Anemoi Rotor Sails

SETTING THE WORLD IN MOTION WITH WIND

ANEMOI

Find out more at
anemoimarine.com

WIND ASSISTED
SHIP PROPULSION

It is a crucial turning point for the shipping industry. The backbone of world trade, shipping is responsible for nearly 90% of traded goods and, as a result, the industry is accountable for about 3% of global emissions.

The International Maritime Organisation (IMO) set initial targets to reduce the total annual GHG emissions by at least 50% compared to 2008 levels by 2050. Ongoing discussions are underway regarding more stringent IMO targets. To achieve these targets, new regulations have been introduced, such as Energy Efficiency Design Index (EEDI), Efficiency Existing Ship Index (EEXI) and the Carbon Intensity Indicator (CII). These, coupled with a clear drive to decarbonise from other areas, for example the EU Emissions Trading System (EU ETS), means industry stakeholders are searching for new and proven ways to lower emissions.

LIMIT HARMFUL EMISSIONS WITH THE UNLIMITED RESOURCE OF WIND

Anemoi Marine Technologies (Anemoi) was born from a shipping professional's desire to minimise the impact ships have on the environment. After many years of research, development and successful pilot installations, our commercial Rotor Sail product was brought to market in 2020 and has garnered the interest of ship owners, managers and charterers looking to address their environmental strategies (ESG) ever since, and subsequently multiple commercial contracts have been secured.

Rotor Sails, also known as Flettner Rotors, are an energy saving technology for the maritime industry. These modern mechanical sails are comprised of tall cylinders which, when driven to spin by a motor, harness the renewable power of the wind to provide auxiliary propulsion to vessels, which significantly reduces fuel consumption and lowers harmful emissions entering our atmosphere by 5-30%.

Our mission is to accelerate the maritime industry's transition to zero emission shipping by delivering market-leading wind technology.

Lowers harmful emissions by

5–30%

Anemoi vision:

TO SET THE WORLD IN MOTION WITH WIND

EXPERIENCED WIND PROPULSION SPECIALISTS WITH A BULK CARRIER BACKGROUND

2007 – 12

Initially, Anemoi explored various emission reduction technologies and other wind propulsion systems before our research concluded that Rotor Sails had the most potential. From there we concentrated our efforts on testing and developing Rotor Sail technology.

2013 – 14

Anemoi built its land-based test facility in the UK, equipped with a full-scale Folding Rotor Sail. This site is our R&D hub for continual development and optimisation.

2015

Following successful technology development and prototype testing, Anemoi Marine Technologies Ltd. was incorporated, and preparations began for pilot installations.

2017 – 18

Pilot installations were completed on the m/v Afros, a 64k DWT geared Ultramax and the world's first bulk carrier to be fitted with Rotor Sails, in addition to the m/v Axios, a 'wind ready' Kamsarmax.

2019 – 20

Anemoi underwent a company restructure in advance of commercialising the business and taking its Rotor Sail technology to market. Furthermore, a licence agreement was signed with Wärtsilä Marine for sales and lifecycle services.

2021 – 22

Commercial orders are secured, and production commenced for three major bulk carrier projects. Anemoi continues its growth plans and production scales up to support increasing number of orders.

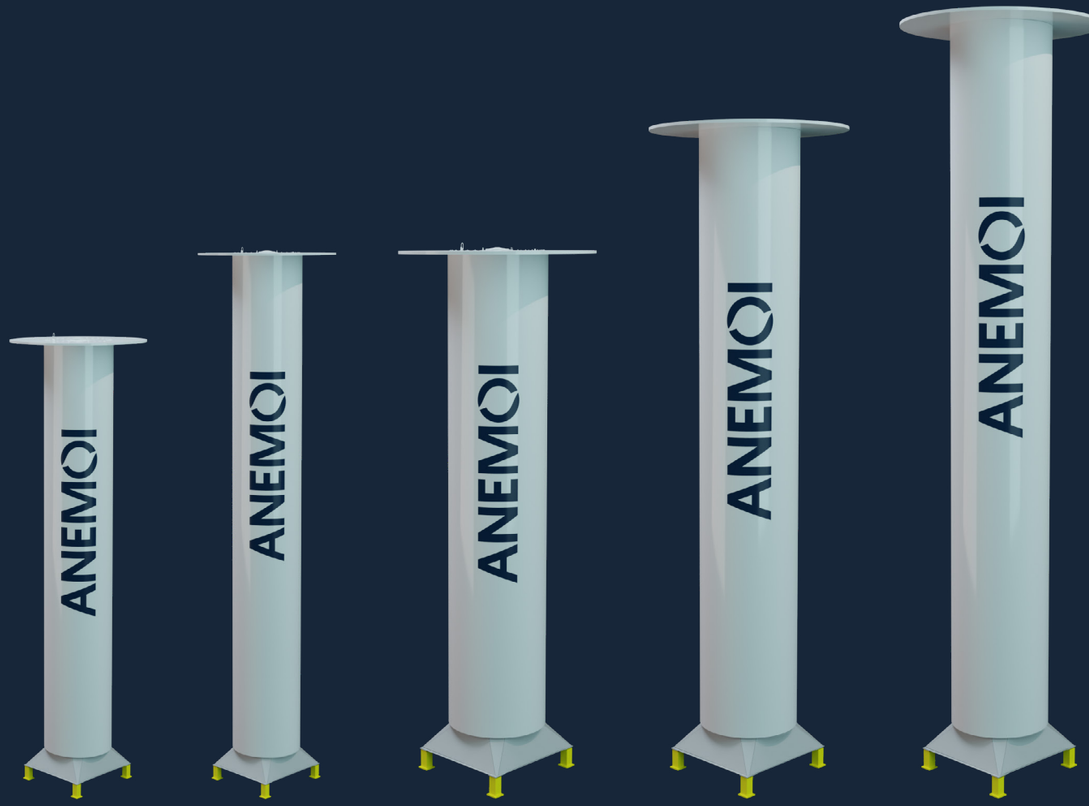
PRESENT

Having established its production with leading partners in China, Anemoi is delivering existing projects and taking orders for new projects.

EMISSION REDUCTION WITH MINIMAL IMPACT ON VESSEL OPERATIONS

ROTOR SAIL SIZES

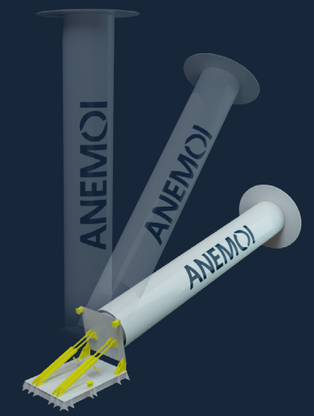
Anemoi offers a range of Rotor Sail sizes to suit most vessel types and sizes. Rotor Sails can be retrofitted to existing ships or delivered with newbuild ships. Our Rotor Sails are movable assets with a 25-year design life so they can be redeployed between vessels.



3.5m × 21m | 3.5m × 24.5m | 5m × 24m | 5m × 30m | 5m × 35m

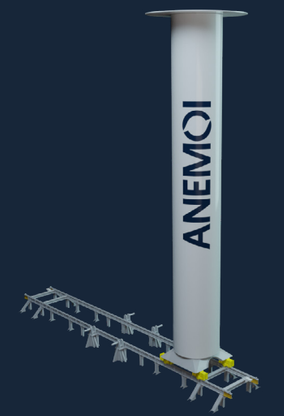
DEPLOYMENT SYSTEMS

As standard, Anemoi Rotor Sails are permanently fixed to the deck. However, we also offer a unique range of 'Deployment Systems' which allow the Rotor Sails to be repositioned in a matter of minutes to significantly reduce impact on vessel business and port operations.



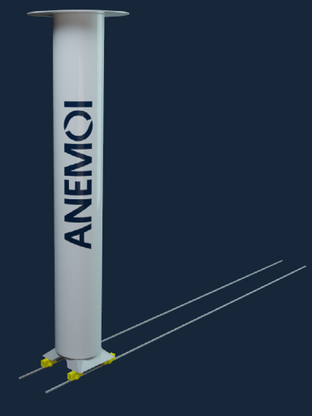
FOLDING DEPLOYMENT SYSTEM

Rotor Sails can be lowered from the vertical to horizontal position.



TRANSVERSE RAIL DEPLOYMENT OPTION

Rotor Sails are transported across the deck by an independent rail system.



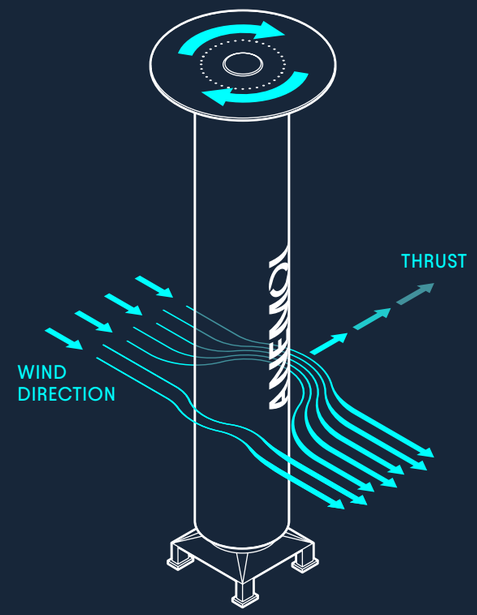
LONGITUDINAL RAIL DEPLOYMENT OPTION

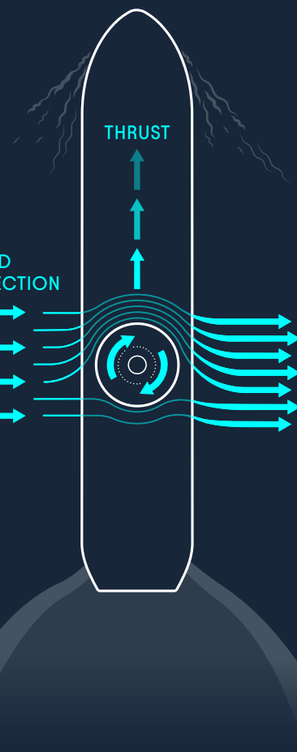
Rotor Sails are transported along the deck by an independent rail system.

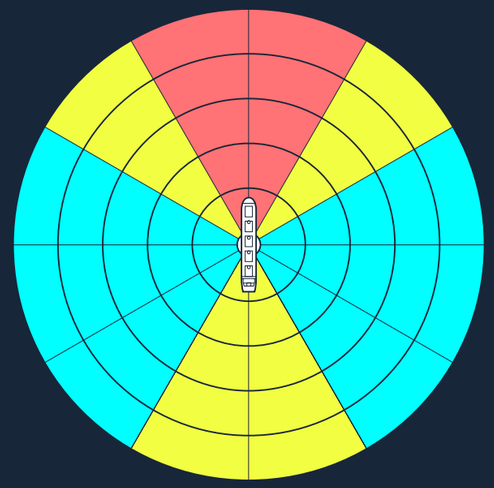
HARNESSING THE MAGNUS EFFECT

When the wind speed and direction is suitable, Rotor Sails are switched on automatically and rotated by an electric motor. As the wind flow meets the spinning Rotor Sails, an aerodynamic phenomenon called the Magnus Effect comes into action.

The wind in front of the Rotor Sail is accelerated as it is pulled in the direction of the spin. This faster-moving wind has a lower pressure, like the wind over the top of an aircraft wing (but up to 10x more effective). Meanwhile, the wind behind the Rotor Sail slows, causing an increase in pressure. This difference in pressure pushes the Rotor Sail forwards and propels the ship. This auxiliary propulsion can be used to increase the vessel speed or reduce the consumption of the main engine.



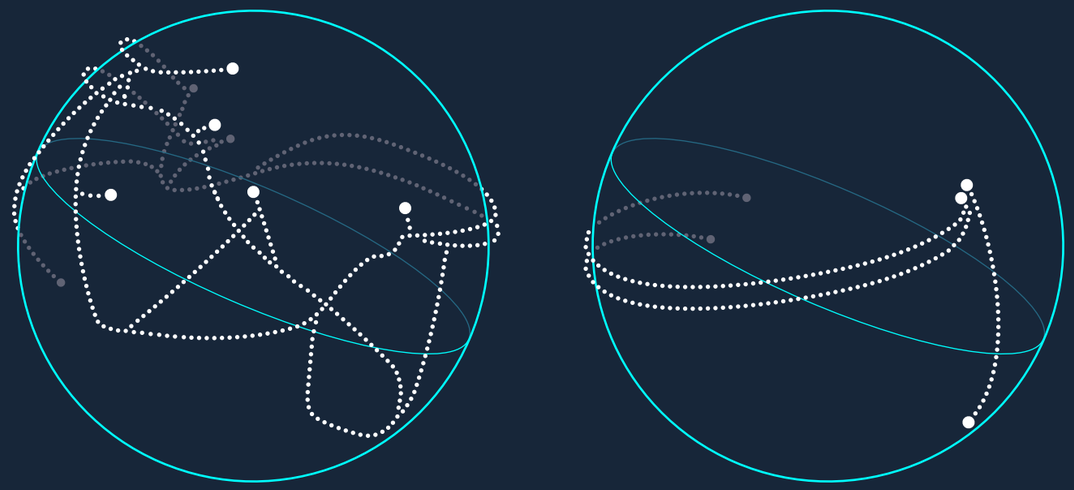




At sea, ships encounter a range of wind speeds and directions. The compact weather stations (anemometers) Anemoi installs as part of equipment delivery detect the wind speed and direction. This then triggers the Rotor Sails to switch on automatically when the winds are favourable (blue and yellow sectors) and off when the wind is unfavourable (red sectors). The Rotor Sail speed is varied automatically to suit changes in the wind speed. Thrust is roughly at right angles to the wind direction. Winds more towards the beam of the ship give the most forwards thrust.

5–30% REDUCTION IN FUEL AND EMISSIONS

Rotor Sails can reduce fuel consumption and emissions by 5-30% and make a significant impact towards regulatory requirements. Anemoi has developed a proprietary "Fuel Saving Assessment Model" (FSAM) to make reliable performance predictions for client installations. Our EEDI calculation method has also been validated by Lloyds Register. Email sales@anemoimarine.com for a bespoke assessment of your ship.



NEWBUILD 210K DWT NEWCASTLEMAX BULK CARRIER WITH 4 ROTOR SAILS*

IMO GLOBAL TRADE ROUTE

- FUEL AND EMISSION SAVINGS: **14.3%**
- ANNUAL FUEL REDUCTION: **1,379t**
- ANNUAL CO2 REDUCTION: **4,345t**
- EEDI SCORE IMPROVEMENT FROM: **1.92 to 1.47**

NEWCASTLE – TIANJIN

- FUEL AND EMISSION SAVINGS: **12.9%**
- ANNUAL FUEL REDUCTION: **1,242t**
- ANNUAL CO2 REDUCTION: **3,915t**

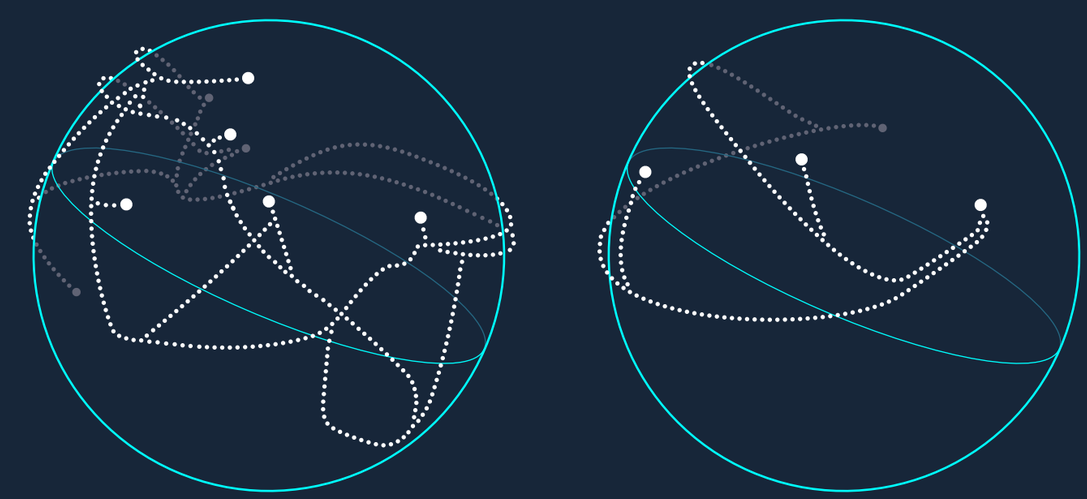
EXISTING VLCC TANKER WITH 5 ROTOR SAILS**

IMO GLOBAL TRADE ROUTE

- FUEL AND EMISSION SAVINGS: **16.3%**
- ANNUAL FUEL REDUCTION: **1,988t**
- ANNUAL CO2 REDUCTION: **6,190t**
- EEXI SCORE IMPROVEMENT FROM: **2.11 to 1.68**

LOOP (LOUISIANA OFFSHORE OIL PORT) – NINGBO VIA CAPE OF GOOD HOPE

- FUEL AND EMISSION SAVINGS: **14.9%**
- ANNUAL FUEL REDUCTION: **1,793t**
- ANNUAL CO2 REDUCTION: **5,584t**



* Results are estimates based on vessel sailing 270 days per year. Fuel type VLSFO. Results are return journeys covering both laden and ballast conditions.

** Results are estimates based on vessel sailing 300 days per year. Fuel type HFO. Results are return journeys covering both laden and ballast conditions.

ANEMOI ROTOR SAIL MAIN COMPONENTS

Anemoi Rotor Sails are comprised of the following main systems and components.

UPPER BEARING SYSTEM

The upper bearing carries the entire axial load of the rotor skin and top disc, and most of the radial load. It connects the rotor skin to the tower.

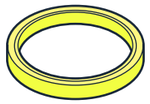
Both the upper and lower bearings are designed to minimise friction and hence unnecessary power consumption and heat generation.

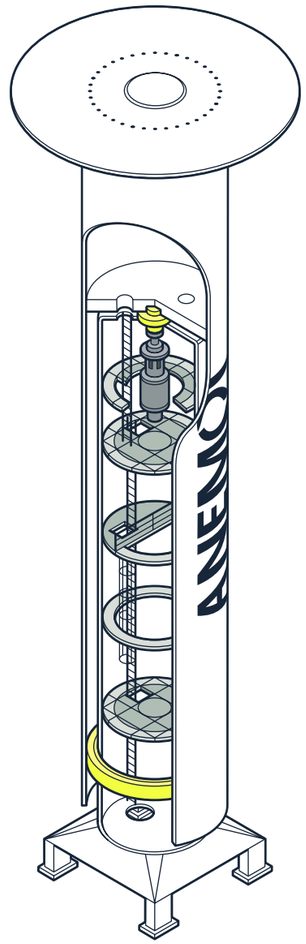
DRIVE SYSTEM (ELECTRIC MOTOR)

Installed at the top of the tower, the efficient electric motor drives the rotor through the upper bearing via a reduction gearbox. Its speed is automatically controlled by the Bridge Control Unit (BCU) and a variable frequency drive.

LOWER BEARING SYSTEM

Wheels are positioned around the circumference of the base of the tower structure to carry some of the radial loads.





ACCESS

Access is provided through a series of ladder runs, rest platforms and associated handrails. Access into the Rotor Sail is via a weathertight door in the pedestal.

PEDESTAL

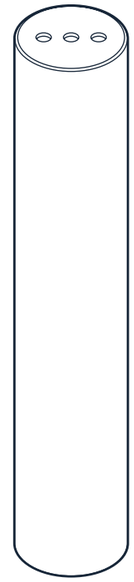
The pedestal is the connection point between the deck and the Rotor Sail equipment. The pedestal is included as part of Anemoi's scope of supply.

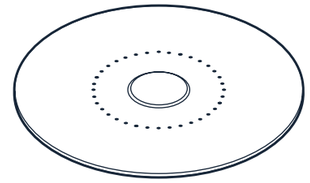
ANEMOMETER

Included in Anemoi's scope of supply is one anemometer, mounted on the fore or aft mast. This measures the environmental conditions, which input to the control system. It is recommended to also connect the BCU to the vessel's existing anemometer, which can be used as a back-up.

PAINT AND COATINGS

High performance coating is applied to the exterior of the Rotor Sail, providing protection from UV and water absorption. The tower structure is painted with a marine grade paint system, including a UV resistant topcoat.





TOP DISC

Made from lightweight but durable composite, the top disc improves the aerodynamic performance of the Rotor Sail.

LIGHTNING PROTECTION

The receptor is mounted to the top surface of the top disc with a low resistance route to ground, in accordance with Classification Society rules.

TOWER

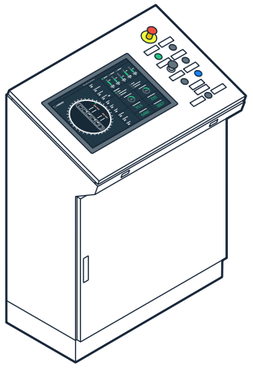
Made from steel and designed to withstand extreme loads.

The tower is home to various electrical and mechanical components. It has been designed for safe access should maintenance be required, though this is infrequent.

ROTOR SKIN

The rotating component of Rotor Sails that generates thrust. The rotor skin is made from epoxy composite material, which is lightweight, durable and proven in a marine environment (used for offshore wind turbine blades).

CONTROL AND MONITORING SYSTEM



The main point of control for the Rotor Sail System is located on the bridge at the Bridge Control Unit (BCU), regardless of the number of Rotor Sails. The BCU interfaces with vessel systems and processes vessel and Rotor Sail data to make operational decisions.

Anemoi Rotor Control System (ARCS) software running on the BCU makes the decisions on when, how fast, and which direction to run each Rotor Sail.

From the Bridge Control Unit, the user can:

- Start and stop Rotor Sails, although this is typically an automated activity
- Select control modes
- View the status and performance of the vessel, Rotor Sail System, and individual Rotor Sails
- Initiate emergency stops and block operation of any Rotor Sail
- View and respond to alarms

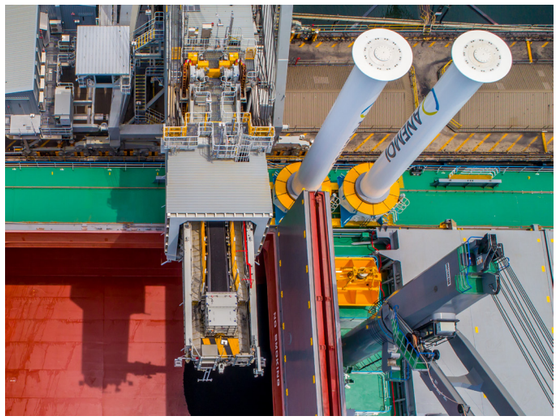
> The main point of control for the Rotor Sail System is located on the bridge at the Bridge Control Unit

CABLING

Electrical connections need to be made to connect each Rotor Sail to the BCU with a data cable, and to the main switchboard with a power cable.

For the Rail Deployment System, each Rotor Sail requires connection to the vessel cabling via plug and socket connectors protected in a deck box adjacent to each Rotor Sail, so that the Rotor Sail can be disconnected for movement along the rail.

When the Folding Deployment System is selected, fixed wiring is terminated in a deck box adjacent to each Rotor Sail. Flexible cabling from the deck boxes in flexible cable trunking allows folding of the Rotor Sails without disconnecting.



Reduce EEDI by around **20%**

CLASSIFICATION

Dependent on the client's requirements, Anemoi can support through all stages of the plan approval process. Additionally, the Rotor Sails and associated Deployment Systems for each installation are certified in accordance with leading classification society rules.

The equipment is also designed to meet the requirements of Lloyd's Register Guidance Notes for Flettner Rotor Approval, including applicable references to Lloyd's Register Code for Lifting Appliances in a Marine Environment, in addition to the DNV guidance document.

Lloyd's Register have also validated the calculation methodology showing the reduction in attained EEDI/EEXI as a direct result of installing Anemoi Rotor Sails.

The results of a collaborative effort between Anemoi, Lloyd's Register, the Shanghai Design and Research Institute (SDARI), Oldendorff Carriers and the Liberian Registry, showed that the installation of Anemoi Rotor Sails on a Newcastlemax bulk carrier can reduce EEDI by around 20%.

DNV

Lloyd's Register

SELECTING THE OPTIMAL ROTOR SAIL ARRANGEMENT

The size and number of Rotor Sails installed is determined by vessel size, available deck space and operating profile. We work closely with clients during the technical feasibility stage of the project to ensure maximum performance is achieved with the optimal configuration. Anemoi has 5 standard Rotor Sail models to optimise performance for a vessel.

Based on experience, we recommend the arrangements outlined in Table A, although a detailed assessment is completed with the client before the final solution is agreed. All proposed arrangements take the following factors into account:

- Fuel and emissions savings
- Available deck space
- Vessel trim and stability
- Percentage of lightship weight
- Rotor Sail motor total rated power (kW) and usage of generators
- Percentage change in vessel vertical centre of gravity (VCG) value

MODELS	ROTOR SAIL DIAMETER	ROTOR SAIL HEIGHT	AVAILABILITY
3.5 × 21	3.5m	21m	Coming soon
3.5 × 24.5	3.5m	24.5m	Available now
5 × 24	5m	24m	Available now
5 × 30	5m	30m	Available now
5 × 35	5m	35m	Available now

The main Anemoi scope of supply for each Rotor Sail installation is:

- → Anemoi Rotor Sails, creating the thrust for additional propulsion
- → Choice of Deployment System, providing flexibility for cargo operations
- → Bridge Control Unit (BCU), for easy control of the Rotor Sail system from the bridge
- → Anemoi Rotor Control System (ARCS) software, automating the control of the Rotor Sail system
- → One Engine Room Remote I/O Station, to simplify cable connections to existing vessel sensors required by the control system
- → One Anemoi anemometer, to feed live environment data to the Rotor Sail system for optimal operation

Five standard Rotor Sail models to suit most vessel types

5

VESSEL SEGMENT	TYPE OF VESSEL	SUGGESTED MODEL	NUMBER OF ROTOR SAILS	DEPLOYMENT SYSTEM
Bulker	Ultramax (60k-70k DWT)	3.5m × 24.5m	3	Rail System
	Kamsarmax (80k-85k DWT)	5m × 24m	3	Rail System
	Minicape / Babycape (100k-125k DWT)	5m × 30m	4	Folding System
	Capesize (125k-200k DWT)	5m × 35m or 5m × 30m	4	Folding System or Rail System
	Newcastlemax (200k-212k DWT)	5m × 35m	4	Folding System
	VLOC (>212 DWT)	5m × 35m	4 or 5	Folding System
Tanker	MR Tanker (40k-55k DWT)	5m × 35m	2	Fixed or Folding System
	LR1/LR2 Tanker (55k-125k DWT)	5m × 35m	4	Fixed or Folding System
	Suezmax (125k-200k DWT)	5m × 35m	4	Fixed or Folding System
	VLCC (>200k DWT)	5m × 35m	5	Fixed or Folding System
Other	RoRo (>10k GT)	5m × 35m	TBD	Fixed or Folding System

[Table A]

QUALITY, SAFETY AND THE ENVIRONMENT ARE AT THE TOP OF THE AGENDA FOR ALL OUR PROJECTS

M/V AFROS

- **SHIP TYPE:**
  64k DWT geared Ultramax Bulk Carrier
- **CLIENT:**
  Blue Planet Shipping
- **ROTOR SAIL CONFIGURATION:**
  4 Rotor Sails (2m × 16m) on Longitudinal Rail Deployment System
- **SOLUTION:**
  Delivered in January 2018, the m/v Afros has visited over 100 ports since with a 100% port acceptance rate

VLOC

- **SHIP TYPE:**
  400k DWT VLOC
- **CLIENT:**
  Vale
- **ROTOR SAIL CONFIGURATION:**
  5 Rotor Sails (5m × 35m) on Folding Deployment System
- **SOLUTION:**
  Coming soon! This vessel typically trades on Oman-Brazil and China-Brazil routes, which are particularly well suited for wind propulsion

M/V AXIOS

- **SHIP TYPE:**
  82k DWT Kamsarmax Bulk Carrier
- **CLIENT:**
  Blue Planet Shipping
- **ROTOR SAIL CONFIGURATION:**
  Vessel made 'wind ready' so Rotor Sails can be installed simply in the future
- **SOLUTION:**
  4 Transverse Rail Deployment Systems were installed along with the electrical and control hardware

NEWCASTLEMAX

- **SHIP TYPE:**
  210k DWT Newcastlemax Bulk Carrier
- **CLIENT:**
  Berge Bulk
- **ROTOR SAIL CONFIGURATION:**
  4 Rotor Sails (5m × 35m) on Folding Deployment System
- **SOLUTION:**
  Coming soon! Savings of 1,200–1,500 tonnes of fuel per year are predicted

BERGE NEBLINA

- **SHIP TYPE:**
  388k DWT Valemax Ore Carrier
- **CLIENT:**
  Berge Bulk
- **ROTOR SAIL CONFIGURATION:**
  4 Rotor Sails (5m × 35m) on Folding Deployment System
- **SOLUTION:**
  Coming soon! Savings of 1,200–1,500 tonnes of fuel per year are predicted

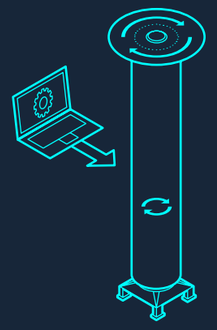
TR LADY

- **SHIP TYPE:**
  82k DWT Kamsarmax Bulk Carrier
- **CLIENT:**
  Tufton Investments
- **ROTOR SAIL CONFIGURATION:**
  3 Rotor Sails (5m × 24m) on Transverse Rail Deployment System
- **SOLUTION:**
  Delivered in June 2023. Initial results indicate savings will exceed 10% annually. Performance validation is ongoing.

"We firmly believe wind propulsion can help achieve our decarbonisation commitments and are therefore pleased to be rolling out Anemoi Rotor Sail technology on our vessels."

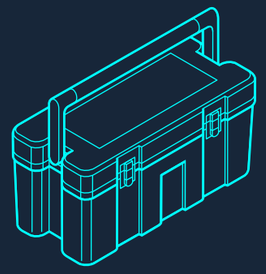
Paolo Tonon, Technical Director of Berge Bulk

KEY BENEFITS



FULLY AUTOMATED SYSTEM MINIMISES CREW INPUT AND MAXIMISES BENEFITS

When the wind is favourable, our Rotor Sails will automatically switch on and adjust the rotation speed to ensure maximum savings are achieved. The crew can also monitor the performance of the Rotor Sails via the control unit located in the bridge, which also houses features such as manual override.

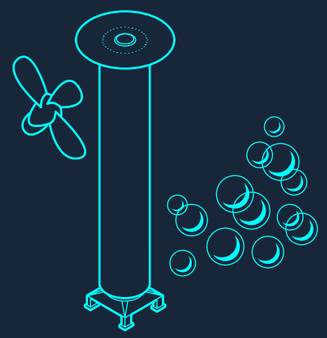


LIMITED MAINTENANCE REQUIRED

Anemoi Rotor Sails have been designed to require minimal and infrequent maintenance. If maintenance is necessary, this is communicated to the crew via the bridge control unit.

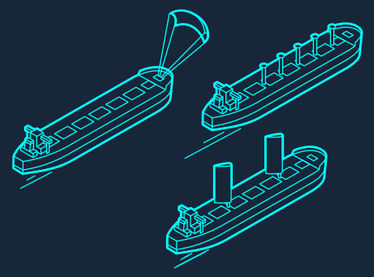
REDUCE COSTS FROM EXPENSIVE ALTERNATIVE FUELS

Alternative fuels, when market ready, are expected to come at a high price. Rotor Sails reduce fuel consumption, irrespective of fuel type. Installing
Rotor Sails can future proof vessels against these new operational costs.



CAN BE EASILY COMBINED WITH OTHER ENERGY SAVING TECHNOLOGIES

For further vessel efficiency, our Rotor Sails can be combined and clustered with other energy saving devices, such as those offered by our partners at Wärtsilä Marine.



MORE THRUST PER SQUARE METRE

Per square metre of projected sail area, Rotor Sails offer a much greater thrust force to propel ships compared to other wind propulsion technologies.

APPROVED BY LEADING CLASSIFICATION SOCIETIES

Our Rotor Sail design has been certified by Lloyd's Register. Anemoi works with all classification societies during the installation process to achieve the necessary quality standards.

WHY ANEMOI?

- Over 15 years' experience in wind propulsion
- Shipping background – we understand vessel operations
- Innovative approach to technology development
- Turnkey installations possible through key collaborations with COSCO Shipping Heavy Industries and Chengxi CSSC
- Supported by industry leaders such as Wärtsilä Marine
- Dedicated, passionate team working to protect our environment
- Offer a large scope of services to meet client requirements
- World class supply chain with partners including CRRC Corporation Limited

Wind propulsion is one of the most sustainable ways to lower ship emissions

FAQ

A few of the most commonly asked questions and high-level answers are presented here. If your question has not been covered or you would like more detail, please get in touch with us.

HOW DO THE ROTOR SAILS COMPLY WITH VISIBILITY REQUIREMENTS?

→ We work in accordance with the current visibility regulations and consider blind spots when assessing where to place the Rotor Sails. Our proposed configurations aim to ensure compliance on visibility as per Annex A SOLAS V/22 - Navigation Bridge Visibility. We also have solutions to mitigate blind sectors in navigation lights.

HOW DO THE ROTOR SAILS AFFECT VESSEL STABILITY?

→ Typically, when analysing a specific configuration for a vessel, a preliminary stability analysis is conducted to understand if the lightship weight has increased over the threshold of 2% and whether VCG has increased over the threshold of 1%. If this is the case, the analysis is expanded to include assessing the worst loading condition in the stability booklet and checking the main stability criteria are still met (e.g. GM in intact stability, area under GZ curve, damage stability etc).

WILL PORTS ACCEPT OUR VESSEL WITH THE ANEMOI ROTOR SAILS?

→ Anemoi's pilot vessel, the m/v Afros, a 64k Ultramax bulk carrier, has been operating since January 2018 with four Rotor Sails installed on a longitudinal Rail System. As of 2023, the vessel has visited over 100 ports worldwide and has been accepted at 100% of these ports. For the other ship types, with different Rotor Sail sizes and configurations, we have conducted port assessments of over 150 berths worldwide and found positive results for Rotor Sails with any of our Deployment Systems.

DOES POSITIONING ROTOR SAILS CLOSER TOGETHER IMPACT THE PERFORMANCE?

→ In general, positioning a pair of Rotor Sails closer together negatively impacts performance of the downwind Rotor Sail, as would be the case with any wind energy system. From certain wind angles the interaction can be beneficial, although the effect is typically negative. Anemoi has conducted aerodynamic interaction studies for various Rotor Sail arrangements. We have concluded that the best overall aerodynamic performance is typically reached when the Rotor Sails are positioned more than 7x the Rotor Sail diameter apart, although sometimes this is impractical to achieve. The Anemoi Rotor Control System automatically adjusts the speed of each Rotor Sail individually to maximise the performance of the whole system, accounting for Rotor Sail-to-Rotor Sail aerodynamic interaction. This is customised for each installation according to the number, size and position of the Rotor Sails on the ship.

ARE THERE SOME SAILING CONDITIONS WHERE THE ROTORS SAILS CANNOT BE TURNED ON?

→ Anemoi Rotor Sails can operate with wind speeds of up to 35 m/s (68 kts), although sailing in such conditions is uncommon. The control system has a motion reference unit that measures pitch, roll, and linear accelerations of the ship. If the accelerations or wind speed exceed the design limits, then the Rotor Sails are automatically turned off. Additionally, when the apparent wind angle is within 30 degrees of the bow, the Rotor Sails are off or producing low thrust.

OFFICES IN UK AND CHINA

We supply the global shipping industry with our smart, proven Rotor Sail technology.

TEST FACILITY

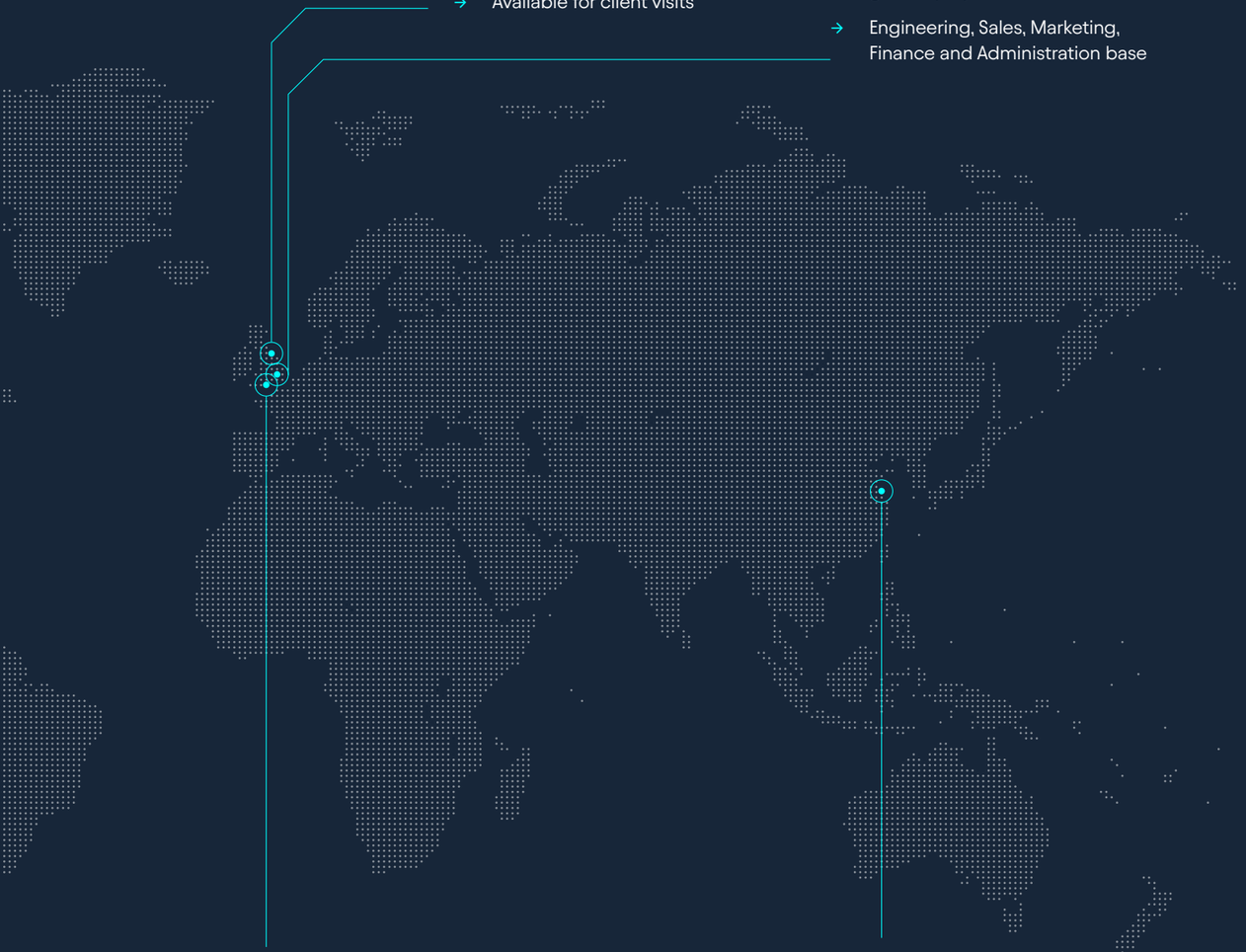
Port of Blyth, UK

- Full scale land-based Rotor Sail
- Available for client visits

HEAD OFFICE

London, UK

- Open-plan space to support growth projections
- Engineering, Sales, Marketing, Finance and Administration base



BRANCH

Brockenhurst, UK

- Expert teams in Projects and Engineering

ANEMOI PRODUCTION & QUALITY ASSURANCE TEAM

Jiangsu Province, China

- World class production partners
- 170+ production staff in addition to Anemoi staff

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