Enercon E-Ship 1

A Wind-Hybrid Commercial Cargo Ship

4th Conference on Ship Efficiency
Hamburg, 23-24. September 2013

ENERCON
ENERGY FOR THE WORLD

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Agenda

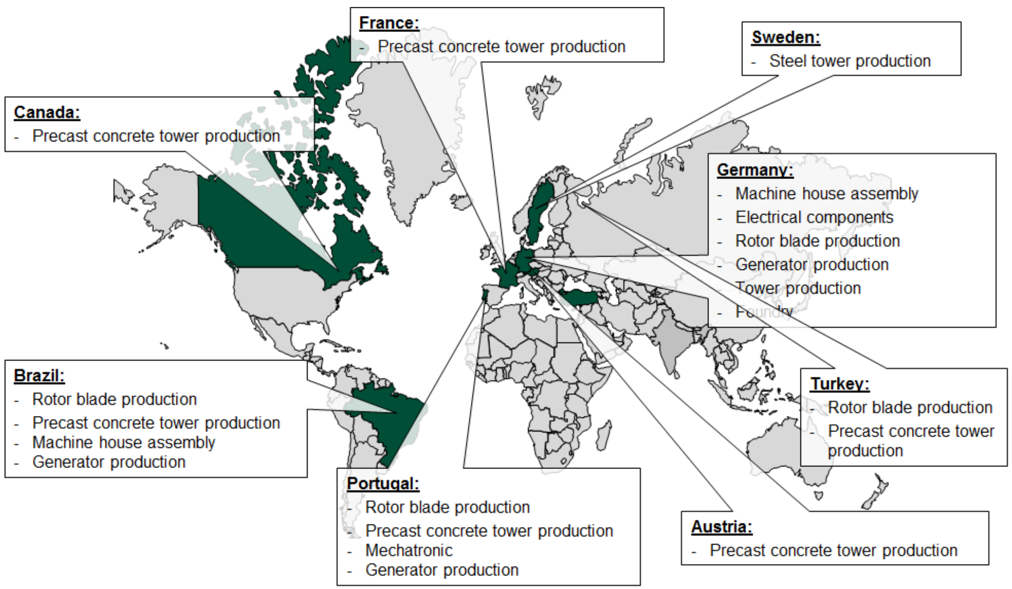
- About Enercon
- Motivation und Objectives
- Features and Innovations
- Evaluation, Experience und Results
- Way forward

Enercon - basic facts

ENCERCON high vertical integration

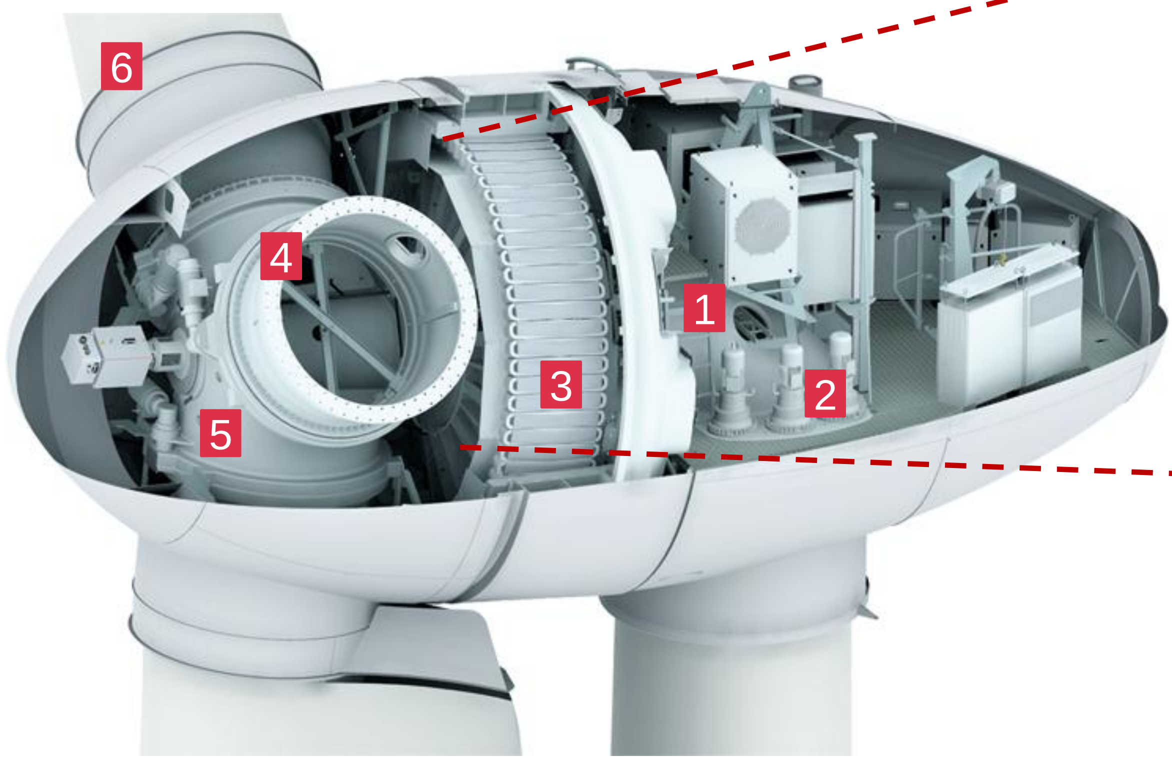
- Rotor blade production, 11 factories worldwide
- Generator production, 4 factories worldwide
- Electrical components, 3 factories worldwide
- Tower production, 11 factories worldwide
- Machine house assembly, 4 factories worldwide
- Foundry, 1 factory worldwide

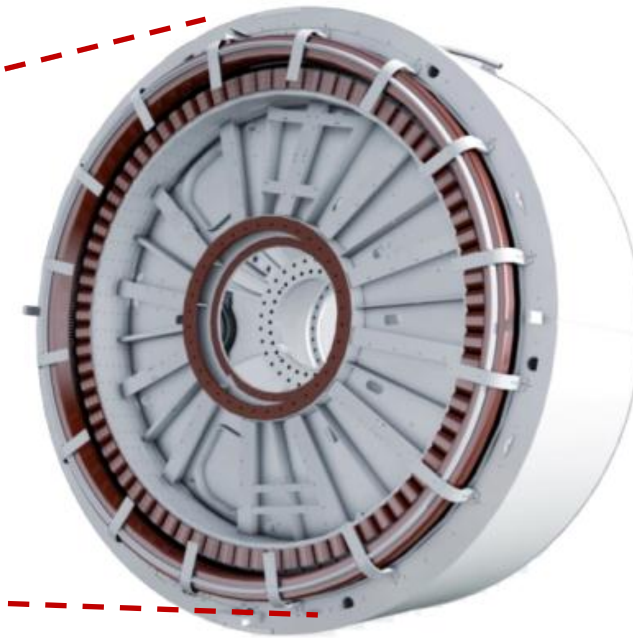
Total production area 820,500 m^2



ENERCON concept

When it comes to performance, ENERCON's **gearless** generator concept is superior to conventional generators.





Advantages:

- Less wear due to slower rotation
- Very little machine stress due to high level of speed variability
- Yield optimized control system High grid compatibility

1 Main carrier

2 Yaw drive

3 Annular generator

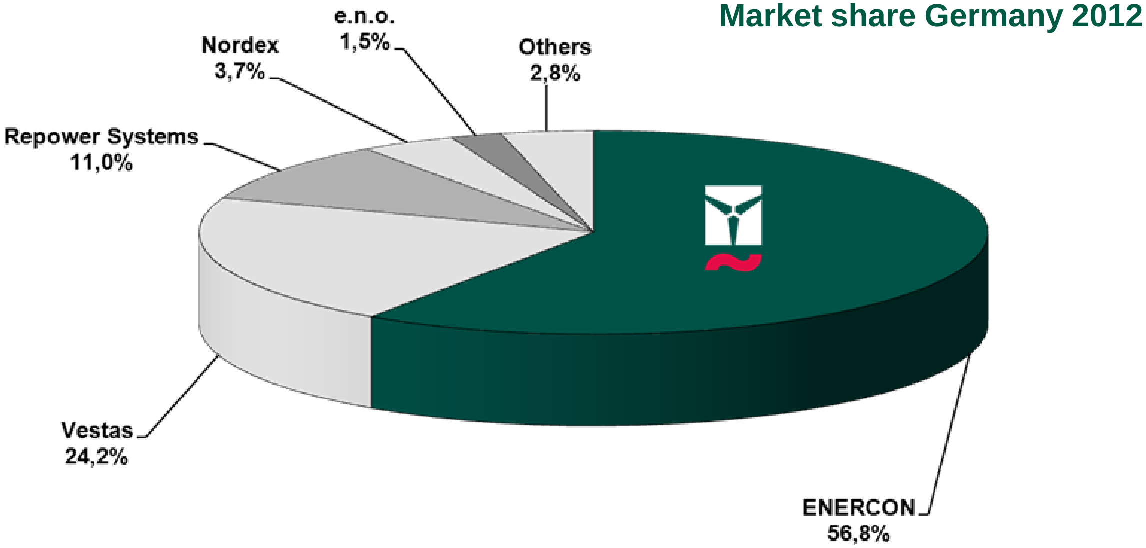
4 Blade adapter

5 Rotor hub

6 Rotor blade

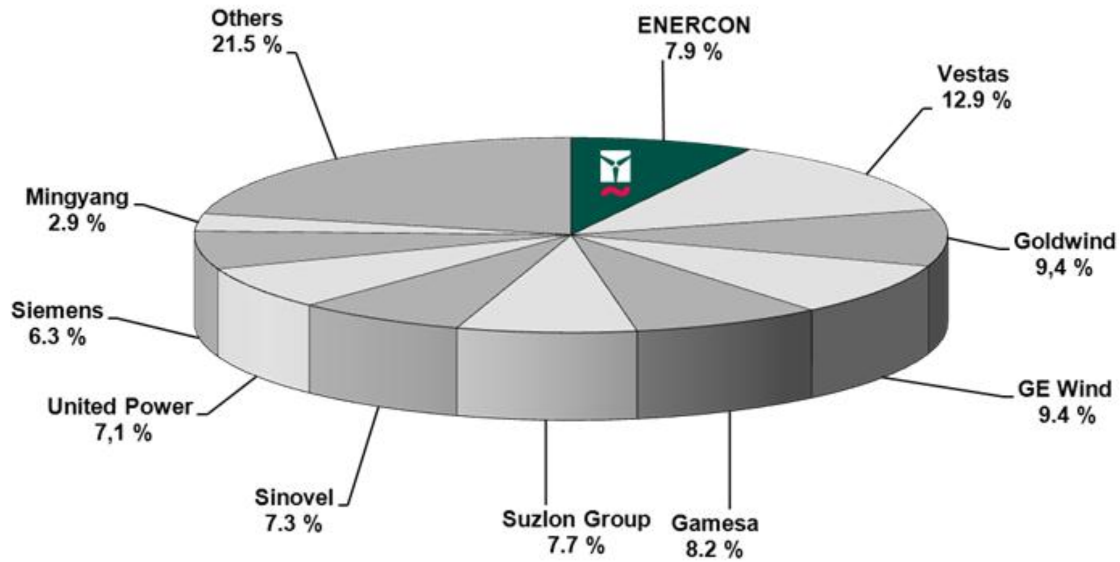
Enercon market share

Market share Germany 2012



Source: Deutsche WindGuard 2013

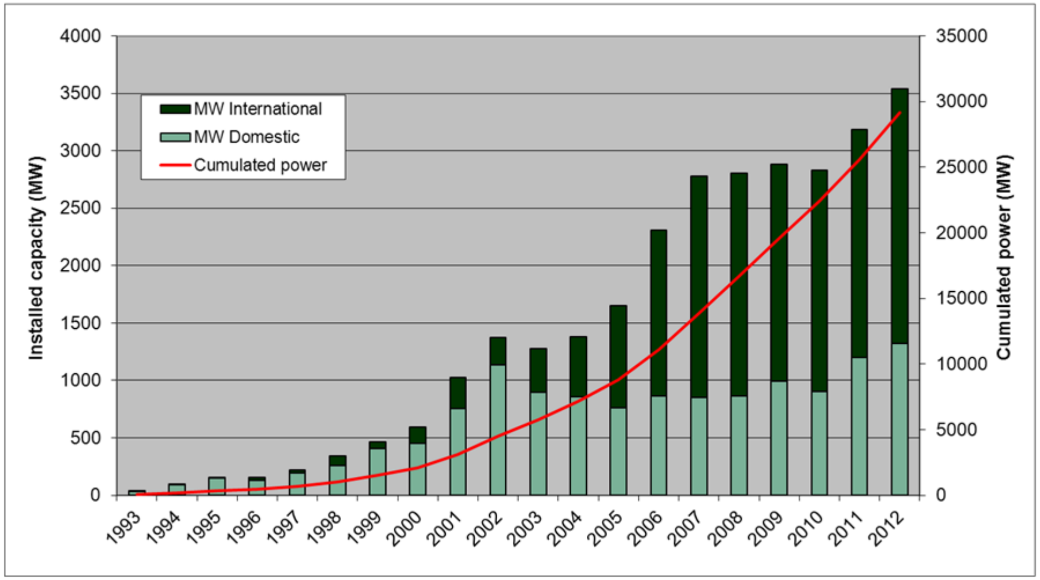
Market share worldwide 2011



Source: BTM 2012

Motivation for E Ship 1

- **Increase demand and special requirements for transport of wind turbines and parts**
- **Conventional cargo vessels not optimal capable for ENERCON freight**
- **Demand for sustainable shipping / Green shipping**



CO2 Emission of shipping yet highly underestimated

CO2-Emissionen der Schifffahrt bisher stark unterschätzt

Text Bild add2any

13.02.2008, veröffentlicht von *Greenpeace Redaktion*

Die Treibhausgas-Emissionen der Schifffahrt sind dreimal höher als bisher angenommen. Das geht aus einem neuen UN-Bericht hervor, der der englischen Zeitschrift *The Guardian* vorliegt.

Wie das Blatt in seiner Online-Ausgabe am Dienstag berichtet, beträgt der jährliche CO2-Ausstoß der weltweiten Handelsschifffahrt 1,12 Milliarden Tonnen. Das entspricht einem Anteil von 4,5 Prozent der globalen Treibhausgas-Emissionen. Allein das weltgrößte Containerschiff, die Emma Maersk, pustet auf den Fahrten zwischen China und Europa 300.000 Tonnen CO2 pro Jahr in die Luft - etwa so viel wie ein mittelgroßes Kohle-Kraftwerk.

© Max Seiler / Greenpeace

Containerschiff beim Anlegen im Hamburger Hafen stoesst Dieselrauchwolke aus. Laut eines UN-Berichtes gehoeren die Emissionen von Schiffen zu einer der groessten CO2-Quellen...

Bildergalerie starten

Source: www.greenpeace.de

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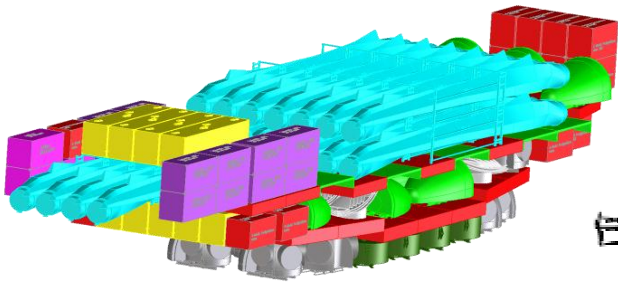
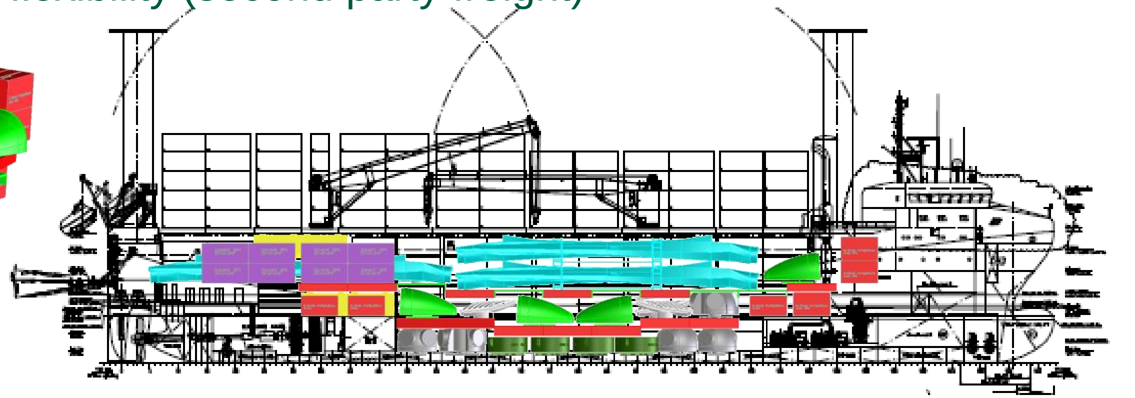
Objectives for E-Ship 1

1. Cargo vessel - optimized for Enercon freight.
Multipurpose features for maximal flexibility (second party freight)





2. Transportation of Enercon freight with a minimum impact on the environment, ecological responsibility as technological leader for renewable energy

3. Research „Green-Shipping“ Technology: Rotor-Sail System, Propeller, Eletric Propulsion Systems

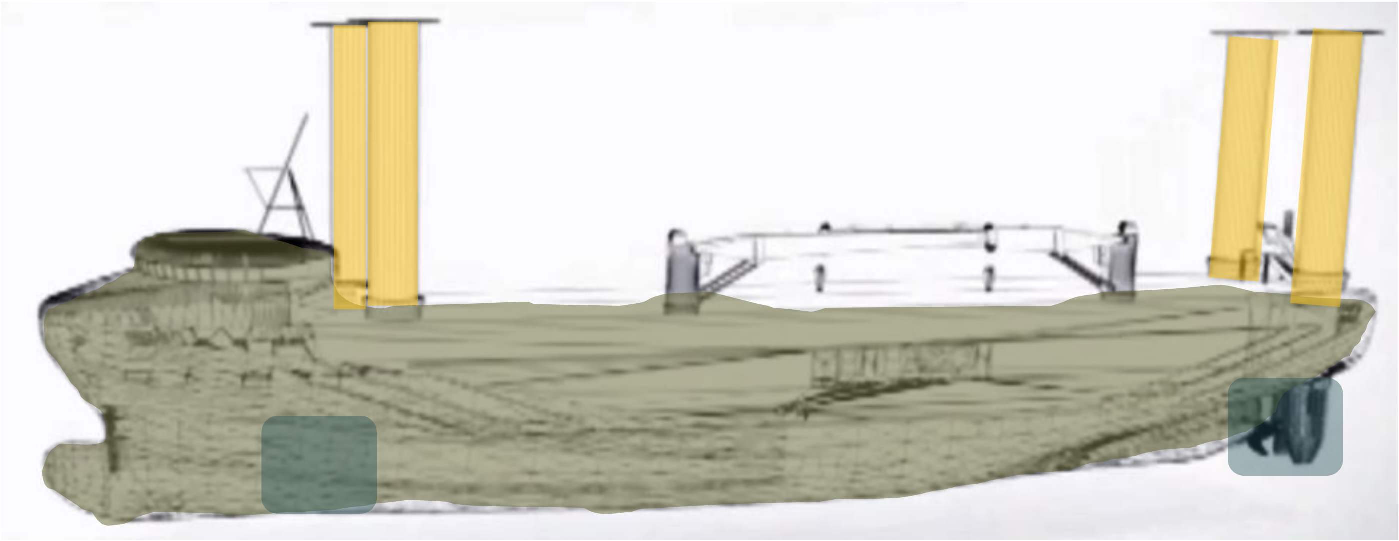
4. Second-Source Shipping Capabilitiy

E-Ship 1

Features

Wind Assisted Propullsion
- Fletttner Rotor-Sail system

Optimized hull and superstructure



Optimized propeller and rudder design

Diesel-Electric Propulsion System

- Diesel-Electrc Power Generation (only with MGO Fuel)
- Enercon Propulsion Motor
- Intelligent PMS (incl. Integration of Rotor Sail System)
- Waste Heat recovery (Turbo Generator, Absorption chiller)

Green Shipping Waste Reduction Systems

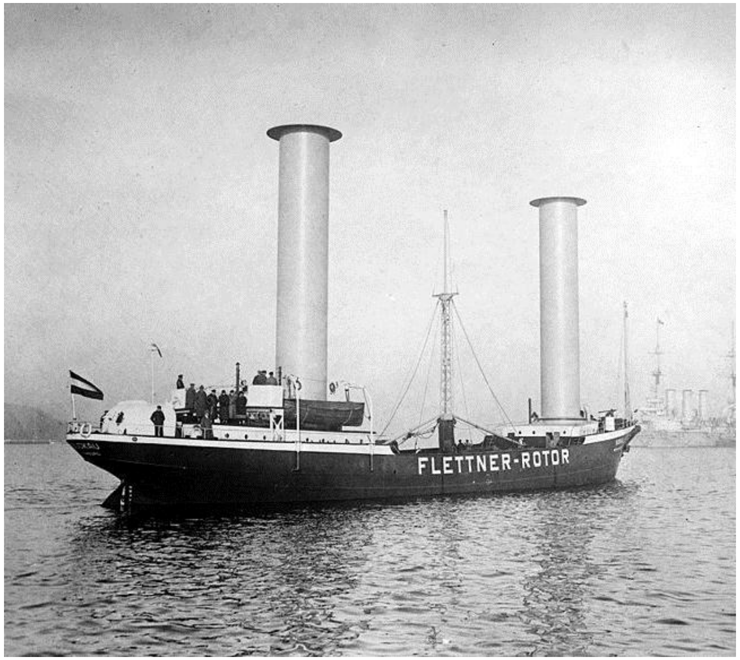
- Biological clarification plant
- Waste Management System
- Ballast Water Treatment Systems
- Fuel / Oil tanks behind double hull
- SCR Catalytic converter for Harbor- and Emergency Power Systems

Green-Shipping Innovation: Rotor-Sail System

E-Ship 1 Rotors-Sail System

Green-Shipping Innovation: Rotor-Sail System / Flettner Rotor

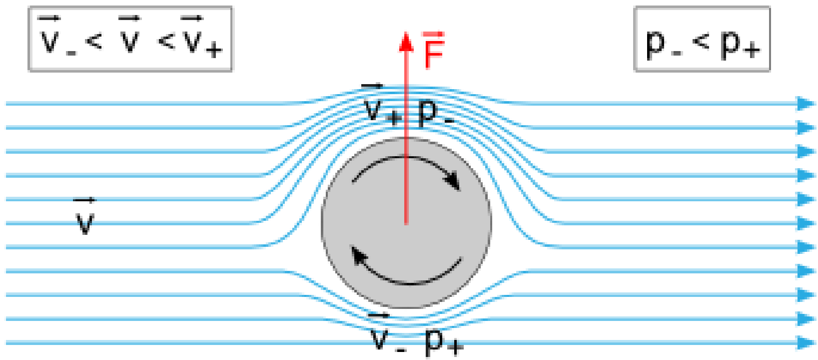
2000: First ideas for a wind-assisted propulsion cargo vessel based on ideas of Anton Flettner

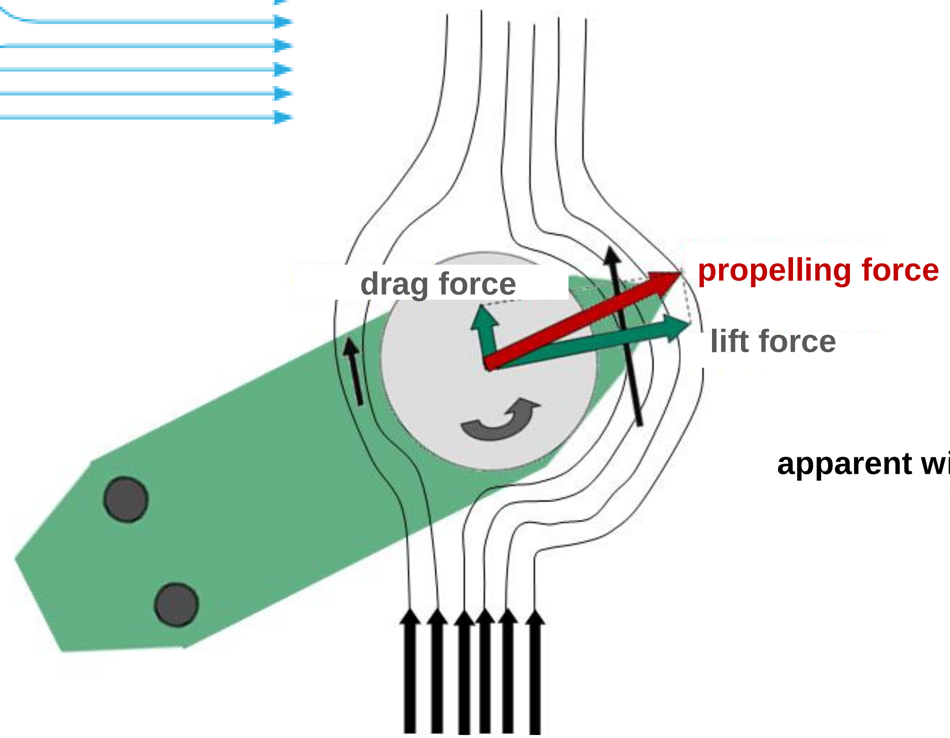


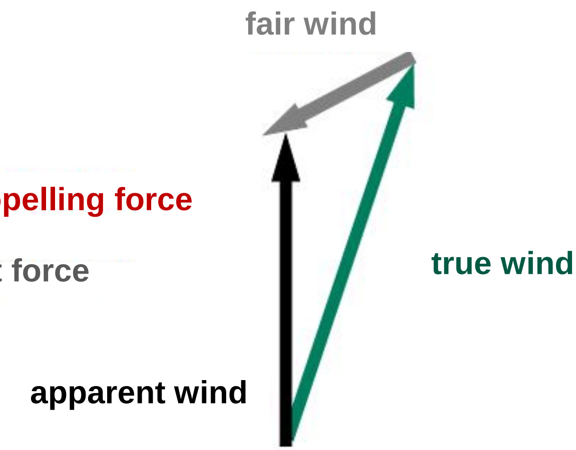
1924 “Buckau” (LOA approx. 54m)
First Trails by Anton Flettner
2 Flettner Rotors 18m/2,8m

1927 “Barbara” (LOA approx. 90m)
Second Trails by Anton Flettner
3 Flettner-Rotors 17m/4m

Magnus-Effect

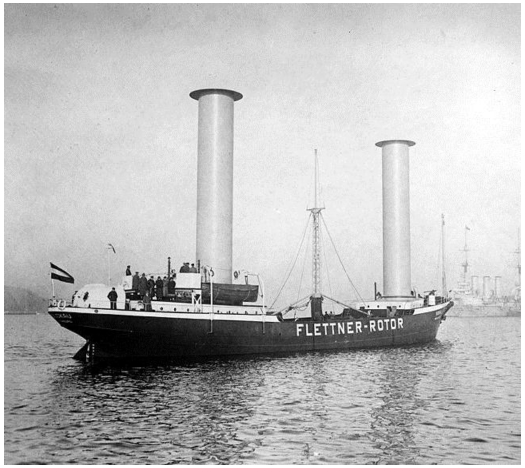






E-Ship 1 - Technology and Innovation

Green-Shipping Innovation: Rotor-Sail System / Flettner Rotor



1924 “Buckau”
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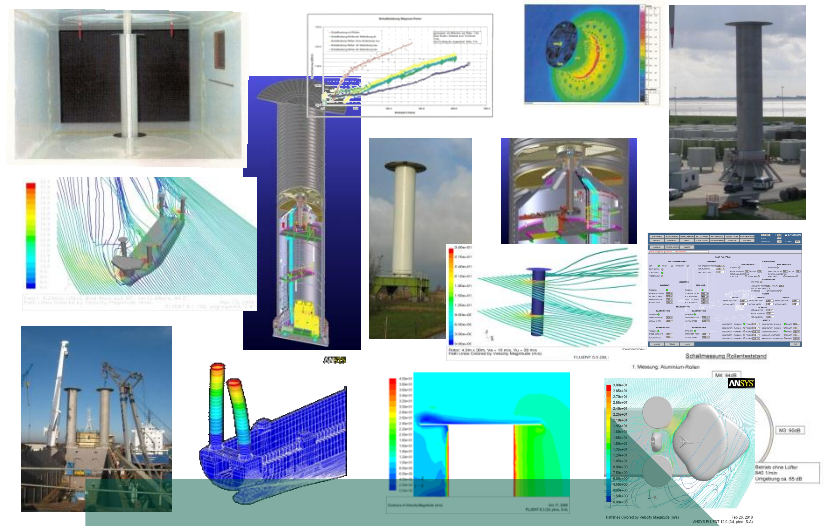
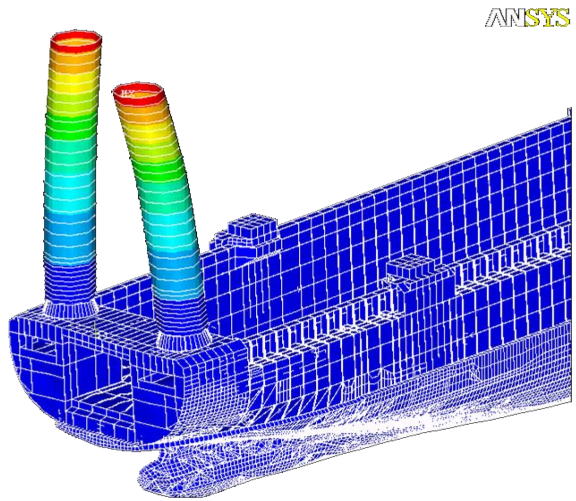
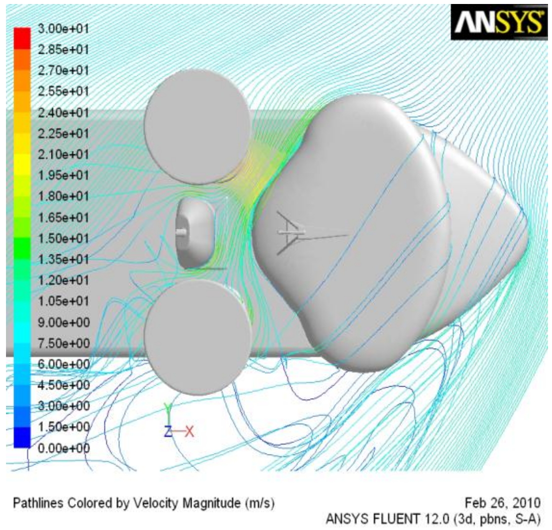


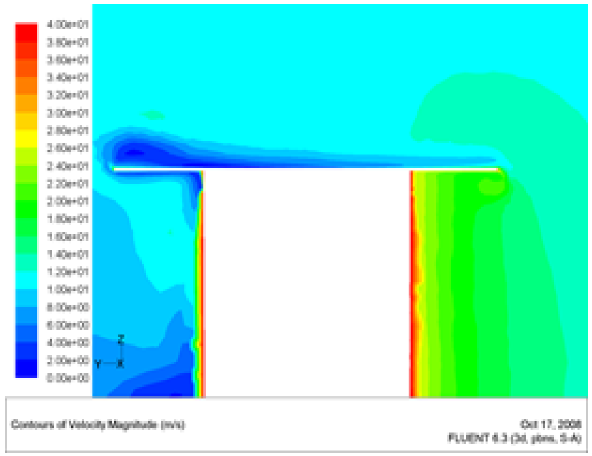
2010
MV „E-Ship 1“

2000: First ideas for a wind-assisted propulsion cargo vessel
2000: Start of research and first case studies
2002: 1st Enercon Test Rig for Evaluation of Flettner-Rotor Technology
2004: Concepts for E-Ship 1 starts to get shape
2007: 2nd Enercon Test Rig for Evaluation and Optimization of Flettner-Rotors, „Full-Scale Test“
2007: Keel laying, Lindenau Werft Kiel
2008: Launching and christening
2010: First Commerical operation of E-Ship 1

Design and Optimisazion of Sail Rotor System





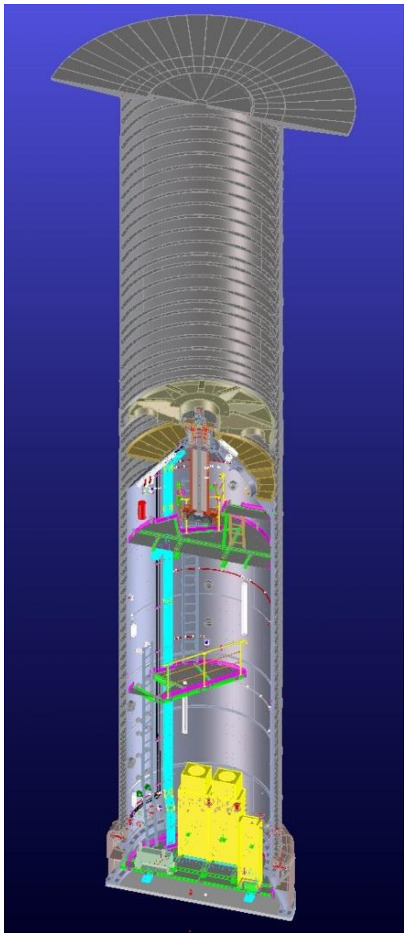


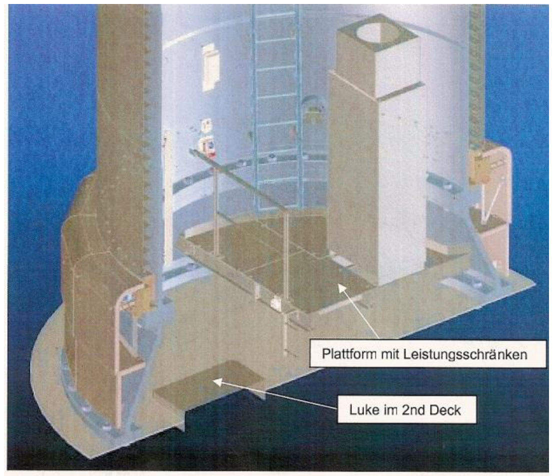
Calculation of fundamental structure and operation parameters:

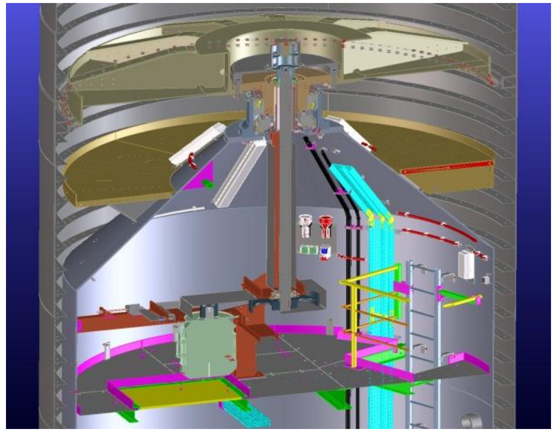
- Static and dynamic structure behavior
- Determination of fundamental operation parameters, e.g. lift (thrust), revolution speed
- Determination of required drive power
- Integration into overall ship structure

E-Ship 1 - Technology and Innovation

Detailed Design of Sail-Rotors







Design

- Static and dynamic loads
- Fluid mechanic
- Drives and control technology

Set-up of Rotors Sails

- Supporting column
- Rotor
- Rotor hub / support
- Drive
- Rotor heating (cover plate)

Operation

- Operation manuals
- Inspection and maintenance manuals

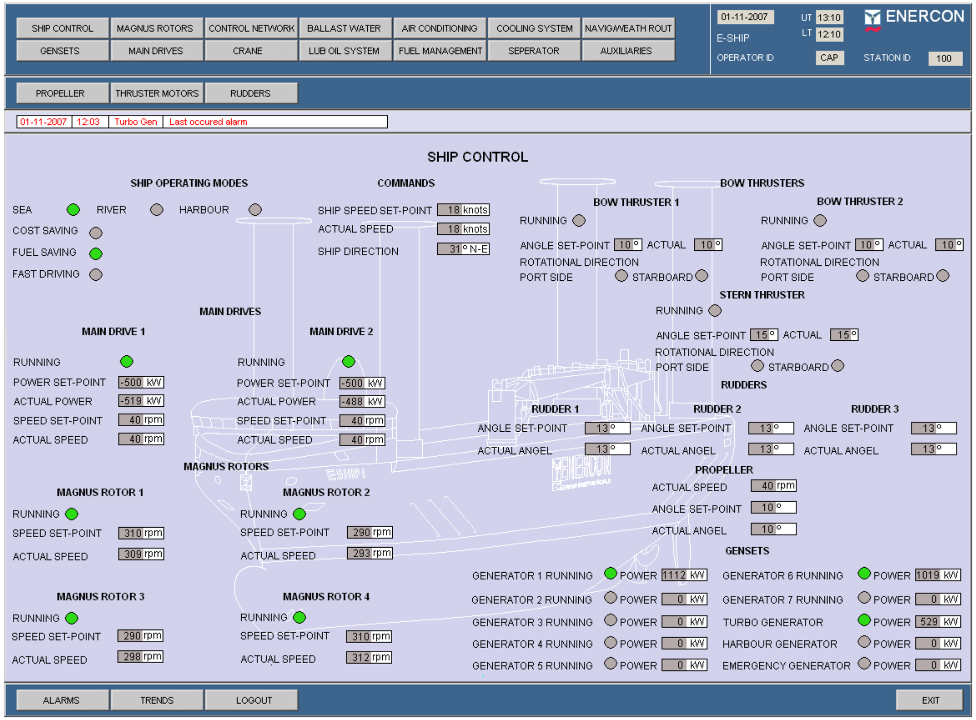
Full scale test and evaluation of Rotors-Sails

Validation and Optimization of Rotors-Sails

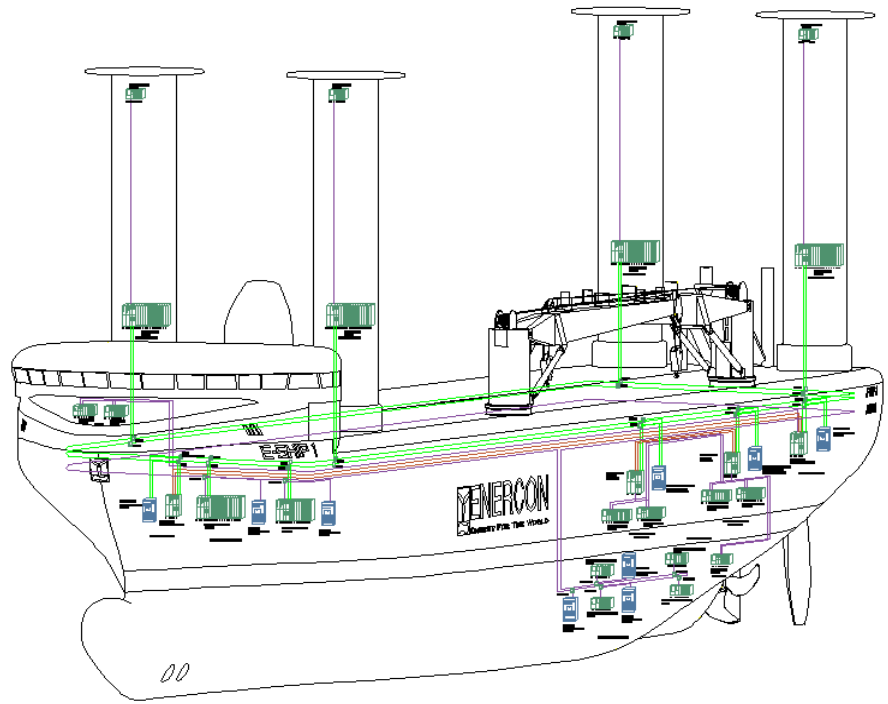
- Measuring of static and dynamic behavior
- Measuring of performance
- Validation of drive-power assumptions
- Validation of thermal behavior
- Optimization of machine elements ,e.g. support
- Optimization of control technology
- Development of solutions for noise reduction
- Balancing of rotors

E-Ship 1 - Technology and Innovation

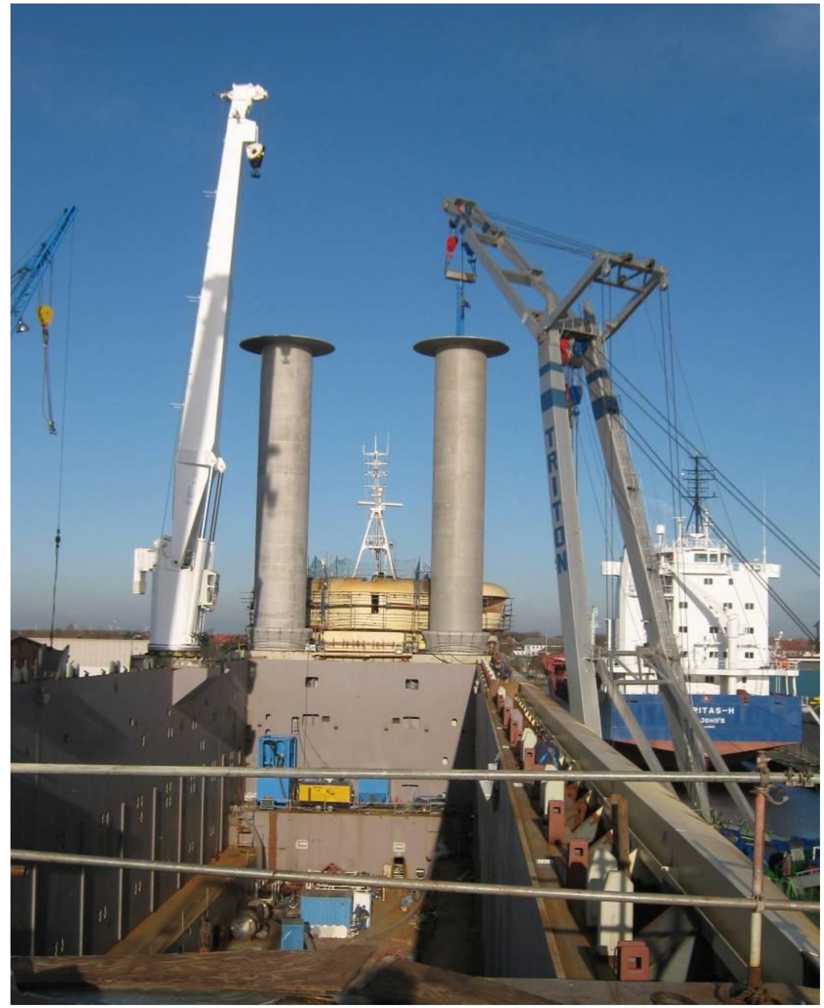
Control Technology and PMS



- Development of Control Technology to enable fully automated operation
- Integration into Power Management System
- Development of sea-worthiness components (GL approved)



Manufacturing and Integration



E-Ship 1 – Evaluation, Operating Experience and Results

Shipping routes

Miles travelled: 150.000 nm

Operating Experience

Behavoir at sea conditions

E-Ship 1 has a very good sea condition characteristic .
The Rotor-Sail System contribute to absorption of sea disturbance.
(aerodynamic damping, gyroscopic absorption).
Safe to operate.

Crew requirements

Control system enables fully automated operation of Rotor-Sail System. Direction and speed of rotation are set Depending on wind conditions.

Rotor-Sail Sytems requires low maintenance

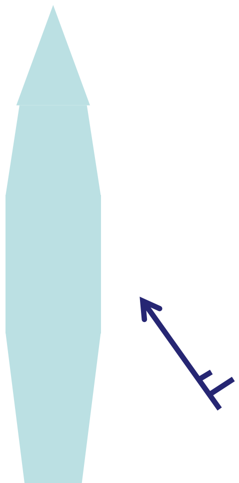
- No special crew know-how / training required
- No additional crew required.

Determination of Power Saving Potential

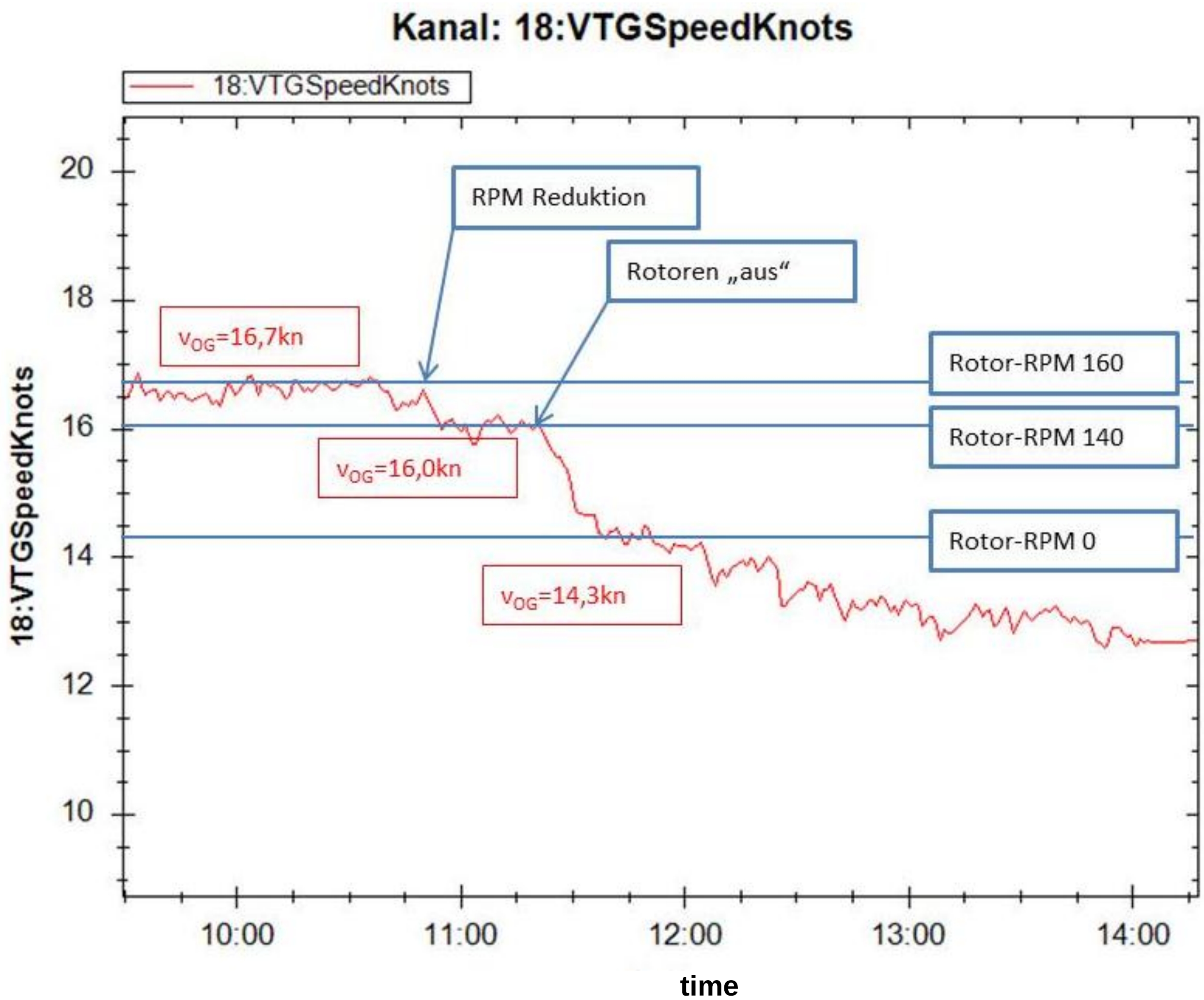
Continuous recording of performance data:

- Vessel speed
- Rotor-RPM
- ➢ dv = f(Rotor-RPM)

Power on drive shaft = constant !

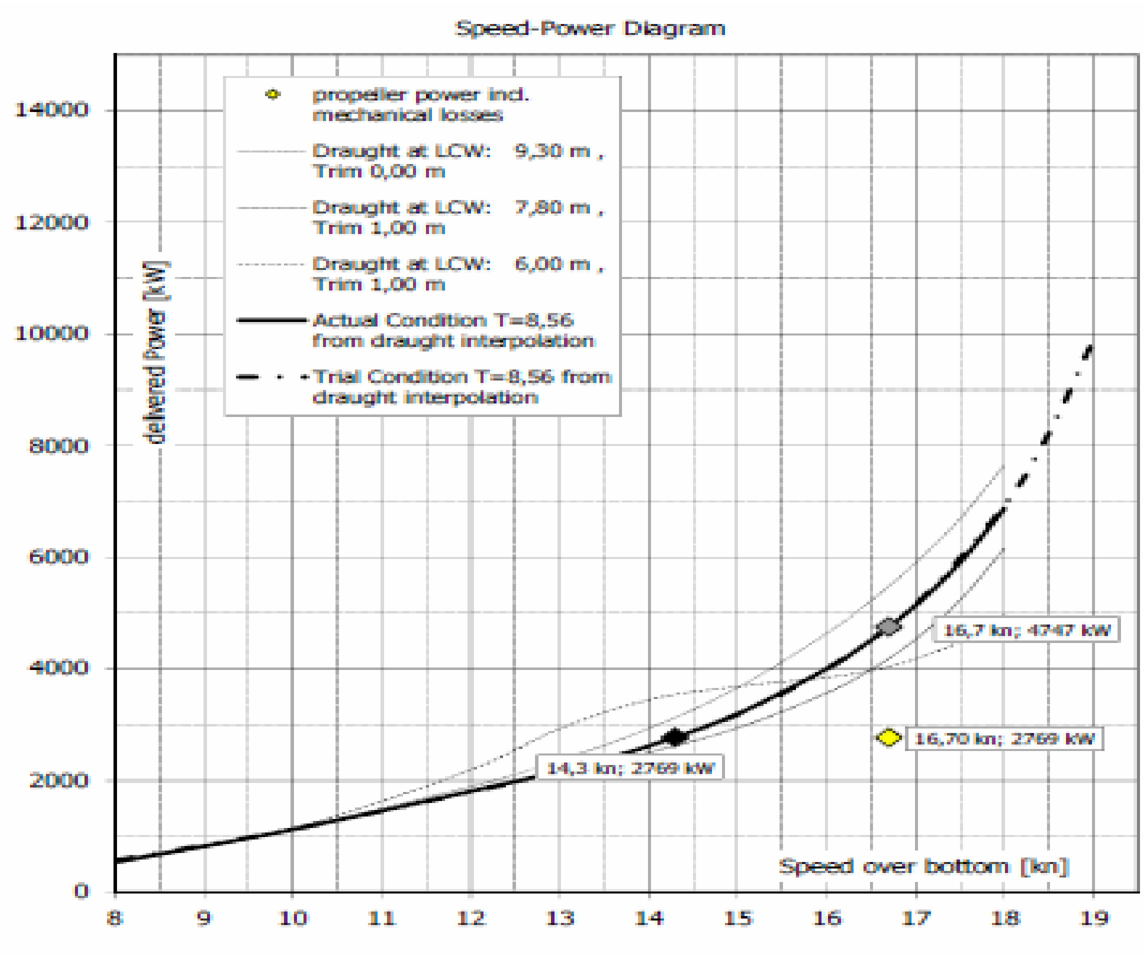


Wind: Bft 6 (12,2 m/s)
Stb abaft (ca. 135°)



Determination of Power Saving Potential

Calculation of saved power (as result of speed difference) under consideration of trail conditions



$v_{\text{with Rotors}}$ = 16,7 kn
P_{Shaft} = 2769 kW
$P_{\text{Shaft theor.}}$ = 4747 kW

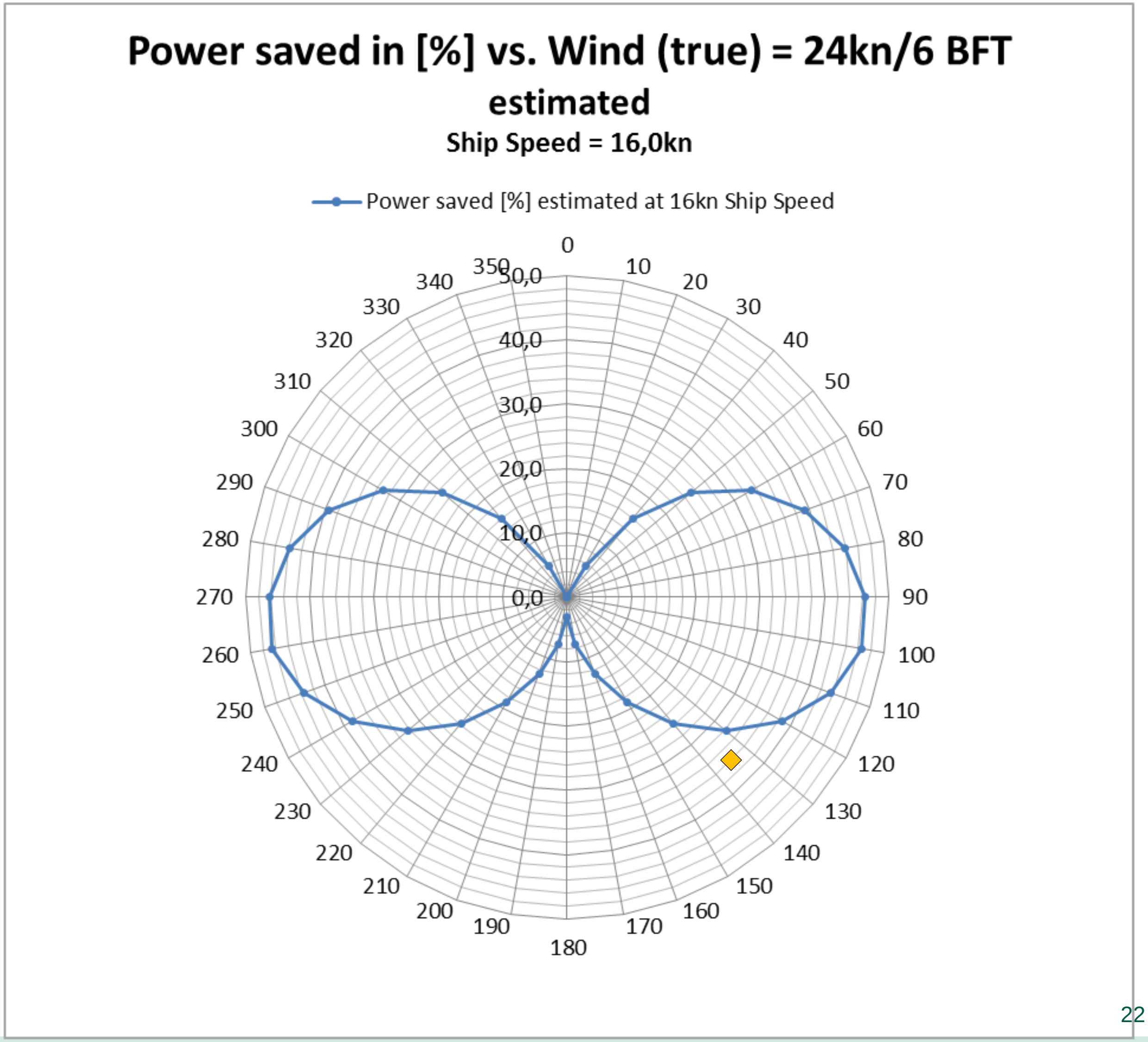
$v_{\text{without Rotors}}$ = 14,3 kn
P_{Shaft} = 2769 kW

delta P_{Shaft} = 1978kW
- Rotor P_{rotors} = 280 kW
netto P_{red}. = 1698kW

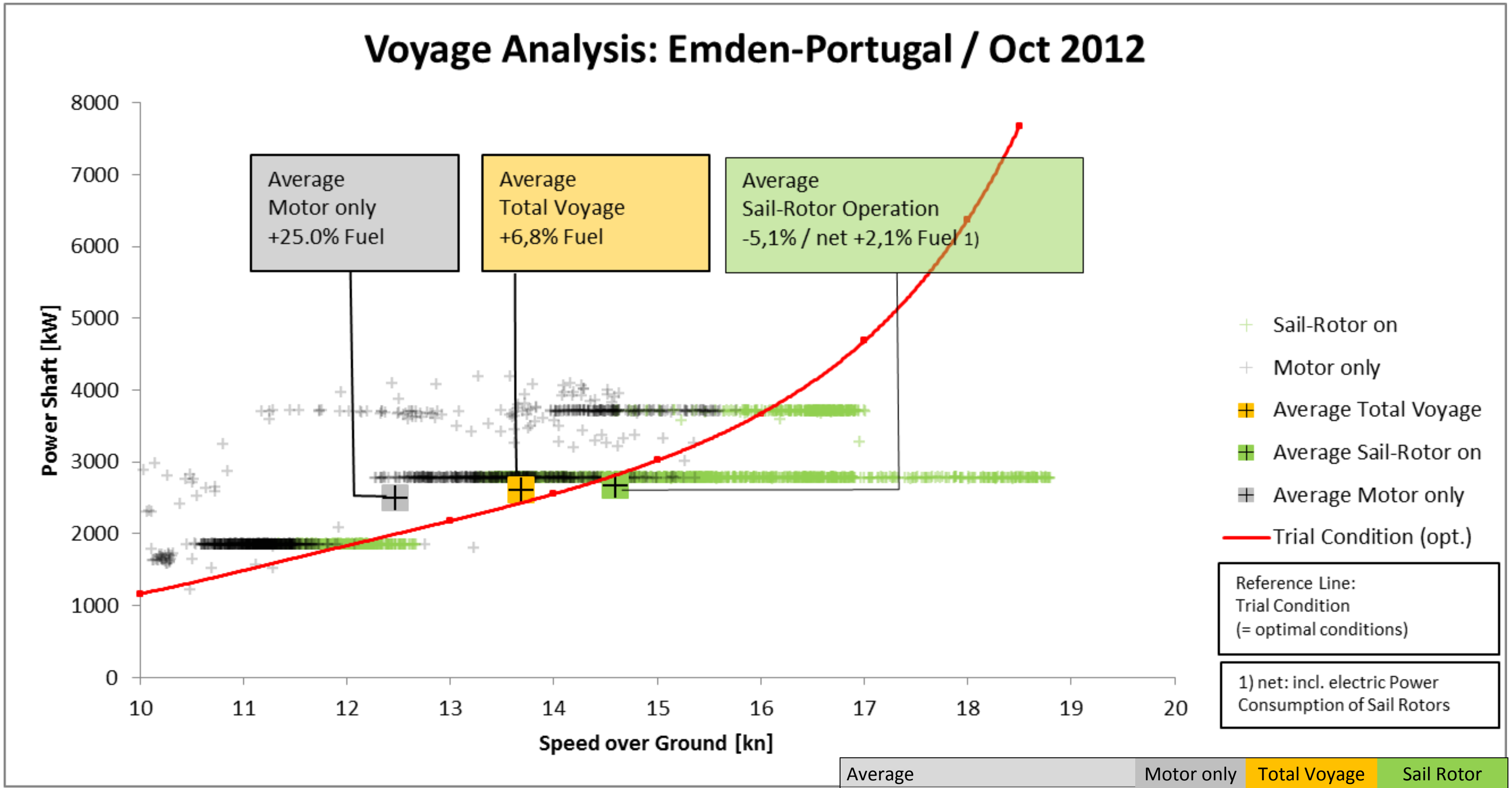
Determination of Power Saving Potential

Rotor Sail CFD Performance Modell:

Calculation with CFD and Validation with measurement data



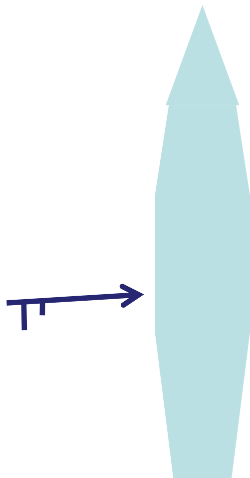
E-Ship 1 – Evaluation, Operating Experience and Results



Average	Motor only	Total Voyage	Sail Rotor
SPEED [kn]	12,47	13,69	14,59
P-Shaft [kW] Trial Cond.	1997	2432	2816
Counts [min]	1519	3569	2050
Time Ratio %	43	100	57
P-Shaft actual [kW]	2497	2598	2673
dP Ref Trial Cond. [kW]	500	167	-143
P el Rotor [kW]			203
dP Ref Trial Cond. net [kW]			60
dP brutto %			-5,1
dP netto %	25,0	6,8	2,1

E-Ship 1 – Evaluation, Operating Experience and Results

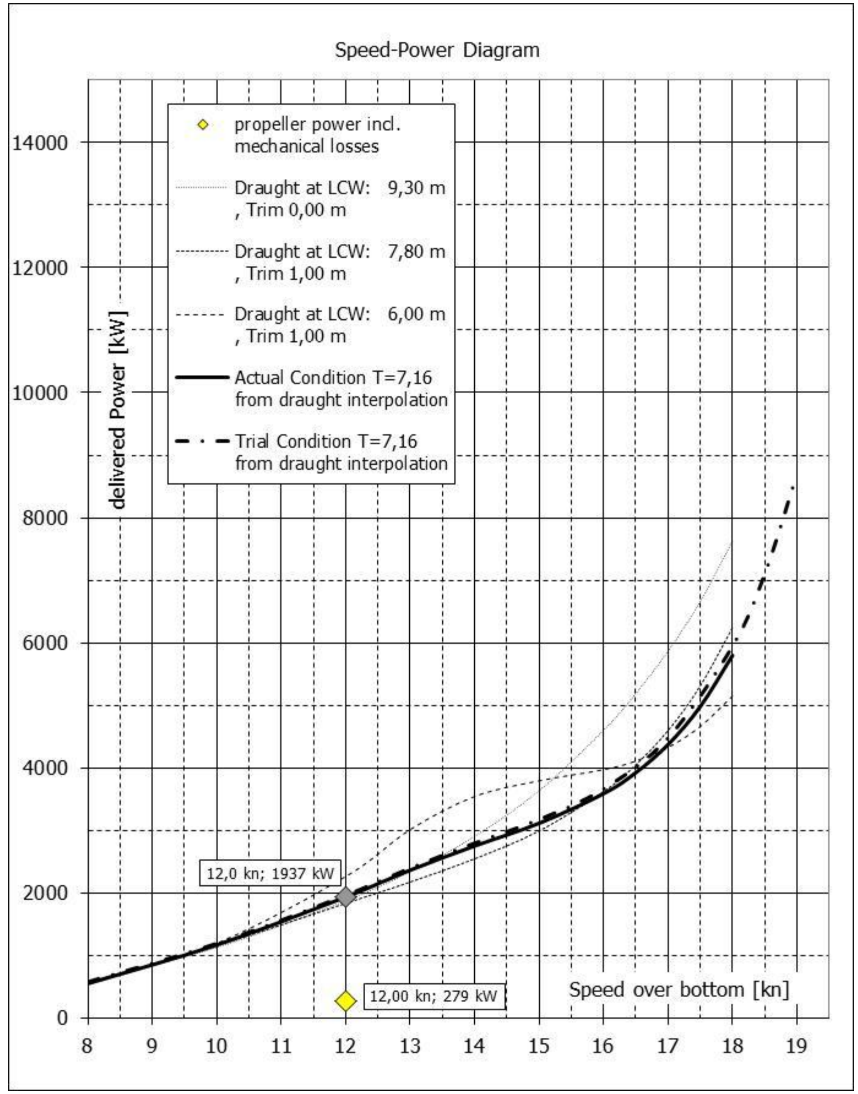
Sailing along Brazilian cost , July 2011



Wind: Bft 6-7 (13,5 m/s)
Portside abeam (ca. -90°)

$v_{\text{with Rotors}}$ = 12,0 kn
P_{Shaft} = 297 kW
$P_{\text{Shaft theor.}}$ = 1937 kW

delta P_{Shaft} = 1640 kW
\- Rotor P_{rotors} = 390 kW
netto $P_{\text{red.}}$ = 1250 kW



Way Forward Enercon E-Ship 1

- Further Evaluation and improvement of vessel operation
- Optimization and development of innovations for maritime applications:
  - Rotor-Sail Systems
  - Control technology
  - Systems for operation support

Thank you for attention!

Publisher:
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