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Agenda item 7

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# REDUCTION OF GHG EMISSIONS FROM SHIPS

## Wind Propulsion

**Submitted by Finland, France, Saudi Arabia, Solomon Islands, Spain, Union of Comoros, RINA, International Windship Association**

### SUMMARY

| | |
|---|---|
| *Executive summary:* | This document considers several areas relevant to the characterization of the current state of technology and development of Wind Propulsion Technologies (WPTs) for ships. The role of such technologies is presented in the wider context of decarbonization in shipping enabling the sector to go 'beyond compliance' and future-proof ships. In addition to technological aspects, the document includes references to several projects highlighted as case studies. Market forecasts, policy/regulatory development, technical studies and standardization/class developments are also included as part of a developing framework where wind propulsion takes shape as a technically reliable and mature technology option |
| *Strategic direction, if applicable:* | 3 |
| *Output:* | 3.7 |
| *Action to be taken:* | Paragraph 33 |
| *Related documents:* | Resolution MEPC.304(72); MEPC.1/Circ.896, MEPC.1/Circ.815; MEPC 62/INF.34; MEPC 74/5/30, MEPC 74/INF.39; MEPC 75/INF.26; MEPC 76/6/2, MEPC 76/6/6, MEPC 76/6/7, MEPC 76/6/8, MEPC 76/6/10, MEPC 76/7/31, MEPC 76/INF.30; and MEPC 77/6 |

## Introduction

1 The upcoming revision of the *Initial IMO Strategy on Reduction of GHG Emissions from Ships* (resolution MEPC.304(72)), adopted at MEPC 72, in 2023 increases the need for all energy sources to be assessed and treated equitably along with all effective energy efficiency measures using the most up-to-date and credible information available.

2 Short term measures based on EEXI and CII are being prepared for implementation in 2023 and will have profound effects on the decarbonisation of shipping and the discussions on some form of Market Based Measure (MBM) and other medium- to longer-term measures that are becoming increasingly needed and likely instruments.

3 Existing bunker fuel cost rises, the volatility and risk profile of fuel markets have all been starkly evidenced this year. Linking these with the uncertainty over decarbonisation and energy transition pathways along with associated compliance burdens and higher costs for new fuels and technologies leave many in the industry with challenging and risky decisions to be made. The introduction of carbon pricing will also add further price pressure to fossil fuels and their derivative fuel products in the near future. Generally, the higher the price of fuel the higher the benefit in monetary terms as any differential will impact whichever MBM is finally decided upon. Wind Propulsion Technology (WPT) solutions are however currently ready, sufficiently mature and available, in order to assist operators designing compliance strategies in the future developing regulatory framework.

4 Since the submission of MEPC 75/INF.26 in 2020 by the Union of the Comoros, that outlined the viability of wind propulsion for commercial shipping there have been considerable advances in WPT system development, deployment and regulatory action. While this document already provides an overview of the various WPTs, listing an overview of existing installations, market forecasts and the potential for both large-scale shipping and LDC/SIDS, the outlook today for WPT has evolved significantly.

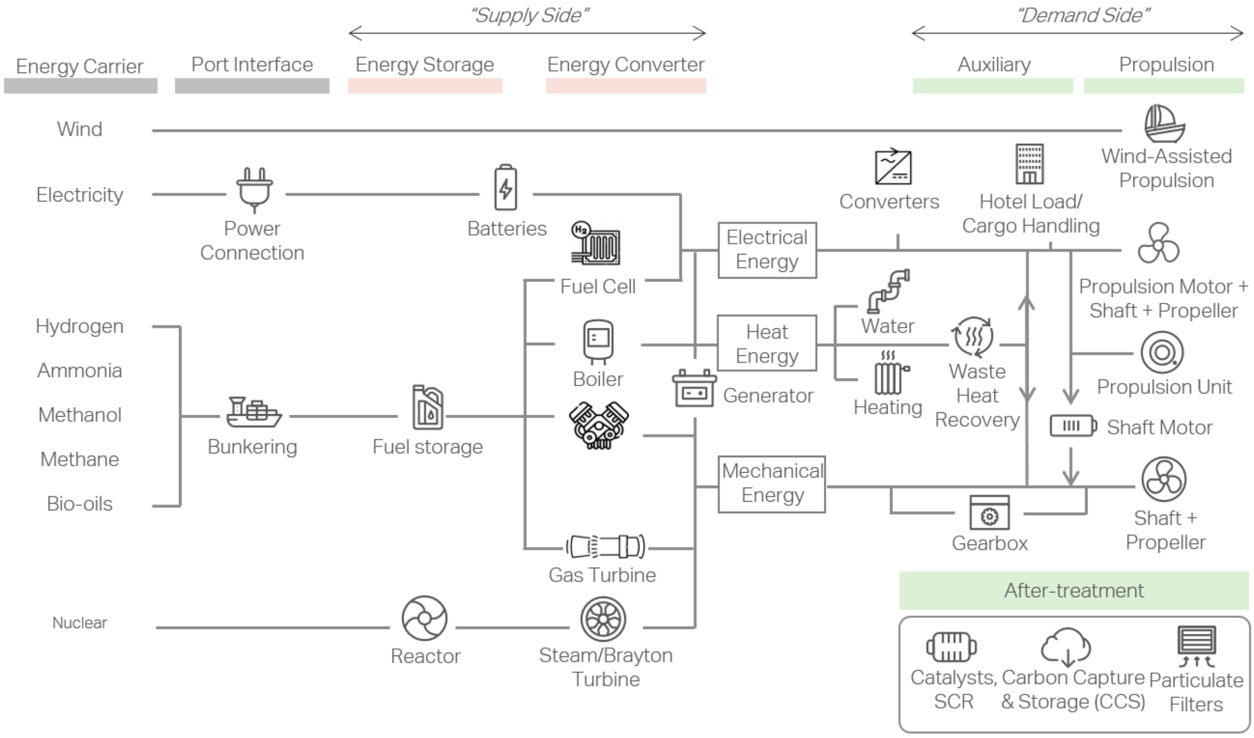

**Figure 1: Industry Transition Report, Mærsk Mc-Kinney Møller Center for Zero Carbon Shipping 2021, page 20, https://cms.zerocarbonshipping.com/media/uploads/documents/MMMCZCS_Industry-Transition-Strategy_Oct_2021.pdf**

5 As Figure 1 indicates, the provision of energy is multi-faceted and complex, including the presence of one or more energy carriers, used in different combinations of energy conversion systems. Inevitable energy losses of different magnitudes are associated to the different processes. Typical conversion efficiencies on an internal combustion engine, or even fuel cells, do not go beyond 50%. Any claims of higher efficiencies are only viable with the use of heat recovery systems (only viable for very highly exothermic processes, such as high-temperature fuel cells.) Wind propulsion bypasses all energy conversion complexities and, using the wind energy source directly, and mechanically converted to propulsion, presents an efficient energy option, compatible with all other energy sources selected.

### Key Considerations with directly harnessing wind energy

6 Table 1 below, summarises many of the key considerations pertaining to the direct use of wind energy for propulsion and the technologies used to harness that.

| **Direct Wind Energy Use** | |
|---|---|
| Propulsion vs Fuel Efficiency | A direct propulsive energy source that can be used as a partial or main propulsion system. |
| Emissions | An efficient zero-emissions energy source requiring no conversion thus avoiding power loss of up to 90% for alternative fuels based on a Well-to-Wake (WtW) calculation. |
| Infrastructure | Requires no ongoing mining, refining, bunkering or transport – delivered directly to the point of use. |
| Storage | Requires no storage tanks onboard the ship, though requires installation space on deck. Wind solutions also reduce propulsion energy requirements, therefore can also reduce other energy storage systems requirements, such as batteries. |
| Energy Cost | Cost of direct wind energy is zero and tax free for the lifetime of the ship without competition for supply. |
| Energy Availability | Abundant and freely available worldwide today. Wind is however intermittent and irregular and this variability is route specific with some routes having more wind resources than others. |
| Predictability | Increasingly predictable with modern forecasting technologies, a century of wind data and onboard weather stations/sensors, LiDAR etc. |
| Facilitation | With this free energy source integrated into an energy efficiency strategy, the use of WPT reduces the amount needed of new alternative fuels/technologies, thus helping to facilitate their deployment in a cost-efficient way. |
| **Wind Propulsion Technologies & Ships** | |
| Wind-assist | 5-20% of the propulsive energy requirement delivered as a retrofit based on motor ship profiles with the potential to optimise these operationally up to 30%. |
| Primary Wind | 50%+ of propulsive energy requirement (potential for 100%) especially on newbuild ships & using wind optimisation techniques. |
| Viability | WPT are already demonstrating their viability as a technology on 21 vessels (25 vessels by end of Q4 2022) across six fleet segments. |
| Safety | All systems and ship designs are certified by class and comply with SOLAS/COLREGS. WPT have the potential to also add to safety as a secondary propulsion system in case of engine failure in certain conditions. Certain wind systems can also improve the stability and comfort onboard, as they can dampen rolling, etc. |
| Operations | Air draft and port operations are key issues solved with folding/retracting/movable systems + modular possible. |

| | |
|---|---|
| Availability | Available now with 10+ companies supplying varied size/power WPT already into the market. 10+ more are in pre-market, 20+ in R&D pipeline. |
| Compatibility | WPT are compatible with all other fuel and technology choices and various types can be deployed in all fleet segments. |
| Integration | Integrating WPT into Energy Management Systems (EMS) will further optimise systems and fuel savings. |
| Speed | While speed is primarily determined by market factors, if ships do reduce speed, then the ratio of the power delivered by WPT rises. However, WPT can also be used to maintain higher speeds with lower fuel consumption. |
| Routing for Wind | Increasingly sophisticated wind-routing software is available, enabling operators to maximise wind/minimise fuel and/or maintain schedules. |
| Range | Using this free energy source, WPTs can increase ship range for the same fuel usage. |
| Onboard Energy Production | Surplus wind power can be harvested and used to produce electricity/alternative fuels through onboard wind turbines or by other means. |
| Autonomous Shipping | Wind gives a large degree of energy autonomy to ships aligning with development of autonomous ships. |
| Lifecycle Analysis | The energy used in the production and operation of the WPT is minimal and recouped quickly. Materials will increase in recyclability as production processes develop. |
| Training & Crew | Highly automated + Remote sensors help with predictive maintenance. No extra crew required but some training is necessary. |
| Underwater Sound | Additional benefit of WPT is the reduction of underwater noise with the option to be fully silent when in sensitive marine areas. |

**Table 1: Key considerations for direct wind energy, WPT and ships**

## Technologies and performance

7 As noted in MEPC 75/INF.26, there are seven categories of wind propulsion technologies (rotor sails, kites, hard or rigid sails, soft sails, suction wings, turbines and hull forms) (see annex 1 for further details). Each of these systems has varied properties and adaptations that can make them suitable to all ship types or selected fleet segments, but as a whole, wind propulsion solutions are deployable on virtually all ship types across the fleet.

8 Care must be taken when it comes to comparisons of performance and Key Performance Indicators (KPI). A standardised approach is being discussed and formulated through multi-stakeholder work underway in the International Towing Tank Conference (ITTC) Wind Powered Ships Specialist Committee, European Sustainable Shipping Forum (ESSF) Wind propulsion workstream, WiSP Phase II Joint Industry Project, NORVENT project and through the EU funded WASP project. Further details are listed in paragraphs 26-32 of this document.

9 The performance of a WPT retrofitted onto a standard ship design is often designated by the "fuel saving" observed, however this percentage is derived from a standard motor ship operational profile where no adjustment has been made for weather-routing, speed variation, etc. which help optimise WPT performance.

10 Many previous assessments of WPT solutions have failed to address the following points:

.1 optimisation factors that enhance WPT solutions;

.2 lack of adequate emphasis on new build design optimisation for wind-assist or primary wind vessels, being excessively focused on retrofit designs;

.3 underestimation of the number of vessels that can utilise wind systems (i.e. fleet-wide) such as covered by the IMO Third and Fourth GHG Studies;

.4 under-valued size and scaled potential for energy provision from WPT; and

.5 no relevant consideration for materials and support systems, automation and innovative approaches in dealing with air draft and operational constraints (movable, hinged, retractable, modular etc.).

11 The optimisation of WPT solutions and their integration into a holistic approach to ship design, full fleet deployment and operations has the potential to deliver substantially on meeting the targets in the *Initial IMO Strategy on Reduction of GHG Emissions from Ships* (MEPC.304(72)). While WPT can strongly contribute to the meeting of the targets, the comparison used in Figure 2 with IMO Carbon intensity reduction targets is only indicative as these are fleet targets and individual ship savings do not translate directly to fleet savings. From a single ship perspective. Figure 2 therefore indicates that adding WPT alone could deliver 22.3% reduction in carbon intensity in conjunction with the speed reductions and other measures already instituted from 2008 onwards (based on a wind-assist Panamax bulk carrier with 4 rotor sails installed), in comparison with a Business As Usual (BAU) voyage from the ship without WPT of 13.6% (Quantifying voyage optimisation with wind-assisted ship propulsion: a new climate mitigation strategy for shipping, p.246, Mason, 2021, https://www.research.manchester.ac.uk/portal/files/209787529/FULL_TEXT.PDF). Note that these findings would likely be comparable for other similar size/power WPT solution options. Add in voyage optimisation which will be a combination of weather routing for wind and some speed modification but maintaining the ship ETA, then that jumps to 27.8%, but then by using a wider range of weather routing and speed changes thus increasing voyage time by 20%, the IMO 2030, 40% reduction in carbon intensity target is surpassed (for this single ship simulation). Increasing voyage time by 50%, then the IMO 2050, 70% reduction target is already in sight (Quantifying voyage optimisation with wind-assisted ship propulsion: a new climate mitigation strategy for shipping, p.246, Mason, 2021, https://www.research.manchester.ac.uk/portal/files/209787529/FULL_TEXT.PDF).

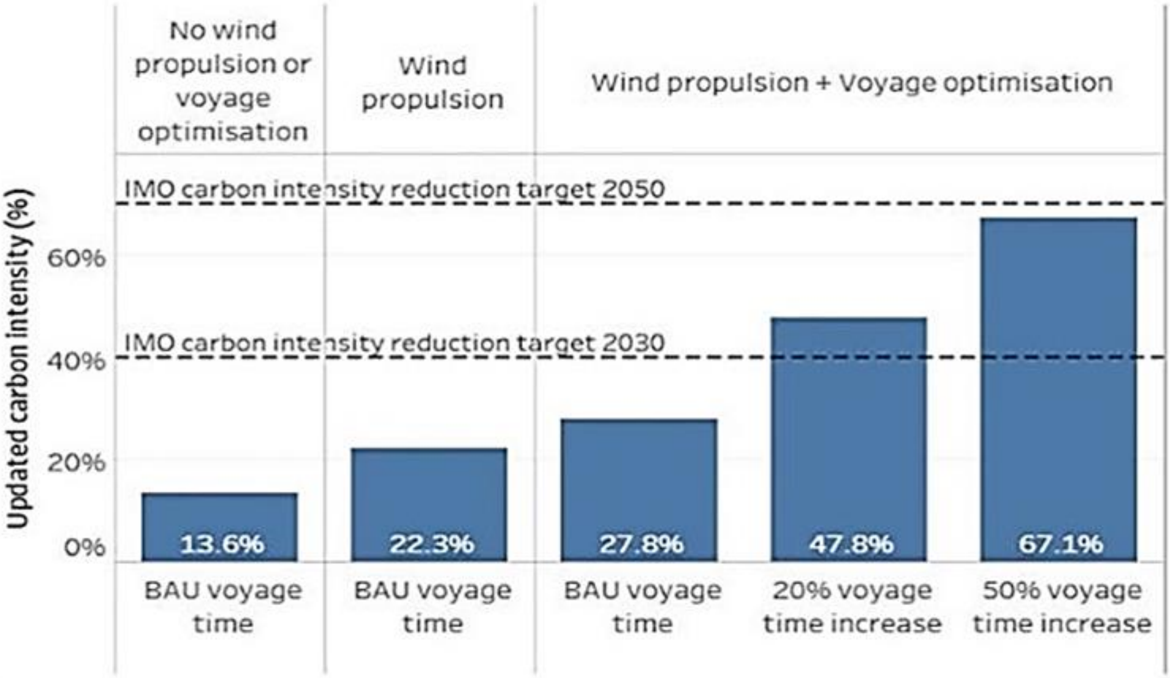

**Figure 2: Annual $CO_2$ savings relative to IMO 2030 & 2050 CI targets. All cases are compared to operational practices of the sector in 2008, at a speed of 13 knots. Business As Usual (BAU) signifies no change to current arrival times (Figure 5.28, Quantifying voyage optimisation with wind-assisted ship propulsion: a new climate mitigation strategy for shipping, p.246, Mason, 2021, https://www.research.manchester.ac.uk/portal/files/209787529/FULL_TEXT.PDF)**

**Wind propulsion case studies**

12 There is a growing body of data on WPT performance, however openly available public, third party validated material is still hard to find. In annexes 2 and 3 there are some recent case studies that will help to highlight the application, size and performance of a series of technologies and installation types.

**Market overview**

13 There has been significant growth in industry interest in WPT systems across a range of segments since 2020 along with a noted upsurge in research, technology projects and new installations. By the end of 2022, the International Windship Association (IWSA) estimates that WPT systems will be installed on 25 large commercial ships, with over a combined 1.2 million DWT (GT for Ro-Pax/Ro-Ro ships) and 51 rigs installed. Annex 4 gives a list of installations as of September 2023. By Q4 2023, the combined tonnage will be circa 3.3 million DWT on 49 ships with 105 rigs (note that the 2023 forecasts are based on public announcements and yard orders to date, numbers may adjust upwards with additional retrofits or downwards with yard/logistics/covid-19 restrictions).

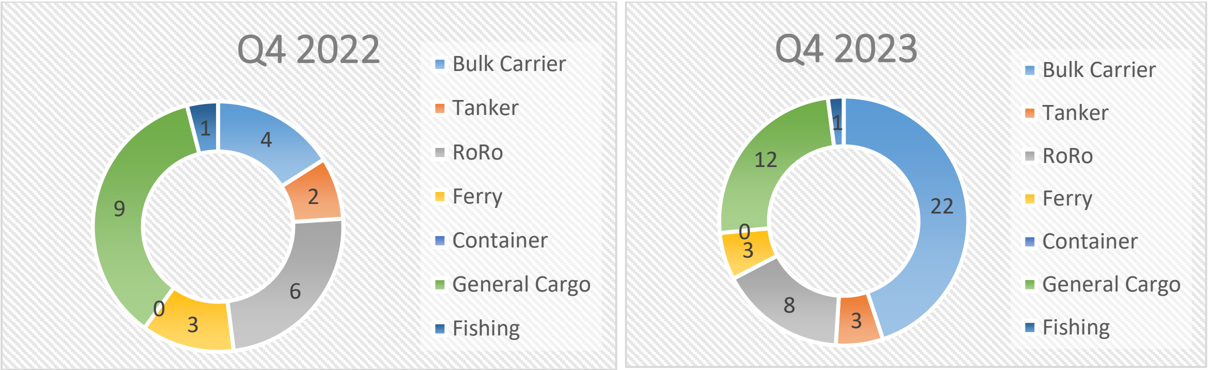

**Figure 3: WPT installations by fleet category 2022 and 2023 (source: IWSA, August 2022)**

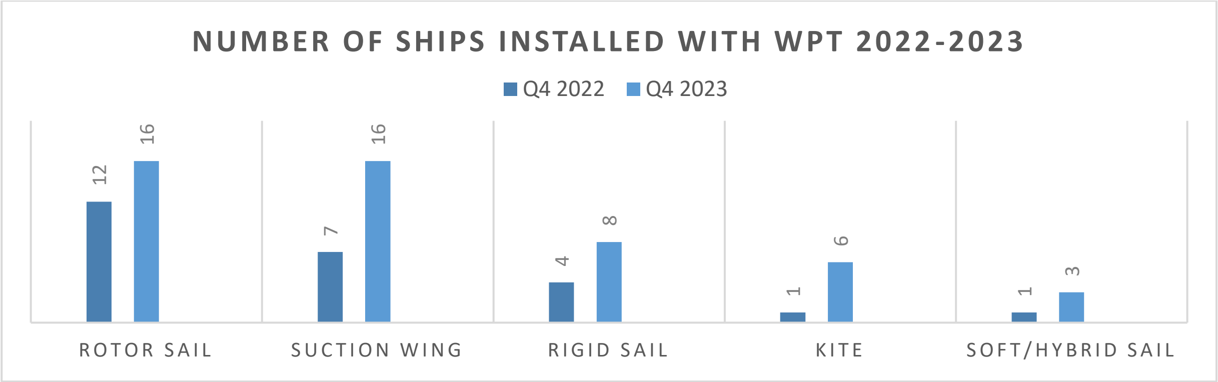

**Figure 4: Ships installed by WPT category (source: IWSA Members Survey, May 2022)**

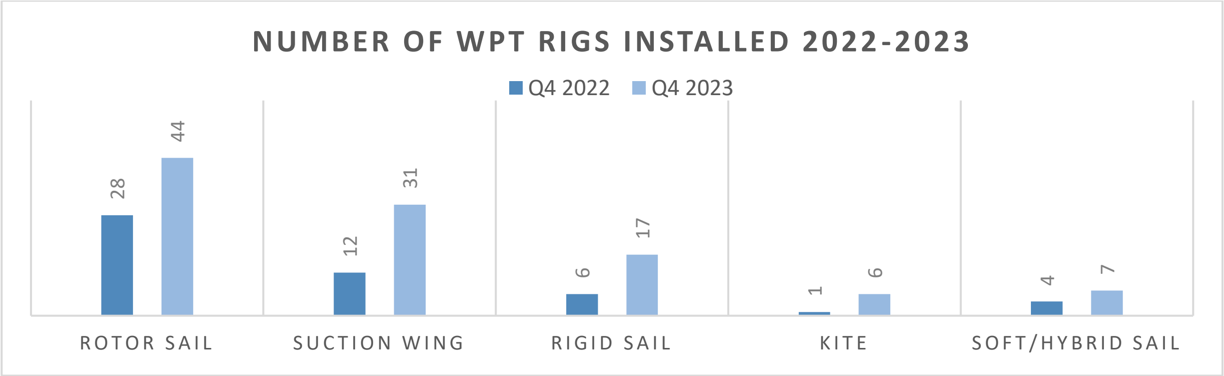

**Figure 5: Rigs installed by WPT category 2022 and 2023 (source: IWSA Members Survey, May 2022)**

14 The overall tonnage for the 10 small cruise ships using traditional sail is approximately 50,000 GT and smaller sail cargo ships (under 400 GT) will likely see an increase in numbers as ships are converted to sail cargo and retrofits on small fishing ships continue in 2023.

### *Market forecasts*

15 Large ship deployment forecasts have been made through EU and UK government research. An EU commissioned report (CE Delft 2016/7) headlined that the maximum market potential primarily for bulk carriers and tankers would range between 3,700-10,700 installed systems by 2030 depending on bunker fuel price, speed of the ships, and discount rate applied. Note that this forecast covered only three fleet segments and assessed only a small selection of WPT (four rig systems).

16 The diffusion modelling results (fuel price of US $450/tn) shows the uptake of these four WPT systems in the two most applicable fleet segments (tankers and bulkers) identified in the report. This naturally does not take into account recent Covid-19 pandemic and conflict challenges and disruption. The model does however give a clear outline for the diffusion pathway for the technology (likely with a 12 to 18-month lag to the numbers outlined in the table below)

| Ship type | Build Type | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Tanker (5,000-120,000 dwt) | Fleet | 2,892 | 2,915 | 2,938 | 2,961 | 2,984 | 3,008 | 3,022 | 3,036 | 3,050 | 3,064 | 3,078 |
| | New build with sail | 0 | 3 | 14 | 64 | 70 | 107 | 120 | 154 | 160 | 169 | 175 |
| | Retrofit with sail | 0 | 0 | 23 | 122 | 199 | 201 | 201 | 202 | 203 | 204 | 205 |
| Bulker (0-100,000 dwt) | Fleet | 10,718 | 11,231 | 11,743 | 12,256 | 12,768 | 13,281 | 13,914 | 14,547 | 15,180 | 15,813 | 16,446 |
| | New build with sail | 0 | 8 | 31 | 166 | 339 | 528 | 620 | 632 | 631 | 641 | 575 |
| | Retrofit with sail | 0 | 6 | 23 | 122 | 426 | 443 | 464 | 485 | 506 | 527 | 548 |

**Figure 6: Sensitivity Analysis: Slow speed, oil price $450, discount rate 5%. Note that total fleet numbers quoted here are taken from the study where certain specialist vessel types (e.g. chemical tankers) may have not been included () – (Study on the analysis of market potentials and market barriers for wind propulsion technologies for ships, CE Delft 2016/7, p123-4, Orders of WPT ships to 2030, https://cedelft.eu/wp-content/uploads/sites/2/2021/04/CE_Delft_7G92_Wind_Propulsion_Technologies_Final_report.pdf)**

17 Another important market projection has been made in the UK Government's Clean Maritime Plan (July 2019), with the research backing the plan (p43-44) forecasting the market size by 2050 (assuming 50-100% abatement of GHG) for wind propulsion would be 37,000 to 40,000 ships or 40-45% of the global fleet (Clean Maritime Plan, Department for Transport, UK, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/815664/clean-maritime-plan.pdf).

18 In the small ship segment, the largest group of small ships in operation that can benefit from WPT are the 2.86 million motorised fishing ships (63% of the total), however currently there are only a small number of projects in this segment. There are also 64,000 larger fishing ships over 400 GT. These fishing ships have special considerations, usually with limited working area on deck, challenging operational profiles and stability limitations, however ships with long voyage times could make substantial fuel savings from the use of WPT. Additional research and demonstrator ships are required to assess and validate these installations. (The State of World Fisheries and Aquaculture 2020, Sustainability in action, FAO Rome, 2020, p41, https://doi.org/10.4060/ca9229en).

### *Learning curve for wind propulsion technologies*

19 By adopting the assessment from the EU report (CE Delft 2016/7), we are likely to see a learning curve of 10%, a level which is also shared by other developments in maritime equipment as observed in the offshore wind sector (as opposed to onshore wind (18%) and solar PV (33%)), this means that we will observe a 10% reduction in cost for each doubling of installed capacity. With this assumption in place, and taking the installations rate, approximately doubling every 12 months, then installation costs will have nominally dropped from the 2019 costs by approx. 40-50% by 2025/26 (though as with all machinery deployments these are subject to recent inflationary considerations).

### Classification societies

20 The installation and deployment of WPT is fully supported by the main classification societies, especially with increasingly standardised approaches to wind-assist installations. These guidelines cover all installation, safety, operation, materials and SOLAS/COLREG compliance issues. There is still a level of flexibility and need to further develop these guidelines as new system variations, innovations and integration are forthcoming and the increase of demonstrator ships using different rig configurations will help further accelerate that process. Large, new build, primary wind ships will also require more standardised approaches as these come into the fleet from 2024 onwards. Links to class WPT guidelines are provided in appendix 5 to annex 5.

### Small Island Developing States (SIDS) and Least Developed Countries (LDC)

21 There are substantial benefits for less developed regions to deploy WPT systems that can offset the cost of decarbonisation, extend range and also deliver regional employment. Most regions are forced to purchase fossil fuel on international markets, using foreign currency which multiplies costs, already often elevated by the need to transport those fuels to markets using small tankers, especially the case of SIDS with limited or non-existent domestic production. If we take an assessment of WPT potential in a single region, the South Pacific, there has been extensive modelling done by the Micronesian Center for Sustainable Transport. Wind propulsion is found to have high potential dependent upon application, deck space available and ship/WPT type. Many of the findings are collated and summarised in this paper: Pacific island domestic shipping emissions abatement measures and technology transition pathways for selected ship types (Marine Policy, Vol 132, 2021, P. Nuttall, A. Newell, I. Rojon, B. Milligan, A. Irvin, https://doi.org/10.1016/j.marpol.2021.104704).

## Regulation and policy

22 The need to improve the guidance and provisions for wind propulsion technologies was reflected in the multiple submissions made at MEPC 76 (MEPC 76/6/2, MEPC 76/6/6, MEPC 76/6/7, MEPC 76/6/8, MEPC 76/6/10, MEPC 76/7/31 and MEPC 76/INF.30) proposing updates to the *2013 Guidance on treatment of innovative energy efficiency technologies for calculation and verification of the attained EEDI* (MEPC.1/Circ.815). An informal working group was assembled to work on a single submission, MEPC 77/6 submitted by Comoros, Finland, France, Germany, Japan, Spain, Netherlands and RINA and following discussion the *2021 Guidance on treatment of innovative energy efficiency technologies for calculation and verification of the attained EEDI and EEXI* was adopted as MEPC.1/Circ.896, effectively updating the provisions for WPT.

23 The full integration of wind propulsion into the regulatory process at the earliest possible stage will be highly beneficial as it will avoid difficulties later when wind propulsion comes to be included. This will need additional work as policy makers and decarbonisation pathway developers still class wind propulsion systems exclusively as 'fuel efficiency measures' rather than 'propulsive power providers'. However, this increase of engagement with WPT has also been evidenced by the IMO Consultative status granted to the International Windship Association (IWSA) by the IMO Council in late 2021. Also recently, the European Sustainable Shipping Forum (ESSF) Ship Energy Efficiency sub-group, initiated a broad workstream on wind propulsion in April 2022 analysing different aspects and opportunities of the WPTs.

24 As part of the ongoing policy debate covering proposed mid-term measures such as the adoption of carbon pricing, it is increasingly important that a level playing field is developed that fully recognises and incorporates wind propulsion and other forms of non-commoditised energy sources (such as wave) into those mechanisms. Rather than adopting a simplistic fuel-centric approach, mechanisms such as 'Contracts of Difference' should be carefully considered, as proposed in Clark 2021, available at the website: https://www.inet.ox.ac.uk/files/zero-emissions-shipping-FINAL.pdf. The more detailed and holistic 'Total Cost of Ownership' (TCO) models described could be key to incorporating the assessment of all energy sources along with full lifecycle analysis (LCA) of the fuel and the equipment and ships.

## Barriers and drivers

25 There are two recent reports on barriers and drivers in wind propulsion:

.1 Barriers & Overcoming Strategies for Accelerating the Uptake of WASP https://vb.northsearegion.eu/public/files/repository/20220111103132_WASPWP4.D5B_BarriersandovercomingstrategiesforacceleratingtheuptakeofWASP.pdf; and

.2 IWSA Multi-stakeholder workshop report (June 2021), Table 2, is a brief summary of the workshop outcomes, based on the barriers identified in the earlier EU wind propulsion report (CE Delft 2016/17). This workshop involved 40 leading shipping, finance, policy and WPT experts. This workshop adopted a traffic light appraisal: Red – No action taken, Red/Amber – limited action underway, Amber – action solidly underway but not completed, Green – completed/effectively solved. The full report is available at the following website: https://www.wind-ship.org/wp-content/uploads/2021/08/Wind-Propulsion-Strategy-Workshop-June-2021.pdf

| Challenges | Development 2017-2021 | 2022-23 Outlook |
|---|---|---|
| **Technical Issues** | | |
| Diffusion of Knowhow | [Red → Red/Amber] | Increasing but need to move faster/wider |
| Class Guidelines for WPT | [Red/Amber → Amber] | Need primary wind guidelines |
| R&D Pipeline of WPT | [Holding at Amber] | Needs additional work |
| **Policy, Regulation & External Issues** | | |
| Existing Regulations to Reduce GHG | [Holding at Red/Amber] | Increased movement at IMO, EU and national levels |
| Incentives for Energy Efficiency/Reduce GHG | [Holding at Red] | Improvement with movement at IMO, EU and national levels |
| Inclusion of WPT in Policy Pathways & Regulations | [Red → Red/Amber] | Some improvement with movement at IMO & EU levels |
| **Business, Operations & Finance Issues** | | |
| Availability/Access to Capital for R&D, Pilots & Installations | [Red/Amber → Amber] | Improvements in R&D funding & some in installation funding |
| Diffusion of Demonstrators & Knowledge of WPT | [Red → Amber] | Increasing number of WPT & ships aligned with forecasts |
| Trusted 3rd Party Performance Information | [Holding at Red] | Some improvement but requires more development |
| Fuel Prices & ROI | [Red → Red/Amber] | Higher fuel prices and carbon pricing under consideration. |
| Commercial Agreements/Legal | [Red → Amber] | Additional work required |
| Scepticism/Perception Issues | [Holding at Red/Amber] | Gradual improvement |

**Table 2: Outcomes of the IWSA Multi-stakeholder workshop, based on the barriers identified in the earlier EU wind propulsion report (CE Delft 2016/17)**

### Wind propulsion facilitation projects and organisations

26 Wind Assist Ship Propulsion (WASP): 3.5-year project launched in Oct 2019 and part funded by the Interreg North Sea Europe programme, part of the European Regional Development Fund (ERDF). The project brings together universities, WPT providers and five ship owners to research, trial and validate the operational performance of a selection of WPT solutions (rotors, suction wings and wing sails). More information is available at the following website: https://northsearegion.eu/wasp/ The project has also developed a number of online

tools to assist with technology assessments that are freely available. Two of these help with the assessment of WASP against other technical options. For further information: https://hhx.blue/eu-projects/wasp/tools-supporting-wasp-related-decisions.

27 WiSP: Phase II: This Joint Industry Project (JIP) (launched July 2019) led by ABS and MARIN has the objective to overcome barriers to the uptake of WPT, specifically to improve methods for transparent performance prediction, use these improved methods to provide ship owners/operators with fast low-cost predictions for their fleet and to review the regulatory perspective including status of rules and regulations, identify gaps and make recommendations, and provide examples on establishing compliance. Phase II started in Q3 2021. More information available here: https://www.marin.nl/en/jips/wisp-2

28 Optiwise: The project scope involves extensive simulations where different disciplines, such as aerodynamics, hydrodynamics, routing and energy management are holistically brought together. The systems being tested include rotors sails, wing sails and a hybrid sail. Great attention will be applied to ensure realistic operational applications of the developed designs. Thus, these will be complemented with basin tests to assess manoeuvring and seakeeping, bridge simulations to assess crew operation, and land-based wind propulsion tests to verify better control. The project will deliver open guidelines for integrated system optimisation with wind propulsion and smart measurement and control for best operation. More information available here: https://www.marin.nl/en/jips/optiwise

29 The International Towing Tank Conference (ITTC) has a ‘Specialist Committee on Performance of Wind Powered and Wind Assisted Ships’. The Terms of Reference (TOR) may be found in appendix 6 to annex 5.

30 The European Sustainable Shipping Forum (ESSF) – Ship Energy Efficiency Sub-Group has a Wind Propulsion Workstream (Apr-Dec 2022), and the Terms of Reference may be found in appendix 7 to annex 5.

31 International Windship Association (IWSA): This not-for-profit membership association established in 2014 now has over 180 members and associates with the objective to facilitate and promote wind propulsion for commercial shipping and bring together all parties in the development of a wind ship sector. Activities include the development of wind propulsion regional hubs worldwide, communications, policy work, research, education and development of a WPT accelerator program etc. The campaign website is here www.decadeofwindpropulsion.org and the main website www.wind-ship.org.

32 NORVENT project: This project will establish a state-of-art needs and procedures used for WPT performance assessment to help deliver shared reliable guidelines. The DIGI4MER – WP2 project will deliver an online theoretical training in wind propulsion for seafarers. The projects are led by the IWSA Europe-Atlantic hub. (www.wind-ship.fr)

## Action requested of the Committee

33 The Committee is invited to take note of the information provided in this document and the annexes and that further technical documents will be submitted at subsequent MEPC meetings.

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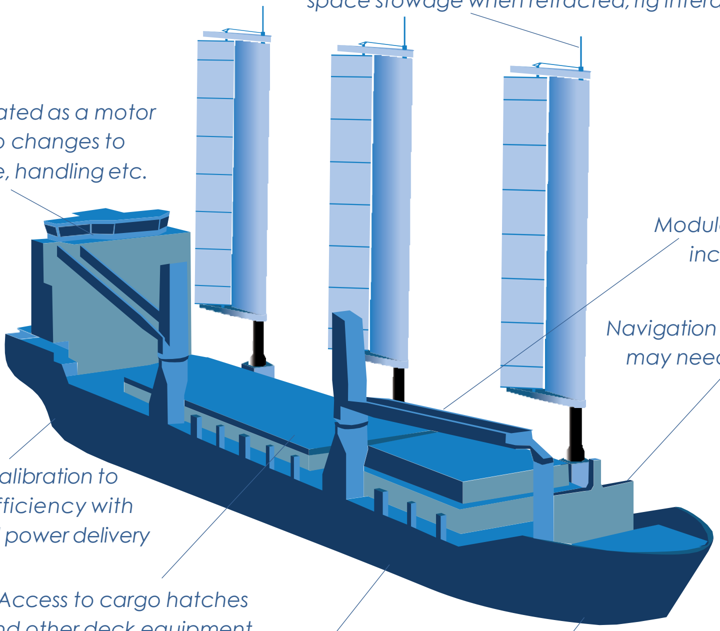
# Some Key Considerations Assessing WPT

## Wind-Assist



*Size limitation & location – air draft, deck space stowage when retracted, rig interaction*

*Often operated as a motor vessel – no changes to speed, route, handling etc.*

*Modularisation possible to increase flexibility*

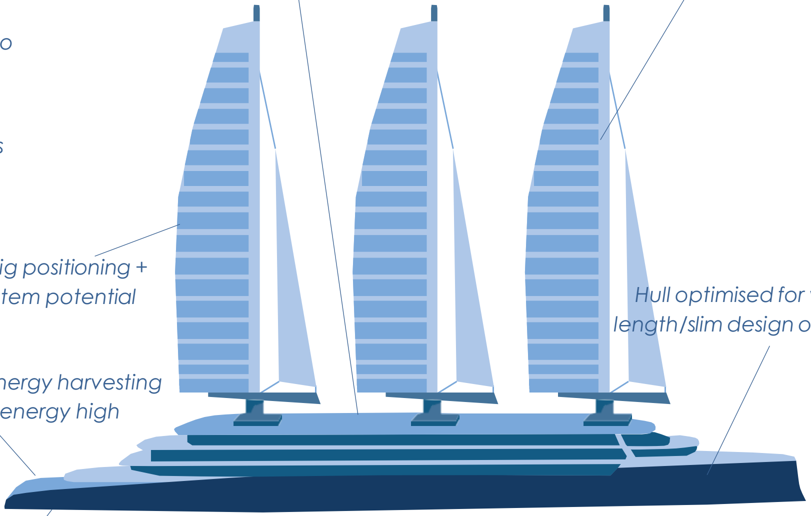
*Navigation and other systems may need reconfiguring*

*Engine calibration to maintain efficiency with variable wind power delivery*

*Access to cargo hatches and other deck equipment*

*Freeboard Interaction*

*Standard Hull Design*



*Integrated design elements – access, stability, ballast, cargo/passenger configurations etc.*

*Weather routing for wind and voyag optimisation lead to substantial increased performance*

*Optimal rig positioning + hybrid system potential*

*Hull optimised for wind, length/slim design options*

*Potential for energy harvesting when wind energy high*

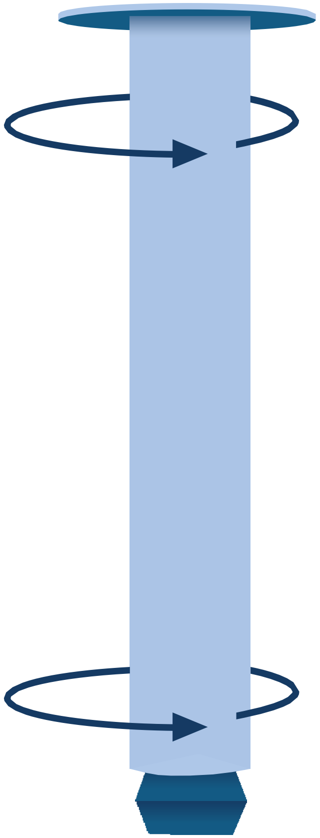
*Full integration wind/engines. Hybrid/electric options.*

## Primary Wind & Newbuild Wind-Assist

IWSA
International Windship Association

## Rotor sail

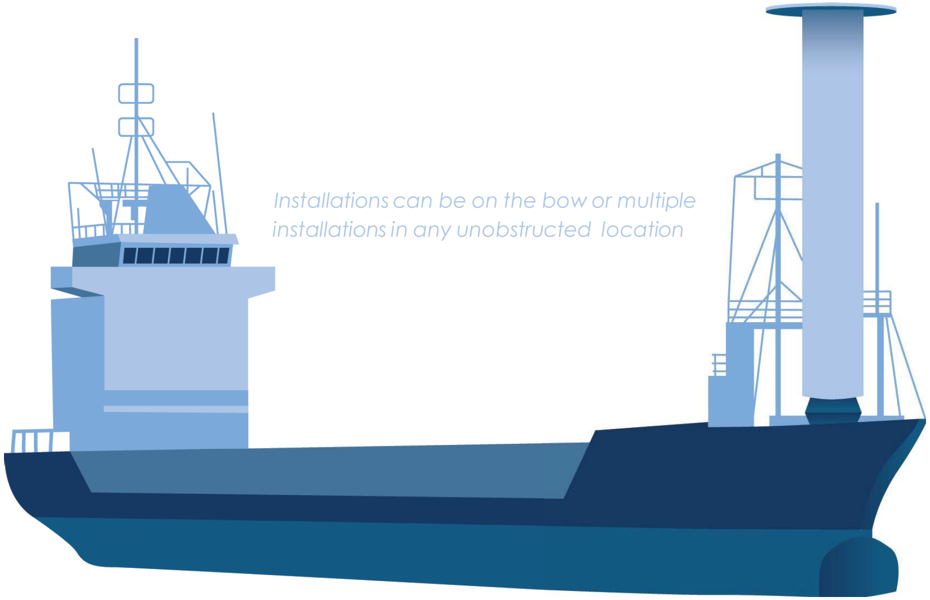
Flettner Rotor or Rotor Sails are rotating composite cylinders with a top disc and possibly a bottom disc that are rotated at up to 300 rpm (dependent on size/application) by low power motors and as the wind catches the rig, they use the Magnus effect (difference in air pressure on different sides of a spinning object) to generate thrust. Systems already designed include ones deployed on rail systems, hinged and telescopic versions. The original concept was developed in the 1920's with a small number of installations, however the modern, upgraded version of these sails were first installed on modern vessels in 2010's.



### Considerations

Deck space
Retractability
Navigation/Line of Sight
Beam/Head Wind Performance
Vibration/Motor

**Installed Sizes** (to date)
1m x 18m – 5m x 35m

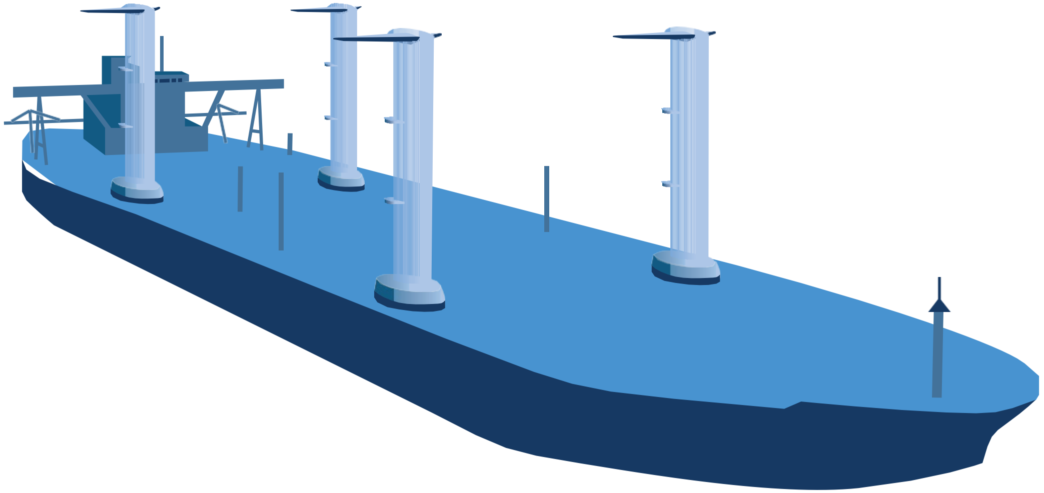


*Installations can be on the bow or multiple installations in any unobstructed location*

## Suction wing

Suction Wings (Ventifoil, Turbosail, eSAIL) are stubby, non-rotating wing sails with vents and an internal fan (or other device) that creates suction which pulls in the boundary layer around the wing generating enhanced effect. Installations to date have been deployed on the bow, stern and as deck containers and flatrack.

The system was originally designed and deployed in the 1980’s



## Considerations

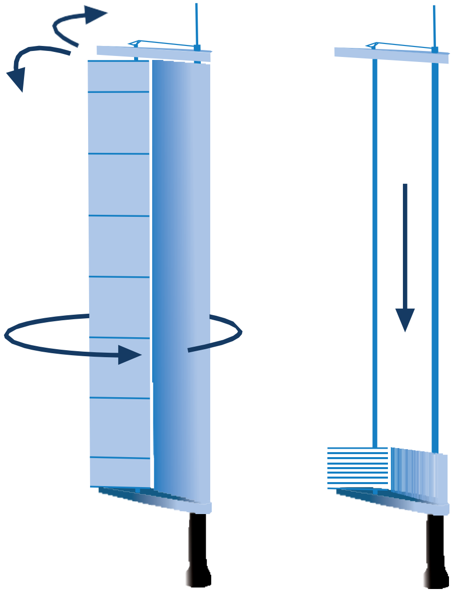
Deck space
Retractability
Navigation/Line of Sight
Suction device

**Installed Sizes** (to date)
10m-17m

## Hard sail

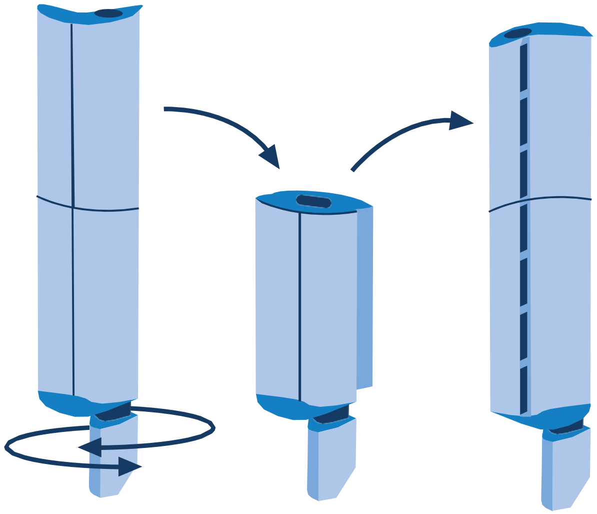
Hard or rigid sails are defined by the use of a rigid materials and design and these types of system have been used extensively in the racing world. There are quite a variety of different systems from wing sails, foils and JAMDA style rigs, some with single or multiple foils, others deploying movable flaps and some segmented. Some rig designs have solar panels for added ancillary power generation.

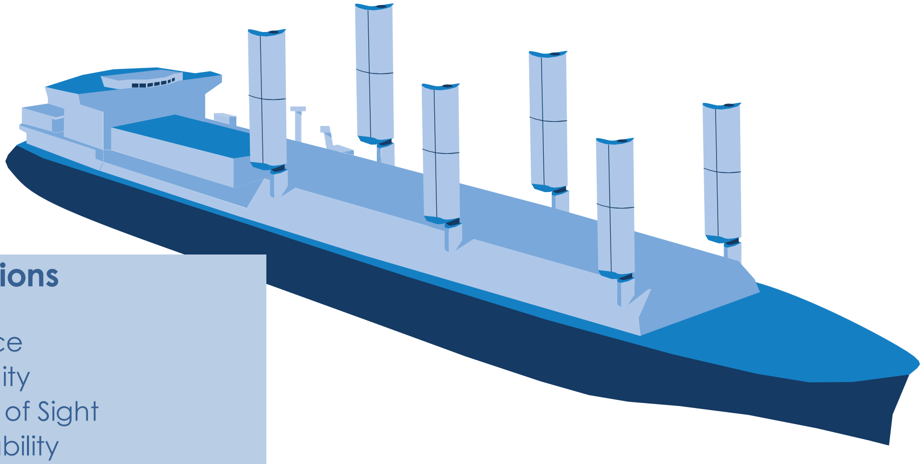
Note: There are also hybrid wing sails developed that have a rigid frame, but flexible soft coverings. Rigid sails were first deployed on modern commercial vessels in the 1970s and 1980's.



*Hybrid wing sail with flap with soft membrane*

*Single wing sail with flap and retractability*

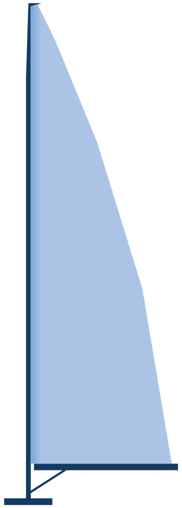




### Considerations

Deck space
Retractability
Navigation/Line of Sight
Windage/Stability

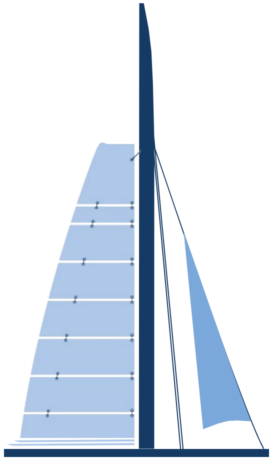
**Installed Sizes** (to date)
2m x 9m -15m x 35m



## Soft sail & Hybrid sail

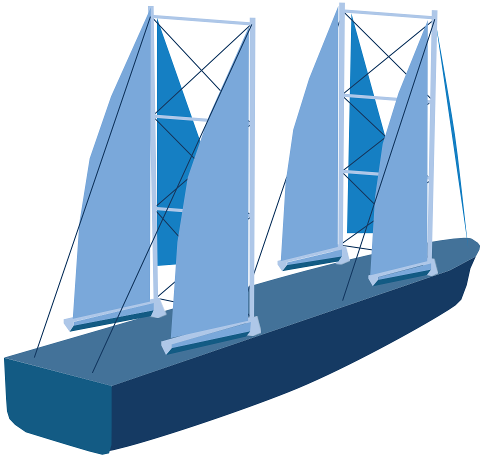
Soft sails come in a wide variety of configurations and these include both traditional sail rigs and new designs such as the dynarig system. Many of these systems are well-tested and their use has been extensive throughout the world both commercially and more prevalently in leisure sailing recently.

New robust materials & production techniques are lengthening their usability/lifespan and automated furling systems and control systems reduce the need for additional crew for large installations (smaller rigs can still be handled manually). Commercial applications require masts to be either retractable or foldable.



*Hybrid rig design using furlable rigid panels and soft sail combo*

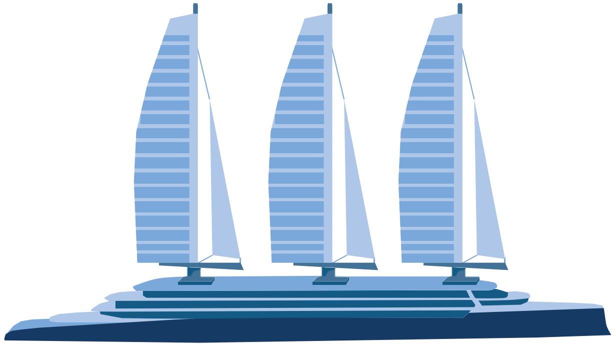
*Auto-furling systems are configured for large traditional soft sail installations*

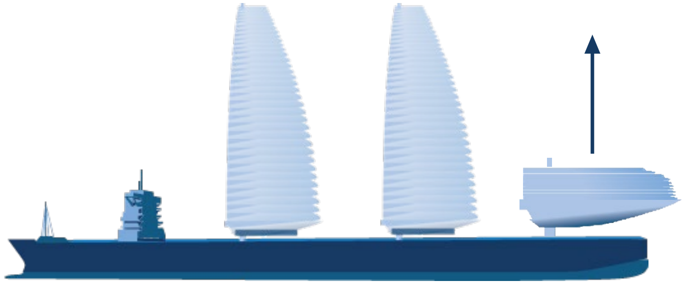


### Considerations

Deck space
Retractability
Navigation/Line of Sight
Windage/Stability
Material longevity

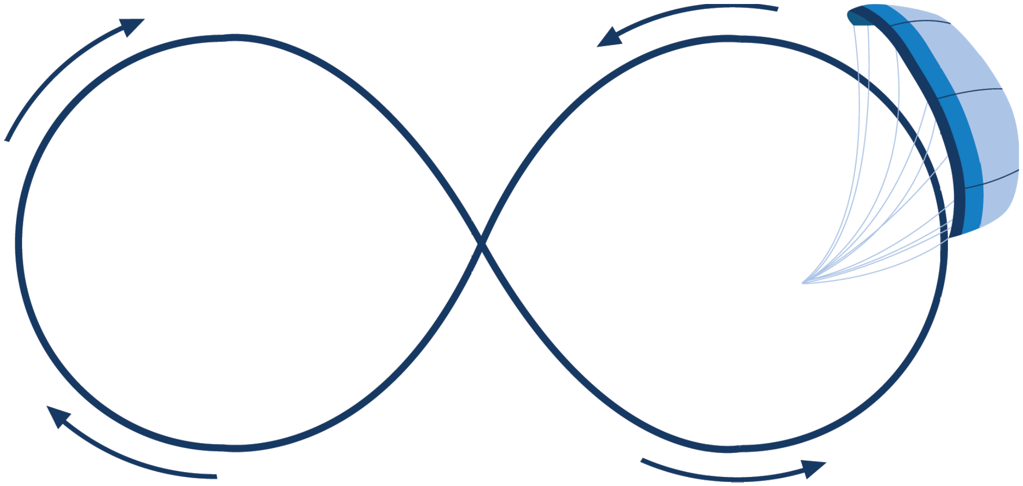
**Sizes**
highly variable/flexible





*One of many new designs, this one is using an inflatable sail system*

*Dynamic kite example with a figure of eight deployment to enhance power delivered*



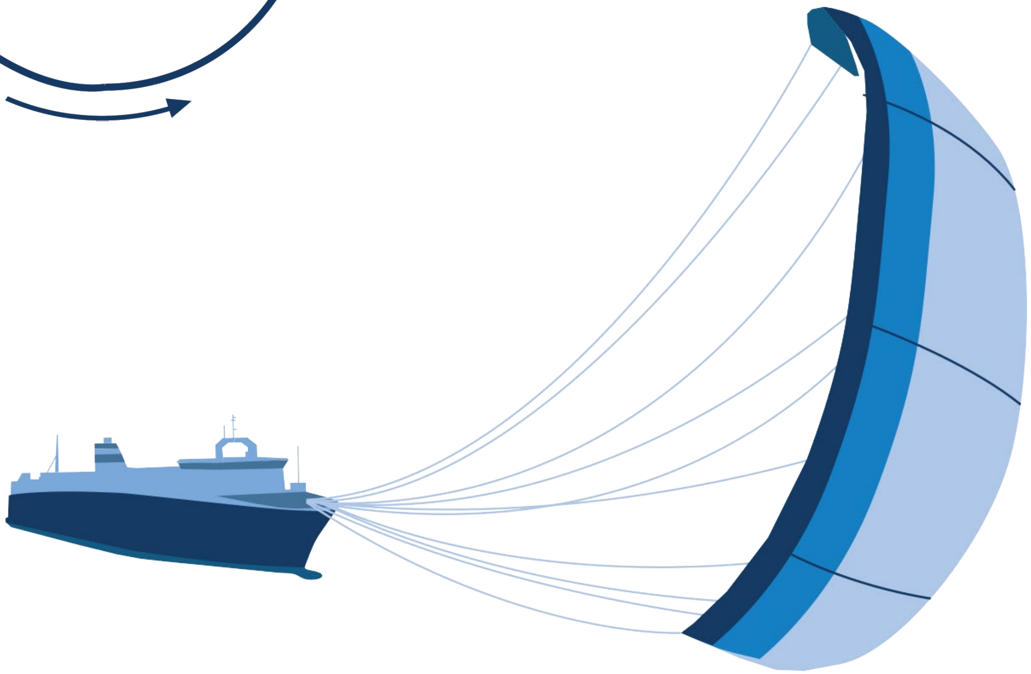
## Considerations

Wind Resources/Direction
Deployment/Retrieval
Control systems
Material longevity

**Sizes**
(deployed/designed)
500m2 – 1000m2

## Kite

Kites are deployed at over 200m above the vessel with a tether attached to the bow of the vessel (or assisting tug) to assist with propulsion. The kites take advantage of constant winds at those high elevations and can either be passive (maintain a single position) or dynamic (controlled deployment in a figure of eight or other configuration to maximise thrust). Kites are primarily generating thrust however the tether could also be used to generate electrical energy. First generation towing kites were first deployed in the 2010's.



## Turbine

Turbines using marine adapted wind turbines to either generate electrical energy or a combination of electrical energy and thrust. Turbine systems are being designed that are both vertical and horizontal configurations.

### Considerations

Wind Resources/Direction
Mountings/Forces
Vibration/Stability
Material longevity

### Sizes

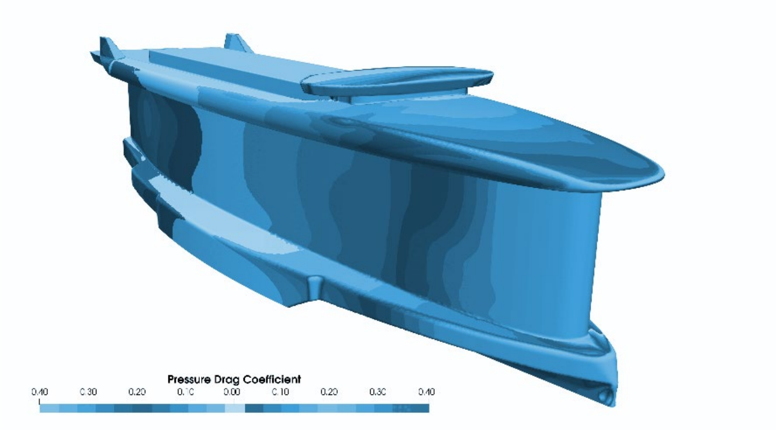
Containerised or Free Standing

### Considerations

Stability / Ballast
Extreme Weather Performance
Ship Type / Adaptation

### Sizes

Vessel Size



## Hull Form

Hull Form designs take the whole of the vessel and adapt the ship’s hull itself so that it functions as a large ‘sail’, capturing the power of the wind to generate thrust. Applicable primarily to newbuilds.

# ANNEX 2

# CASE STUDIES - MARKET ANALYSIS

## Wind Propulsion Market Analysis & Related Studies

Publicly available, third-party analysis of the wind propulsion market and case studies covering the diffusion of technologies, the economics and investment potential and the financing of these systems are still quite limited, however this list of reports, white papers and articles should give a broad overview of the development of wind propulsion internationally both for large commercial vessels and smaller scale sail cargo vessels. There are also two reports included in the list that give an insight into national and regional level opportunities.

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**A Comeback of Wind Power in Shipping: An Economic and Operational Review on the Wind-Assisted Ship Propulsion Technology** (2021), Chou, T.; Kosmas, V.; Acciaro, M.; Renken, K. [Hapag-Lloyd Center for Shipping and Global Logistics (CSGL), Kühne Logistics University], Sustainability 2021, 13,

Discusses the status quo of the WASP technological growth within the maritime transport sector by means of a secondary data review analysis, presents the potential fuel-saving implications, and identifies key factors that shape the operational efficiency of the technology. The analysis reveals three key considerations. Firstly, despite the existing limited number of WASP installations, there is a promising trend of diffusion of the technology within the industry. Secondly, companies can achieve fuel savings, which vary depending on the technology installed. Thirdly, these bunker savings are influenced by environmental, on-board, and commercial factors, which presents both opportunities and challenges to decision makers.

https://doi.org/10.3390/su13041880 PDF download https://www.mdpi.com/2071-1050/13/4/1880/pdf?version=1614298851

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**Barriers and overcoming strategies for accelerating the uptake of WASP** (2021) – Report compiled for EU Interreg WASP project, Pomaska, L., Rafaelova, Z., Kosmas, V., Acciaro, M. [Hapag-Lloyd Center for Shipping and Global Logistics (CSGL), Kühne Logistics University],

Wind Assisted Ship Propulsion (WASP) is seen as a potential solution to the environmental challenges of the maritime industry, still broader uptake is limited by barriers that hinder its adoption, implementation and upscaling. The purposes of this report are as follows: (i) Identify overcoming strategies to accelerate the uptake of WASP. (ii) Create a framework that shipowners can consult or adapt to their specific needs in order to evaluate strategies for investments in CO2 abatement technologies. (iii) Create a foundation of suggestions for WASP technology providers that can be adapted internally to overcome certain market barriers. (iv)Provide a basis for policymakers with respect to regulation and incentives that can be provided to accelerate the uptake of WASP technologies. (v)Provide managerial and policy insights for all stakeholders that are involved in the process, mainly WASP technology providers, shipowners and policymakers.

https://vb.northsearegion.eu/public/files/repository/20220111103132_WASPWP4.D5B_Barriersandovercomingstrategiesforacceleratingtheuptakeof WASP.pdf

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**Study on the analysis of market potentials and market barriers for wind propulsion technologies for ships.** (2016/7), Nelissen, D. (CE Delft), Traut, M. (Tyndall Centre), Köhler, J. (Fraunhofer ISI), Mao, W. (Chalmers University), Faber, J. (CE Delft), Ahdour, S. (CE Delft)

This study, commissioned by EU DG Climate Action, focuses on the direct utilisation of wind for the propulsion of commercial ships in the form of wind-assisted shipping. In order to determine the savings potentials, models have been developed for the different wind propulsion technologies. The models have been used to determine the technologies' power savings for six sample ships across AIS-recorded voyage profiles and for sample routes, differentiating two speed regimes respectively for four different technology groups, Flettner rotors, wing sails, kites and turbines.

Should some wind propulsion technologies for ships reach marketability in 2020, the maximum market potential for bulk carriers, tankers and container vessels is estimated to add up to around 3,700-10,700 installed systems until 2030, including both retrofits and installations on newbuilds, depending on fuel price, vessel speed, and discount rate applied. The use of these wind propulsion systems would then lead to CO2 savings of around 3.5-7.5 Mt CO2 in 2030 and the wind propulsion sector would then be good for around 6,500-8,000 direct and around 8,500-10,000 indirect jobs.

PDF download: https://cedelft.eu/wp-content/uploads/sites/2/2021/04/CE_Delft_7G92_Wind_Propulsion_Technologies_Final_report.pdf

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**National Case Study: France**
**White Paper title: The Propulsion of Ships by the Wind: Technologies ready to decarbonize maritime transport - An industrial opportunity for France** (2022) [in French]
Association Windship (IWSA Europe: Atlantic hub), Detrimont, L.

This white paper presents keys facts relating to wind propulsion systems and development of the wind propulsion sector in France. It focuses on the key French projects under development and the opportunities this presents to the country for a new way for a clean and decarbonized transport, which is anchored in the French territories and renews the link between the citizen, the sailor and the sea. This paper also draws on the experiences and testimonies of many actors in the maritime world, local authorities and administrations, institutions and schools, innovation stakeholders, industry, associated services and of course project promoters.

https://drive.google.com/file/d/1OHUxqPXxij13nQFxfirADMkr-8m_lzo_/view [in French]

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**Regional Case Study: Brittany**

**Overview of Wind Propulsion for Shipping developments in Brittany, France.** (2022)
This paper maps out a growing network of projects, companies and initiatives in the wind propulsion field in the Brittany region of France. Bretagne Développement Innovation states that the sector relies on the expertise of naval, nautical and competitive sailing companies in the region and the desire of the Brittany Region to include the territory in the ecological transition through the Breizh Cop, its "low-carbon mobility" roadmap and the regional research and innovation strategy.

https://www.bdi.fr/wp-content/uploads/2022/09/2111110-BDI-Developpement-Innovation-Propulsion-par-le-vent-Brochure_en_def-1.pdf [in English]

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**Financing Ships with Wind-Assisted Propulsion Technologies** (2019) Schinas, O and Metzger, D. [Hamburg School of Business Administration, Germany & Helmut Schmidt University, Germany] - Presented at the International Conference on Wind Propulsion (2019), London, UK

The issue of financing green ships as well as of financing decarbonization of maritime operations has already attracted the interest of experts from the academia and the industry. Given that green ships do not enjoy a freight premium and their operating expenses are at the level of conventional assets, the inherently higher capital expenses required for green assets deteriorate profit margins and deter investors from relevant outlays. Hence, financial engineering is required in order to make investors indifferent to cost and riveted to the decarbonization aspects of any ship financing project. This paper summarizes research results and presents illustrative cases and structures. The analysis considers sharing economy models, such as the 'pay as you save', that perfectly suit solutions involving wind-assisted propulsion, and will also identify risks and ways of mitigating them. The approach considered may assist in the analysis of various wind-assisted and power-boosting technologies.

PDF download: https://www.researchgate.net/profile/Orestis-Schinas/publication/335961845_FINANCING_SHIPS_WITH_WIND-ASSISTED_PROPULSION_TECHNOLOGIES/links/5daae557a6fdccc99d91cf30/FINANCING-SHIPS-WITH-WIND-ASSISTED-PROPULSION-TECHNOLOGIES.pdf

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**Sail Freight Revival: Methods Of Calculating Fleet, Labor, And Cargo Needs For Supplying Cities By Sail.** (2021) Woods, S.

Sail Freight has slowly worked its way into the realm of sustainability discourse as a way of reducing emissions from transportation, providing logistical solutions using the emissions free power of the wind and technologies proven effective for over 5000 years. This paper proposes methods of understanding this issue of scale by calculating the needs of a city for food. Using foodshed analysis to calculate necessary fleet capacities therefrom, as well as the labor needed to support this fleet, a model is provided for the New York Metro Area. The capacity for building this fleet and training sailors with current sail freight infrastructure and operations is then examined, with recommendations and analysis for addressing these challenges over the coming decades.

PDF download: https://www.researchgate.net/profile/Steven_Woods8/publication/354841970_Sail_Freight_Revival_Methods_Of_Calculating_Fleet_Labor_And_Cargo_Needs_For_Supplying_Cities_By_Sail/links/614f3ad8522ef665fb5ec30d/Sail-Freight-Revival-Methods-Of-Calculating-Fleet-Labor-And-Cargo-Needs-For-Supplying-Cities-By-Sail.pdf

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# ANNEX 3

# CASE STUDIES - TECHNOLOGY, PERFORMANCE, VERIFICATION

## Wind Propulsion Technology, Performance & Verification

The analysis of technology developments, performance and verification methods are of vital importance and recent papers, reports and simulations are listed below. These case studies will be further bolstered as more third-party verification and public data is made available.

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**Speed Trial Verification for a Wind Assisted Ship** (2021) Werner, S., Nisbet, J., Hörteborn, A. [SSPA Sweden AB], Nielsen R, [Scandlines]. Presented at RINA International Conference on Wind Propulsion (2021), London, UK

As the number of wind assistance installations in commercial shipping grows and the industry matures, the need for full-scale verification of the performance increases. Standard procedures or guidelines for conducting such full-scale trials are still lacking. One strategy is proposed and discussed here. The method is demonstrated using a speed trial conducted with Scandlines' hybrid ferry Copenhagen equipped with a rotor sail. The trial result is extrapolated to yearly power saving using a statistical route analysis. With this approach, the result can be derived at a feasible cost, within a limited time frame and using commercially available tools and established procedures.

https://vb.northsearegion.eu/public/files/repository/20211208153521_Werner2021SPEEDTRIALVERIFICATION.pdf

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**Example Reports (EU Interreg WASP Project):**

**Speed trial and route analysis of m/v Frisian Sea with suction wings** (2022)
https://vb.northsearegion.eu/public/files/repository/20220707112304_RE40201042-02-00-A.pdf

**Speed trial and route analysis of m/v Annika Braren with rotor sail** (2022)
https://vb.northsearegion.eu/public/files/repository/20220707112458_RE40201042-03-00-A.pdf

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**Performance Prediction & Design of Wind-Assisted Propulsion Systems** (2021) Thies, F., Ringsberg, J. W., Chalmers Univ., Presented at RINA International Conference on Wind Propulsion (2021)

Wind-assisted propulsion is seen as one of the main alternatives to potentially achieve large emission reductions in shipping. However, wind-assisted propulsion introduces new challenges in the design, retrofitting and performance prediction as well as the performance analysis. This paper presents and compares methods to predict the performance of wind-assisted propulsion, using the validated performance prediction model ShipCLEAN. Focus is put on evaluating the difference between 1 degree of freedom (1 DOF) and 4 DOF methods as well as the impact of aerodynamic interaction effects in between multiple sails. Practical design considerations and performance differences are also discussed. The study includes a comparison of the performance of different sail types (Flettner rotors, Wing sails and Suction wings) under realistic operational conditions.

PDF download:
https://vb.northsearegion.eu/public/files/repository/20220502151951_20220411155441_Thies2021PERFORMANCEPREDICTIONANDDESIGNOFWIND-ASSISTEDPROPULSION.pdf

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**Quantifying voyage optimisation with wind-assisted ship propulsion: a new climate mitigation strategy for shipping** (2021), Mason, J. University of Manchester PHD Thesis

This work computationally models voyage optimisation with wind propulsion to estimate the carbon savings on thirteen globally distributed shipping routes. Findings from this thesis demonstrate that four Flettner rotors can reduce the carbon emissions from an 80,000 dwt Panamax bulk carrier ship by 10.5% relative to contemporary operations, increasing up to 17.0% when using voyage optimisation under current operational practices. Add speed reductions and flexible arrival times to the mix, and carbon savings increase to 44% with a one-fifth increase in arrival time. Crucially, this analysis highlights that significant short-term carbon reductions are feasible, providing a clear steer to the sector that it is practical and appropriate to strengthen their decarbonisation targets to bring them in line with the Paris Agreement goals.

PDF download https://www.research.manchester.ac.uk/portal/files/209787529/FULL_TEXT.PDF

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**Decarbonising Bulk Carriers with Hydrogen Fuel Cells and Wind-Assisted Propulsion: A Modelled case Study Analysis** (2022), Comer, B., Georgeff, E., Mao, M., Osipova, L. [International Council on Clean Transportation] and Stolz, D. [Cross Product Atmospheric LLC]

This study investigates the potential of both liquid and compressed hydrogen fuel cells to replace fossil fuels for bulk carriers including when paired with wind-assisted propulsion in the form of rotor sails. The study models three bulk carriers a 57,000-dwt coastal dry bulk carrier sailing in China a 69,000-dwt ore and coal carrier sailing the North American Great Lakes and a 7,570-dwt cement carrier in northern Europe. The report used 2019 AIS ship traffic data and weather data observations to estimate the ships' total energy use and the energy saving potential of rotor sail for two routes for each ship. Each route is divided into legs. Ship energy use was estimated with ICCT Systematic Assessment of Vessel Emissions (SAVE) model.

Download PDF: https://theicct.org/sites/default/files/publications/Hydrogen-and-propulsion-ships-jan22.pdf

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**A Review of Wind-Assisted Ship Propulsion for Sustainable Commercial Shipping: Latest Developments and Future Stakes** (2021) Khan, L., Macklin, J.J.R, Peck B.C.D, Morton, O., Souppez, J-B.R.G. Aston University, UK   Presented at the RINA International Conference on Wind Propulsion (2021), London, UK

Wind-assisted ship propulsion appears as an undeniable part of the future of maritime transportation, offering the greatest long-term potential for emission reduction, as highlighted in this paper. Furthermore, several vessels, utilizing an array of wind-assisted propulsion systems, are already in service, with significant new projects in development. The main considerations for sails, rotors and kites are reviewed and the theory underpinning performance prediction programs presented, with recommendation on the applicable constraints for all degrees of freedom. The validation of such performance predictions however remains an area of future work, with greater sea trial data available in the public domain being necessary.

PDF download:
https://publications.aston.ac.uk/id/eprint/43134/1/Khan_et_al_2021_RINA_Wind_Assisted_Ship_Review.pdf

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**Lifecycle Modelling of a Wind Powered Car Carrier: An Assessment of Cost and Greenhouse Gas Emissions.** (2020) Olsson, T. & Carlsson, J.

A simulation of the 210m, 13,021 dwt wPCC (Oceanbird) car carrier with a 7,000-car capacity. To accurately compare the wPCC to a car carrier that does not sail, a preliminary power-speed curve was obtained to determine the power needed for the hull at 8.0 and 11.4 knots [Av. propulsive load @ 11.4 knots = 2,680 kW & Av. propulsive load @ 8.0 knots = 992 kW]

Using a Total Cost of Ownership (TOC) model, the wPCC's propulsion system ranges between €48.9m and €128.1m. The cost of a ship using BioMeOH and reaching a similar climate impact ranges between €159.7m and €1,268.6m. In the scenario using the lowest speed of 8.0 knots, when discounted cash flow has been applied and conditions are most favourable to the ships without sails, the ship using BioMeOH is 2.5 times as expensive as the wPCC which is operating under its most unfavourable conditions. In the same scenario the ship using LBG is 2.6 times more expensive but with a climate impact at least five times as high. Furthermore, this is also the scenario where the LNG ship and wPCC is closest in total ownership cost and differs by 68% in favour of the wPCC. Without applying discounted cash flow, the ship using BioMeOH is at least three times as expensive as the wPCC.

https://odr.chalmers.se/bitstream/20.500.12380/301648/1/Life%20cycle%20modeling%20of%20a%20wind%20powered%20car%20carrier%20-%20final%20examinator%20version.pdf

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**Techno-Economic Assessment of Wind-Assisted Ship Propulsion (2019)**
van der Kolk et al (Delft University of Technology, University of Manchester, University College London]

Simulations are based on a 19,500-dwt asphalt bulker on a North Sea route with three 30m rotors installed have shown savings of 21.7% on the straight or shortest distance route and reduction on the fuel optimised route of 29.5%.

The costs of the installations are based on 2019 prices, with the cost for three rotors set at $3.5m and assuming a 5% discount rate and with a fuel cost of $550/t (2019) the ROI was found to be 13.1 and 9.7 years respectively. These calculations utilised routing optimisation, however, speed was kept steady to reduce significant schedule/utilisation changes on the fuel optimised route, however speed-optimisation would also likely lead to significant improvements while fuel costs will likely rise, and equipment costs decrease.

PDF download: https://www.researchgate.net/profile/Nico-Van-Der-Kolk/publication/335542956_Wind-Assist_for_Commercial_Ships_A_Techno-Economic_Assessment/links/62584fa09be52845a9034b89/Wind-Assist-for-Commercial-Ships-A-Techno-Economic-Assessment.pdf

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**Transitioning to Low Carbon Sea Transport project 2017-2023 – Marshall Islands**

The project is to start the new build of a 48m long, 290 dwt inter island supply vessel with sail propulsion for climate-neutral ship operations. This project involves Germany's University of Applied Sciences Emden/Leer, the German society for international cooperation (GIZ) and the Ministry of Transport, Communication and Infrastructure, Republic of the Marshall Islands.

Due to the good local wind conditions, the ship will be equipped with a powerful sailing system that is easy to operate and capable of automation. The sail area of the three-master will be around 500m2. The power supply for the auxiliary operation is also to be provided by regenerative energy via photovoltaics, small wind turbines and a shaft generator. A small diesel engine will be used for manoeuvring and propulsion in unfavourable wind conditions and conversion to coconut-based biodiesel should be possible in the future.

https://www.giz.de/en/downloads/giz2022-en-transitioning-to-low-carbon-sea-transport.pdf

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# ANNEX 4

## TABLE - LARGE COMMERCIAL VESSEL - INSTALLATIONS Q3 2022

### Large Commercial Vessel - Wind Propulsion Installations (Q3, 2022)

| | Ship Name | Ship Type | DWT | GT | Length | Technology Installed | Installation Year | Installation Type |
|---|---|---|---|---|---|---|---|---|
| 1 | E-Ship 1 | General Cargo/Ro-Lo | 10,020 | 12,968 | 130 | 4 x 27m fixed rotor sails | 2010 | newbuild |
| 2 | Estraden | Ro-Ro | 9,741 | 18,205 | 163 | 2 x 18m fixed rotor sails | 2014 | retrofit |
| 3 | Adria Kvarner | General Cargo | 4,250 | 2,844 | 90 | 1 x 18m fixed rotor sail | 2018 | retrofit |
| 4 | New Vitality | Tanker VLCC | 306,751 | 162,636 | 333 | 2 x 32m retractable wing sails | 2018 | newbuild |
| 5 | Timber Wolf | Tanker - LR2 Product | 109,647 | 61,724 | 245 | 2 x 30m fixed rotor sails | 2018 | retrofit |
| 6 | Afros | Bulk Carrier - Ultramax | 63,223 | 36,452 | 199 | 4 x 16m movable rotor sails | 2018 | newbuild |
| 7 | Copenhagen | Ferry | 5,088 | 24,000 | 169 | 1 x 30m fixed rotor sail | 2020 | retrofit |
| X | Axios | Bulk carrier - Kamsarmax | 81,960 | 44,113 | 229 | wind ready (rotor sails) | 2020 | newbuild |
| 8 | Ankie | General Cargo | 3,638 | 2,528 | 90 | 2 x 13m hinged suction wings | 2020 | retrofit |
| 9 | Annika Braren | General Cargo | 5,023 | 2,996 | 85 | 1 x 18m fixed rotor sail | 2021 | retrofit |
| 10 | SC Connector | Ro-Ro | 8,843 | 12,251 | 155 | 2 x 35m hinged rotor sails | 2021 | retrofit |
| 11 | Sea Zhoushan | Bulk Carrier VLOC | 324,268 | 173,504 | 340 | 5 x 24m hinged rotor sails | 2021 | newbuild |
| 12 | Ville de Bordeaux | Ro-Ro | 5,200 | 21,528 | 154 | 1 x 500m2 dynamic kite | 2021 | retrofit |
| 13 | Frisian Sea | General Cargo | 6,477 | 4,298 | 118 | 2 x 11m flatrack/hinged suction wings | 2021 | retrofit |
| 14 | Balueiro Segundo | Fishing Vessel | n/a | 593 | 41 | 1 x 12m fixed suction wing | 2021 | retrofit |
| 15 | Naumon | Cargo/theatre vessel | 1,006 | 1,057 | 59 | 1 x 17m fixed suction wing | 2021 | retrofit |
| 16 | Tharsis | General Cargo | 2,300 | 1,801 | 88 | 2 x 9m hinged wing sails | 2021 | retrofit |
| 17 | GNV BRIDGE | Passenger | 8,632 | 32,581 | 203 | 1 x 12m retractable wing sail | 2021 | retrofit |
| 18 | Marfret Niolon | RoRo | 5,282 | 7,395 | 123 | 2 x 12m hinged/containerised suction wings | 2022 | retrofit |
| 19 | Anna | General Cargo | 5,097 | 2,993 | 90 | 2 x 16m hinged suctions wings | 2022 | retrofit |
| 20 | Berlin | Ferry | 4,835 | 22,319 | 169 | 1 x 30m fixed rotor sail | 2022 | retrofit |
| 21 | Shofu Maru | Bulk Carrier | 99,000 | n/a | 235 | 1 x 48m retractable wing sail | 2022 | newbuild |

Source: International Windship Association (IWSA) Members Survey 2022.

Note: This listing doesn’t include the c.10 traditional rigged small cruise vessels in operation or small traditional rigged sail cargo vessels (under 400GT)

## APPENDIX 5 – Classification Society Guidelines

Links to a selection of classification society guidelines for wind propulsion systems:

Bureau Veritas Guidelines: https://erules.veristar.com/dy/data/bv/pdf/206-NR_2021-02.pdf

ClassNK Guidelines are downloadable from https://www.classnk.com/hp/en/index.html

DNV Guidelines: https://rules.dnv.com/docs/pdf/DNV/ST/2019-11/DNVGL-ST-0511.pdf

ABS Guidelines: https://ww2.eagle.org/content/dam/eagle/rules-and-guides/current/other/315_gn_wind_assisted_propulsion_system_installation/wind-asisted-propulsion-guide-aug21.pdf

Lloyds Register Guidelines:
Sail-assisted Ships https://www.lr.org/en/rules-for-sail-assisted-ships
Rotors https://www.lr.org/en/guidance-notes-for-flettner-rotor-approval/

Masts & Rigging https://www.lr.org/en/guidance-notes-for-masts-spars-and-standing-rigging/

## APPENDIX 6 - 30th International Towing Tank Conference (ITTC) 'Specialist Committee on Performance of Wind Powered and Wind Assisted Ships'

Terms of Reference:

1. Review technologies for wind propulsion and wind assistance. Clarify the distinction between wind powered and wind assisted ships.

2. Review methods of ship model hydrodynamic tests, wind tunnel tests, CFD, ship dynamics simulations and routing relevant for predicting the performance and safety of wind powered and wind assisted ships at design stage with particular attention paid to higher side forces and drifting of the ship due to wind powering.

3. Review long-term statistics of winds and waves from the point of view of applicability for the evaluation of wind assisted ships at design stage.

4. Derive a guideline for predicting the fuel consumption of a wind propulsion ship on a route at design stage with the consideration of weather-routing effects.

5. Review safety and regulatory issues related to hydro/aero dynamic testing and evaluation and recommend measures to take at design stage.

6. Derive performance indicators for comparing the performance of wind propulsion at design stage.

7. Investigate the effect on propulsive factors due to reduced propeller load arising from the use of wind power. Identify the effects of wind propulsion on the propulsion system, e.g. pressure side cavitation occurrence. Liaise with Resistance and Propulsion Committee and SC on Cavitation and Noise.

8. Derive a modified procedure for full scale trial of wind propulsion ships. Liaise with Full Scale Performance Committee.

9. Cooperate with MEPC on the continuous development of the EEDI for wind propulsion ships. Liaise with Full Scale Ship Performance Committee.

10. Liaise with the Ocean Engineering Committee regarding their work on SiL and controllable fans to model wind loads.

https://ittc.info/media/10159/tor-revised-after-conference.pdf

## APPENDIX 7 - European Sustainable Shipping Forum (ESSF) – Ship Efficiency Sub-Group - Wind Propulsion Workstream (Apr-Dec 2022)

Terms of Reference

Task 1 - Overview of Wind (Assisted) Propulsion Systems

Objectives

1.1a Develop state-of-the-art WAPS whitepaper

- System types, installations
- Regulatory aspects
- Operational feedback
- Economic benefits, optimal conditions as a function of ship type, route, retrofit / newbuild; include macro aspects (market, fleet segments, fuel savings, emission reduction)
- Recommendations

1.1b Develop a Holistic Design and WAPS whitepaper

1.2 Describe methodology for evaluating WAPS performance

- Use input from WiSP2 JIP, EU WASP project and ITTC
- How to measure WAPS performance during operation (fuel savings, emissions, thrust, …)
- Performance prediction, including effects of e.g. weather routing, wind and wave statistics, arrival times
- Recommendations

1.3 Regulatory gaps and barriers analysis

- Use input from WiSP2 JIP, EU WASP project and ITTC
- Emission regulations, navigational safety, class rules
- Barriers to uptake of WAPS
- Recommendations

Task 2 - EU Regulatory Incentives

Objective: review current and planned EU regulations and recommend any amendments re application of WAPS – FuelEU Maritime, RED, MRV, ETS, EU Taxonomy

- Overview of timeline of regulatory decision-making process, incl. FuelEU and ETS
- Impact study for ships with WAPS
- Framework for consistent treatment of energy efficiency improvements
- Predicted vs. measured performance of ships with WAPS (define a priority credit for WAPS in regulations)
- Recommendations for EU COM

Task 3 - IMO / MEPC Matters

Objective: consolidate WAPS related information and prepare submission to MEPC [80]

- Consider: MEPC.1/Circ. 896, GHG regulations, Interim Guidelines; EEDI, EEXI, CII
- Input for improvements from Task 1.2, WiSP2 and other projects
- Impact analysis of the changes in Circ. 896 vs. Circ. 815
- How do WAPS fit into the framework for EEXI and CII calculations, with some examples
- Nonconventional / hybrid propulsion considerations and definition for WAPS
- Prepare submission to MEPC:
- INF paper with a SOA overview of the current market/installations (see item 1.1)

- Technical paper – extending Circ.896 to primary wind considerations

Task 4 - Recommendations for Further Research (2023)

Objective:  Consolidate input from Tasks 1.2, 1.3, 2 and 3 & Consider technical, operational (ship and ports), economic (finance, market barriers), legal (chartering) aspects; regulatory elements.