sail

Sail into a sustainable future

Factsheets hybrid shipping

Port Oostende

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The Interreg IVB North Sea Region Programme

European Union

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Introduction

The North Sea Region is the carrier of import and export of freight streams. Over 500.000 people are employed in the shipping industry and ports, hosting seven large ports, handling 1.000 million tonnes per year. However cargo shipping, using heavy fuel, is one of the main producers of polluting emissions. Commercial shipping is the third largest source of climate effecting toxic exhausts after industrial production and road traffic. The decarbonisation transition of the North Sea Region is therefore very relevant for the maritime shipping industry.

Having much new sustainable solutions on the horizon, combined with a tradition of innovation and ambitions, the North Sea Region seems to be an excellent living lab for developing and testing zero emission freight sailing solutions. Building an (almost) emission free freight ship today seems to be possible.

Alternative propulsion systems have high potentials. Hybrid sailing concepts include wings, kites, electricity, biofuel, etc. Expertise and opportunities in hybrid sailing concepts is fragmented over different North Sea regions and needs clustering, validation and upgrading. Economic return of sustainable investments in the shipping market needs further research.

SAIL aims to contribute to:

- **the long-term objective of 'zero-waste emission maritime transport' of the European Maritime Transport Strategy 2018.**
- **the objectives of the International Maritime Organization (IMO) which recognizes difficulties to meet climate targets. IMO regards wind propulsion as a serious option to further explore and to integrate its assets in the Energy Efficiency Design Index for new ships.**
- **the Europe 2020 strategy of smart growth and sustainable growth leading to a Resource Efficient Europe among others modernize the transport sector and promote energy efficiency.**
- **the objectives of organizations like EMSA, HELCOM and OSPAR**

Technology

Technological concept
Wind Assisted Shipping applies modern rigging and optimized hulls for cargo sailing vessels. This rigging include concepts as flettner rotors using the Magnus effect and Dynarig solutions. The hybrid shipping concept 'Ecoliner' was developed by ship design company Dijkstra Naval Architects[1] with the objective to create a prototype of a hybrid cargo vessel. The design uses a combination of:

- Automated Dynarig sails: the entire 3600 m^2 rig can be operated by a single person operating a control panel;
- Auxiliary engine propulsion power;
- An advanced weather routing programme that optimizes the use of wind to cut in fuel costs;
- Optimized hull design for sailing performance;

The Ecoliner uses sails and/ or engine depending on sea and weather conditions and the desired speed. It is a very efficient way of propulsion because the speed gained from the engine results in an increased apparent wind to be used by its sails.

This results in a large speed gain with only a small amount of engine power. Every day under sail means less fuel costs.

1 www.dykstra-na.nl

A couple of days with favorable winds leads to more fuel savings than more days with less wind power, according to recent findings.

Specifications

Technical ship characteristics hybrid dynarig vessel (Ecoliner):

Length	138 m
Draft	7.2 m (no keel)
Airdraft	62.5 m
Deadweight	8210 tonnes
Gross Tonnage (GT)	7548 tonnes
Maximum heel	10 degrees
Estimated maintenance period	Renewal of sails and rigging every 5 years
Maximum access because of air draft	Panama and Suez Canal
Engine power	Suggested 3.000 kW

Both towing tank and wind tunnel tests were performed for the Ecoliner during the SAIL project. Based on these tests, rig performance, loads and hull forces could be determined. The maximum optimal ship length for an Ecoliner is about 200 meters. This is based on the current available performance data. New designs, new materials and first experiences may lead to application of Dynarig technology on larger sized vessels in the future.

Hybrid shipping market opportunities

Niche market

Wind Assisted Shipping (WASP) is most feasible for smaller sized vessels (Handy Size) as the dimensions of a ship limit the use of sails on larger vessels up to about 15.000 DWT or 200 meters. In addition, the most optimal routes for hybrid shipping are the sea lanes compatible with the larger trade winds, such as show on the map for the Atlantic ocean.

Early new results also suggest viable short sea routes in the North Sea and Mediterranean. The Baltic is of interest as part of a greater voyage, but its access is limited due to several bridges in the Kieler Canal which bring height restrictions.

Drivers
WASP economical drivers are mainly the fuel price (over 50% of total costs) and incentives and awareness to green the economy. Supporting factors are IMO and EU policies and subsidies for the first real-life experiments. Knowledge and technical requirements are meanwhile tested and established.

Hybrid shipping helps tackle exhaust limits in (S) ECA zones. The existing ECA in the US Caribbean and East Coast area include both SOx and NOx requirements. The North Sea ECA only includes SOx reduction requirements and is likely to contain NOx requirements within 5 to ten years.

Potential applicability
Given cargo handling operations, desired service speeds, risks and exposure effects, WASP potential vessels are likely to include dry bulk carriers, tankers (chemicals, juices, other liquids), passenger cruise ships and RORO (cars). Second, piece goods and project cargo may be of interest. Third, self-loading vessels carrying cranes may be of interest to deliver cargo and containers to less equipped peripheral ports in the developing world or to isolated islands. The table shows potential suitable cargo for hybrid shipping which are compatible with the trade winds.

Policy and regulation of hybrid shipping

Emissions from shipping are expected to increase considerably in the forthcoming decades. In a business as usual scenario, they are expected to double within 25 years and be around be four to five times higher by the year of 2050.

The diagram[2] shows that the current policy measures (being Monitoring, Reporting and Verification) taken by both the EU and IMO will not significantly reduce CO2 emissions from shipping in Europe. For effective results, more significant emission reductions are necessary.

For both sulphur (SOx) and nitrogen (NOx), shipping is expected to be the largest source by the year of 2050[3] and particle matter emissions (PM) are largely unregulated.

Hybrid shipping offers a promising and valuable alternative to conventional shipping and underpins the further development of various policy developments and regulatory bodies:

- Efforts of the International Maritime Organization (IMO) for market based measures and emission baselines and standards will be strengthened.
- Hybrid shipping vessels will be 'environmental flag ships' in the Energy Efficiency Design Index (EEDI) and have impressive and inspiring scores for the rest of the shipping sector.
- Hybrid shipping vessels will enhance compliance with the current SOx, NOx and PM Emission Control Areas (SECA's) in the Baltic, North and North American Seas.

Hybrid shipping vessels also assist in minimising engine room waste streams like sludge (a waste product of heavy fuel oil (HFO) engines) and solid waste from conventional ship engines. Thereby assisting the goals set out in Marpol and for example the EU ship waste directive 2000/59.

Hybrid shipping contributes to various focus areas of EU policy. It adheres to Europe 2020, a European strategy for smart, sustainable and inclusive growth[4]. It is an excellent example of decoupling economic growth from fossil resources, a powerful shift to low carbon economy, fosters the use of renewable energy, promotes energy efficiency and serves as boost for innovation and R&D performance.

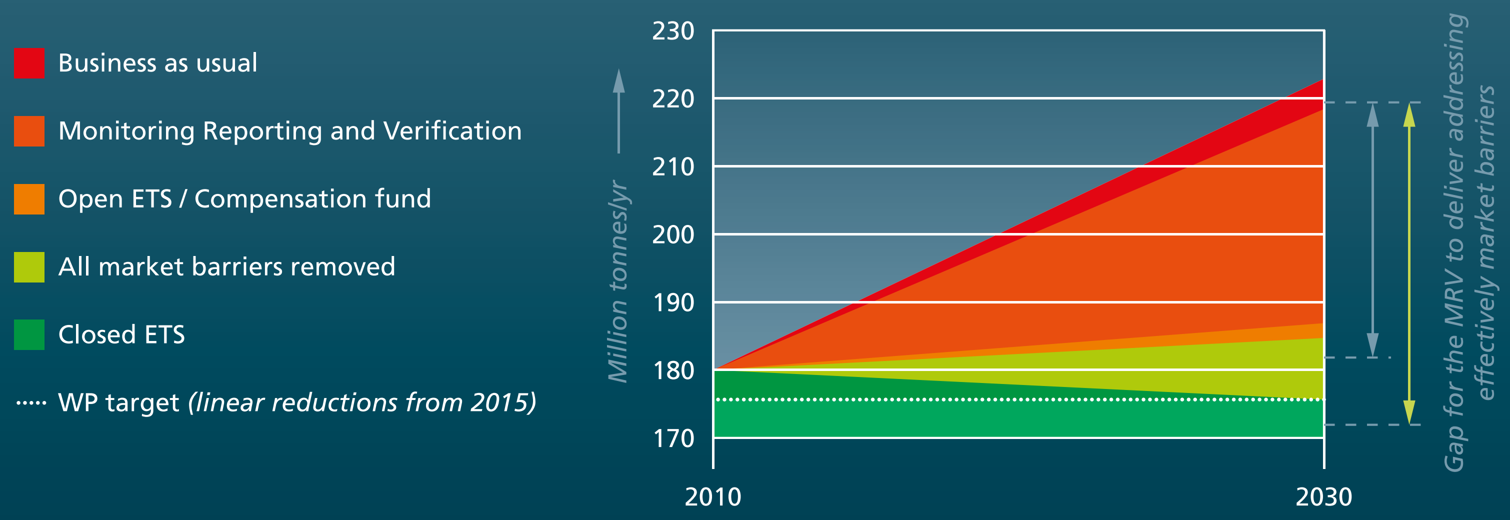
Existing environmental incentive schemes are currently discovering and embracing the first wind powered and hybrid sailing vessels. One of the world's first wind powered cargo vessels, the Tres Hombres has achieved the highest score in the Clean Shipping Index. Other hybrid sailing vessels, like the Ecoliner are getting comparable favourable results and set a powerful example of more ambitious environmental standards for the maritime sector as a whole. The Green Award system is planning to establish a stimulation scheme for future hybrid vessels. The Environmental Ship Index (ESI) of ports and other incentive initiatives will most likely equally stimulate hybrid shipping.

The promotion of hybrid shipping offers a powerful tool and opportunity for policy makers and incentive schemes to put a green beacon at the horizon of 21st century shipping!

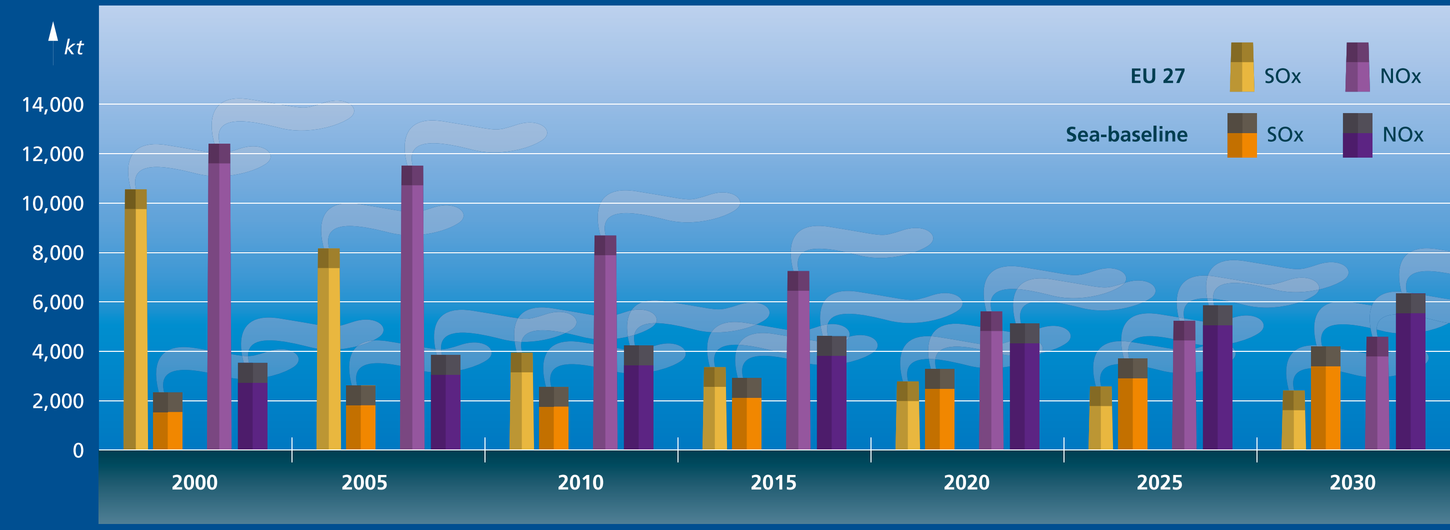
2 (A. Kedziersky, Transport and Environment, presentation for the European Parliament, 2014), 3 (Air Pollution and Climate secretariat and www.eeb.org), 4 (A Resource-Efficient Europe – Flagship initiative under the Europe 2020 Strategy)

Emissions from maritime transport

Trends and projections of different policy options



Emission of SOx and NOx



Certification of hybrid ships

For ages, virtually all international commercial cargo has been transported under sail. Consequently, the existing regulatory frameworks and maritime certification and inspection procedures contain regulations for sailing vessels. With the major shift to motorized sea borne trade in the beginning of the previous century, certification for merchant ships has become increasinlgy focused on non-sailing vessels. The certification for sailing vessels has been focused at other than cargo sailing vessels. The basic guidelines for safety and seaworthiness certifications for sailing vessels stem from the following international conventions (and their subsequent amendments):

- IMO International Convention on Load Lines (1968)
- IMO International Convention for the Safety of Life at Sea (SOLAS 1974), under the chapter 'ships not propelled by mechanical means'
- IMO International Convention for the Prevention of Pollution from Ships (MARPOL, 1973 and 1978) and their affiliated Conventions (Anti Fouling and Ballast Water Convention)
- IMO International Convention on Standards of Training, Certification and Watchkeeping for Seafarers, (1978)
- ILO Maritime Labour Convention (2007)

Flag state certification procedures are also provided at a variety of countries with maritime fleets.

Optimizing certification for sailing & hybrid ships

All major and most smaller classification societes have certification frameworks for vessels under sail. The major categories are yachts, leisure craft, passenger and other non-cargo vessels. The few existing sailing cargo vessels have also been succesfully certified by such societes. For a further shift from motorized to sail cargo transport the challenges are:

- The development of prescriptive rules for sailing & hybrid commercial ships generally requires significant R&D investment from classification societies. Therefore, certification will be treated on a case-by-case basis using risk-based methodologies, especially where existing prescriptive rules may not apply. This results in a challenge for hybrid ship designers to demonstrate that all risks are managed to a tolerable level, rather than simply having to demonstrate compliance with a specific rule.
- Compliance with SOLAS requirements on navigational bridge visibility is challenging for sail-assisted ships with the accommodation positioned at the aft, which is the case for the retrofit hybrid

shipping technologies. While the regulations allow for ‘equivalent’ arrangements, it is up to the flag administration to decide whether to accept them or not. E.g. the use of cameras is not seen as favourable by many flag states.

- In flag state procedures, some materials used on board (for example wood, polyesther) are safe but unaddressed in regulations. A list of accepted and safe materials need development to ensure that more maritime administrations around the world will be familiar with the equipment used on board of modern cargo sailing vessels and hybrid ships. The Maritime and Coast Guard Agency (MCA) in the UK for example, has designated a dedicated certification guideline for sailing vessels over 24 meters length. These standards could be transferred and adapted to global guidelines for hybrid cargo vessels.
- Wind routing and meteorological capacities of the crew needs further enhancement to ensure the optimal use of wind power. This could partly be mitigated by software tools.
- Rigging, sails and maintenance aspects need more robust regulation.
- Improvement of crew training and certification to optimise manoeuvring under sail and to improve situational awareness at sea
- Designation, when necessary, of a maximum accepted continuous heel when sailing with cargo, in relation to ILO regulations. Other safety measures will need to be secured.
- Integration of skills such as environmental conscious navigation and awareness about hybrid shipping and modern sail technology in the IMO Model Courses, like Marine Environmental Awareness.

Various maritime academies that are specialized in training crew for sailing vessels exist. Their expertise needs dissemination throughout the maritime education sector. When certification and training certificates are granted to seafarers, sailing skills should be included to provide companies with skilled staff on hybrid ships.

Flettner Freighter by C-Job Naval Architects

Working principle of rotors

The cylinders are rotated with aid of an electric motor. The air attaches to the cylinder surface and is lead in a curve. By bending the air stream lift arises. This is the so-called Magnus effect. With a rotating cylinder 8 – 10 times more power can be absorbed from the wind compared to sails or wing-shaped structures of similar size. This makes Flettner rotors especially suitable for wind assisted propulsion of ships.

Fuel Saving

- While sailing at 13 knots of speed, fuel can be saved on headings between 30 – 170 degrees relative to the true wind. The greatest contribution can be obtained at headings between 80 – 100 degrees;
- The rotor applied on a vessel is effective from windspeeds starting from 2 Bft and its effectiveness increases significantly with the wind speed;
- In fully loaded condition while sailing in 4 Bft wind, the average power contribution over all headings of four Flettner rotors can be approximately 18% of the normal upright resistance, with a maximum of 38% when sailing at half wind headings (power delivered to rotors subtracted in calculations). In 6 Bft wind, the average contribution can be approximately 50% with a maximum of 95%;
- The aft set of rotors can be moved longitudinally over the hold. This feature ensures the sail balance can be obtained in all headings and wind speeds resulting in the optimum forward thrust and minimum resistance;
- Another side effect which can also contribute to fuel savings is the gyroscopic force that is generated by the rotors while rotating, which may contribute to the damping of undesirable rolling motions.

Practical advantages

- The size of the rigging can be greatly reduced compared to sails or wing-shaped structures, by the use of rotating cylinders. This is due to the high effectiveness of the rotor, since they produce 8 – 10 times more lift force per unit area of the projection;
- Another great advantage of the rotors is that they need no adjustment for changes in the direction of the wind. This makes them very easy to handle;
- Flettner ships are highly manoeuvrable. When rotating the two sets of rotors in opposite directions, the ship can turn in place;
- Also from a safety point of view, Flettner ships perform better in strong winds. The force on a rotor increases more slowly than on sails, due to constant circulation of the air dictated by the rotation speed of the rotor. Further lift decrease is possible by reducing the rotational speed;
- In a heavy storm, the power can be entirely switched off. The adverse effect of the wind on the rotors is then very small.

General

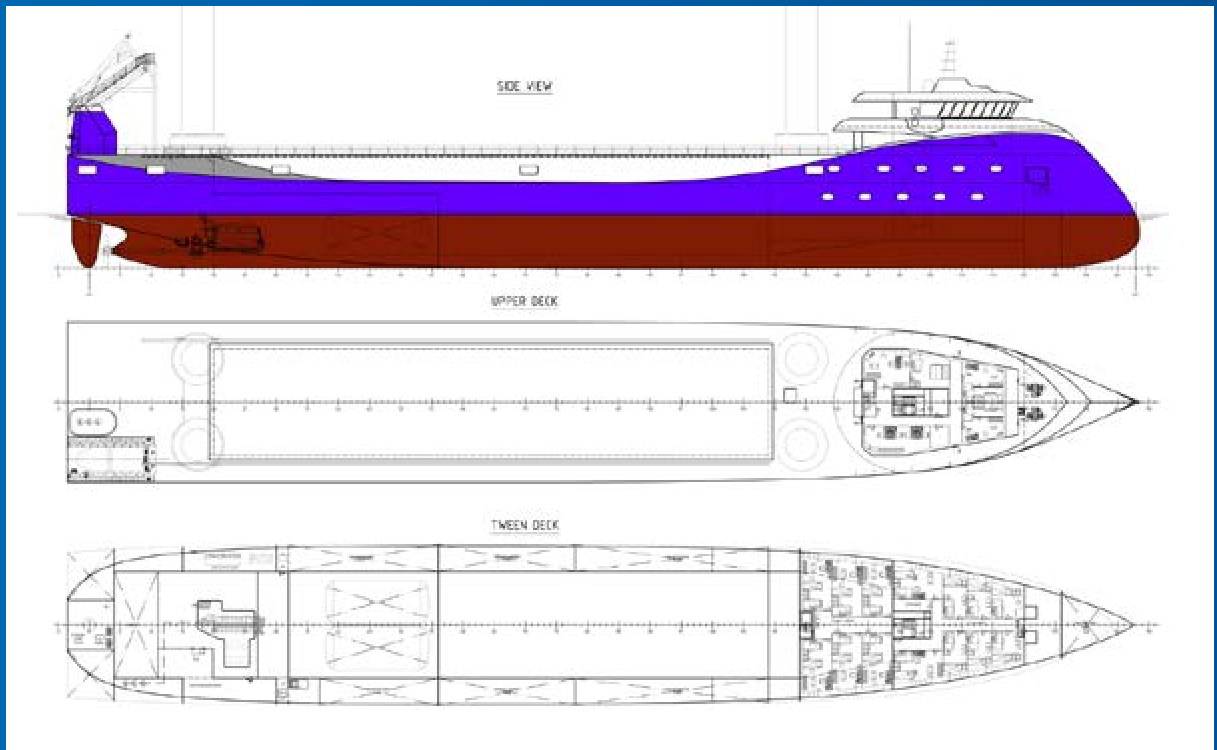
Length overall	120,46 m	Air draught (top of Flettner rotor)	35,0 m
Length between perpendiculars	117,38 m	Design speed	13,0 kts
Breadth hull	18,00 m	Deadweight	5000 t
Depth maindeck	9,53 m		
Design draught	6,00 m		

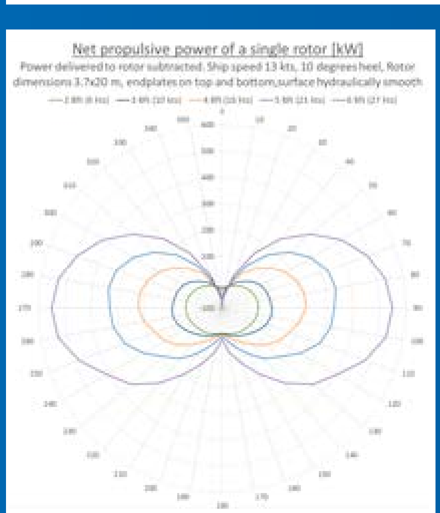
Loading Capacities

Total hold volume	6320 m³	Area floor hold	445 m²
Dimensions hold opening	62,3 x 12 m	Area maindeck hold	747,6 m²
Height closed hold	16,90 m	Displacement	7956 t

Propulsion & Manoeuvring particulars

Main engine (approx.)	4000 kW	Flettner rotor diameter	3,70 m
Number of Flettner rotors	4	Flettner rotor end disc diameter	7,40 m
Flettner rotor height	20,0 m	Rotational speed	300 rpm
		Required power Flettner rotor (approx.)	4 x 70 kW





Environmental performance

The challenge and solutions of air pollutant emissions by shipping
Hybrid shipping offers a feasible solution for emission reduction of many air pollutants. Such measures of emission reduction would be a welcome positive turn in an issue of growing concern.

Total NOx (nitrogen oxides, causing smog, acidification and eutrophication[5], SOx (sulphur oxides) and PM (particulate matter, causing health problems) emissions from shipping are increasing due to increased global ship traffic. In coastal regions, shipping emissions are a mounting challenge because of the vicinity to coastal ecosystems and urban areas.

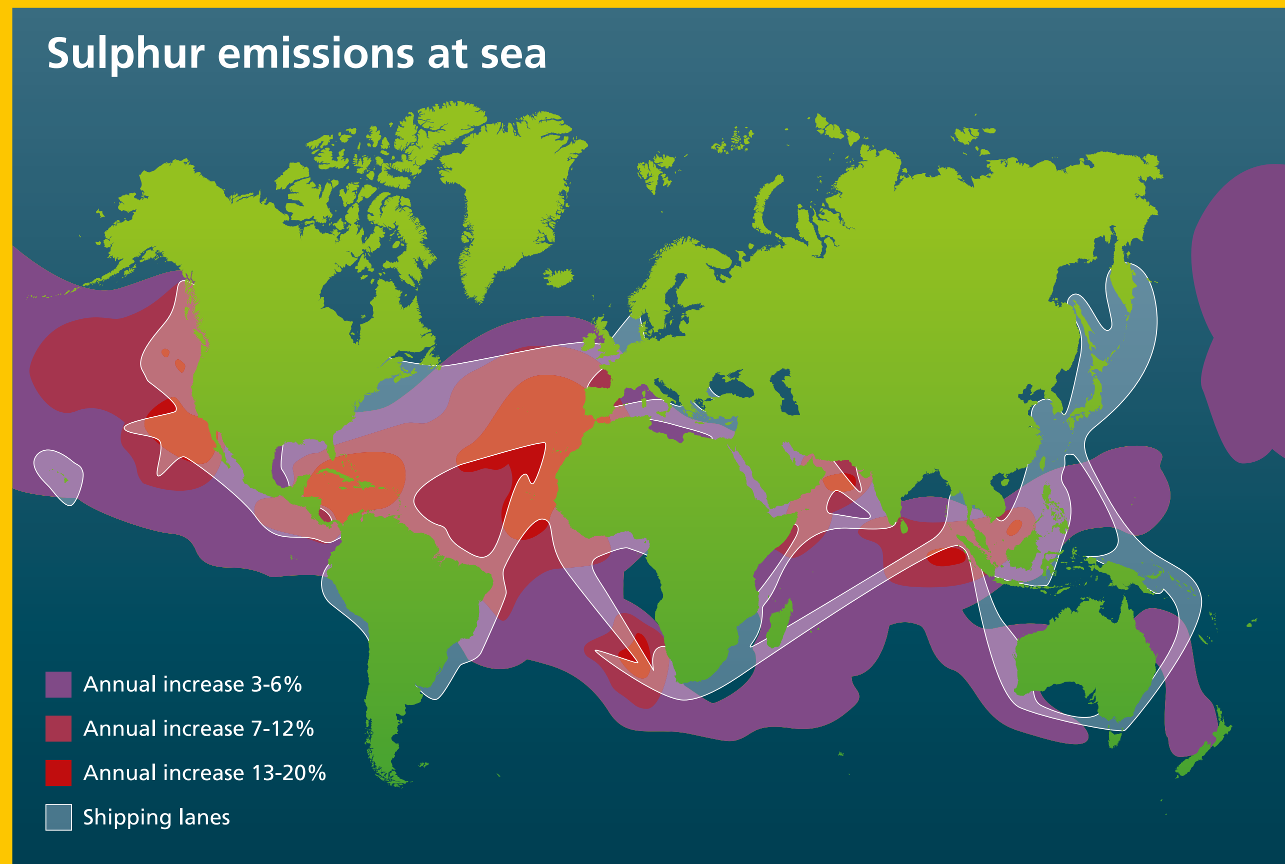
This contradicts with the preferred image that the maritime sector would like to pursue in the 21st century: that of a clean transport mode. Regarding CO_2, the IMO has recognized that without further measures, emissions will triple – or more – in decades to come. In addition, the IMO has indicated that reductions of 25% to 75% of CO_2 are feasible[6] (Second IMO Greenhouse Gas Study, 2009).

The map shows an indication of the rise of SOx emissions without effective policy measures. In general, high SOx levels coincide with high PM levels. With 70% of all shipping activities taking place within 400 km from the coasts, the increasing pollution levels from shipping have a significant influence on the surrounding air quality. In 2020 and 2025 stricter SOx emission thresholds will apply to the shipping sector which will most likely lead to a improvement of the environmental performance of shipping.

Investments in low carbon and low emission shipping are urgent from both an environmental and public health point of view. Hybrid shipping meets the needs of society, politics, supervisors and the maritime sector.

Environmental performance of Ecoliner(s)
In sea areas with favourable wind conditions, a hybrid ship has the potential of considerable fuel

5 Causing a loss of biodiversity and domination of certain plant species, 6 Second IMO Greenhouse Gas Study, 2009



Global ship traffic density - National Center for Ecological Analysis and Synthesis, University of California, Santa Barbara.and Journal of Geophysical Research.

and emission reductions, depending on actual weather conditions, engine type, ship characteristics and speed.

Three hybrid wind propulsion scenarios were assumed which differ in the type of ships equipped with sails: realistic, far future I and far future II. Fuel savings and emission reductions of 35% per vessel were assumed and savings for the whole fleet were calculated. The emissions were calculated based on data in Aulinger et al[7]. The table illustrates that hybrid ships are potential 'Green Flag Vessels' in future fleets of ship and cargo owners, being part of a convincing and powerful CSR approach of both ship operators and cargo owners.

Emission reduction potential [ton/yr] in three different scenarios

values in ton/yr	*realistic*	*far future I*	*far future II*
Fuel	7,334	287,078	256,353
NO_x	545	21,507	19,121
SO_2	118	4,906	4,395
CO_2	23,229	908,170	811,617

Based on 35% fuel savings per hybrid fright sailing vessel. Three considered scenarios by name and type of ship equipped with wind propulsion devise: realistic (Bulk Carriers; 3,000 < GT < 10,000), far future I (all bulk carriers), far future II (all freight vessels; 3,000 < GT < 10,000).

7 Aulinger et al. , 2013. The impact of shipping emissions on air pollution in the Greater North Sea region – Part 1: Current emissions and concentrations.

Hybrid vs Conventional | Assumptions

SAIL calculated the economic viability of bringing an Ecoliner into service. Major drivers for investment decisions are perceived risks, the price of fuels (oil) and the expected returns on initial investment. This factsheet compares the Ecoliner with a similar size conventional vessel.

The business case proposition is based on serial production of hybrid dynarig vessels based on the Ecoliner concept. It is estimated that additional costs for the first prototype (4.000.000) will be the same as the amount of (EU) subsidy available as incentive to develop hybrid shipping.

Assumptions for both vessels, per year over 10 years

Size	8.000 DWT
Passengers, crew	0, 12
Useful lifespan	20 years, comparable
Management fees, salaries, provisions	comparable
Depreciation method	linear (straight-line), comparable
Average price MDO per ton	612,6 EUR/ton (Rotterdam)
Fuel consumption (conventional vessel)	MDO: 6,9 ton/ day (Ecoliner) and 10,7 ton/ day
Engine type	comparable
Fuel savings Ecoliner speed (10,5 kts)	35% (by 12 kts) and significantly more by economical
Canal fees	none
Harbor costs, taxes, average tariff per ton/mile & tons cargo per trip	comparable
Estimated Time of Arrival (ETA)	comparable: the voyage of the Ecoliner takes more miles as it needs to navigate optimal winds, but it will cruise faster (using its engine and sails) where needed.
Actual days sailing per year	250 days (not in port, not in maintenance)

Component	**Ecoliner 8000 DWT**	**Freight motor ship 8000 DWT**
	Configuration	
10th build, including Dynarig, no cranes	19.500.000 EUR (of which rig is 4.500.000)	15.000.000 EUR
Residual Value (15%)	2.925.000 EUR	2.255.000 EUR
Average speed for comparison	12,0 kts	12,0 kts
Average economical speed	10,5 kts	12,0 kts
	Extra revenues	
Promotional activities	375.000 EUR	0 EUR
Feasible subsidies OR additional costs for first build	4.000.000 EUR	0 EUR
	Costs	
Yearly maintenance costs (+20%)	91.200 EUR	76.000 EUR
Extensive maintenance, costs (25% of Ecoliner)	Extensive maintenance, costs	20 years, 87.500 EUR
Insurances	115.000 EUR	69.300 EUR

Miscellaneous

Under sail or motor sailing: ca. 75% of voyage, of which 19% without engine
Engine: 80% of the time at nominal power
20% less fuel on board compared with a conventional vessel
ECA/ SECA zones (EU/ USA) not incorporated in model

Hybrid vs Conventional | Performances

An Ecoliner is performing well against a similar conventional vessel as is suggested by the compared knowledge of the SAIL project. Considering four potential routes, the performances of both vessels were examined.

Routes considered in business case

Route	*From*	*To*	*Miles**
North Sea	Rotterdam, NL	Bodø, NO	1.181
Atlantic	Rotterdam, NL	Recife, BR	4.858 - 6.072
Atlantic triangle	Le Havre, FR (return)	New York, USA by Puerto Rico	4.747 - 5.934
Cape	Lisbon, PT	Capetown, SA	5.914 - 7.393

* distance dependent on voyage with/ without wind assistance

Comparison of operational costs	*Motorship*	*Ecoliner*
Fuel costs (MDO Hybrid)	57,1	45,0
Dotation Extensive Maintenance Provision	0,1	2,1
Yearly Maintenance Costs	2,6	3,9
Labor Costs	12,1	15,4
Management fee	3,4	4,3
Cost Provisions	2,7	3,4
Harbor Costs	19,5	20,7
Other Taxes	0,2	0,3
Cost of Insurances	2,3	4,9
Total	**100,0**	**100,0**

The business case compares performances on the four routes mentioned. Not every route shows the same results, as will the actual real-life results depend on the precise configuration.
In general, the Ecoliner has a 3% benefit compared with a similar conventional vessel after 10 years of operation, taking depreciation and other capital costs into account (Net Present Value). The operational costs however are 22% less for the Ecoliner, due to its benefits of 35% savings in fuel costs.

Business Case Results		
Net Present Value after 10 years (%)	100,0	97,0
Operational costs/ year (%)	100,0	78,0
Fuel costs/ year (%)	100,0	65,0

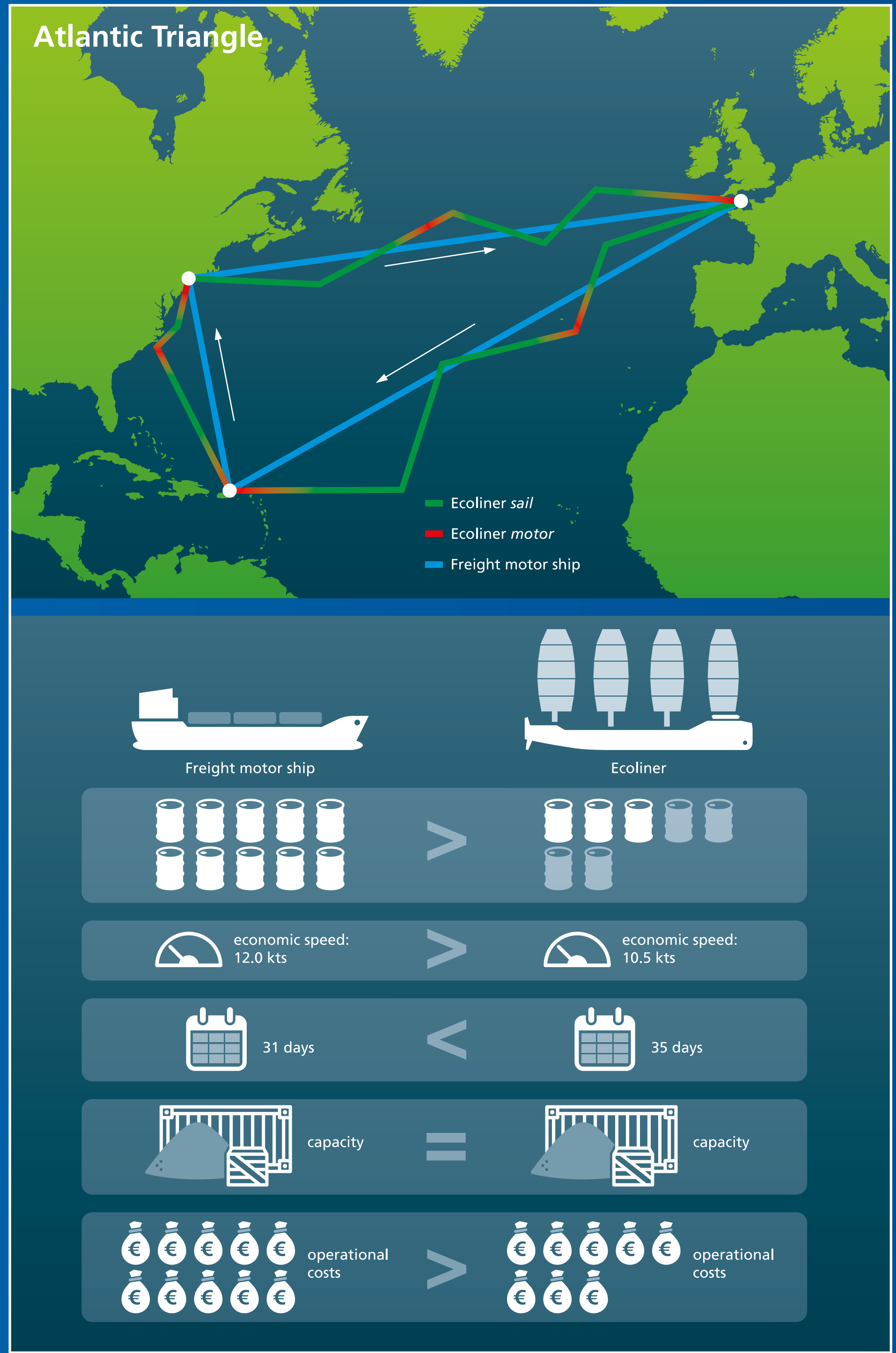
Operational principle

The Ecoliner is a hybrid vessel which makes use of trade winds by searching the optimal route given the existing wind conditions. The map indicates a theoretical voyage from the English Channel by Puerto Rico to New York. The blue line shows the approximate route of a conventional vessel.

The green line indicates a possible voyage by an Ecoliner. For 23% of an average trip, winds are not beneficial for propulsion, indicated by orange and red. The vessel alters its course to gain wind assistance. The Ecoliner travels more nautical miles compared to a conventional vessel in this example business case, but saves 35% fuel (at 12 kts) or considerably more at lower speeds.

The most economic speed combing both fuel and wind propulsion is about 10,5 kts. In some very favorable cases this appears to more than double the amount of fuel saved, further validation is under progress. The map shows an indication of a sample voyage.
The Ecoliner concept therefore enables flexibility in arrival times. Either at economic speed optimizing its course to wind patterns or at similar speed of same size conventional vessels following the same travel path, fuel savings are considerable starting with 35% at 12 kts.

This type of configuration is expected to be economically viable, as the developed business case suggests.



Estimating the power of the wind

Reduction in fuel consumption saves the finite oil resources for the future, it helps to achieve emission reduction goals and keeps the fuel bill low. Different from using sails: the datasheet for a conventional engine shows the delivered power together with the required fuel. With the existence of global wind, ocean current and wave databases rather precise performance estimates for sail driven ships have become straightforward.

Software for estimating power savings by sails is currently available. Wind data is considered for this approach but sea state is ignored. Based on route, waypoints, sail type and the time of arrival at each waypoint it calculates the power generated by the sails.

Several individual voyages can be calculated easily for statistical analyses. Sample results[7] of energy savings per mile are shown for three different routes. The second graph shows energy savings on the same route but in opposite direction.

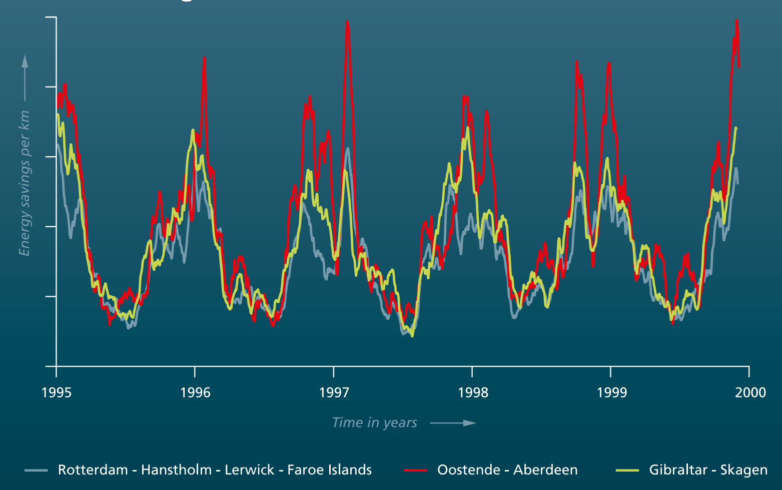
The energy savings peak in winter due to stronger winds. The Aberdeen-Oostende route has very strong peaks indicating the need to analyse the data in more detail. The direction of travel appears less important on the presented routes compared to the seasonal influences. This might be different on other routes.

This algorithm is rather fast and allows comparing different scenarios – routes and rig types – within short time. Actual fuel reduction calculation requires a more elaborated procedure including construction details such as the layout of the drive system and resistance properties of the hull. These calculations are available when an operation area and ship characteristics are known. Detailed calculations of this type were done by MARIN, showing very accurate data on fuel savings based on detailed ship characteristics, involving significant calculation times.

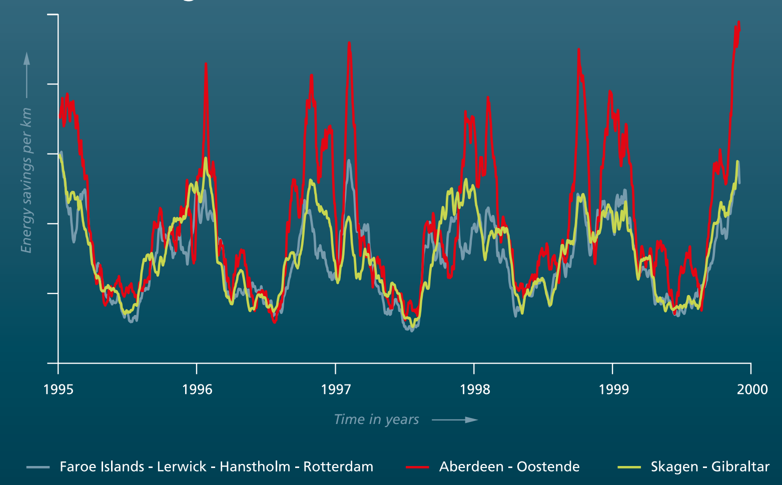
No absolute numbers are given because validation of the estimation programme is still ongoing.

7 savings were calculated on the base of wind data from the coastDat-database (www.coastdat.de) Data for the years 1995 to 1999.

Power savings on three different routes



Power savings on three different routes



Ecoliner detailed voyage simulations

MARIN conducted detailed voyage simulations for the Ecoliner within the SAIL project. The aim was to verify the fuel performance of the vessel on specific routes and to feed data for the faster simplified prediction (see "Estimating the power of the wind"). At the same time a lot was learned about this type of vessel in general and the behavior of the Ecoliner specifically.

Why do voyage simulations?
Voyage simulations are done to replicate in as much detail as possible the ship performance on a specific route. Wind, waves and current that actually occurred on the route in the past is taken from databases. This is combined with data regarding the engine installation onboard and the hydrodynamic and aerodynamic performance. Data often comes from previous detailed experiments or calculations. Hundreds of departures are modeled. Each individual voyage is optimized to follow the best course and speed profile.

The total package results in a detailed understanding of the performance on a route, including the limitations embedded in the ships design. Typically the simulations are used to determine the engine size that is required to maintain a fixed schedule, the frequency that people get sea sick or the fuel that is required on a specific route. The result of voyage simulations allow to adapt a ship design based on a prediction of the operational performance.

In the SAIL project the focus was on the average fuel consumption required on a few routes. The input for the simulations was received from Dykstra Naval Architects. MARIN conducted voyage simulations including seakeeping calculations that are also required as input.

Results
Interesting insights were obtained regarding the main propulsion that is still onboard to maintain the schedule. The power provided by the wind is actually quite modest compared to the engine power required to achieve the same speed. However, as the energy losses incurred with sail power are less than those associated with engine propulsion the nett result is a significant fuel saving..

On the other hand it is noted that the engine and propulsion installation must work at both very high power (strong head wind) and very low power (good tail wind). It is an ongoing challenge to design a propulsion installation that can deliver good efficiency in both operating regimes.

Overall fuel savings were determined in comparison to an identical vessel without sailing rig. The savings range between about 20% for a route that is unfavourable to in excess of 40% for a very favourable route, both simulated at a mean speed of 11 kn.

Ecoliner Route	Fuel saving
Trinidad – Gibraltar	21%
Gibraltar – Trinidad	27%
Skagen – Gibraltar	26%
Gibraltar – Skagen	28%
Oostende – Aberdeen	43%
Aberdeen - Oostende	42%

EU Interreg VB SAIL partnership

1 - Province of Fryslân
3 - Plymouth University
4 - Jade Hochschule
5 - Helmholtz-Zentrum Geesthacht
6 - Aalborg University
7 - North Sea Foundation
8 - Fairtransport Trading and Shipping
9 - Municipality of Harlingen
10 - C-Job
11 - Ameland Shipping
12 - NHL Northern University of applied sciences
13 - MARIN
14 - E&E consultant
15 - Avel Vor Technology
16 - Port of Oostende
17 - ECO Council
18 - World Maritime University

www.nsrsail.eu

Hybrid Shipping

Combined use of sea, wind and engine power

- Optimal use of wind power
- Modern sail technology adds to engine propulsion
- Optimized weather routing
- Saving fuel costs 35%
- Top performance low emission shipping
- Reliable & competitive with today's shipping

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