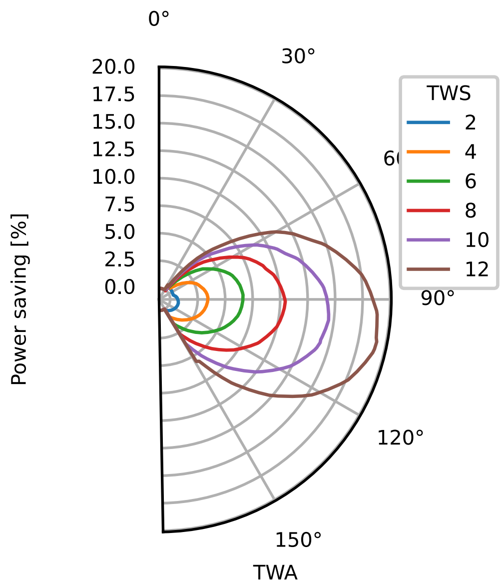
Route analysis report: WPS evaluation

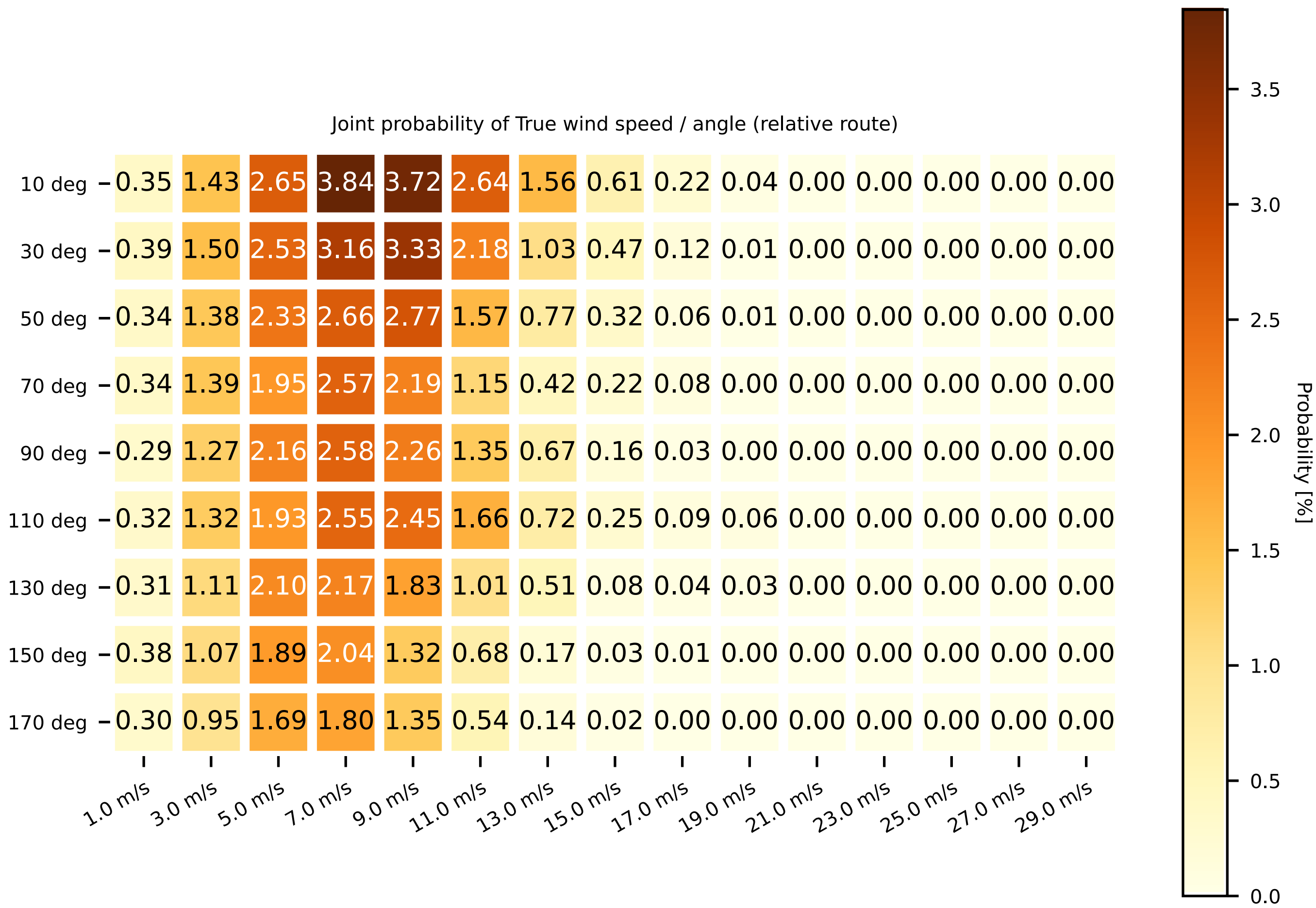
Results for a route analysis for ship: Ankie (ballast) on route: Rotterdam – Riga via Skagen (inbound) with total distance: 1070.5 nm

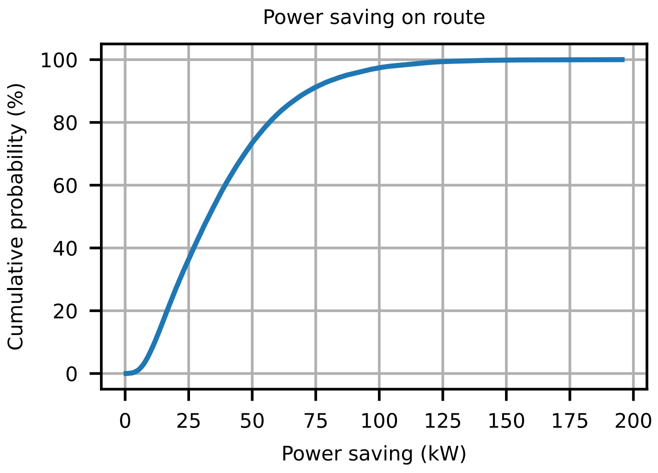
	Average	Min (2.5%)	Max (97.5%)
Power saving (kW)	38.21	6.82	100.65
Energy saving on route (MWh)	4.24	0.73	11.23
Energy saving on route (%)	3.8	0.6	10.2

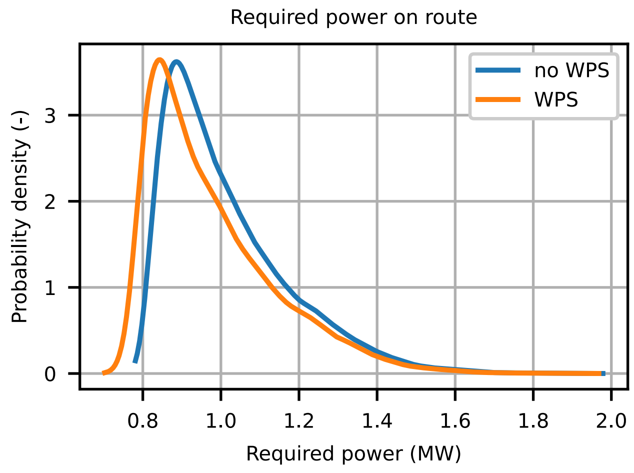



0°
30°
60°
90°
120°
150°
200
175
150
125
100
75
50
25
0
Power saving [kW]
TWA
TWS
2
4
6
8
10
12


0°
30°
60°
90°
120°
150°
20.0
17.5
15.0
12.5
10.0
7.5
5.0
2.5
0.0
Power saving [%]
TWA
TWS
2
4
6
8
10
12


Joint probability of True wind speed / angle (relative route)
10 deg 0.35 1.43 2.65 3.84 3.72 2.64 1.56 0.61 0.22 0.04 0.00 0.00 0.00 0.00 0.00
30 deg 0.39 1.50 2.53 3.16 3.33 2.18 1.03 0.47 0.12 0.01 0.00 0.00 0.00 0.00 0.00
50 deg 0.34 1.38 2.33 2.66 2.77 1.57 0.77 0.32 0.06 0.01 0.00 0.00 0.00 0.00 0.00
70 deg 0.34 1.39 1.95 2.57 2.19 1.15 0.42 0.22 0.08 0.00 0.00 0.00 0.00 0.00 0.00
90 deg 0.29 1.27 2.16 2.58 2.26 1.35 0.67 0.16 0.03 0.00 0.00 0.00 0.00 0.00 0.00
110 deg 0.32 1.32 1.93 2.55 2.45 1.66 0.72 0.25 0.09 0.06 0.00 0.00 0.00 0.00 0.00
130 deg 0.31 1.11 2.10 2.17 1.83 1.01 0.51 0.08 0.04 0.03 0.00 0.00 0.00 0.00 0.00
150 deg 0.38 1.07 1.89 2.04 1.32 0.68 0.17 0.03 0.01 0.00 0.00 0.00 0.00 0.00 0.00
170 deg 0.30 0.95 1.69 1.80 1.35 0.54 0.14 0.02 0.00 0.00 0.00 0.00 0.00 0.00 0.00
1.0 m/s
3.0 m/s
5.0 m/s
7.0 m/s
9.0 m/s
11.0 m/s
13.0 m/s
15.0 m/s
17.0 m/s
19.0 m/s
21.0 m/s
23.0 m/s
25.0 m/s
27.0 m/s
29.0 m/s
Probability [%]
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0

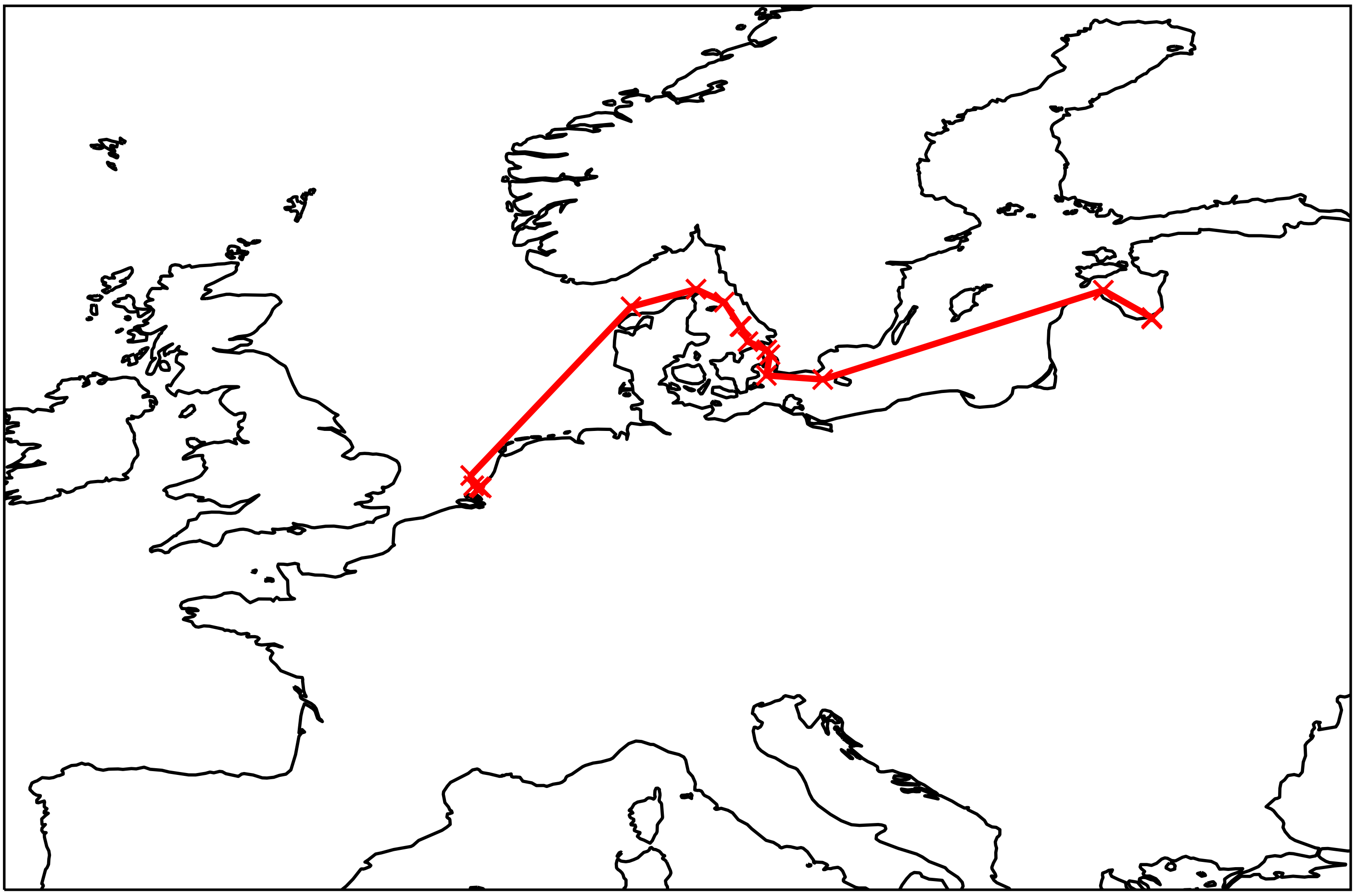

Power saving on route
Cumulative probability (%)
0
20
40
60
80
100
0
25
50
75
100
125
150
175
200
Power saving (kW)

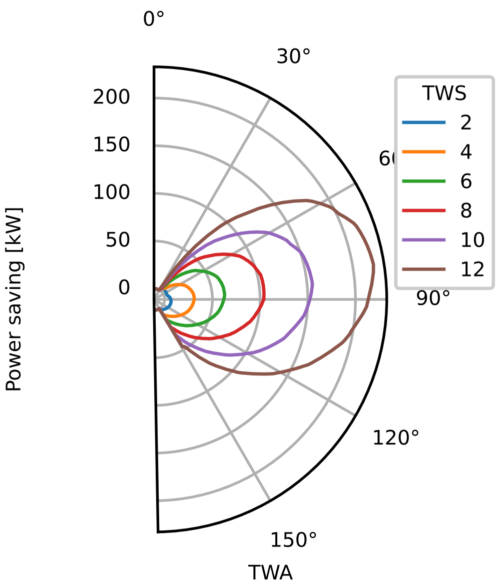

Required power on route
Probability density (-)
0
1
2
3
0.8
1.0
1.2
1.4
1.6
1.8
2.0
Required power (MW)
no WPS
WPS

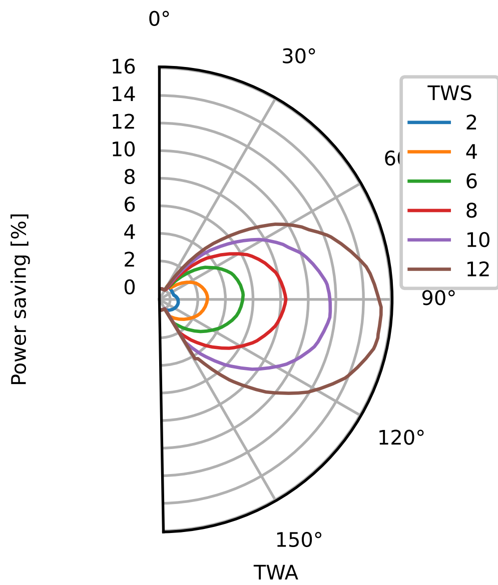
Route analysis report: WPS evaluation

Results for a route analysis for ship: Ankie (laden) on route: Rotterdam – Riga via Skagen (outbound) with total distance: 1070.5 nm

	Average	Min (2.5%)	Max (97.5%)
Power saving (kW)	45.45	8.32	118.46
Energy saving on route (MWh)	5.10	0.93	13.31
Energy saving on route (%)	3.6	0.7	8.7

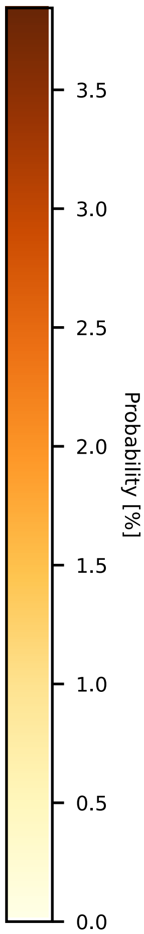


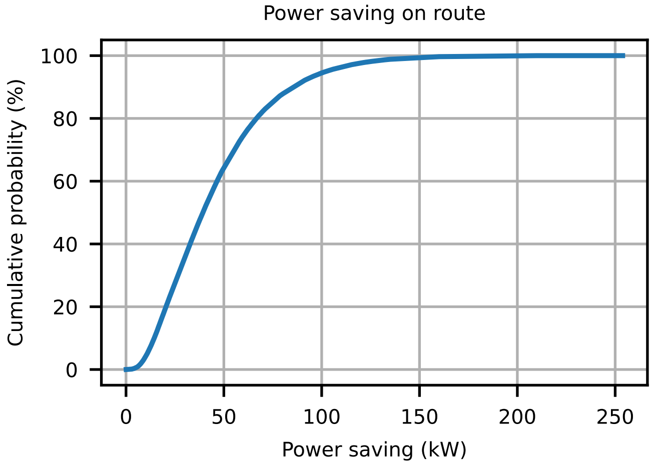


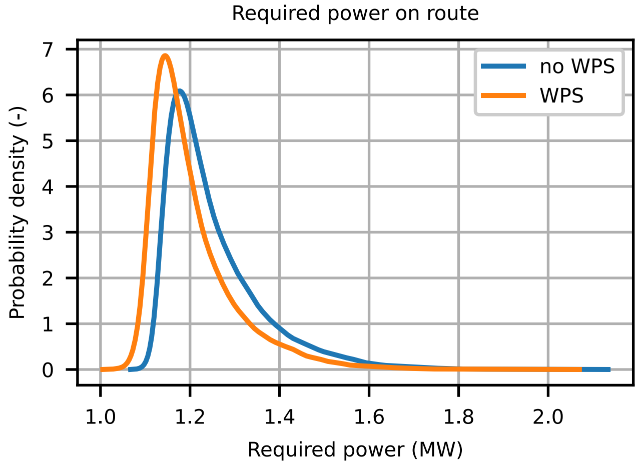


Joint probability of True wind speed / angle (relative route)

	1.0 m/s	3.0 m/s	5.0 m/s	7.0 m/s	9.0 m/s	11.0 m/s	13.0 m/s	15.0 m/s	17.0 m/s	19.0 m/s	21.0 m/s	23.0 m/s	25.0 m/s	27.0 m/s	29.0 m/s
10 deg	0.30	0.95	1.69	1.80	1.35	0.54	0.14	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30 deg	0.38	1.07	1.89	2.04	1.32	0.68	0.17	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.00
50 deg	0.31	1.11	2.10	2.17	1.83	1.01	0.51	0.08	0.04	0.03	0.00	0.00	0.00	0.00	0.00
70 deg	0.32	1.32	1.93	2.55	2.45	1.66	0.72	0.25	0.09	0.06	0.00	0.00	0.00	0.00	0.00
90 deg	0.29	1.27	2.16	2.58	2.26	1.35	0.67	0.16	0.03	0.00	0.00	0.00	0.00	0.00	0.00
110 deg	0.34	1.39	1.95	2.57	2.19	1.15	0.42	0.22	0.08	0.00	0.00	0.00	0.00	0.00	0.00
130 deg	0.34	1.38	2.33	2.66	2.77	1.57	0.77	0.32	0.06	0.01	0.00	0.00	0.00	0.00	0.00
150 deg	0.39	1.50	2.53	3.16	3.33	2.18	1.03	0.47	0.12	0.01	0.00	0.00	0.00	0.00	0.00
170 deg	0.35	1.43	2.65	3.84	3.72	2.64	1.56	0.61	0.22	0.04	0.00	0.00	0.00	0.00	0.00




Power saving on route
Cumulative probability (%)
100
80
60
40
20
0
0
50
100
150
200
250
Power saving (kW)


Required power on route
Probability density (-)
7
6
5
4
3
2
1
0
1.0
1.2
1.4
1.6
1.8
2.0
Required power (MW)
no WPS
WPS