THE ANNALS OF “DUNAREA DE JOS” UNIVERSITY OF GALATI
FASCICLE XI – SHIPBUILDING. ISSN 1221-4620, e-ISSN 2668-3156
DOI: https://doi.org/10.35219/AnnUgalShipBuilding/2024.47.20
2024

HARNESING WIND POWER IN MARITIME SHIPPING: A COMPARATIVE ANALYSIS OF INNOVATIVE HULL DESIGN AND RETROFITTED SOLUTIONS FOR DECARBONISATION

Florin Barbu
“Dunarea de Jos” University of Galati,
Faculty of Engineering, Galati,
47 Domneasca Street, 800008, Romania,
E-mail: florin.barbu@ugal.ro

Costel Ungureanu
“Dunarea de Jos” University of Galati,
Faculty of Naval Architecture, Galati,
47 Domneasca Street, 800008, Romania,
E-mail: costel.ungureanu@ugal.ro

Eugen-Victor-Cristian Rusu
“Dunarea de Jos” University of Galati,
Faculty of Engineering, Galati,
47 Domneasca Street, 800008, Romania,
E-mail: eugen.rusu@ugal.ro

ABSTRACT

The maritime sector, responsible for approximately 2.5% of global carbon dioxide emissions, faces mounting pressure to implement sustainable practices in line with international decarbonization goals. Wind energy has emerged as a promising solution, with innovative applications being explored to enhance fuel efficiency and reduce emissions. This study undertakes a comparative evaluation of two vessels—Vindskip and Pyxis Ocean—that integrate wind power through distinct technological approaches. Vindskip utilizes an aerodynamic hull design, functioning as a large airfoil to harness wind energy directly for propulsion. This innovative concept has the potential to achieve fuel savings of up to 60% and greenhouse gas emission reductions of approximately 80%. In contrast, Pyxis Ocean employs a wind-assisted propulsion system, utilizing rigid OceanWings sails as a supplementary energy source. This retrofitting approach enables fuel consumption reductions of around 30%, offering a scalable and practical solution for existing vessels. The comparative analysis examines these vessels across critical performance metrics, including energy efficiency, emissions reduction, scalability, and technological maturity. Vindskip exemplifies a forward-looking design for next-generation maritime operations, while Pyxis Ocean demonstrates the feasibility of integrating renewable energy technologies into current fleets. The findings highlight the complementary roles of innovative vessel designs and retrofitting solutions in advancing the maritime industry’s transition toward a sustainable and low-emission future.

Keywords: wind energy, aerodynamic hull design, rigid sails, maritime decarbonization, renewable propulsion technologies.

1. INTRODUCTION

The maritime industry, responsible for the transport of approximately 90% of global goods, is a major contributor to greenhouse gas (GHG) emissions, accounting for around 2.5% of global CO_2 emissions annually [1]. This significant environmental impact has placed the sector under growing scrutiny as international efforts to mitigate climate change intensify. The International Maritime Organization (IMO) has responded by introducing the IMO 2050 Strategy, which aims to cut GHG emissions by 50% by 2050 compared to 2008 levels. Achieving these ambitious targets necessitates innovative approaches to decarbonize maritime operations and reduce reliance on fossil fuels [2].

Among the emerging solutions, renewable energy technologies stand out for their potential to transform maritime propulsion while significantly lowering emissions [3]. Wind power, in particular, has garnered attention due to its capacity to offer substantial fuel savings and emission reductions. This study examines two vessels—Vindskip and Pyxis Ocean—that utilize wind energy in distinct ways, demonstrating the potential of renewable energy integration in maritime transport.

The Vindskip adopts an innovative aerodynamic hull design, which effectively harnesses wind energy by acting as a sail, providing up to 60% fuel savings and reducing emissions by approximately 80%. This concept introduces a transformative approach to wind propulsion by integrating renewable energy into the vessel's core design. However, Vindskip remains in the conceptual phase, necessitating further research and operational testing to validate its real-world applicability and scalability for large cargo vessels [4].

Conversely, the Pyxis Ocean represents a practical and operational approach through its use of OceanWings rigid sails. This wind-assisted propulsion system achieves measurable fuel savings of up to 30%, offering a scalable and economically viable solution by retrofitting existing vessels. Unlike Vindskip, which is designed from the ground up as a wind-powered vessel, the Pyxis Ocean emphasizes incremental adoption of renewable energy technologies. Its modular nature highlights the feasibility of deploying wind propulsion systems across a wide range of commercial fleets without extensive structural overhauls [5].

By focusing on these two vessels, this study highlights the comparative strengths and limitations of harnessing wind energy through innovative hull designs versus retrofitted wind-assisted propulsion systems. It emphasizes the transformative potential of renewable energy technologies in reducing GHG emissions and operational costs while advancing the maritime industry's transition toward sustainable practices. This analysis underscores the critical role of both innovation and scalability in meeting the IMO's decarbonization targets and achieving long-term environmental sustainability in global shipping.

2. MATERIALS AND METHODS

This study undertook a comparative analysis of two innovative approaches to utilizing wind energy in maritime propulsion: the aerodynamic hull design of Vindskip and the wind-assisted propulsion system employed by Pyxis Ocean. These vessels represent distinct strategies for integrating renewable energy technologies into maritime operations, aimed at reducing greenhouse gas (GHG) emissions and enhancing fuel efficiency. The analysis drew on data from advanced simulation models, operational performance reports, and peer-reviewed research published between 2013 and 2024, enabling a robust evaluation of their energy efficiency, emissions reduction potential, and operational feasibility.

The Vindskip was examined for its groundbreaking aerodynamic hull design, which optimizes wind energy capture to serve as a primary propulsion source. Computational fluid dynamics (CFD) simulations and technical studies were used to project its performance, demonstrating the potential for up to 60% fuel savings and an 80% reduction in CO_2 emissions compared to conventional vessels. These simulations modeled varying wind speeds and directions, providing comprehensive insights into how the hull design maximizes aerodynamic efficiency. While Vindskip remains at the conceptual stage, its innovative integration of renewable energy highlights its potential for long-haul cargo shipping.

The Pyxis Ocean, by contrast, was analyzed as an operational example of wind-assisted propulsion. Retrofitted with OceanWings rigid sails, the vessel demonstrates how wind energy can be effectively utilized as a supplementary propulsion source alongside conventional engines. Operational data from voyages indicate fuel consumption reductions of approximately 30%, with corresponding decreases in GHG emissions. The modular design of the OceanWings sails enables scalability across different vessel types, offering an economically viable and practical approach to integrating renewable technologies within the existing maritime fleet.

To ensure a comprehensive comparison, both vessels were evaluated using standardized performance metrics, including energy efficiency, emissions reductions (CO_2 and NOx), scalability, and the time required for either construction or retrofitting. Vindskip's conceptual design was compared against Pyxis Ocean's real-world implementation to assess the relative feasibility and effectiveness of these wind-powered systems. Additionally, visual aids such as bar charts and tables were employed to present the findings clearly, enabling an accessible comparison of the two approaches.

This comparative analysis provided valuable insights into the potential of wind energy as a renewable propulsion source in the maritime industry. By examining the aerodynamic innovations of Vindskip and the wind-assisted retrofitting exemplified by Pyxis Ocean, the study underscores the critical role of renewable energy technologies in advancing the sector's transition toward sustainable and low-emission operations. The findings contribute to the broader understanding of how wind energy can be harnessed effectively in both conceptual designs and operational vessels, offering pathways to achieving the decarbonization targets set by international climate agreements.

3. CHALLENGES AND CASE STUDIES IN RENEWABLE ENERGY INTEGRATION IN MARITIME TRANSPORT

The integration of wind energy into maritime transport through renewable energy technologies offers significant potential for reducing greenhouse gas emissions and improving fuel efficiency [6]. This study focuses on two distinct approaches: the innovative aerodynamic hull design of Vindskip and the wind-assisted propulsion system of Pyxis Ocean, each presenting unique opportunities and challenges. While these technologies represent promising advancements in maritime decarbonization, their adoption faces hurdles related to technological constraints, economic viability, and operational complexities.

Technological Constraints

The Vindskip leverages an aerodynamic hull design that uses wind energy as a primary propulsion source, enabling projected fuel savings of up to 60% and reducing CO_2 emissions by approximately 80%. This design relies on computational fluid dynamics (CFD) simulations to optimize wind capture and performance under varying conditions. Despite its potential, the Vindskip remains at the conceptual stage, with no full-scale operational prototypes. Transitioning from concept to application requires significant technological refinement, particularly in integrating its aerodynamic design with auxiliary systems such as LNG engines [7]. Additionally, the effectiveness of this solution is highly dependent on favorable wind conditions, necessitating advanced route optimization to maximize energy efficiency.

In contrast, the Pyxis Ocean adopts a practical and modular approach through the retrofitting of OceanWings rigid sails. These sails provide supplementary propulsion, achieving fuel savings of approximately 30%, with emissions reductions directly proportional to reduced fossil fuel usage [8]. Unlike Vindskip, which is designed as an entirely new vessel, Pyxis Ocean demonstrates how renewable technologies can be integrated into existing fleets. However, the performance of wind-assisted propulsion systems like OceanWings is contingent on consistent wind patterns, which may not be available along all shipping routes. The long-term durability of the rigid sails and their resistance to harsh maritime environments also require further study to ensure reliability and cost-effectiveness over extended periods [9].

Economic Viability

Economic challenges remain a key barrier to the adoption of these technologies. The Vindskip, as an entirely new vessel concept, involves substantial research and development costs. Estimates suggest that building such a vessel could cost between \$20 million and \$30 million, reflecting the need for advanced materials, aerodynamic modeling, and specialized manufacturing processes. The absence of standardized production frameworks for such innovative designs further exacerbates costs, limiting its feasibility for large-scale adoption in the near term [10].

The Pyxis Ocean, by comparison, represents a more financially accessible pathway through retrofitting. The installation of OceanWings rigid sails costs approximately \$1 million to \$5 million per vessel, depending on size and configuration. This approach reduces upfront expenses and allows operators to adopt wind propulsion incrementally. However, the lack of financial incentives, such as subsidies or tax breaks for retrofitting, remains a significant obstacle, particularly for smaller shipping companies that may struggle to absorb the initial costs [11].

Operational Complexities

Both approaches involve operational challenges that require careful consideration. The Vindskip's aerodynamic hull design introduces complexities in crew training and operational planning. Effective utilization of its wind propulsion system relies on sophisticated energy management technologies and precise route optimization to align with favorable wind conditions. These requirements differ significantly from conventional vessel operations, potentially increasing training demands for crew members [12].

The Pyxis Ocean faces fewer operational challenges but still requires adjustments in daily practices. The deployment and adjustment of the OceanWings rigid sails depend on real-time wind conditions, which can vary significantly across routes. While the sails are designed for ease of operation, maintaining their performance and structural integrity under harsh maritime conditions requires regular monitoring and maintenance. Automation and energy management systems could mitigate some of these complexities, but their implementation introduces additional costs and technical requirements [13].

Comparative Analysis and Future Directions

The comparative evaluation of Vindskip and Pyxis Ocean underscores the diverse strategies for integrating wind energy into maritime transport and the specific challenges associated with each. Vindskip's innovative aerodynamic hull design offers a bold vision for the future of shipping, providing long-term solutions for decarbonization through substantial fuel and emissions reductions. However, its high development costs and conceptual status limit its immediate applicability. By contrast, Pyxis Ocean demonstrates the practicality and scalability of retrofitting, offering measurable environmental benefits with lower economic and operational barriers. Its modular design ensures that renewable energy technologies can be incrementally adopted without significant disruption to existing fleets.

Addressing the challenges associated with these technologies will require continued research and investment. For Vindskip, pilot projects and scaled-down prototypes could validate its aerodynamic performance and bridge the gap between conceptual design and operational implementation. For Pyxis Ocean, broader adoption could be encouraged through financial incentives, such as subsidies for retrofitting, and the establishment of international standards for wind-assisted propulsion technologies.

Both approaches highlight the transformative potential of renewable energy in reducing the maritime industry's environmental impact. By combining innovative designs like Vindskip with practical retrofitting solutions like Pyxis Ocean, the sector can achieve meaningful progress toward decarbonization, aligning with global sustainability goals and ensuring its long-term viability in a climate-conscious world.

4. COMPARATIVE ANALYSIS OF VESSELS THAT ARE USING WIND POWER

Utilizing wind power as a renewable energy source has become a groundbreaking method for lowering greenhouse gas emissions and enhancing fuel efficiency in the maritime sector. The Vindskip and Pyxis Ocean exemplify two innovative approaches to incorporating wind energy into ship propulsion, providing important perspectives on the possibilities for achieving decarbonization.

Table 1 Renewable energy vessels specifications

Feature	**Vindskip**	**Pyxis \Ocean**
Primary Energy Source	Wind (Aerodynamic Hull Design)	Wind-Assisted Propulsion (Rigid Sails)
Energy Storage	LNG (Auxiliary Engine)	None
Design Innovations	Aerodynamic Hull	Rigid Wind Sails
Fuel Savings	Up to 60%	Up to 30%
Emissions	Reduced by 80%	37% savings
Operational Scope	Long-haul Cargo Shipping	Commercial Cargo Operations
Speed	Up to 18 knots	Up to 15.2 knots
Technology Level	Conceptual	Operational
Use Case	Cargo Transport	Freight Transport

Vindskip is still a concept even if all the engineering is done and patented and his primary energy source is wind harnessed by his aerodynamic hull design while the other vessel is using the wind power by the means of rigid sails.

We can conclude that the storage of the energy is not needed or used for Vindskip that is using all the wind power transmitted directly to the propulsion by shape of the hull and also the same in case of Pyxis Ocean in which case the wind power will assist the propulsion by the means of rigid sails.

After analysing these designs, it seems that the innovations stand into aerodynamic hull which was optimized at his best in order to reduce fuel consumption up to 60% in case of Vindskip concept. The fuel savings during optimal conditions seems to be around 30% for Pyxis Ocean and 37% less emissions [14].

The above numbers may be improved if the vessels designation will be different but in our study, we see clear that the concept vessel and Pyxis Ocean are cargo vessels but their technologies can be used on other vessels also.

For the Pyxis Ocean, his speed can vary because wind can have different force that will always add to the traditional propulsion set-up which in best conditions reached a maximum 15.2 knots [15].

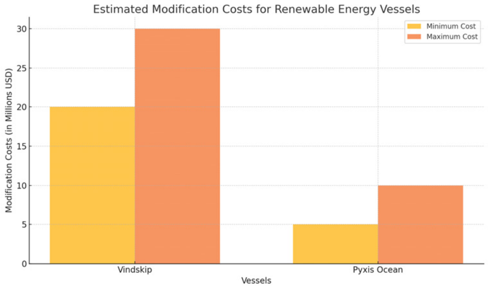

Fig.1 Estimated Modification Costs for Renewable Energy Vessels

The bar chart presents the projected minimum and maximum modification costs associated with Vindskip and Pyxis Ocean. It emphasizes the wider cost variation observed for Vindskip in comparison to Pyxis Ocean, which is indicative of their distinct methodologies and technological frameworks. The figures depicted are hypothetical approximations, intended to provide a comparative perspective on the expenses involved in adapting these vessels for renewable energy integration.

Table 2 Technology and Estimated costs for renewable energy vessels

Vessel	Technology Integration	Estimated Cost (USD)
Vindskip	Aerodynamic Hull + LNG Systems	$20-30 million
Pyxis Ocean	Rigid Wind Sails (OceanWings Technology)	$5-10 million

The one which is not built from zero from our study is Pyxis Ocean, but some engineering still must be done in order to adapt the Cargil system to the vessel and will be different from vessel to vessel, in our case the costs for retrofit will be between 5-10 USD millions. Costs are significantly lower than new builds due to the modular nature of the retrofit, which minimizes disruptions to operations.

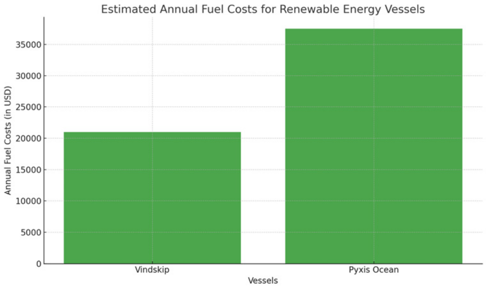

Fig.2 Estimated Annual Fuel Costs for Renewable Energy Vessels

Taken into consideration that an average consumption of a medium-sized cargo vessel is between 70-80 tons/year, it seems that for Vindskip, the LNG fuel consumption will be around 30 tons/year with a medium density of 450 kg/m^3 so the fuel cost will be 21000 USD/year. Then we can consider for the quantity of 50 tons of marine diesel fuel with a medium density of 840 kg/m^3 which will cost 37.500 USD for Pyxis Ocean [12].

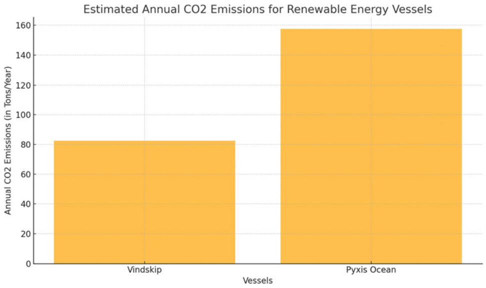

Fig.3 Estimated Annual CO_2 Emissions for Renewable Energy Vessels

The final goal of using these renewables energy harvesting technologies is the reduction of CO_2 emissions.

Although there are some significantly emission reductions by up to 30% in the case of wind-assisted propulsion of Pyxis Ocean, by using marine diesel oil, the CO_2 emissions are 157,5 tons per 50 tons of estimated fuel.

Because using a reduced fuel consumption of LNG due to the aerodynamic hull, the CO_2 emissions for Vindskip will be 82,5 tons/year [16].

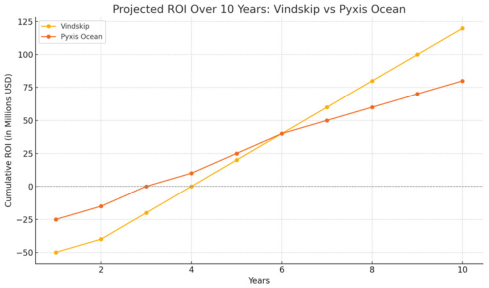

Fig.4 Projected ROI Over 10 years for Renewable Energy Vessels

This chart illustrates the projected ROI (Return of Investment) for Vindskip and Pyxis Ocean over a 10-year period. Vindskip shows a delayed break-even due to higher initial costs, while Pyxis Ocean reaches profitability earlier due to lower upfront investment.

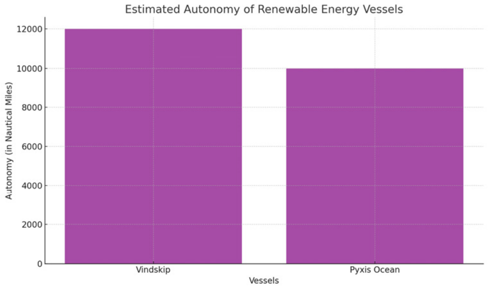

Fig.5 Estimated autonomy of renewable Energy Vessels

If the aerodynamic hull of Vindskip promises 60% reduction of fuel consumption and if typical medium-sized cargo vessels with LNG propulsion can carry fuel for up to 12,000 nautical-mile voyage (approximately 27 days at 18 knots), this would equate to a maximum storage capacity 400 tons of LNG.

The estimated autonomy of Pyxis Ocean was defined after taking into consideration multiple data. If the Pyxis Ocean is a Kamsarmax bulk carrier which measures approximately 229 meters in length with a beam of 32.26 meters, and Kamsarmax vessels of this sizes generally have fuel storage capacity for long voyages, we can assume that the actual storage of the vessel will be between 2500-3500 cubic meters of fuel oil. If we convert this fuel capacity storage, will result approximately 10000 nautical miles vessel autonomy [17].

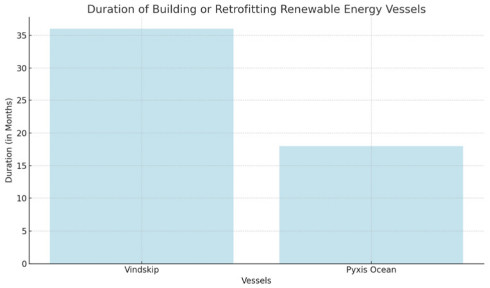

Fig.6 Duration of Building or Retrofiting Renewable Energy Vessels

The Vindskip's aerodynamic hull and wind-assisted propulsion required CFD simulations which typically take 12–18 months for innovative designs. Also, the pre-construction phase includes technical validation and securing international patents for Vindskip project. The fabrication phase typically takes around 18–20 months for fabrication and fitting for similar LNG vessels. The use of modular construction techniques helps with the integration of the aerodynamic hull and propulsion systems. The sea trials and certification processes will take for Vindskip between 3–6 months [18]. Regulatory compliance, including emissions and fuel efficiency testing, is also completed during this phase to meet IMO standards [19].

The retrofitting of the Pyxis Ocean into a wind-assisted vessel was a meticulously planned process spanning approximately 18 months. The first 4–6 months was intensive feasibility studies and design adjustments. The fabrication and installation of the OceanWings sails is taking 8–10 months which include onboard modifications included installing structural supports and advanced sail control. The final 2–4 months were dedicated to sea trials and operational validation.

5. CONCLUSIONS

This study provides a comprehensive evaluation of two distinct strategies for integrating renewable energy technologies in maritime transport: the aerodynamic hull design of Vindskip and the wind-assisted propulsion system of Pyxis Ocean. Both vessels highlight the transformative potential of wind power in reducing fuel consumption and greenhouse gas emissions, albeit through different approaches.

The Vindskip's innovative aerodynamic hull design represents a conceptual leap in vessel engineering, promising up to 60% fuel savings and an 80% reduction in emissions. By integrating wind power directly into its structural design, Vindskip demonstrates the feasibility of developing vessels specifically optimized for renewable energy propulsion. However, as a conceptual model, it faces challenges related to high development costs and the need for extensive validation through real-world testing before large-scale adoption.

Conversely, the Pyxis Ocean showcases a practical and scalable approach through retrofitting rigid sails for wind-assisted propulsion. With potential fuel savings of up to 30%, this system offers a more immediate solution for reducing the environmental impact of existing fleets. The modularity and cost-effectiveness of retrofitting make it particularly appealing for widespread application, though its performance depends on consistent wind conditions, and the technology has less potential for emissions reduction compared to purpose-built designs like Vindskip.

The findings underscore the complementary nature of these two approaches. While Vindskip illustrates the long-term potential of designing vessels around renewable energy principles, Pyxis Ocean provides a near-term solution for mitigating emissions through incremental improvements to existing ships. Achieving the ambitious decarbonization goals outlined in the IMO 2050 Strategy will require a combination of such forward-looking innovations and practical, adaptable solutions.

Both pathways demonstrate the importance of continued research, investment, and policy support to overcome the economic, technical, and operational challenges inherent in adopting renewable energy technologies. Together, these strategies represent significant steps toward the realization of a sustainable and low-emission future for the maritime industry.

REFERENCES

[1]. *Fourth Greenhouse Gas Study 2020*. (f.a.); https://www.imo.org/en/OurWork/Environment/Pages/Fourth-IMO-Greenhouse-Gas-Study-2020.aspx

[2]. **Rusu, E.,** *"Marine Renewable Energy and the Transition to a Low-Carbon Future"*, Journal of Marine Science and Engineering, 12(4), 568., 2024; https://doi.org/10.3390/jmse12040568

[3]. **Barbu, F., Rusu, E.,** *"A review of the harvesting methods for offshore renewable energy – advances and challenges"*, Journal of Marine Technology and Environment, 2, 7–17,2024; https://doi.org/10.53464/JMTE.02.2024.01

[4]. Wind Power at Sea: The Vindskip Merchant Ship | HeroX. (f.a.); https://www.herox.com/blog/195-wind-power-at-sea-the-vindskip-merchant-ship

[5]. Cargill Reports Encouraging Results from 6-Month Sail Test on Bulker. (f.a.). The Maritime Executive. https://maritime-executive.com/article/cargill-reports-encouraging-results-from-6-month-sail-test-on-bulker;

[6]. **Bilgili, L., and Ölçer, A. I.,** *"IMO 2023 strategy-Where are we and what's next?"* Marine Policy, 160, 105953, 2024; https://doi.org/10.1016/j.marpol.2023.105953

[7]. **Qi, J., Wang, H., & Zheng, J.,** *"Promoting Liquefied Natural Gas (LNG) Bunkering for Maritime Transportation: Should Ports or Ships Be Subsidized?"* Sustainability, 14(11), 6647, 2022; https://doi.org/10.3390/su14116647

[8]. **Tillig, F., Ringsberg, J. W., Psaraftis, H. N., & Zis, T.**, „*Reduced environmental impact of marine transport through speed reduction and wind assisted propulsion"*, Transportation Research Part D: Transport

and Environment, 83, 102380, 2020; https://doi.org/10.1016/j.trd.2020.102380

[9]. **Khan, L., Macklin, J. J. R., Peck, B. C. D., Morton, O., & Souppez, J.-B. R. G.,** "*A REVIEW OF WIND-ASSISTED SHIP PROPULSION FOR SUSTAINABLECOMMERCIAL SHIPPING: LATEST DEVELOPMENTS AND FUTURE STAKES*", Wind Propulsion, 2021; https://doi.org/10.3940/rina.win.2021.05

[10]. **Chou, T., Kosmas, V., Acciaro, M., Renken, K.,** *"A Comeback of Wind Power in Shipping: An Economic and Operational Review on the Wind-Assisted Ship Propulsion Technology"*, Sustainability, 13(4), 1880, 2021; https://doi.org/10.3390/su13041880

[11]. **Ghorbani, M. T., Slaets, P., Lacey, J.,** *"A numerical investigation of a wind-assisted ship to estimate fuel savings",* OCEANS - *Chennai*, 1–10, 2022; https://doi.org/10.1109/OCEANSChennai45887.2022.9775386

[12]. **Al Baroudi, H., Awoyomi, A., Patchigolla, K., Jonnalagadda, K., Anthony, E. J.,** *"A review of large-scale CO2 shipping and marine emissions management for carbon capture, utilisation and storage",* Applied Energy, 287, 116510, 2021; https://doi.org/10.1016/j.apenergy.2021.116510

[13]. **Malzer, T., Ecker, L., Schöberl, M.,** *"Energy-based Control and Observer Design for higher-order infinite-dimensional Port-Hamiltonian Systems"*, IFAC-PapersOnLine, *54*(19), 44–51, 2021; https://doi.org/10.1016/j.ifacol.2021.11.053

[14]. *Pyxis Ocean Makes First Docking with Metal Sails*., 2023. MarineLink. https://www.marinelink.com/news/pyxis-ocean-makes-first-docking-metal-508366;

[15]. *New technology uses good old-fashioned wind to power giant cargo vessels*.,2023, KOSU; https://www.kosu.org/energy-environment/2023-10-05/new-technology-uses-good-old-fashioned-wind-to-power-giant-cargo-vessels

[16]. **Wang, Y., Wright, L. A.,** *"A Comparative Review of Alternative Fuels for the Maritime Sector: Economic, Technology, and Policy Challenges for Clean Energy Implementation",* World, 2(4), 456–481, 2021; https://doi.org/10.3390/world2040029

[17]. **Zhang, R., Huang, L., Peng, G., Ma, R., Wang, K., Tian, F., Song, Q.,** *"A novel method of desynchronized operation of sails for ship wind-assisted propulsion system",* Ocean Engineering, 288, 115964, 2023; https://doi.org/10.1016/j.oceaneng.2023.115964

[18]. **Werner, S., Nisbet, J., Hörteborn, A., Nielsen, R.,** *"SPEED TRIAL VERIFICATION FOR A WIND ASSISTED SHIP",* Wind Propulsion 2021; https://doi.org/10.3940/rina.win.2021.09

[19]. **Arief, I. S., Fathalah, A.,** *"Review Of Alternative Energy Resource For The Future Ship Power",* IOP Conference Series: Earth and Environmental Science, 972(1), 012073, 2022. https://doi.org/10.1088/1755-1315/972/1/012073