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STRATEGY OF THE MARITIME TRANSPORT DECARBONISATION BY ZERO EMISSION VESSELS DEVELOPMENT

Abstract: The article discusses the strategy of decarbonising maritime transport by developing zero-emission ships. The requirements resulting from the introduction of the following indices by IMO: EEDI (Energy Efficiency Design Index): EEXI (Existing Energy Efficiency Index), CII (Carbon Emission Intensity Index) and SEEMP (Ship et al. Plan). Decarbonisation strategies adopted by selected shipowners were presented. The methods of adapting ships to ecological engine drives and other technologies for reducing fuel consumption by ships were presented. The market for ships powered by gas, methanol and other fuels was developed. The development of the hybrid and electric ship market was discussed.

All shipowners will have to issue a passport to their vessels: the IMO Energy Efficiency Index EEXI (International Maritime Organization Existing Index) in January 2023. More than 75% of all tankers, bulk carriers and container ships will not comply with the requirements of the International Maritime Organization today[1]. For about 98 thousand. Merchant ships only about 25 thousand. Meets the conditions recommended by the IMO. In the awareness of shipowners and ship design offices, there is common knowledge of the necessity to include appropriate indicators in the design of new units. These are EEDI (Energy Efficiency Design Index) as well as EEXI (Existing Energy Efficiency Index), CII (Carbon Emission Intensity Index) and SEEMP (Ship Energy Efficiency Management Plan)[2].

Keywords: decarbonisation maritime transport, zero-emission ships, Ship Energy Efficiency, electric and autonomous ships

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[1] Joey Daly, EEXI, Achieving Vessel Compliance, VesselsValue, London, June 2022, p. 3.

[2] Energy Efficiency Measures, https://www.imo.org/en/OurWork/Environment/Pages/Technical-and-Operational-Measures.aspx [2022-08-08].

1. THE ESSENCE OF ENERGY EFFICIENCY INDICATORS

EEXI will be effective from January 2023 and is calculated using modifications to the formula used for EEDI. EEXI will apply retrospectively to existing ships that may have yet to be built with sustainability and energy efficiency in mind, unlike EEDI. EEDI applies to ships constructed after 2013 and EEXI to ships constructed before 2013. The index measures the number of grams of CO2 the engine emits per tonne (gCO2 / ton-miles). The indicators take into account a large number of variables related to the ship specification. EEDI regulation applies to ships of 400 gross tonnage and above engaged in international voyages (except platforms, drilling rigs, and those not propelled by mechanical means such as barges)[3].

The calculations made by VesselsValue show the poor condition of the world's merchant fleet. In the case of bulk carriers, the proportion of the fleet compliant with IMO requirements is only 10%. Even though the fleet is rela-

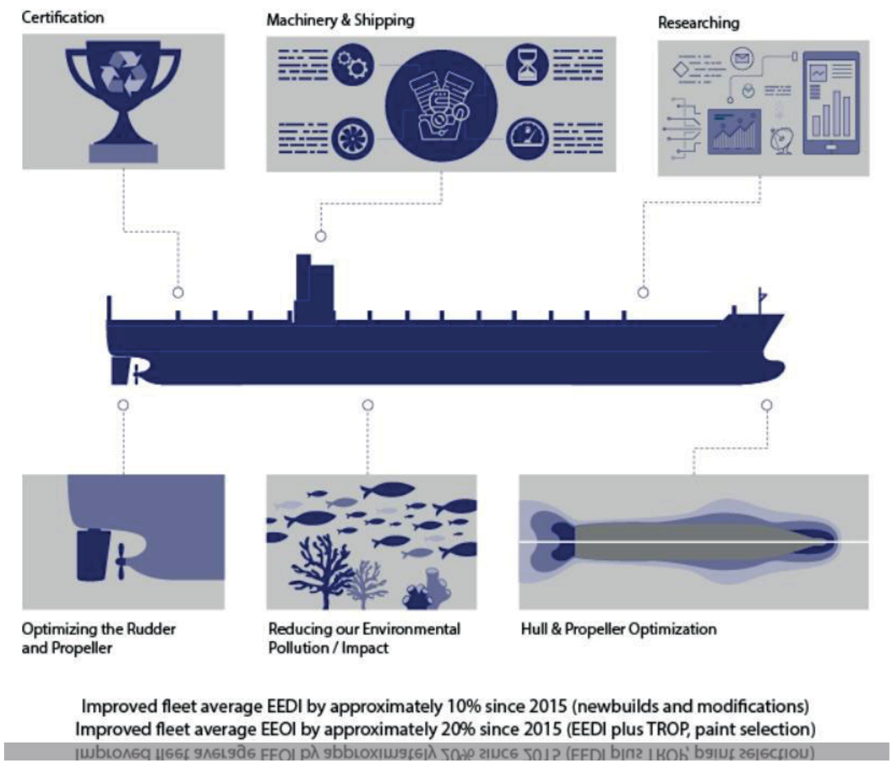

Figure 1. Areas of decarbonisation in sea transport
Source: BLUE TRANSITION BOND FRAMEWORK, SEASPAN, JUNE 2021

[3] EEDI regulation, https://www.classnk.or.jp/hp/en/activities/statutory/eedi/index.html, [2022-08-08].

tively young, with a ship's average age of 11.4 years, only 1 in 10 bulk ships would meet the current EEDI / EEXI regulations[4]. The only way to ensure a smooth ship's compliance with IMO regulations is to use information about their technical condition to start planning fleet modernisation now – says Simon Hodgkinson, head of loss prevention at West P&I[5].

It was a long time ago to start adapting ships to EEXI. While EEXI will enter into force on 1 November 2022, ship inspections after 1 January 2023 will

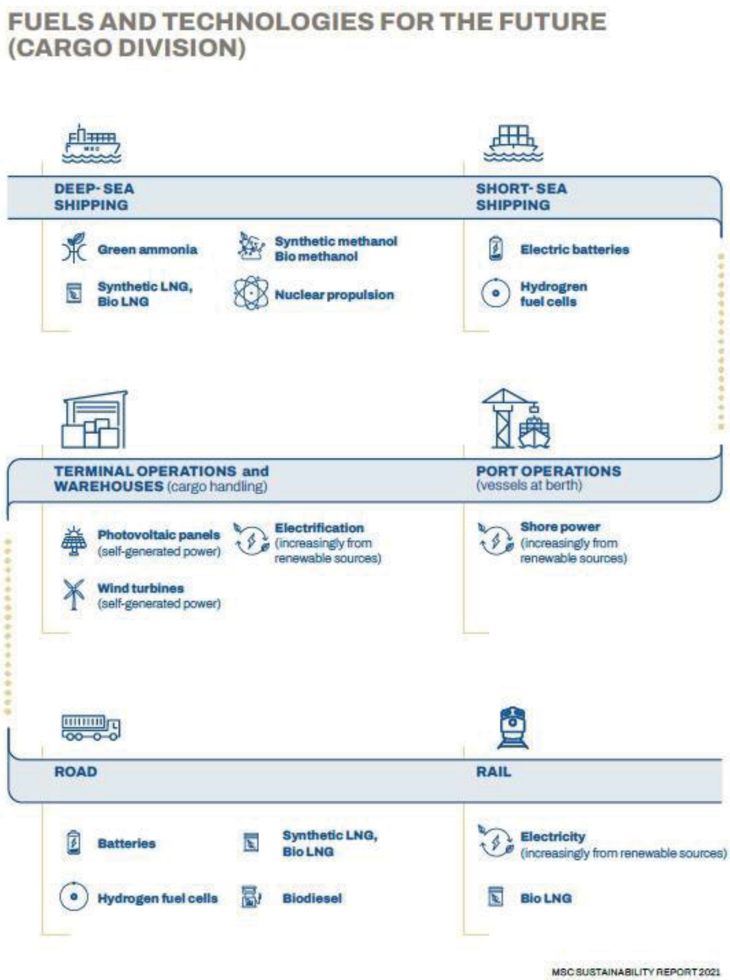

Figure 2. Decarbonisation tools in the MSC Logistics chain
Source: MSC Sustainability Report 2021

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4 Joey Daly, EEXI, Achieving Vessel Compliance, VesselsValue, London, June 2022, p. 4.

5 More than 75% of all tankers, bulkers and containerships are not EEXI compliant, https://splash247.com/more-than-75-of-all-tankers-bulkers-and-containerships-not-eexi-compliant/ [2022-07-22].

have to consider energy consumption and CO2 emissions. This will apply to ships above 400 GT and in line with Annex VI to MARPOL. Ships must be systematically prepared for EEXI requirements to meet the expected standards in the following survey. Amendments to MARPOL Annex VI that make the regulation of the Energy Efficiency Design Index (EEDI) and Ship Energy Efficiency Management Plan (SEEMP) mandatory were adopted at the 62nd session of the Marine Environment Protection Committee (MEPC 62) held in July 2011 and entered into force as from 1 January 2013[6].

2. EEXI CATEGORIES

VesselsValue divides the units that do not meet the conditions of the IMO index into three groups. The primary criterion for creating a category is the difference between its identified and the required EEDI / EEXI level. This measurement makes it possible to determine how much the "energy efficiency" of the ship needs to be improved.

The categorisation is based on the difference between the achieved and the required rate and the effectiveness of the technological improvements. Category 1. Includes ships that can be customised with ESD (Energy Saving Devices) installed in the main structure.

Category 2. groups the ships for which the EPL (Engine Power Limitation) procedure is most likely. In contrast,

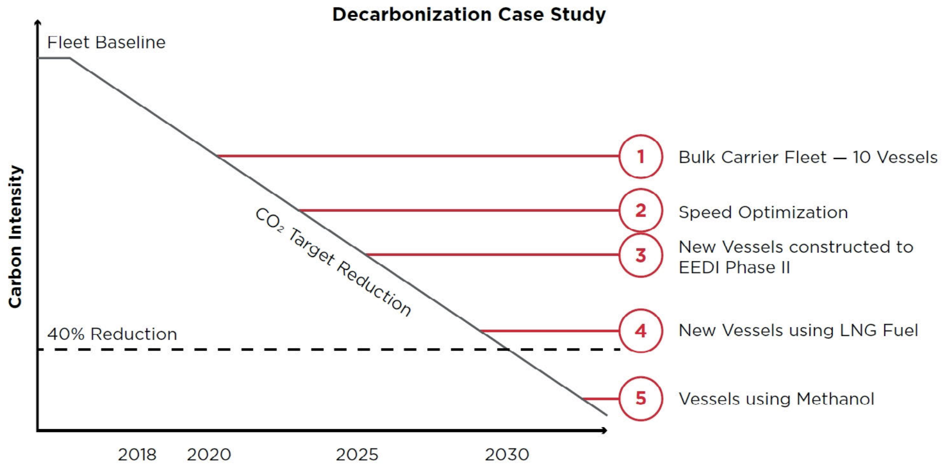

Figure 3. Decarbonization ABS Case Study
Source: SETTING THE COURSE TO LOW CARBON SHIPPING, American Bureau of Shipping, JUNE 2021

[6] EEDI regulation, https://www.classnk.or.jp/hp/en/activities/statutory/eedi/index.html, [2022-08-08].

Category 3. covers ships that must drastically reduce speed and fuel consumption to comply with EEDI / EEXI. Reconstruction or modernisation of these ships could be more profitable.[7].

Failure to adapt ships to IMO requirements carries many risks. Therefore, shipowners should get to know the EEXI of their ships as soon as possible. Calculating the index should be a relatively simple task for the shipowner as most classification societies now offer online tools. These tools can be applied to most ships as ships built after 2015 are already EEDI assessed.

3. A.P. MOLLER – MAERSK DECARBONIZATION STRATEGY – CASE STUDY

Maersk ECO Delivery is an Ocean transport customer offering that uses green fuels. Since its start in 2019, customer demand for Maersk ECO Delivery has grown more than 170% year-on-year. We expect the growth in sales for this solution to continue at least at equally significant levels in the coming years. In 2022, we will expand our current ECO Delivery product to third-party verified emission-reduced Logistics and Services products to serve customers across the entire value chain with green solutions. For air, we are helped by joining United's Eco-Skies Alliance and committing to SAF for our customers in 2021.

We launched a new Emissions Dashboard in 2021 to help customers reach their increasingly ambitious carbon reduction targets. The dashboard will allow customers to measure their carbon footprint across Maersk-controlled and non-Maersk-controlled logistics, including all transport modes such as trucks, trains, aeroplanes, or vessels. The dashboard will increase emissions transparency, allowing customers to identify supply chain carbon hot spots and make sustainable choices for their cargo flows. To ensure that the dashboard meets customer needs and expectations, it was piloted and developed with leading Maersk customers who provided valuable and positive feedback.

4. AIR LUBRICATION, SAILS AND ROTORS

One of the most popular methods of improving a ship's EEXI is to reduce the power of the main engine. The ship's speed is maintained by improving the hydrodynamics of the ship's hull and changing the propeller during the ship's modernisation in the repair yard. For example, a system of "air lubrication" of the hull is being introduced. This solution improves the efficiency of the vessel and reduces CO2 emissions by about 10% during the ship's passage between ports[8].

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7 Joey Daly, Energy Efficiency White Paper, VesselsValue, London, 2022, p. 3.
8 Air Lubrication Technology, ABS, 1 April, 2019, p. 2–4.

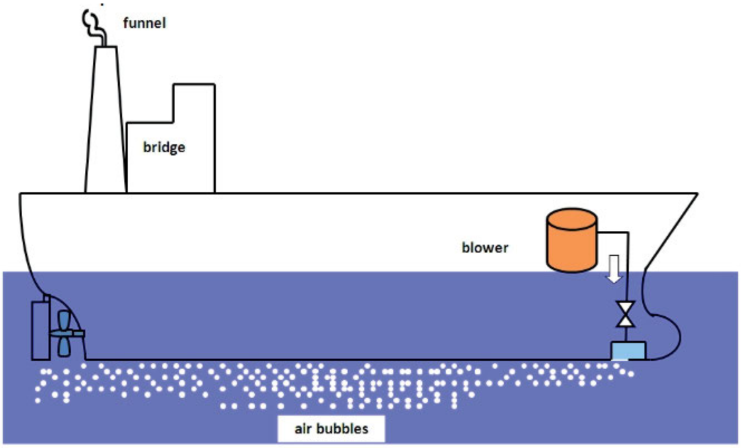

Figure 4. Lubricaton system
Source: SETTING THE COURSE TO LOW CARBON SHIPPING, American Bureau of Shipping, JUNE 2021

Mitsubishi Air Lubrication System (MALS) was one of the first commercial air lubrication systems developed in the marine industry by the Japanese Shipbuilder Mitsubishi Heavy Industries (MHI), based on research developed in the 1980s in Japan. The MALS is a patented air lubrication system using the BDR method. MHI developed their turbo blowers specifically used for the MALS, named Mitsubishi Turbo-blower, for air lubrication[9].

Wärtsilä proposes such a system. Energy-Saving Devices (ESDs) directly impact a ship's propulsion efficiency by reducing hull resistance and improving propeller thrust. Wärtsilä offers anti-cavitation devices such as Wärtsilä Ener-

Figure 5. Newcastlemax Ship With Rotors
Source: Norsepower's Rotor Sails

9 MHI Installs MALS (Mitsubishi Air Lubrication System) on a Ferry For First Time and Verifies Over 5% Fuel Efficiency Improvement, https://www.mhi.com/news/1210031580.html, [2012-10-03].

goFlow and Wärtsilä EnergoProFin, as well as high-performance hull coatings. These solutions ensure the reduction of the hull resistance while sailing and, as a result, reduce environmental pollution[10].

In category 1. ships, improving their EEXI using sails or rotors is possible. Such solutions are proposed, for example, by Norsepower's Rotor Sails. The Norsepower rotor system is an upgraded version of the Flettner rotors. The Rotor Sail technology is based on the Magnus effect. As the wind passes around the spinning Rotor Sail, the airflow accelerates on one side and slows down on the opposite side. Changing the airflow speed causes a pressure difference that creates a lift perpendicular to the direction of the wind flow[11]. Michelin estimates the wing can improve a ship's fuel efficiency by up to 20 per cent, based on measurements from technical tests and simulations, said Benoit Baisle-Dailliez, who leads Michelin's WISAMO initiative. For a large container ship, that could mean avoiding burning tens of thousands of fuel on a given day. The company plans to test the technology on a commercial freighter in 2022[12].

5. ENGINE POWER LIMITATION

The installed energy-saving devices on category two ships will not significantly change the EEXI value. This applies to units that require Engine Power Limitation (EPL) or Shaft Power Limitation (ShaPoLi). EPL is the general name given to a technology that limits the maximum engine power that a marine engine can achieve. ShaPoLi technologies reduce the power transmitted by the shaft to the propellers[13].

Limiting the maximum power of an engine will directly reduce its maximum power. The MCR (Maximum Continuous Rating) power rating is a critical component of the EEXI equation. This makes the EPP an essential factor in reducing emissions from ships. With the improved application of ESD, ships can meet EEXI requirements[14].

Reducing speed and fuel consumption is essential for economic efficiency on ocean shipping lanes, and services can significantly improve the competitiveness of a vessel operator. Chris-Marine of Sweden has introduced a new hardware and software-based system to assist vessel operators in monitoring shaft power,

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10 Charlie Bass, Complying with EEXI – how to speed up decarbonisation without slowing down vessels, Wärtsilä, 7 September 2021.

11 More: https://www.norsepower.com/story [data pobrania 2022-08-01].

12 Maria Gallucci, Michelin Puts Puffy Sails on Cargo Ships The move could boost a vessel's fuel efficiency by 20 per cent [25 June 2021].

13 More: EEXI Vibration Pre-Check, DNV, https://www.dnv.com/maritime/insights/topics/eexi/advisory-service-vibration-pre-check.html [2022-08-01].

14 EPL WORKING PRINCIPLE, https://www.kongsberg.com/maritime/campaign/eexi_cii/epl/ [2022-08-01].

	FUEL CAPACITY (m^3)	SPEED (KNOTS)	RANGE (nm)	CAPEX (-)	EEDI COMPLIANCE	CARBON INTENSITY (gCO_2/dwt ton-nm)
Baseline Chinamax Bulk Carrier, LNG Ready	8,490	14.2	37,284	$	Phase 2	1.74
Chinamax Bulk Carrier, LNG Ready to LNG	13,000	14.5	30,406	$$$	Phase 3	1.33
Chinamax Bulk Carrier, LNG Ready to Ammonia	13,000	14.5	17,855	$$$$	Phase 3	0.12
Baseline Chinamax Bulk Carrier, DF VLSFO/LNG	13,000	14.5	30,406	$$	Phase 3	1.33
Chinamax Bulk Carrier, DF VLSFO/LNG to Ammonia	13,000	14.5	17,855	$$$	Phase 3	0.12
Baseline Chinamax Bulk Carrier, DF VLSFO/LPG	13,000	14.5	34,513	$	Phase 2	1.53
Chinamax Bulk Carrier, DF VLSFO/LPG to Ammonia	13,000	14.5	17,855	$$	Phase 3	0.12
Baseline Aframax Tanker, DF VLSFO/LNG	2,250	13	8,967	$$	Phase 2	2.74
Aframax Tanker, DF VLSFO/ LNG to LNG + 20% Hydrogen	2,250 + 3,550	13	14,857	$$$$	Phase 3	2.11
Baseline 1,800 TEU Feeder Containership	1,140	18.5	11,793	$	Phase 3	13.14
1,800 TEU Feeder Containership, VLSFO to Methanol	1,140	18.5	4,330	$$	Phase 3	12.77

Table 1. Low Carbon Ship Transition
Source: Setting The Course To Low Carbon Shipping, American Bureau of Shipping, June 2021

optimising their ship CII (Carbon et al.) ratings and ensuring compliance with new EEXI (Energy Efficiency eXisting ship Index)requirements[15].

Chris-Marine's ShaPoLi system aims to support this process by enabling ship owners to limit their vessels' maximum shaft power output without having

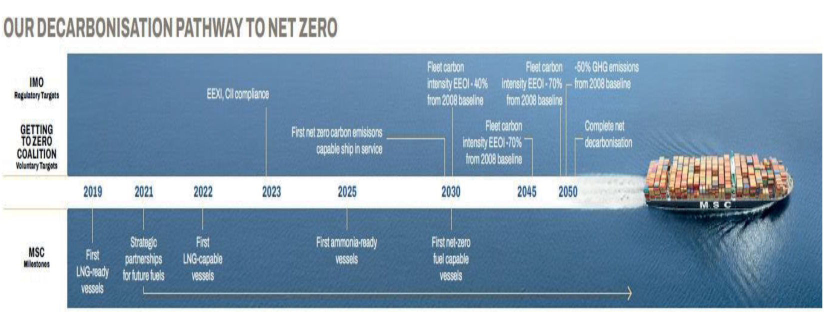

Figure 6. MSC Decarbonisation Pathway
Source: MSC

15 Rob O'Dwyer, Shaft power limitation system to assist EEXI compliance, [2022-03-10].

to modify any of their existing machinery to have greater control over their emissions. Shipowners of vessels that do not meet IMO requirements can expect that countries' maritime administrations will impose severe penalties on ships for not meeting IMO requirements.

6. MSC – CASE STUDY DECARBONIZATION STRATEGY[16]

MSC is uniquely positioned to contribute to the decarbonisation of global supply chains. With the scale and breadth of our operations comes a responsibility to show leadership by pioneering innovative, sustainable and scalable solutions. We aim to reduce emissions across our global operations by adopting an end-to-end perspective. Taking leadership to drive the decarbonisation of shipping demands concrete action to promote the broader adoption of low- and zero-carbon fuels. We collaborate with industry peers and engage through multi-stakeholder platforms across the maritime ecosystem. We capitalise on the interdependencies between our shipping and other sectors, providing fuels, distribution systems and infrastructure.

MSC DECARBONISATION GOALS

- Carbon intensity (EEOI) reduced to 13.61 g/mt-nm by 2023
- Carbon intensity (EEOI) reduced by 70% by 2045 from the 2008 baseline
- First net zero carbon emissions capable ship in service by 2030
- Complete net decarbonisation in 2050

ORDERS FOR ZERO-EMISSION SHIPS

About 1% of merchant ships out of 98,000 (over 100 GT) operated by marine services can be considered environmentally friendly. 3.7 million fishing vessels and as many large yachts are beyond this statistic. Ships adapted to alternative fuels accounted for 62% of orders in 2022 in terms of CGT in mid-2022 – the Clarksons Research experts calculated[17].

Leading shipowners are consistently implementing strategies to rebuild their fleets with greener ships. There is a record pace of orders for ships powered by LNG gas engines. According to the latest data from the Alternative Fuels Insight DNV platform, orders for LNG remained high in May 2022. Orders for new eco-friendly ships significantly exceeded the level from the year before[18].

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16 MSC Sustainability Report 2021, p. 34.

17 James Allen, Who is Building The Alternative Fuel Capable Orderbook? https://www.clarksons.net/wfr/ [2022-08-02].

18 Alternative Fuels Insight DNV, https://www.dnv.com/services/alternative-fuels-insight-128171 [2022-08-03].

Figure 7. LNG fueled Ships Order Book till 2023
Source: DNV

Thirty new orders for ships with dual-fuel engines were placed at the shipyards in May 2022. This means that the second quarter of 2022 is the best in the history of orders for this type of vessel. Container and car transport vessels dominate the shipyard's order book. Shipowners placed 51 contracts in shipyards in April 2022. The demand for LNG will increase by about half a million tonnes of LNG after the ordered ships are put into service.

The increasing use of dual-fuel solutions in large seagoing vessel projects is the reason for the increase in gas-fueled vessel contracts. DNV calculates that a total of 151 orders have been placed since January 2022[19]. This accounts for almost a fifth of gas-powered vessel order backlog. Shipyards have orders for 805 gas-fired vessels at the end of May 2022. Container vessels (175 vessels) dominate, followed by car carriers (95) in the shipbuilding portfolios. The following places are tankers (88 units) and 44 bulk carriers. These maritime transport segments account for half of the orders for LNG-powered ships. The remaining contracts are scattered across all major types of maritime transport vessels.

The rapid expansion of the fleet may need fixing with bunkering ships in seaports. The ports need to develop LNG bunkering infrastructure more quickly as the number of units with gas propulsion is growing. DNV has calculated that there are currently 38 LNG bunkers in operation worldwide. Nevertheless, order books for LNG bunkering vessels are growing. The shipyards are executing orders for another 18 ships, and DNV has agreed that talks are underway to construct another 17 bunkers[20].

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19 Alternative Fuels Insight DNV, https://www.dnv.com/services/alternative-fuels-insight-128171 [2022-08-03].

20 Alternative Fuels Insight DNV, https://www.dnv.com/services/alternative-fuels-insight-128171 [2022-08-03].

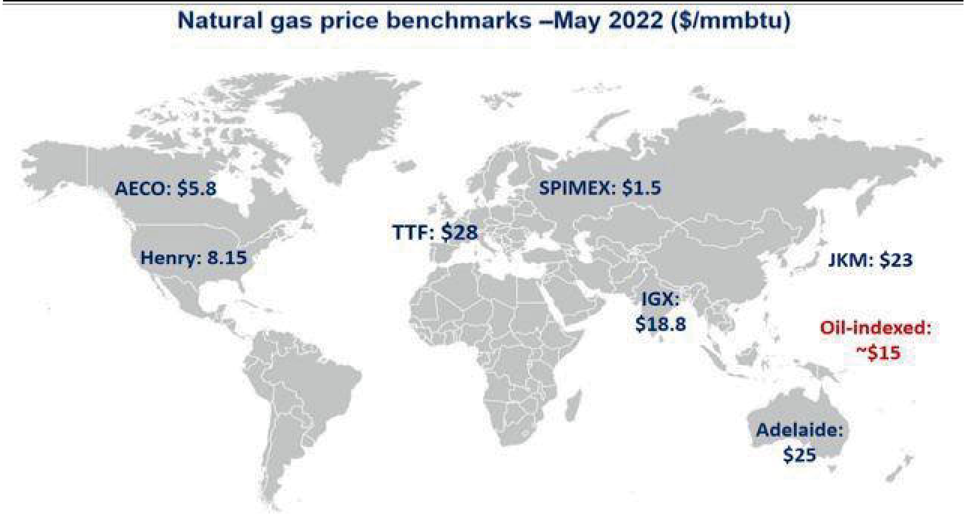

Figure 8. Natural Gas Price Benchmark in May 2022
Source: US Energy Information Administration

A good trend for environmentally friendly ships began in the first quarter of 2022. At the end of it, it was noted that 61% of ship orders were vessels with power plants for alternative fuels. If gas carriers are excluded, this share was 48%, and 10% of all orders were for LNG and ammonia-ready fuels[21].

57% of orders by tonnage (101 orders of 9.3 million GT) were for the use of gas as fuel, 3.4% of methanol (4 orders of 0.6 million GT), 0.6% of ethane orders (2 orders of 0.1 million GT)) and 0.7% including hybrid or electric ship. Another 12% of orders are shipped with engines prepared for ammonia fuel (26 orders for 2.0 million GT), 1.4% are ships adapted to the use of gas as fuel (10 orders for 0.2 million GT) and 0.1% with systems for hydrogen-fueled engines (3 orders for 15,000 GT)[22].

7. ELECTRIC SHIP MARKET

The global electric ship market will grow from $ 4.9 billion in 2021 to $ 12.78 billion by 2030, with an annual growth rate of 11.24% between 2022 and 2030[23].

Polish shipyards are booming in this innovative market. Electric propulsion systems will become increasingly common in maritime transport. Their intro-

21 Record 61% of orders are alternative fuel-capable, says Clarksons Research, https://www.tradewindsnews.com/esg/record-61-of-orders-are-alternative-fuel-capable-says-clarksons-research/2-1-1253706 [2022-04-06].

22 James Allen, Who's Building The Alternative Fuel Capable Orderbook? https://www.clarksons.net/wfr/ [2022-08-02].

23 Electric Ship Market. Market and Markets, 2022, London, p. 12.

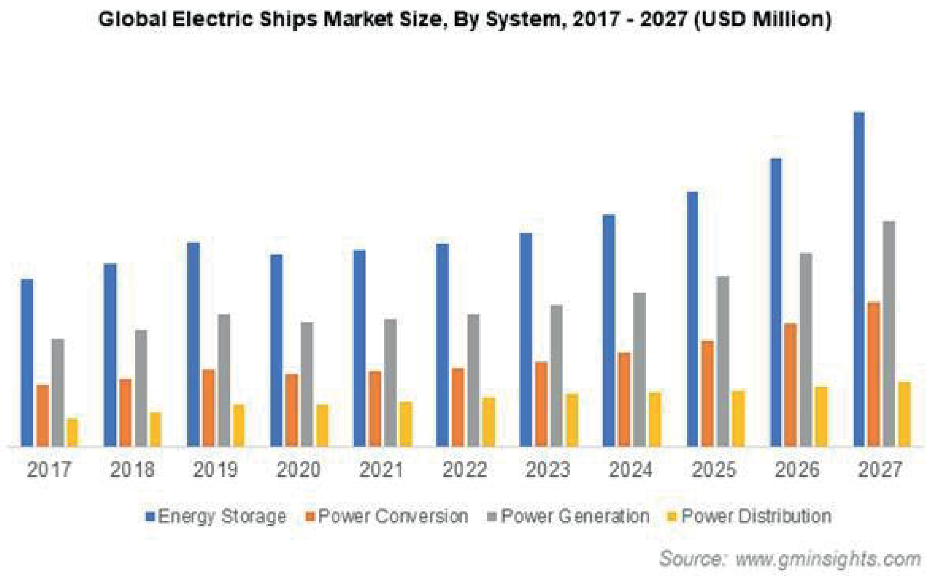

Figure 9. Global Electric Ships Market Size
Source: GminSights

duction to the shipping market will accelerate after 2025. Experts justify this by tightening the policy limiting the use of traditional ship fuels – is on Electric Ship Market by Type – Global Forecast to 2030 report. The electric ship market in Europe will grow by the highest value, from $ 3,358 million in 2021 to $ 11,922 million in 2030, depending on the EU region[24].

Scandinavian countries are the leaders in Europe. Norway, Finland and Denmark actively began replacing conventional passenger ferries with fully electric passenger ferries several years ago. Polish shipyards benefit from this policy together with shipyards from other European countries. Crist and Remontowa Shipbuilding have a strong position in building electric ferries for customers from Scandinavian countries. Electric ships for the Norwegian, Finnish and British markets were built in Gdańsk and Gdynia.

The electric ship market has excellent development potential. With a battery price of $ 100 per kWh, introducing electric ships to service trade routes up to 1,500 km will be profitable, say researchers from the Energy and Resources Group, University of California, Berkeley. However, when the costs related to environmental destruction are considered, running services over distances of up to 5,000 km may be justified[25].

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24 Electric Ship Market. Market and Markets, 2022, London, p. 14.

25 J. Kersey, N.D. Popovich, A.A. Phadke, Rapid battery cost declines accelerate the prospects of all-electric interregional container shipping. Nat Energy 7, 664–674 (2022). https://doi.org/10.1038/s41560-022-01065-y

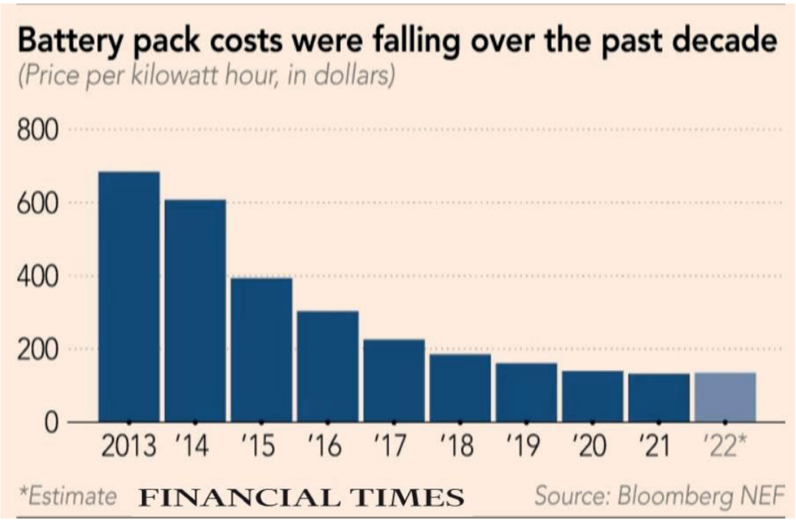

Figure 10. Battery pack cost kW/USD
Source: Bloomberg NEF [FT graph]

8. ELECTRIC AND AUTONOMOUS SHIPS

Some electric ships are also provided as autonomous ships. Rolls-Royce and the Finnish operator FinFerries presented the world's first fully autonomous ferry five years ago. The control system was mounted on the ferry. The 54-meter ferry with 80 passengers detected obstacles at sea thanks to sensors and artificial intelligence – Rolls-Royce Ship Intelligence[26].

Mitsui OSK Lines (MOL) has announced that it has deployed the coastal autonomous container ship Mikage to the sea. The ship has successfully passed sea trials. It is the first ship of this type in the world. The Imoto Lines ship sailed independently from Tsuruga Port in Fukui Prefecture, Japan, to Sakai in Tottori Prefecture. The ship covered the distance between the ports about 300 kilometres. It took place on January 24 and 25 this year[27].

In Norway, the first voyage, still with crew, was made to Oslo by the small container ship Yara Birkeland. It is supposed to be an autonomous ship. In 2020, Yara International (a chemical employer centred in Oslo, Norway) commissioned a completely electric-powered shipment delivery named Yara Birkeland. The overall value of this completely electric-powered shipment delivery challenge is approx. 30 million USD.

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26 Rolls-Royce and Finferries demonstrate the world's first Fully Autonomous Ferry, https://www.rolls-royce.com/media/press-releases/2018/03-12-2018-rr-and-finferries-demonstrate-worlds-first-fully-autonomous-ferry.aspx [2018-12-03].

27 World's First Successful Sea Trial of Autonomous Sailing on a Commercial Container Ship Voyage, https://www.mol.co.jp/en/pr/2022/22007.html [2022-01-25].

Figure 11. Yara Birkeland
Source: Yara

Yara Birkeland turned into advanced to transport the freighter among ports and abandon diesel truck usage; for this reason, it must be capable of updating 40,000 trips in a year. The ship will provide transport between the Yara fertiliser plant in Herøya and the ports of Brevik and Larvik. The vessel will make it possible to eliminate 40,000 road transports between the fertiliser factory and these ports[28].

The electric ship market was USD 5,114.6 million in 2020. The global electric ship market will reach USD 9,361.4 million by 2027. This value will be achieved with the assumed annual growth rate (CAGR) of 10.6% in 2021–2027 – forecast by the authors of the report "Electric Ships Market Statistics 2027"[29].

Shipowners, public administrations and investors from Norway, the United States, Greece, China and France order mainly electric ships. They were actively involved in the modernisation of the fleets. They are ordering hybrid and electric ships on a large scale[30].

9. DEMAND FOR VESSEL CONVERSION

China's first fully electric cargo ship can travel 80 km and carry 2,200 tons. The 70-meter long (229 feet) and 14-meter wide (45 feet) ship has over 1,000 lithium batteries, totalling 2,400 kilowatt-hours. By comparison, Tesla's Model X is equipped with a 100-kWh battery that allows it to drive nearly 570 kilometres (350 miles)[31].

28 Asle Skredderberget, The first ever zero-emission, autonomous ship [2022-08-08].

29 Global Electric Ships Market Report, History and Forecast 2016-2027, Valutes Report, November 2021, p. 21.

30 More: Marek Grzybowski, An exclusive research and analysis for eBlue "Economy Electric Ship Market", https://www.bssc.pl/2022/02/20/electric-ship-market/ [2022-06-06].

31 Echo Huang, China's first all-electric zero-emissions cargo ship, is going to be used to transport coal, https://qz.com/1137026/chinas-first-all-electric-cargo-ship-is-going-to-be-used-to-transport-coal/[2017-11-23]

Demand for converting ships with traditional propulsion to hybrid ships is increasing. Wartsila has signed a contract with Hagland Shipping AS to modernise general cargo carriers operating on the "short see" market with diesel engines to a hybrid battery drive[32].

Installing a Wärtsilä battery hybrid propulsion solution will significantly enhance the ship's environmental performance by reducing emissions, fuel consumption, and noise. Included in the solution is a shore power connection to provide power for loading/unloading operations and for battery charging, a new reduction gear with power take-off (PTO) and power take-in (PTI) technology, and a Wärtsilä NOx Reducer (NOR). It is estimated that the total reduction in nitrogen oxide (NOx) emissions after the retrofit could be as much as 80 to 90 per cent, while overall fuel cost savings are expected to be 5 to 10 per cent.

The battery capacity will be sufficient to sail in and out of the harbour on electric power for approximately 30 minutes, effectively reducing noise and pollution levels in the vicinity of the harbour. Nauta Shipyard performed the conversion for the Scandinavian offshore fleet operator. On the Viking Neptun (Offshore Support Vessel), the propulsion system was upgraded to a hybrid one. Two sets of Wärtsilä batteries with a capacity of 870 kWh were installed on the ship[33].

Four 1.25 MW drives in containers were installed on the ship. Containers with battery packs are connected to switchboards with power and control cables. A new freshwater cooling system for battery packs has been installed. The existing hull structure was strengthened. Power cables for the VLS tower were installed. Norway will continue to convert its fleet of older ferries to electric ferries. Of the 180 Norwegian ferry fleet, 70% of Norway will be converted to battery or hybrid propulsion[34]. The Norwegians will launch 84 new ferries with all-electric propulsion. Forty-three ferries will be replaced with ships using hybrid technology.

Remontowa Shipbuilding has delivered over a dozen electric ferries to Norway and Great Britain operators. On 2021, 4 February, Fodnes (B619/4) – the fourth in the series of hybrid electric-powered ferries, sailed out of Remontowa Shipbuilding in Gdansk. The ferry was handed over to Norled via videoconference the day before, and the Norwegian flag was hoisted[35].

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32 Wärtsilä to deliver world's first hybrid retrofit for short-sea shipping vessel, https://www.wartsila.com/media/news/08-02-2019-wartsila-to-deliver-world-s-first-hybrid-retrofit-for-short-sea-shipping-vessel-2376827, [2019-02-08].

33 Marek Grzybowski, An exclusive research and analysis for eBlue Economy "Electric Ship Market", https://www.bssc.pl/2022/02/20/electric-ship-market/ [2022-09-09].

34 James Ayre, Feasible To Replace 70% Of Norwegian Ferries With Fully Electric Or Hybrid Ferries, https://cleantechnica.com/2016/07/27/feasible-replace-70-norwegian-ferries-battery-hybrid-ferries-study/ [2016-07-27].

35 Electric ferry Fodnes sailed to Norway, https://remontowa-rsb.pl/en/aktualnosci/electric-ferry-fodnes-sailed-to-norway/ [202102-04].

The ferries will be equipped with an innovative and highly efficient Diesel Electric Hybrid system. In regular operation, the required power will be taken from two battery packs installed on board. The batteries will be recharged from the land grid during the vessel's stay at the quay, typically about 11 minutes. The shore charging system will be integrated with an automatic mooring system holding the ferries when at the quay and giving the "green light" for the charging process to start.

Festøya, Solavågen, Mannheller and Fodnes are state-of-the-art modern battery-powered double-ended hybrid ferries designed to minimise energy consumption and built at Remontowa Shipbuilding. Three delivered in 2020 are already sailing in the Norwegian fjords, serving the Festøya – Solavågen and Mannheller – Fodnes connections.

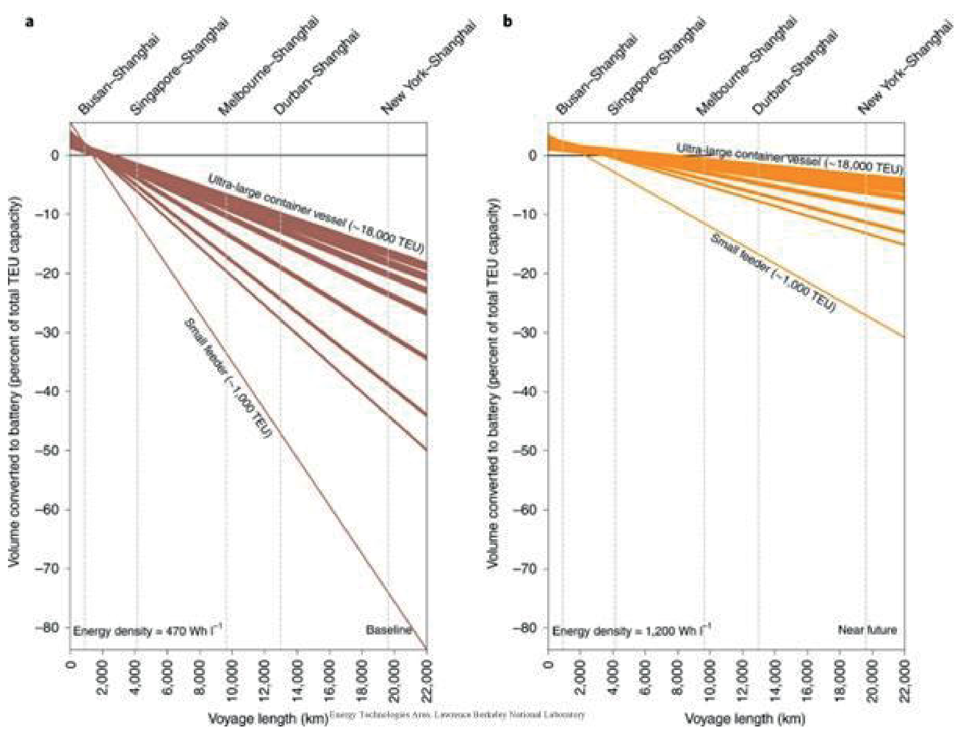

Figure 12. Energy and Resources Group Calculation Results of 13 significant global line connections

Source: Kersey, J., Popovich, N.D. & Phadke, A.A. Rapid battery cost declines accelerate the prospects of all-electric interregional container shipping. Nat Energy 7, 664–674 (2022). https://doi.org/10.1038/s41560-022-01065-y

Eight groups of container ships were examined in terms of capacity by scientists working in the Energy Analysis & Environmental Impacts Division, Energy Technologies Area, Lawrence Berkeley National Laboratory, Berkeley, CA, USA and Energy and Resources Group, University of California, Berkeley, CA, USA. The study was conducted concerning 13 significant global line connections. One hundred four unique scenarios for vessel size and route length were developed that can be compared to almost any container ship operating today. On less than 5,000 km voyages, the necessary power increase is less than 10% of the original power requirement. For example, a small neo-Panamax vessel with a range of 5,000 km will require a 5 GWh LFP battery with a specific energy of 260 Wh / kg. The battery will weigh 20 thousand. Tonnes will increase the draft by 1 m – calculated by Jessica Kersey, Natalie D. Popovich and Amol A. Phadke[36].

10. POLISH ZEV AND ICT HUBS. CRIST AND CADOR MANAGE THE HUBS

A zero-emission vessel production hub has been established in Poland. This hub was built in the Baltic Port of New Technologies in Gdynia, in the Pomeranian Special Economic Zone[37]. The coordinator of BALTIC ZEV INNOVATION HUB is the Crist shipyard, with which Stocznia Remontowa Nauta and the design company Cador Consulting cooperate. CADOR is the coordinator of the Baltic ICT & AI HUB. The ASE Technology Group has joined the hub. The company has energy storage technology that can be used on the land and the electric ships. TSG Poland operates in the hub with refuelling and bunkering ecological fuel technologies[38].

Currently, Crist is building two electric ferries for the Finnish ferry operator Finferries. The operator will receive complete ships where the diesel engine is only used to protect the ship in extreme weather conditions. The new two-sided, environmentally friendly, eco-friendly hybrid ferry will be 100.5 m long and 17.4 m wide. It can accommodate 90 passenger cars and 372 passengers. The ferry is to be operated by a 3-person crew. The first electric ferry was delivered in July 2022[39].

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36 Kersey, J., Popovich, N.D. Phadke, A.A. Rapid battery cost declines accelerate the prospects of all-electric interregional container shipping. Nat Energy 7, 664–674 (2022). https://doi.org/10.1038/s41560-022-01065-y

37 Marek Grzybowski, Pentagon Helix Cluster. Baltic Sea Space Cluster of Hubs [ZEVInnovation, ICT AI, GREENTECH], https://balticcluster.pl/?p=9476 / [2022-08-20].

38 Marek Grzybowski, Pentagon Helix Cluster. Baltic Sea Space Cluster of Hubs [ZEVInnovation, ICT AI, GREENTECH], https://www.bssc.pl/2021/10/31/a-zero-emission-vessel-production-hub-and-ict-it-hub-were-established/ [2021-08-02].

39 Marek Grzybowski, CRIST and Baltic ZEV HUB – course for the United Arab Emirates market, https://www.bssc.pl/2022/07/10/crist-and-baltic-zev-hub-course-for-the-united-arab-emirates-market/ [2022-08-02].

11. "SHIP OF THE YEAR" AND CEMT AWARDS

CRIST shipyard and StoGda Ship Design & Engineering design office won the CEMT 2018 award for outstanding contribution to the success of European marine industries. The award was given for designing and producing the passenger-car ferry Elektra, the first electric ferry in the European Union. Elektra Ferry was awarded "Ship of the Year" by the Marine Propulsion Award 2018 and "Significant Small Ship of 2017" by The Royal Institution of Naval Architects[40].

The Elektra ferry is sailing between Nauvo and Parainen in Finland. It is 96 m long and 15 m wide. It takes 372 passengers and 90 cars on board. The modern unit is served by only a 3-person crew[41].

Figure 13. Electra Electric Ferry
Source: Crist

The novelty is the use of a hybrid diesel-electric drive. Elektra has been equipped with three main diesel engines, two azimuth propulsors and a set of batteries. They are adapted to adverse climatic conditions – a system based on Siemens components with longevity has to cope with northern low temperatures and heavy snowfall. The ferry batteries are loaded during unloading and loading. All it takes is just 7 minutes. Ultimately, the unit is powered by battery power and, if necessary, a diesel engine.

40 Marek Grzybowski, An exclusive research and analysis for eBlue Economy "Electric Ship Market", https://www.eblueeconomy.com/marek-grzybowski-write-an-exclusive-research-and-analysis-for-eblue-economy/ [2022-06-02]

41 Päivitetty 29.6.2022, https://www.finferries.fi/lauttaliikenne/lauttapaikat-ja-aikataulut/parainen-nauvo.html, [2022-08-20]

12. THE LEADING PLAYERS

Polish shipyards belong to the Club of Designers and Construction of Electric Ships. The leading players in the European electric ship market are Kongsberg (Norway), ABB (Switzerland), Wartsila (Finland), and Norwegian Electric Systems AS (Norway). The leading players on the market of building hybrid ships and electrical installations with global potential are Corvus Energy (Canada), General Dynamics Electric Boat (USA), MAN Energy Solutions SE (Germany), Vard (Norway), Siemens (Germany) and Leclanché SA (Switzerland).

Asahi Tanker, Idemitsu Kosan, Exeno Yamamizu Corporation, Mitsui O.S.K. Lines, Tokio Marine & Nichido Fire Insurance, Tokyo Electric Power Company, and Mitsubishi Corporation are active in Japan.

South Korea's Hyundai Mipo Dockyard is beginning construction on an electric propulsion passenger ship that combines, for the first time, eco-friendly designs with smart technologies. China is now the owner of the world's first all-electric cargo ship. Guangzhou Shipyard International Company Ltd constructed the ship.

13. KEY CONCLUSIONS

Key conclusions from the analysis of decarbonisation activities in maritime transport:

1. The International Maritime Organization (IMO) and institutions financing the construction of new ships have forced a transformation in maritime transport;
2. Three-quarters of merchant ships do not meet IMO requirements for the Energy Efficiency Index of Existing Vessels (EEXI) and the Carbon Emissions Intensity Index (CII);
3. Most shipowners have focused on the energy transformation of ships, while some shipowners, such as Maersk, plan to decarbonise the entire logistics chain;
4. Introducing dual-fuel ships is only an intermediate step in decarbonising maritime transport as it uses fossil fuels for the ship's engines.

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