Photo: Sea-Cargo

NORSEPOWER

FLETTNER ROTORS - STATE OF TECHNOLOGY AND POTENTIALS

TUOMAS RISKI, CEO, NORSEPOWER OY LTD

Our Top Reference: One of the most powerful sailing ships in the world

Norwegian Sea Cargo SC Connector RoRo ship, length 155m

- Retrofitted with two tiltable 35-meter Rotor Sails made by Norsepower
- Equivalent traditional sail area = 3000 m^2, making it into the Top 10 sailing ships in the world

- Typical main engine power: 3 MW
- Rotor Sails power: up to 8 MW

- Results:
  - **Average fuel savings up to 25**%
  - Top speed increase from 12 to 20kts
  - Can also sail with Rotor Sails alone

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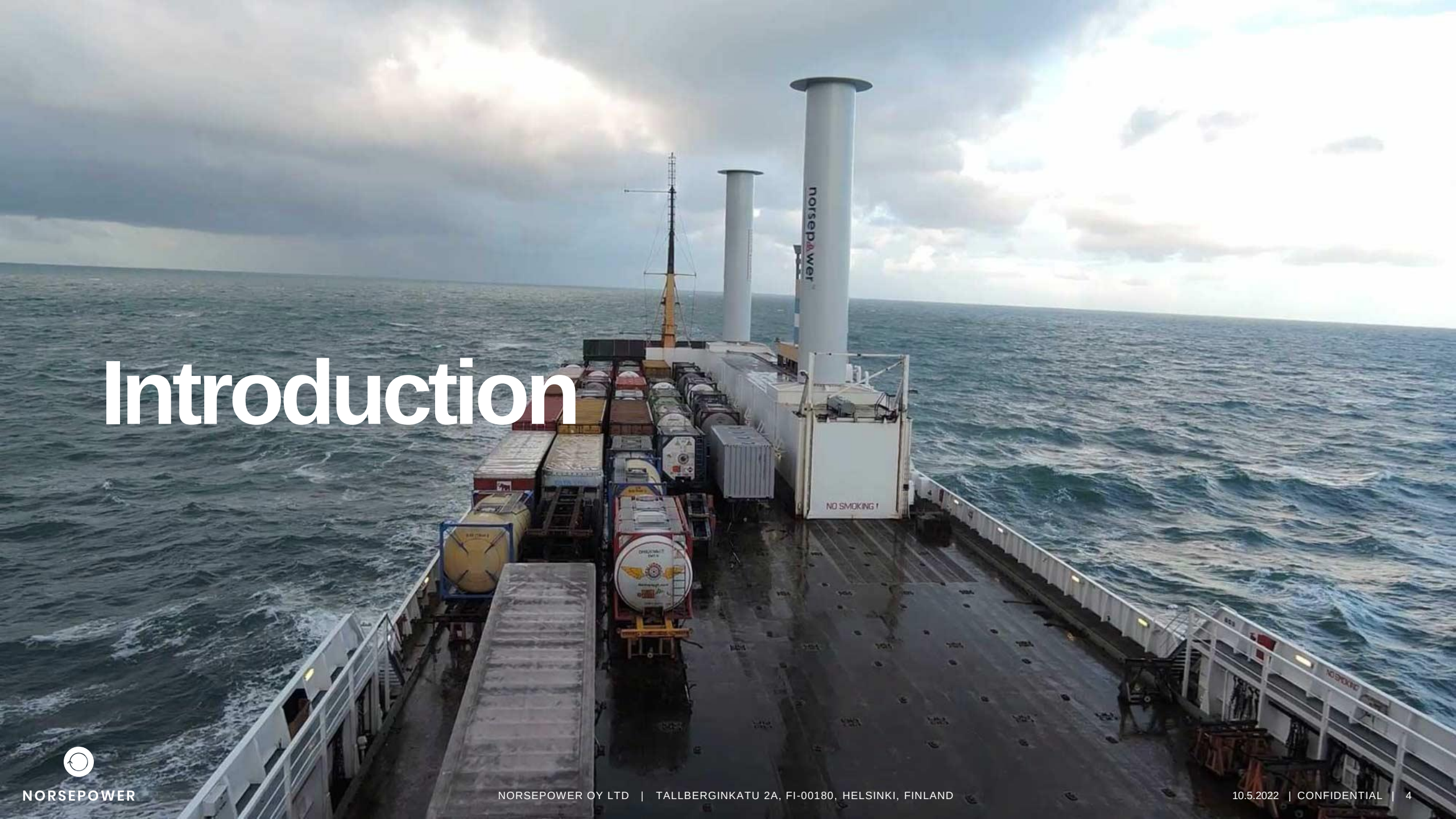
Introduction



Visit https://www.youtube.com/watch?v=5CpwAWBgtxk to see the 1-minute video

Norsepower today

- The first, market-leading, and only commercial provider of auxiliary wind propulsion systems

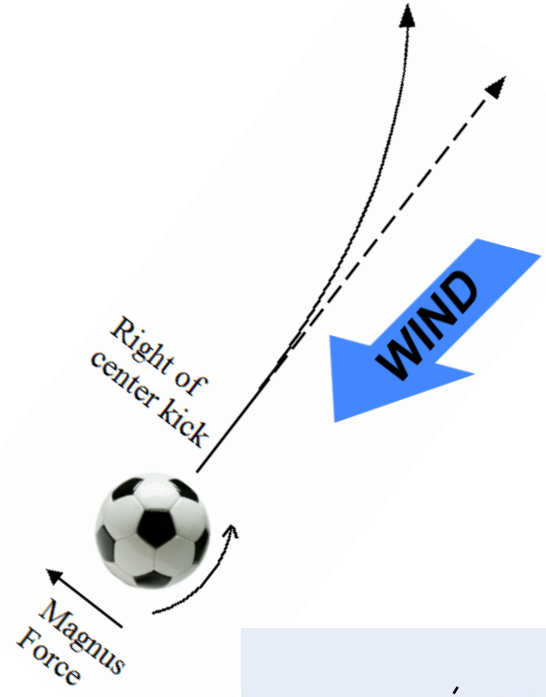
- Rotor Sail technology is already installed on various vessel types with our industry leading client references:
  - RoRo (Sea Cargo, Norway & Bore, Finland)
  - Tanker (Maersk Tankers, Denmark)
  - Ferry (Scandlines, Denmark)
  - Bulk carrier (Vale, Brazil)

- 2021 turnover was 2,5M€
- Order backlog today is more than EUR5M and there are several new deals being negotiated
- First repeat order was received in 2021
- IP has been protected with more than 60 patents
- Based in Helsinki, Finland

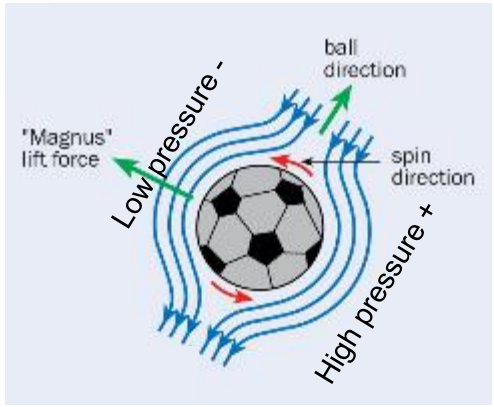
Rotor Sail solution

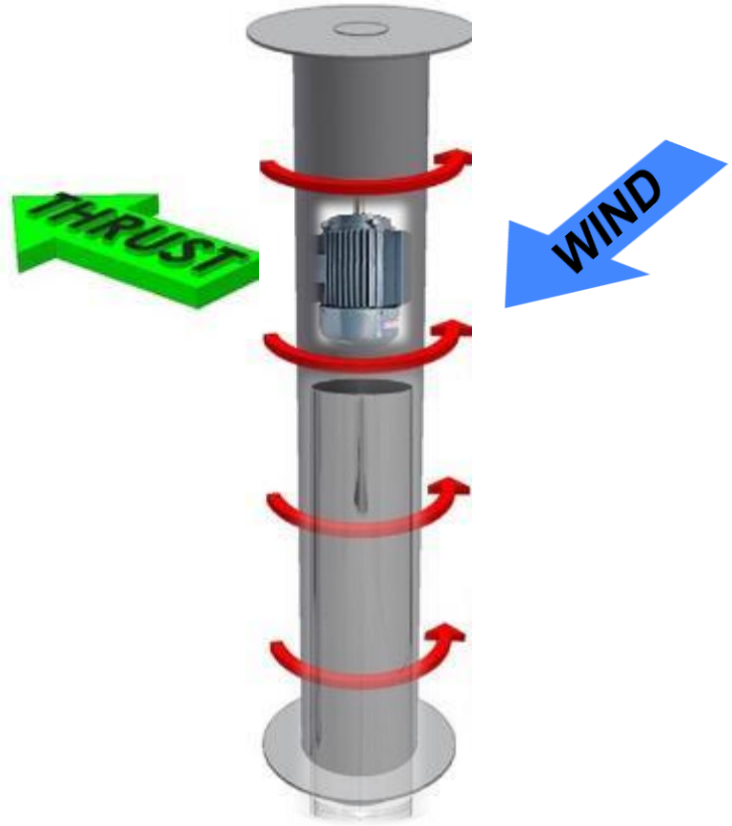
Physics of the Rotor Sail: Magnus Effect explained

- The phenomenon is **most commonly visible in ball games** where **spin is applied** (football, tennis, golf)
- When a spinning object meets relative wind, it results in a **pressure differential**, which creates **thrust** at a 90º angle to the wind



- Scientific undamentals discovered already in the 1920s (“Flettner rotor”)
- Norsepower has modernized the technology – by introducing high-tech materials and automation





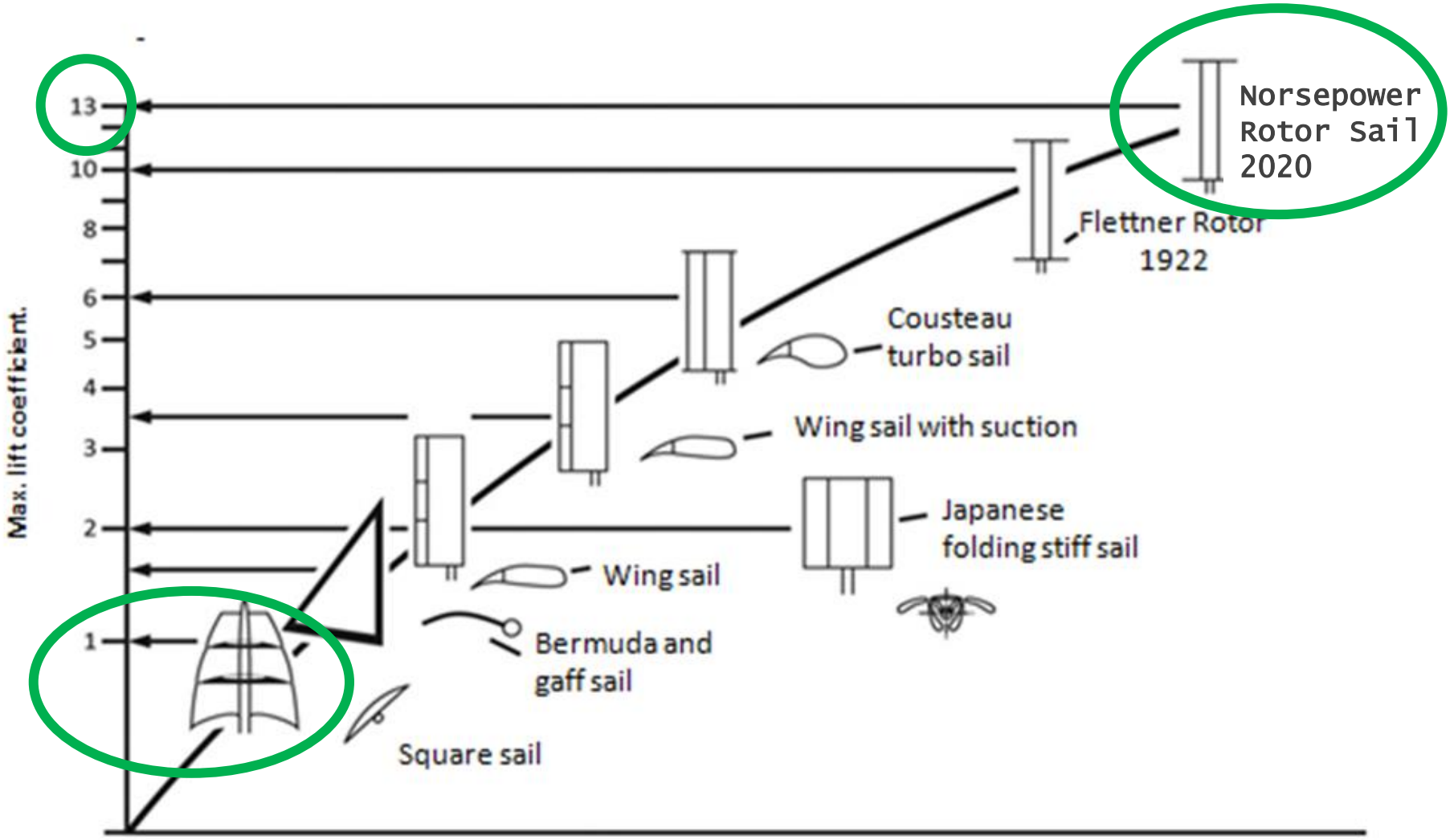
Rotor Sails harness wind energy through a <u>spinning cylinder exposed to wind, creating physical thrust</u>

Using 1x electrical power to rotate the cylinder results in ~14x physical thrust power

Rotor Sail is the most powerful sail in the world

Rotor Sails, in relation to its visible surface area, provide superior thrust in comparison to other sail technologies.

In relation to its visible surface area, Rotor Sail produces >10x more thrust than a traditional sailing ship sail.

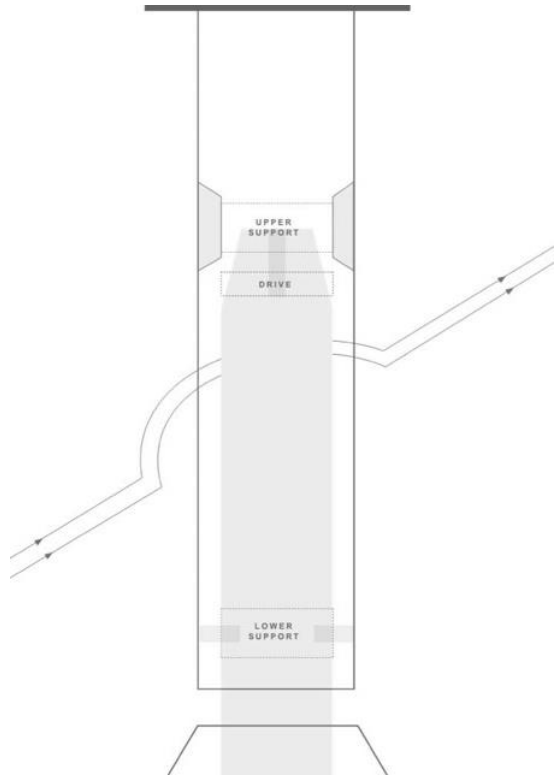


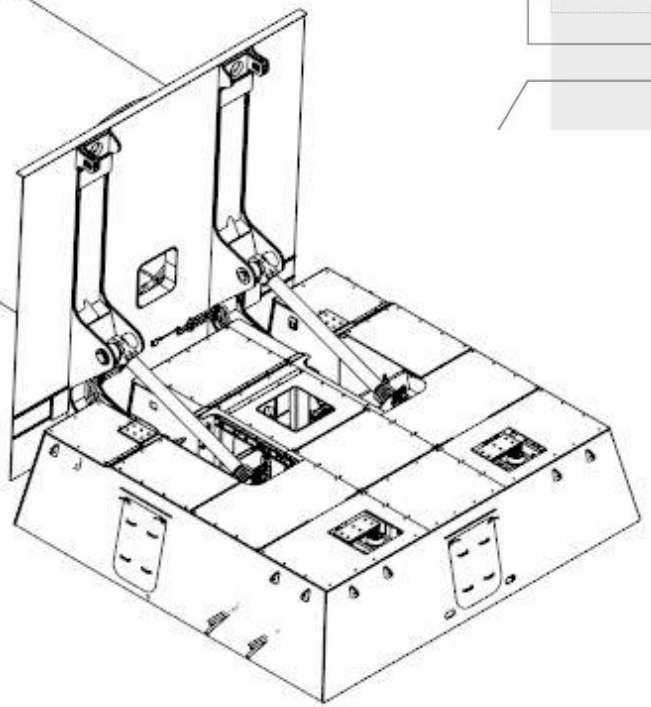
Norsepower Rotor Sails

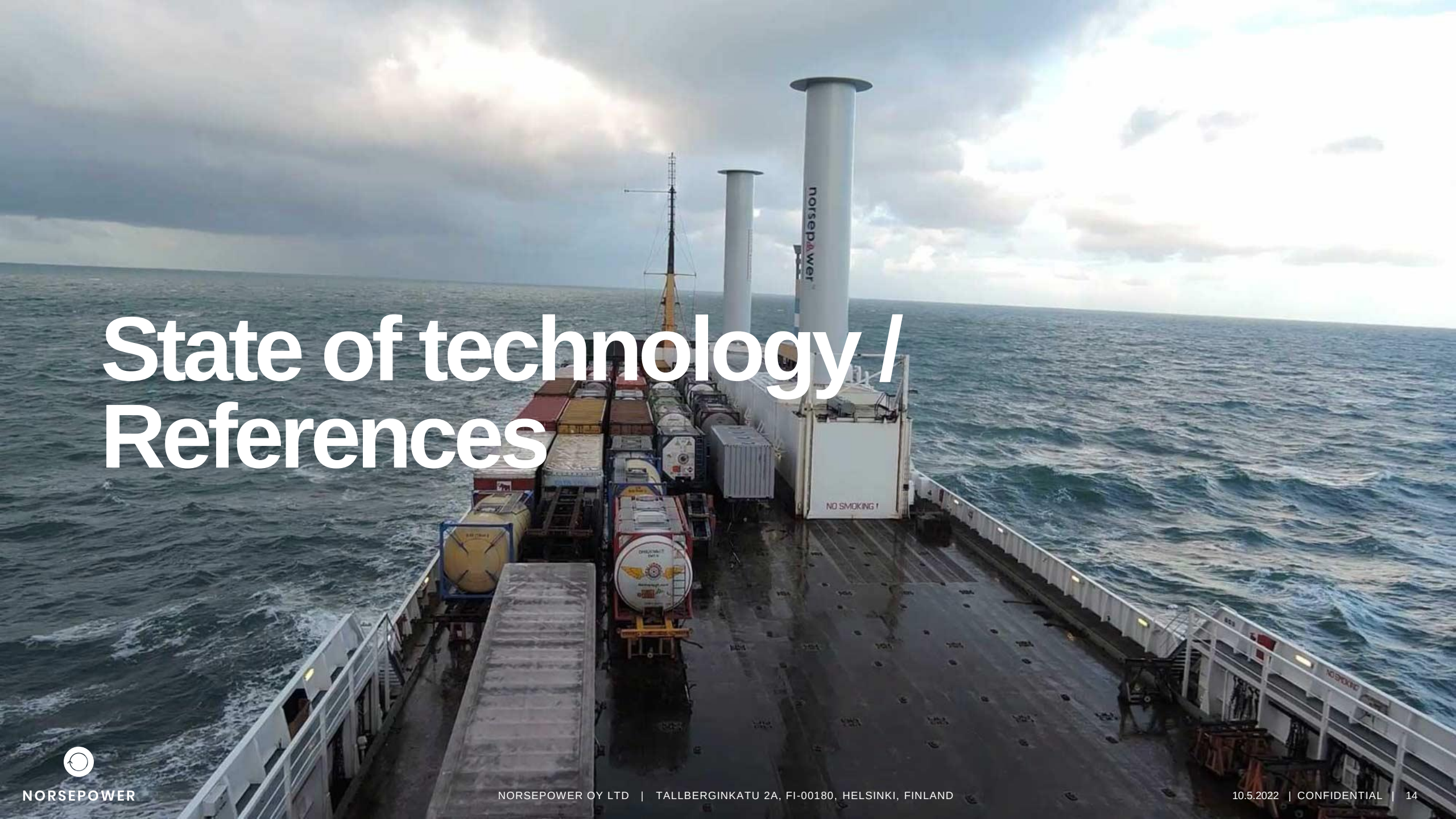
Main components

- Composite rotor
- Internal support steel tower
- Upper support main bearing
- Motor and drive for rotation
- Lower support rollers
- Foundation on ship’s deck
- Tilting option for reducing air draft

Properties	18x3	24x4	28x4	30x5	35x5
Rotor height , m	18	24	28	30	35
Rotor diameter, m	3	4	4	5	5
Weight without foundation, tons	20	27	38	42	59
Speed, rpm	0-250	0-225	0-225	0-180	0-180
Electric motor, kW	30	80	100	115	143
Average el. consumption	15…50 kW				

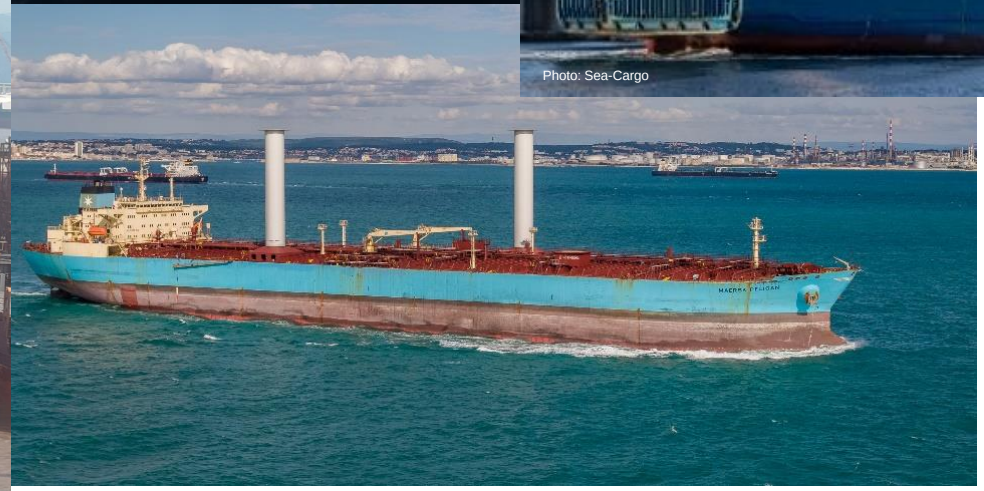






State of technology / References

5 ships, 4 different Rotor Sail sizes, 140.000+ hrs



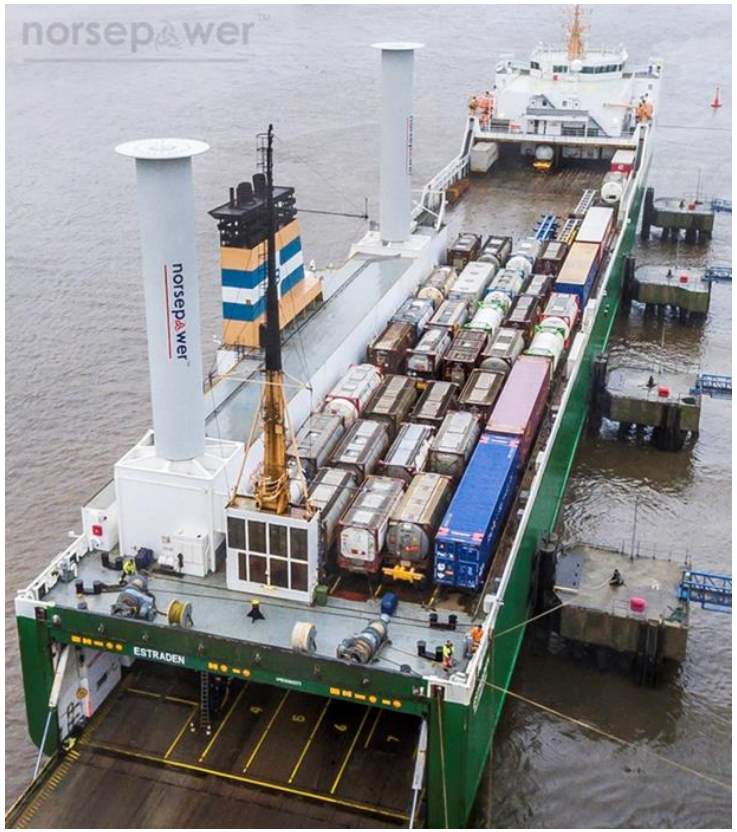
Reference: M/V Estraden, Bore

Technical performance

- Thrust performance as expected
- System availability exceeds 98%
- Noise and vibrations remain at low levels
- The automation system works as intended

Operator experiences

- The rotor has a stabilizing effect on the roll motion of the vessel
- No recognizable effect on rudder angles or leeway
- The system is fully automatic, and the crew can use it after short training



Average annual net savings:	**6,1% (400 t of fuel and 1200 t of CO2)**
Payback period:	**3 years (MGO, 650 USD/t)**

Reference: LR2 tanker Maersk Pelican

- Two 30x5 Rotor Sails were installed as a retrofit in August 2018
- Lloyd's Register has verified fuel savings of 8.2% on actual routes of Maersk Pelican during a 1-year trial period
- Norsepower forecasts up to 20% average fuel savings on routes with favorable wind conditions.

"We see wind technology as one of the technologies that can give us a real breakthrough in reducing CO2 and help us achieve our emission-reduction target of 30% by 2021"

– Tommy Thomassen, CTO, Maersk Tankers.

Average annual net savings:	**8.2%**
Payback period:	**4-9 years, depending on fuel and routes**

Reference: Scandlines hybrid ferry

- One 30 x 5 Rotor Sail was installed in May 2020 as a retrofit on board the M/S Copenhagen, a hybrid passenger ferry.
- According to sea trial results, which were validated by SSPA (Sweden), the project has reduced CO_2 emissions on the Rostock-Gedser route by **4-5%**.
- Based on the successful project, Scandlines has placed a repeat order of a similar 30 x 5 Rotor Sail to sister ship “M/V Berlin”, to be delivered in 2022.

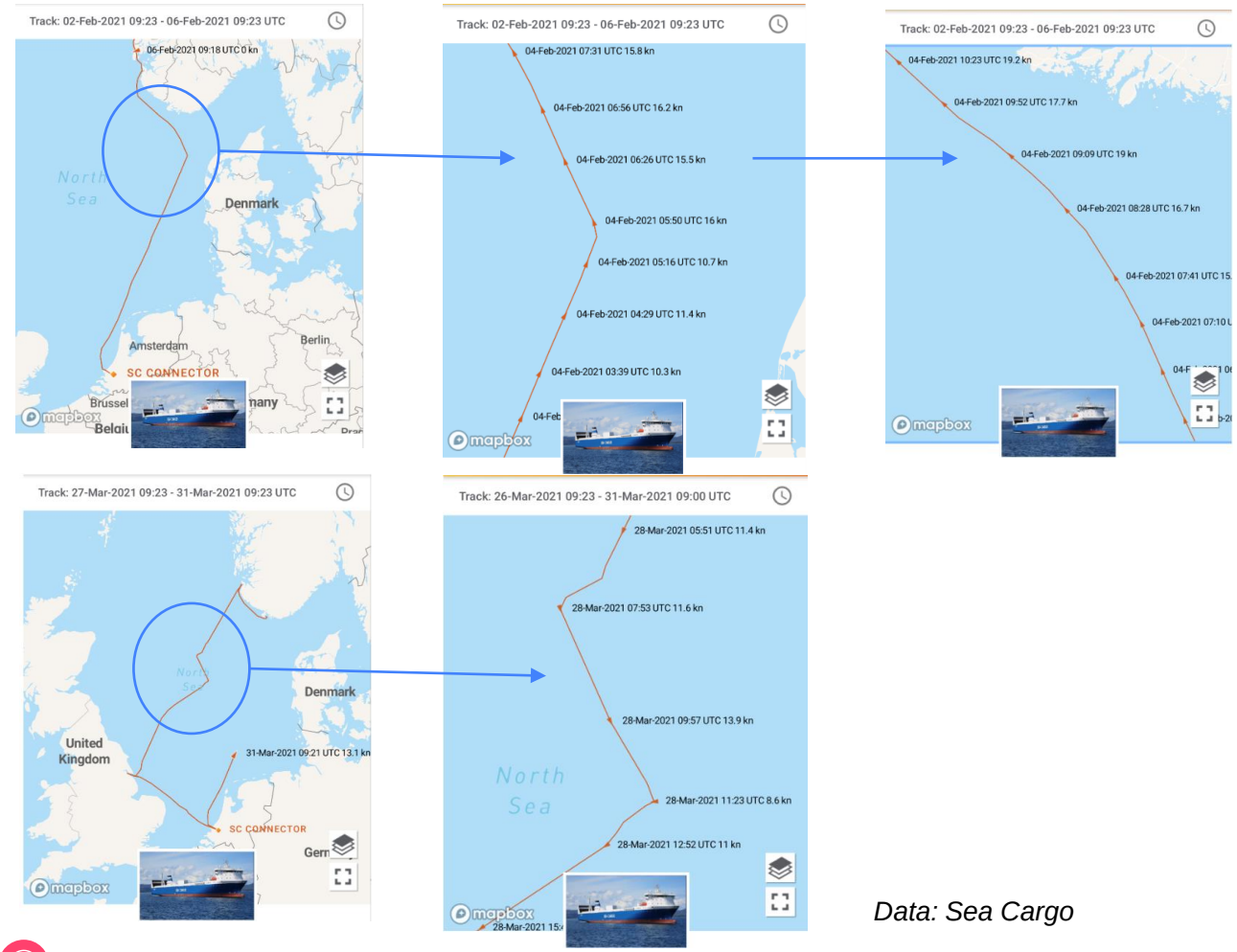
Avda-photo CC BY-SA 3.0

Reference: 325k DWT VLOC ‘SEA ZHOUSHAN’

- Ship is owned by Pan Ocean Ship Management and chartered by Vale.
- Installation of five 24x4 tilting Rotor Sails took place in May 2021.
- Estimated average fuel savings of 8% and annual reduction of 3400 tons of CO_2 on the Brazil-China route.

Photo: Vale

Sea Cargo, SC Connector, *”tall ship sailing”*



Data: Sea Cargo

- *“During testing, the two Rotor Sails on the SC Connector have generated a maximum thrust force equivalent of 8 MW propeller shaft power.”*

- *“The crew of SC Connector has noted that the Rotor Sails have made the seakeeping ability of the ship considerably better by reducing the roll and by enabling higher speed in harsh weather.”*

Large amount of Sail power compared to the ship size bring in subjects that are not that relevant for smaller installations:

- Managing drift
- Steering
- Heeling

All of which can managed with control systems or by other ships systems typically available

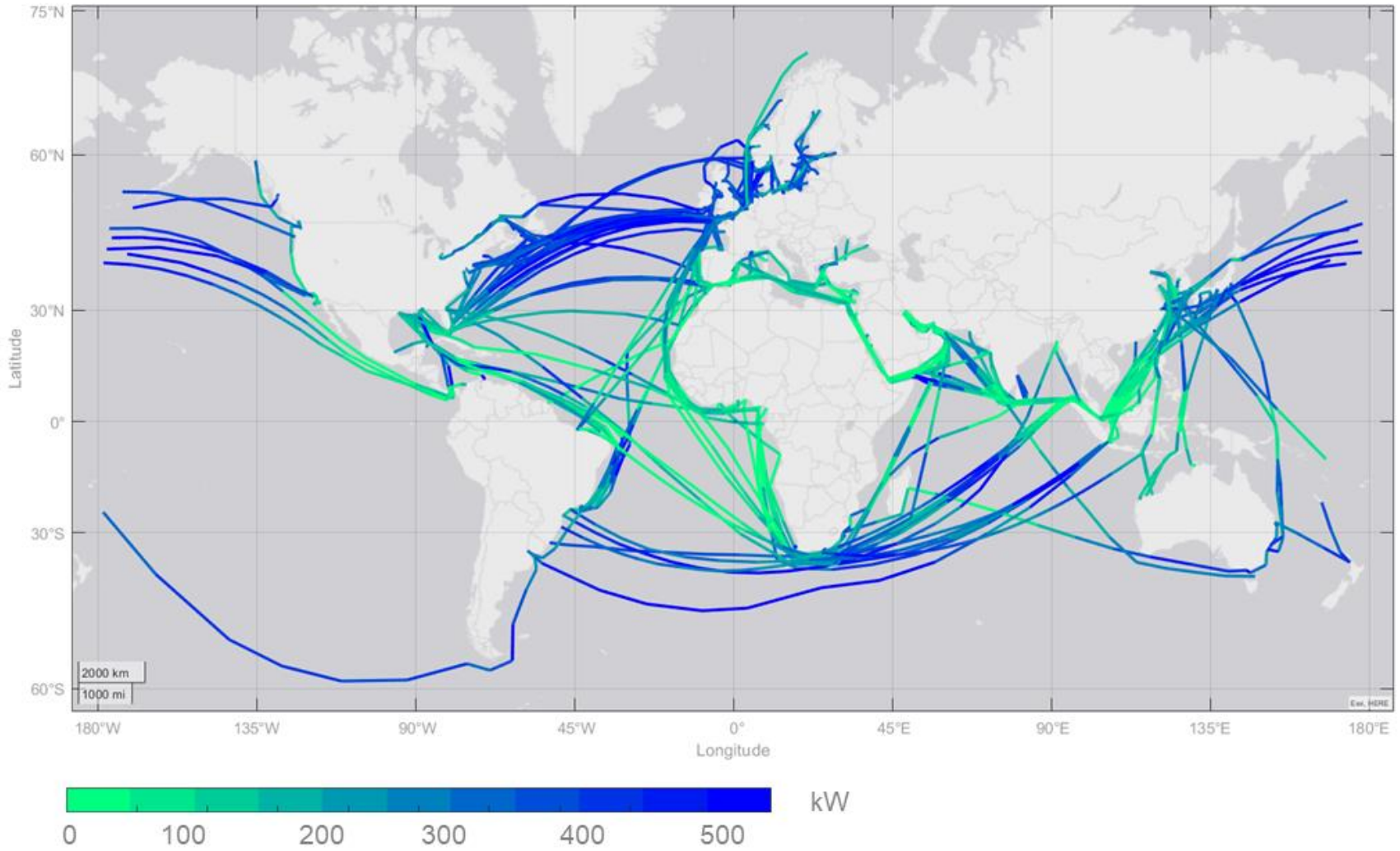
CLdN Ro-Ro vessel ‘MV Delphine’

- The world’s largest short sea ro-ro vessel *MV Delphine* will be equipped with two model 35x5 Rotor Sails with tilting foundations.
- The estimated fuel and emission reduction saving are between 7 to 10% for this vessel, depending on the route.
- Delivery is planned to take place in the end of 2022.

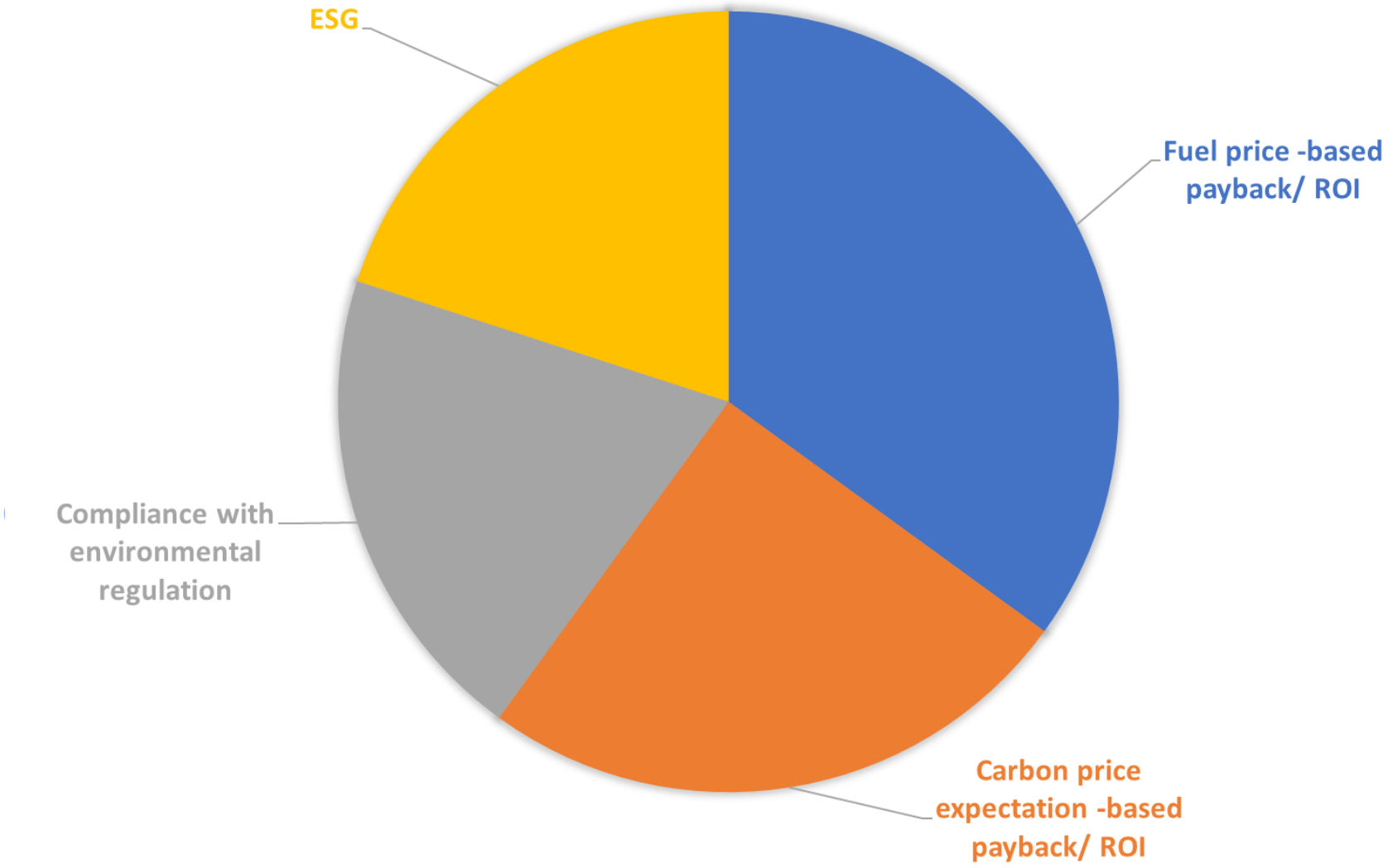
Market outlook and potential

Most of the global shipping routes provide strong and favorable winds for Rotor Sails

Long-term average propulsion power savings for one 30x5m Rotor Sail on a vessel sailing at 15 knots



The demand for Wind Propulsion and Rotor Sails has multiple dimensions and types



Market potential and environmental aspects

- Norsepower's technology is applicable to **both newbuilt ships** as well as existing **30,000 vessels as retrofits.** Average installation of EUR 2M = **EUR 60Bn installation potential**
- Annual fuel savings between **5-25%,** depending on e.g. route & wind conditions
- **Shortest payback** periods today are around **3 years**

- Global CO_2 emissions reduction potential is equivalent to **30 million cars** (82M tons / year)
- Rotor Sail technology is part of the solution to enable zero carbon shipping

Examples of compatible ship types and market size

2 000 ships

13 000 ships

12 000 ships

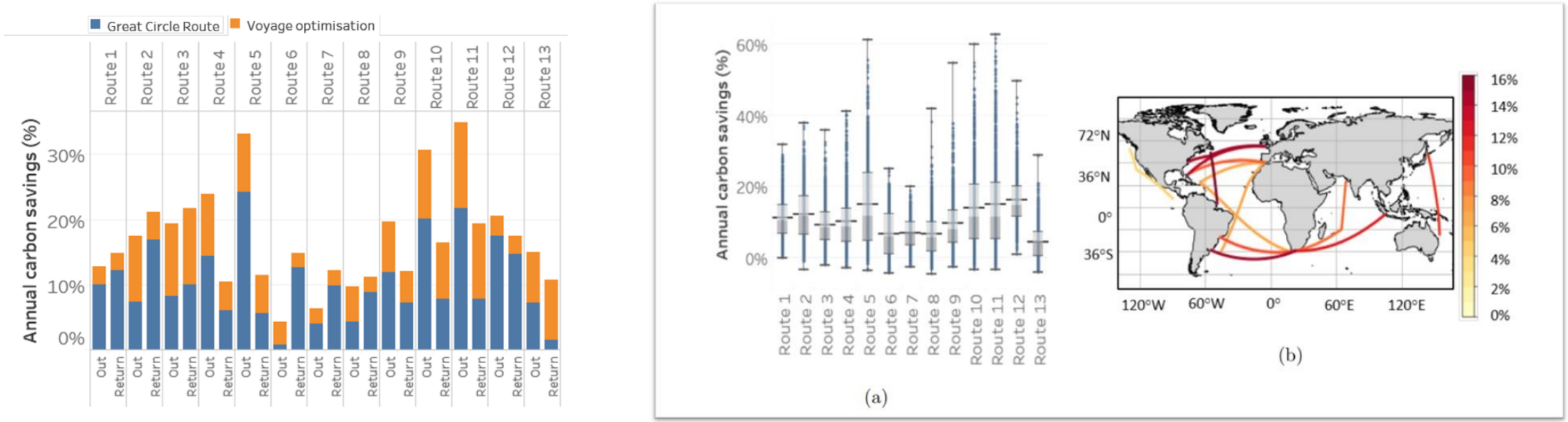
1 400 ships

3 300 ships

Source: Equasis Statistics, The World Merchant Fleet in 2018

Weather routing can in some cases double the Rotor Sail performance

- Independent studies and Norsepower's own simulations have proven, that on typical long-haul routes, weather routing and voyage optimization systems can increase the Rotor Sail performance considerably
- In typical cases, the added benefit of weather routing is between 20% and 60% (percentage of additional average performance of Rotor Sails when compared to shortest "Great circle route" performance)
- NAPA Voyage Optimization software can be included as an option in Norsepower Rotor Sail deliveries



Source: James C Mason, "Quantifying voyage optimisation with wind-assisted ship propulsion: a new climate mitigation strategy for shipping", The University of Manchester, 2021

MISSION

To reduce the environmental impact of shipping through the commercialisation of innovative and modern sail power

VISION

To set the standard in bringing sails back to ocean transportation, and empower shipping towards reaching the goal of zero carbon emissions

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Thank you!

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