Wind Propulsion:
A Breath of Fresh Air in the Delivery of Zero Emissions Vessels

This article suggests wind propulsion as a driver to achieve zero emission shipping vessels and reduce the global shipping industry's carbon footprint.

The International Maritime Organisation (IMO) has issued a challenge to decarbonize the shipping industry by reducing greenhouse gas (GHG) emissions by at least 50% overall and 70% in carbon intensity by 2050, based on a 2008 baseline.[1] The global shipping industry has always been viewed as a hard-to-abate sector and total GHG emissions from the sector are between 2–3% of world emissions (equivalent to that of Germany). That share of total emissions is forecast to rise significantly if no action is taken, especially as land-based emissions reduce sharply and trade volumes continue to grow.

Zero emission vessels (ZEVs) will be very important in achieving that goal, with nearly 2,000 new vessels coming into a fleet of 50,000 or more large commercial vessels every year. The retrofitting of existing vessels to lower their carbon footprint substantially will be crucial as well. To achieve vessels that are carbon neutral, carbon (and other air emissions) zero or fully zero emissions vessels (no emissions to air or water) over their full life cycle, direct wind propulsion should be considered in order to deliver sharp, deep and timely cuts in emissions.

Figure 1 outlines the two ways that wind energy can be used to move a ship; indirectly through the production, transport and combustion of eco-fuel or the far more efficient direct route of capturing and using the energy on the ship itself. Wind propulsion includes everything from rigid sails, to kites, flettner rotors, and traditional soft sail rigs. Many of these systems are not new, but they are being rethought and installed commercially, with currently 10 large vessel installations covering the tanker, bulker, ferry/cruise, roll-on/roll-off (RoRo) and general cargo segments, with a pipeline of installations that will likely double that before the end of next year (see Figure 2).[2]

Wind Propulsion as Part of a Hybrid Solution: W.A.V.E.

If wind propulsion systems are assessed with the standard framework, using motor vessel parameters, retrofit systems are shown to deliver 5–20% of the propulsive energy required by the ship, averaged over a year, with the potential to increase to 30%. This percentage increases substantially for a primary wind vessel, optimised to maximize wind potential, using technology that is readily available or in late-stage development.[3] If these optimised vessels are operated on good wind routes, utilising weather routing software, then wind could provide up to 80% of the total energy requirement for certain segments of shipping. Figure 1 clearly shows that wind propulsion technology solutions require no new infrastructure, and the energy is delivered directly to the vessel at its point of use for free, for the lifetime of that vessel. Just with these numbers we can see that the fleet wide adoption of wind propulsion solutions, both retrofit and new build, would dramatically reduce fuel requirements in the shipping industry. However, if we combine these with other operational changes and energy efficiency measures we can create a hybrid W.A.V.E. (Wind + Activity + Vessel + Eco-Fuel combination) as shown in Table 1, shifting the paradigm away from a one-size-fits-all model.

In the model shown in Table 1, the wind propulsion component is averaged out across the fleet, delivering 20–30% of the energy requirement for vessels by 2050, along with substantial savings gained through operational changes and vessel optimisation. Eco fuels or "secondary renewables" would then only account for up to 40% of the propulsive energy required, reducing the size and cost of those alternative fuel systems and substantially reducing the costs to ship operators of alternative low-carbon or zero emission fuels. The cost of alternative fuels will be especially challenging during their initial rollout when the unit price is predicted to be substantially higher than fossil fuels.[4]

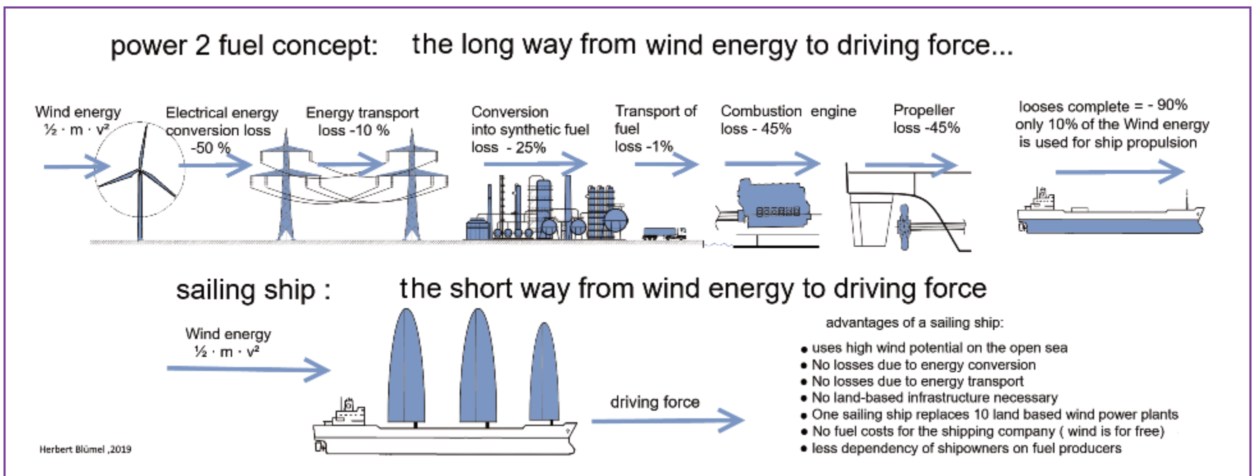

Figure 1. Direct wind propulsion (primary renewable vs. secondary renewable).
Source: Herbert Blumel, Becker Marine Systems.

Figure 2. Example installations: (left) Maersk Pelican, 109,000dwt LR2 Tanker (2 x 30m Norsepower Rotors); (center) MV Ankie, 3,600 dwt (2 x 10m collapsible Econowind Ventifoil Suction Wings); and (right) MV Afros, 64,000dwt Geared Bulker (4 x movable Anemoi Rotors).
Source: International Windship Association.

The Challenges of Decarbonizing Shipping

The UK Clean Maritime Plan released in July 2019, forecasts wind propulsion to be a £2 billion per year market in the 2050s, or 20% of the maritime propulsor market, with alternative fuels making up the other 80%. Importantly, once a wind propulsion system is installed it will deliver effectively free fuel for the next 20 or more years, the lifetime of most vessels.[5]

Most alternative low-carbon zero emission fuels being considered (e.g., ammonia, hydrogen, biofuels, batteries, and a raft of other e-fuels such as synthetic power-to-liquid or power-to-gas fuels), have significant challenges to their installation quickly and at scale. These challenges include:

1. **Cost:** most fuel systems have high capital expense (CAPEX) and at least in the foreseeable future significantly higher operating expense (OPEX) too.

2. **Storage:** the energy density of many of the alternative fuels is significantly lower than current fossil fuel options; therefore, additional storage space for those tanks is required on vessels, which of course reduces cargo capacity.

3. **Supply:** availability of the feedstock is an issue when it comes to biofuels and the large-scale deployment of renewable energy resources is required for the production of e-fuels. Diffusion of bunker supply (fuel distribution) of

Table 1. Hybrid W.A.V.E. approach to decarbonisation.
Source: International Windship Association.

WIND	+	ACTIVITY	+	VESSEL	+	ECO-FUELS
Wind –assist or Primary wind power (Primary Renewable)		Operational optimisation		Vessel optimisation		Renewable energy or waste-derived fuels (Secondary Renewables)
-retrofit wind-assist (5-20% savings – possible up to 30%) -newbuild primary wind 50%++ -today's tech +optimise & cheaper -lease/OPEX approach		-voyage & fleet management -weather routing -speed reduction -virtual arrival -crew training -data/ blockchain -new business models etc.		-design -size & capacity -energy management system -energy efficiency measures -air lubrication -reduced engine power etc.		-2nd gen biofuels -batteries -synthetic fuels + CCS -bio-gas/liquids -H2 & H2 carriers *Electric propulsion systems enables modular approach
20-30%	+	20%	+	20-30%	+	20-40%

Note: All figures are estimates and any one measure in each category could provide a significant portion of the proposed saving.

Figure 3. Primary Wind Designs: (left) Neoliner 136m Roro, (center) Silenseas 210m Cruise vessel (Chantiers de l'Atlantique), and (right) Vindskip Car Carrier Design.
Source: International Windship Association.

these alternative fuels also poses a concern, with a substantial period required to reach maturity and global coverage. A good example is the relatively slow roll out of liquified natural gas (LNG) bunkering worldwide over the last decade.

4. **Volatility:** All fuel markets are prone to volatility due to market and non-market forces. Strong demand for these eco-fuels from land-based users as well as the air transport industry will increase volatility.

5. **Infrastructure:** the delivery of alternative fuels requires the upgrade or deployment of new systems of production, refining, storage, transport, and bunkering. Much of this cost is externalized. A recent Lloyds Register and the University Maritime Advisory Services (UMAS) report stated that 87% of the $1.4 trillion required for decarbonizing shipping will be land-based costs.[6-8]

Reducing the fuel requirement by 60–80% as shown in Table 1, will also solve or significantly reduce many of these barriers to the adoption of low- or zero-carbon fuels especially in the initial stages, also assisting in the diffusion and uptake of these systems earlier and more widely in the market.

Delivering Zero Emissions Vessels

Can large ocean-going, zero-emission vessels be built today? If these are carbon neutral vessels, then yes, we can achieve this by building primary wind vessels with auxiliary engines burning a second-generation biofuel derived from waste for example (see Figure 3). In terms of the zero emission/zero carbon options, wind can serve as the primary system of propulsion if some operational compromises are made in speed and routing. Auxiliary engines or motors fuelled by green hydrogen, ammonia of other e-fuels generated with clean renewable energy are possible, as are batteries, but only if these are limited in size and cost is not a consideration. An option is to spread those costs across the lifetime of the vessel transferring the initial higher capital expenditure to an operational expenditure derived repayment system, a form of pay-as-you-save financing model.[9]

So, in general terms, the inclusion of wind propulsion in the ZEV/decarbonization pathways reduces fuel dependency overall. However, rethinking the current industry paradigm can engender further benefits. IMO is discussing speed limits or mandated restrictions of power on vessels as one of the short-term decarbonization measures. Both approaches have the potential to greatly increase the impact of wind propulsion, with primary wind vessel designs that can deliver 60%, 70%, 80%+ propulsion in the 10–12 knot speed range. Wind propulsion systems can also extend a ship's range, enabling vessels to take longer routes using less fuel on one hand, but also enabling operators to more regularly bunker at major supply hubs where alternative fuels will be more readily available and cheaper, especially in the early stages of development. This will help break a "chicken and egg" issue that plagued the initial roll out of LNG.[10]

One natural drawback of wind propulsion is that at times a huge amount of energy is delivered to the vessel that cannot be harvested, and then on other days, little or no wind exists. Just as offshore wind farm designers are looking at ways

In general terms, the inclusion of wind propulsion in the ZEV/decarbonization pathways reduces fuel dependency overall.

Figure 4. Onboard fuel generation: (left) Wind Hunter (Japan), (center) Bound4Blue (Spain), and (right) Blue Technology (Denmark).

to capture and store this additional energy, so are a number of wind propulsion projects. Options include hull generators, feathered propellers and turbines that turn that wind energy into e-fuel onboard the vessels for later use. Such options could allow vessels to become independent of bunkering, or even possibly provide an additional revenue stream if the energy is offloaded at port.

A note of caution is appropriate. As the industry races to adopt sophisticated, high-tech, and expensive ZEV systems, many developing-world countries will struggle to adopt these approaches. With these countries excluded and locked into another fossil fuel cycle, a two-tier industry could be created. This second tier would likely encompass developing country domestic fleets with millions of small vessels that are aging and primarily used in fisheries, on which tens of millions of people depend. Creation of a two-tier industry is likely to become ever more contentious at an IMO level, and could become a significant obstacle to ZEV development. Wind propulsion is the only currently available technical solution that can immediately reduce fossil fuel dependency and generate a more flexible hybrid approach that reduces the reliance on any single source of energy and opens the door for smaller, more affordable low-carbon fuel systems to be adopted.[11]

Conclusion

A hybrid approach, with a significant wind component can create a robust low-carbon pathway, which helps to facilitate the uptake of alternative low-carbon and zero-carbon fuels faster and at a lower cost for ship operators. This can help to overcome many of the market entry and scaling issues faced by a 100% renewable energy plus ship efficiency eco-fuel approach. The further step of onboard generation of fuel has an added potential to be a game changer in and of itself. Retrofitting the existing fleet with wind propulsion systems also extends the carbon budget available to the industry, creating some added breathing space for the introduction and scaling of alternative fuel supply systems. Where the wind blows, we need to follow. **em**

Gavin Allwright is Secretary of the International Windship Association **(IWSA)** "Promoting Maritime Wind Propulsion Solutions".
E-mail: **secretary@wind-ship.org.**

References

1. The International Maritime Organisation (IMO) strategy on reduction of GHG emissions from ships; Marine Environment Protection Committee 72 (April 2018). See www.imo.org/en/OurWork/Documents/Resolution%20MEPC.304(72)%20on%20Initial%20IMO%20Strategy%20on%20reduction%20of%20GHG%20emissions%20from%20ships.pdf.
2. International Windship Association (IWSA). See www.wind-ship.org.
3. EU-commissioned independent report: Study on the analysis of market potentials and market barriers for wind propulsion technologies for ships (2016/17). See https://www.cedelft.eu/publicatie/study_on_the_analysis_of_market_potentials_and_market_barriers_for_wind_propulsion_technologies_for_ships/1891.
4. OECD International Transport forum (ITF), Decarbonising maritime transport: Pathways to zero-carbon shipping by 2035(2018). See www.itf-oecd.org/decarbonising-maritime-transport.
5. UK Department of Transport, UK Clean Maritime Plan (July 2019). See https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/815664/clean-maritime-plan.pdf.
6. Comparison of Alternative Marine Fuels SEA\LNG Ltd, DNV GL (July 2019). See https://sea-lng.org/wp-content/uploads/2019/09/19-09-16_Alternative-Marine-Fuels-Study_final_report.pdf.
7. Bouman, et al. State-of-the-art technologies, measures, and potential for reducing GHG emissions from shipping – a review; Transp. Res. Part D Transp. Environ. 2017, 52, 408-421; available at https://www.sciencedirect.com/science/article/pii/S1361920916307015/pdfft?md5=514a165c03613da235ff6cb9b3361e26&pid=1-s2.0-S1361920916307015-main.pdf.
8. Techno-economic assessment of zero-carbon fuels, LR & UMAS (March 2020). See https://www.lr.org/en/insights/global-marine-trends-2030/techno-economic-assessment-of-zero-carbon-fuels/.
9. A pay-as-you-save model for the promotion of greening technologies in shipping; Orestis Schinas & Daniel Metzger, Hamburg School of Business Administration (Feb 2019). See https://www.academia.edu/38455023/A_pay-as-you-save_model_for_the_promotion_of_greening_technologies_in_shipping.
10. LNG supply infrastructure makes up for lost time, Selwyn Parker (05 Aug 2019). See https://www.rivieramm.com/news-content-hub/news-content-hub/lng-supply-infrastructure-makes-up-for-lost-time-55766.
11. MEPC75/INF.26 REDUCTION OF GHG EMISSIONS FROM SHIPS: Wind propulsion solutions. Submitted by Comoros (24 Jan 2020). See http://wind-ship.org/wp-content/uploads/2020/02/MEPC-75-INF.26-Wind-propulsion-solutions-Comoros-1.pdf.