Orcelle Horizon

Wind as main propulsion

Deliverable D4.1 – Business case framework for wind-powered shipping

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Abstract

Deliverable abstract	
This report is the result of task 4.1 in the EU ORCELLE project were we propose a business case framework for wind-powered shipping. The framework can be used to explore external causes and potential effects on the business case as a whole, ranging from the value proposition in the service offer, including customers perspective and key activities, resources and partners needed a long with the financial assessments, based on the Business Model Canvas structure. The framework can be used to understand the larger business setting in which a wind-powered vessel will be part of. A general outlook on the shipping industry is taken, while having a specific focus on the RoRo segment as the vessel developed within the EU ORCELLE project is a Pure Car Truck carrier to operate on the global trades. This report is the first out of three deliverables in the work package 4, "Operations, business models and logistics". Four partners have been involved in the work, RISE (as lead partner of the work package), Wallenius Wilhelmsen, Wallenius Marine and NTUA.	

List of Abbreviations

BMC	Business Model Canvas
ETA	Estimated time of arrival
ETD	Estimated time of departure
GHG	Greenhouse gases
IEA	International Energy Agency
IGF Code	International Code of Safety for Ships Using Gases or Other Low-flashpoint Fuels
IMO	International Maritime Organization
ISCC	International Sustainability and Carbon Certification
ITTC	International Towing Tank Conference
IWSA	International Windship Association
LMG	Liquefied Methane Gas (generic term that covers both renewable and fossil methane gas)
LNG	Liquefied Natural Gas (liquefied methane gas produced from fossil gas)
MRV	Monitoring, Reporting and Verification
RT43	A measure used in the RoRo segment to quantity the cargo space or cargo load. The RT43 is based on a 1966 Toyota Corolla, the first mass produced car to be shipped in specialised car-carriers. 1 RT is approximately 4m of lane space required to store a 1.5m wide Toyota Corolla.
UKC	Under Keel clearance
WASP	Wind Assisted Ship Propulsion
WPT	Wind Propulsion Technology

Contents

1 Introduction

This report is written as part of the ORCELLE Horizon project that kicked off in early 2023 with the ambition of launching a multi-wing vessel Orcelle Wind in 2027. The vessel Orcelle Wind will be the first of its kind, a wind-powered RoRo vessel with a capacity of approximately 7000 cars, operating on global trades. The target is to reach efficiency gains of 50% compared to conventional vessels operating in regular trading.

Eleven partners in the project combine improvements to several areas, such as simulation frameworks, wing systems and logistics. This report is the first out of three deliverables in the work package 4, “Operations, business models and logistics”. Four partners have been involved in the work, RISE (as lead partner of the work package), Wallenius Wilhelmsen, Wallenius Marine and NTUA.

1.1 Scope of work

The technology development towards new transport solutions in decarbonised supply chains has currently a large pace. Wind-power is a new-born technology in the shipping sector that is very promising for several reasons. For example, wind-powered vessels use renewable energy, it saves fuel and thereby reduces the operational costs, it limits the need for bunkering alternative fuels and prepares for the tighter legislations coming up (IMO, 2024; EMSA, 2023 and Svanberg, 2023).

However, for a shipping company taking decisions of their decarbonisation actions there are many uncertainties that influences their choice. For wind powered-shipping financial uncertainties are created by both legislative and technological considerations, which all in all affect the technology adoption (Svanberg et al., 2023). Also, for wind-powered shipping, there is no “one-size-fits-all” solution due to that different technical solutions will create a variation in potential performance characteristics for each applicational context (Chou et al., 2021). To understand a shipping company’s business case of wind-powered shipping there are several factors to understand, not only from a financial, legislative and technological viewpoint, but also from the operational factors including environment, onboard operational systems as well as the commercial commitments of the vessel.

This report takes a holistic view of the business case by extending the discussion beyond the pure economic benefits from potential fuel savings. In this report we propose a business case framework for wind-powered shipping which explores external causes and potential effects on the business case as a whole, ranging from the value proposition in the service offer, including customers perspective and understanding key activities, resources and partners needed a long with the financial assessments. The framework can be used to understand the larger business setting in which a wind-powered vessel will be part of. External factors are related (but not limited) to stricter emission regulations, competing zero emission technological development, infrastructural development for supporting zero emission technologies, macro-economic and market trends, and potential market update of zero-emission technologies in which wind-powered ships are part.

The report takes a general outlook on the shipping industry, and has a specific focus on the RoRo segment, as the vessel developed within the EU ORCELLE project is a Pure Car Truck carrier to operate on the global trades.

1.2 Approach

The business model approach was applied to wind-propulsion in shipping. External factors and their current and forecasted development were reviewed in literature as well as discussed with the industry-partners in workshops and interviews. Also, study visits to two port terminals in northern Europe was made.

The following areas were reviewed and analysed in terms of current status, development paths and their potential influence on the shipping company's business case for a wind-powered ship:

- **Regulatory developments,** e.g. GHG regulatory measures and emission trading schemes.
- **Macro-economic trends**, e.g. pandemic and Ukraine war.
- **Commercial conditions,** e.g. market patterns, changed customer needs, operational patterns, ship development in relation of decarbonization of shipping.
- **Technological developments,** alternative zero emission solutions for deep sea shipping within wind propulsion, e.g., regarding performance and function
- **Infrastructure,** development paths for zero emission fuel infrastructure in terms of locations and volumes

For the analysis, the business model canvas, explained below, were used to demonstrate the links between external factors and the business case of a shipping company. Wind powered shipping were discussed in relation to the resulting framework. For the further work, the business case framework will be used in detailing the links in the case study of Orcelle Wind, to propose and develop updated business models for wind-powered shipping.

The business model concept emerged as a useful framework to understand and address the diversity of business enterprises (Schaltegger et al., 2016) and how they create, deliver and capture value (Osterwalder & Pigneur, 2010). Associating the term with business strategy, Chesbrough and Rosenbloom (2002: 533) listed the purpose of business models as to: "i) articulate the value proposition, ii) identify the market segment, iii) define the structure of the value chain, iv) estimate the cost structure and profit potential, v) locate the position of the firm within the value network, vi) formulate a competitive strategy". Hence, from a holistic perspective, a business model is not only concerned about the firm itself and its core logic but also its position in the larger value network and how it relates to the rest of this network. In addition to this, Teece (2010) describes the market fit of not only the product but the holistic and augmented firm offering as a critical component where a firm needs to decide on the target market segments, the customer benefits that are received by these segments and the revenue and cost structures related to delivering such offerings.

Based on Osterwalder and Pigneur's (2010) framework, business models are composed of four main dimensions. The first one is the value proposition which refers to the specialized combination of products, services and other benefits that address a certain customer need (Chesbrough, 2010). The value proposition changes depending on the target market segment, targeted customer needs and with time. Endless benefits can be emphasized with the value proposition such as access, possession, sustainability, product or service identity and the like.

The second and third dimensions of the business model, value creation and value delivery, are representing the supply chain or the supply network that is required to create the proposed value and the network that is required to deliver that value to the target market segments (Osterwalder & Pigneur, 2010). Firms need to collaborate with their networks to perform these activities. Key activities, partnerships and resources are critical to value creation and delivery. Bocken et al (2014) add that the value delivery dimension builds on how firms develop their channels whereas Osterwalder and Pigneur (2010) refer to communication, distribution and sales channels as critical means of a good customer experience.

The last dimension, value capture, considers how an organization may capture a fraction of the created value (Lüdeke-Freund et al., 2019), and includes the revenue streams, cost structure and the applied revenue model (Bocken et al., 2014).

The Business Model Canvas (BMC), developed by Osterwalder and Pigneur (2010), has been selected as a base for the framework development. BMC is a popular and straight forward definition of a business model which is broken down into the four major parts described above – here referred to as *offering, customer,* *infrastructure* and *finances.* The structure of each part is further divided into building blocks, see Figure 1 for an overview.

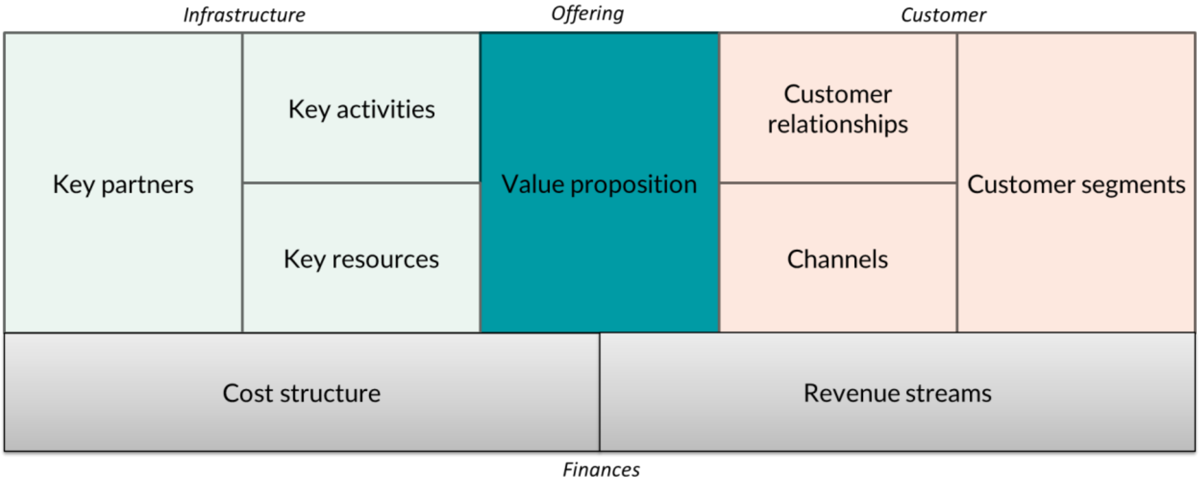


Figure 1 The building blocks in Business Model Canvas (BMC) based on Osterwalder and Pigneur (2010)

The central part of the BMC is hence the *offering*, which is the value proposition towards the customer. The content will influence the performance and in what way the offer meets the customer needs. The *customer* in turn is the part of the BMC that structures which customers are being targeted (customer segments), in what way are they reached (channels) and what the relationship looks like (customer relationships). The *infrastructure* describes the way the business model creates value by defining the most important activities that provide value for the customers, the necessary resources and assets (human, financial, physical and intellectual) as well as necessary partners. The *finances* describe the cost structure and the revenue stream and both these blocks are important for the economic assessment of the business case.

1.3 Structure of the report

In this report we first describe the general development in terms of decarbonisation of shipping (chapter 2), and relate this development to the market development of wind-propulsion as one decarbonisation strategy.

Secondly, macro-economic and market trends are described in general terms as well for the specific RoRo market (chapter 3), followed by a description of the operational patterns, also in general terms as well as for the RoRo segment and for wind propulsion specifically (chapter 4).

Thereafter, chapter 5-9 looks into the four building blocks of the Business Model Canvas, namely the offering (chapter 5), customer perspective (chapter 6), infrastructure (chapter 7) and financial considerations (chapter 9).

To conclude, the resulting framework is summarised by providing some examples of influences on the business case in chapter 10, where also further research is highlighted.

2 Decarbonisation of shipping

In this section we are describing the development in relation to decarbonisation of shipping, first in general terms, second in relation to wind powered shipping as well as in relation to Orcelle wind.

2.1 General development

Shipping is considered as an environmentally friendly mode as it moves large volumes of cargo at a single time and the carbon intensity per unit or ton is relatively lower when compared with road or air transport. However, being dependent on heavy fuel oil and marine diesel oil, shipping is responsible for approximately 3% of global carbon emissions and 30% of global NO_x-emissions. These emissions are expected to increase by 130% if the industry continues with business as usual as the demand for shipping is strongly coupled with global merchandise trade. In addition, the negative environmental impacts from shipping is not solely caused by engine emissions but also because of oil or chemical spills, damages on natural ecosystems and loss of biodiversity in world's oceans caused by shipping operations and marine litter.

Shipping is an international industry, operating beyond the boundaries of national jurisdiction most of the time. The rules and policy measures are discussed, developed, introduced, and regulated by the International Maritime Organization (IMO). On the other hand, there are also national and regional regulations that govern the shipping industry and influence or complement IMO decisions. The 2023 GHG strategy from IMO identifies a carbon emission reduction target of 40% per transport work by 2030, in comparison to the baseline of 2008. The goal is to achieve a net-zero emission level by the international shipping industry as of 2050. Achieving this goal is dependent on many different actions by industry players but before that there are also prospects on global trade trends.

Various scenario assessments indicate emission reduction patterns due to potential demand reductions to move fossil fuel resources such as coal and crude oil. The demand for these commodities derive a significant demand for long distance shipping services. In combination with such potential reductions, technological developments in 3D printing, commercial and technical preferences in circular economy and the impact of market mechanisms such as sulphur cap are expected to decrease shipping demand and shipping emissions consequently. On the other hand, this demand will be replaced by the demand for other commodities such as biogas or alternative fuels as well as the demand for intraregional shipping. Hence, these do not result in the elimination of shipping, but they are expected to contribute to emission reduction targets.

Emission intensity differs between different market segments and ship types. For instance, although tankers, container ships and dry bulkers have equally large total CO_2-emissions, container shipping has the highest carbon intensity per transport work as liner shipping has far more sailings per year when compared with the other segments. This is mostly due to the segment's high reliability requirements and higher speed.

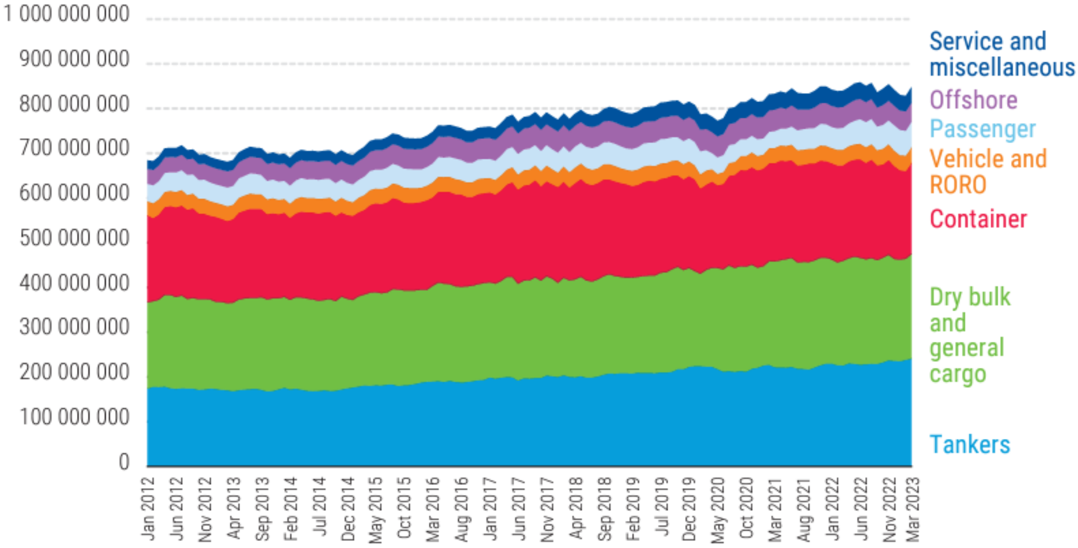


Figure 2 Total carbon dioxide emissions by vessel types, tons, January 2012 - March 2023
Source: UNCTAD, based on data provided by Marine Benchmark, July 2023

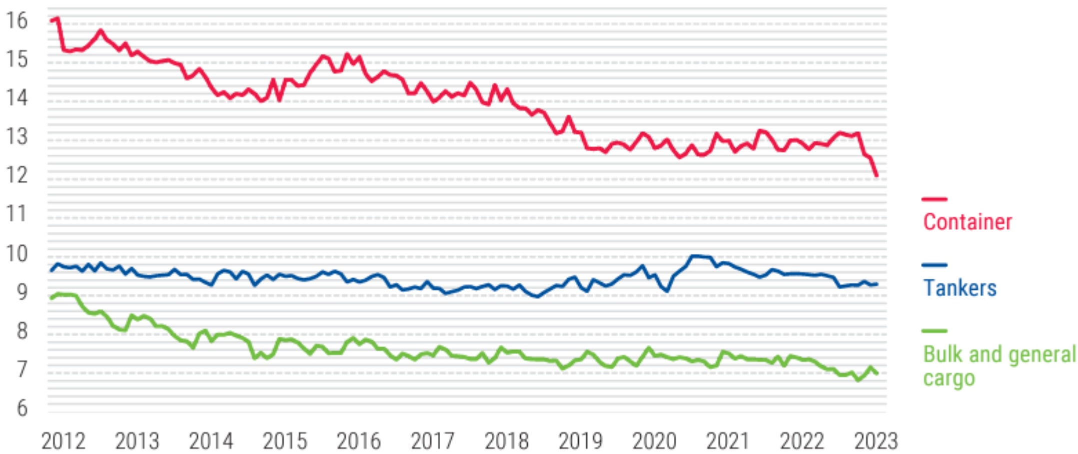


*Figure 3 World fleet, three main vessel types, monthly carbon dioxide emissions per ton-mile, Januari 2012 - March 2023 (Gram/ton*nautical mile)*
Source: UNCTAD, based on data provided by Marine Benchmark, July 2023

For an effective and significant change, there are additional technical and operational measures to take in combination with alternative fuel investments (ITF, 2018). Among technical measures, monitoring and reporting energy efficiency is a mandatory policy. Different vessels are subject to different energy efficiency reporting regimes (Energy Efficiency Design Index, EEDI, Carbon Intensity Indicator, CII, Ship Energy Efficiency Management Plan, SEEMP, Energy Efficiency Operational Indicator, EEOI) which support vessel performance and classification data. Such measures lead to optimization of energy use and data monitoring. Other technical measures relate to ship design and ship building material. The bulbous bow, using lighter materials, using special coating to reduce friction, air lubrication techniques or heat recovery are among such measures.

Operational measures, on the other hand, relate to ship speed, capacity and port operations. Slow steaming is one of the most widely used operational measures for emission reduction but during turbulent times with capacity shortages, just like the Covid-19 period, this measure is hardly applied as most vessels tend to increase their sailing speed to meet their already delayed transit times and meet realiability targets. Reliability is a significant service dimension for liner shipping and is tightly coupled with speed. Hence, whenever reliability is at stake, slow steaming becomes secondary to service delivery goals. Expanding ship sizes to achieve larger economies of scale is another measure to cut emissions per ton-kilometer. This measure is beneficial only if the enhanced capacity is fully utilized. Operational measures at the ship-port interface include the use of electric or renewable energy at berth and during port operations as long as the energy sources are also clean.

In addition to technical and operational measures, the decarbonization intentions in shipping are closely tied to the developments in alternative fuels. Finding an alternative to fossil fuels used by the shipping industry is quite high on the agenda and the main alternatives discussed are ammonia, methanol and hydrogen besides other energy sources such as wind, solar or nuclear energy. However, there are many uncertainties around these alternatives. First, there is the question of availability. It is not only about the availability of a selected alternative fuel but also sustainable and steady supply of that fuel. Hence ammonia itself is not enough, it needs to be green ammonia that is produced by electricity coming from renewable sources. Similarly, bio-methanol needs to be produced by organic waste (Balci and Surucu-Balci, 2023). This requires up to 3,000 terawatt-hours (TWh) of renewable energy per year only by the shipping industry which equals the global production of wind and solar energy today (ICC, 2022). Even if the energy supply problem is solved, there is the supply infrastructure problem as today's ports and bunkering infrastructure is built for fossil fuel supplies. The infrastructure and bunkering operations for alternative fuels must be in place for a smooth transition to alternative fuels in shipping. Then the current ship fleet needs to be either renewed or retrofitted to run on alternative fuels, both of which will require very high amounts of investment. Eventually, the shipping industry players are hesitant to follow one alternative fuel development due to this uncertainty and the path dependence in current systems and infrastructure.

Several market forces are pushing for change towards the decarbonization of shipping. Regulations on the one hand and the shipper demands on the other hand stimulate the strive towards emission reduction initiatives by shipping industry actions. The new Corporate Sustainability Reporting Directive (CSRD) from European Commission is extending the emission reporting requirements for companies to scope 3. Shipping as well as all other transport emissions are reported under scope 3 for cargo owners. Hence, this triggers a push towards more transparent and structured information sharing between shipping companies and their shippers. Similarly, the recently discussed and accepted Corporate Sustainability Due Diligence Directive (CSRDD) is unifying the requirements for sustainability due diligence in the EU and extending the reporting requirements for social and environmental sustainability to the whole value chain. Shippers who are subject to these regulations will ask for more frequent and reliable information flow as well as a reduction of reported emissions within a specified time.

Some regulations also serve as incentives for the decarbonization of shipping such as tax advantages and carbon markets. As of 1 January 2024, shipping industry is now included to the EU emission trading system (EU ETS). All ships larger than 5000 GT need to monitor and report their emissions, purchase or surrender emission allowances under EU ETS. This will cover 50% of emissions from voyages starting or ending outside of the EU and 100% of emissions that occur between two EU ports and when ships are within EU ports. ETS enables emissions to be traded as marketable assets but also serves as an incentive mechanism for a gradual decrease of shipping emissions within the EU. Similarly, the Fuel EU Maritime Regulation is a complementary regulation to the EU ETS, ensuring that the greenhouse gas intensity of fuels used by the shipping sector will gradually decrease over time, contributing to the 2030 and 2050 climate goals of EU. Despite these regulations that aim to facilitate the industry's transition toward decarbonization there are concerns for potential carbon leakage as shipping companies might switch to non-European ports for transshipment purposes and this will have economic consequences for European ports losing cargo.

The response from the shipping industry to these regulations and market pressure is at its infancy stage. The lack of certainty around the availability of alternative fuels, the uncertainty around the regulations, lack of infrastructure for a steady supply of alternative fuels all hinder a faster uptake of actions. The tendency is to wait and see and use operational measures such as slow steaming in the meantime. The problem with slow steaming is its impact on available capacity. It works at high capacity supply but will create capacity problems when active fleet needs to be scrapped after e.g. 20 years when their useful time is over, and the new ship supply will also slow down due to technological uncertainty around alternative fuel pathways. The outcome is strongly dependent on the delivery of new buildings.

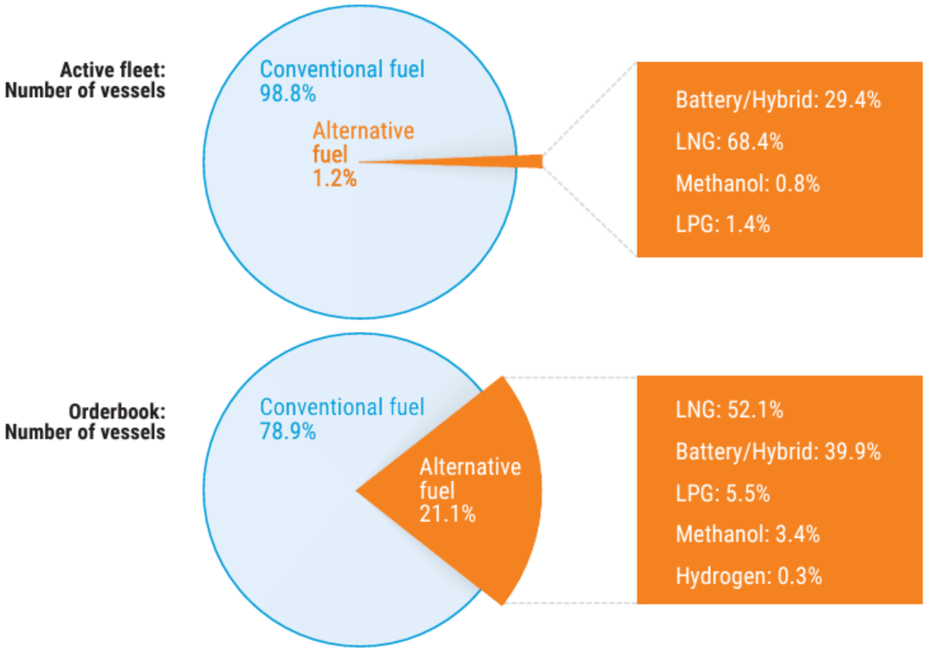


Figure 4 Alternative fuel uptake, world active fleet and orderbook, number of vessels, 2022
Source: UNCTAD based on DNV (2022)

As the figure shows, in 2022, a very small portion of the world fleet was run on alternative fuels and the order book was not very different either. Among alternative fuels, the highest share belonged to LNG powered vessels. Although LNG's carbon footprint is lower, it is still a fossil fuel with significant well-to-tank emissions. Following the developments in alternative fuel supply, these figures reversed in 2023 where methanol powered vessel orders surpassed LNG vessel orders (138 to 130) and the total orders for ships with alternative fuel propulsion increased by 8% (DNV, 2024). On the other hand, strong incentives were made available in the EU for building LNG bunkering infrastructure at major ports. According to the EU directive (EU, 2014) addressing LNG bunkering terminal availability in ports refueling points for LNG at maritime and inland ports of the TEN-T core network should be available by the end of 2025 and 2030, respectively. CO_2-emissions from combustion of LNG are lower than fuel oils but the methane slip from LNG engines and methane leakage in the upstream supply chain mean that LNG can result in higher CO_2 equivalent emissions on a well-to-wake basis for LNG as compared to conventional marine fuels (Comer et al., 2022). Hence, in a recent update, the commission stated that the demand for such an infrastructure at inland ports will not be significant as other technology is coming into the market at a faster pace. Although LNG infrastructure for maritime transport will still be valid, the commission highlighted the need to decarbonize LNG by blending it with other fuels such as e-gas or biomethane. The same infrastructure can be used by these decarbonized fuels as well.

The current state of uncertainty and the incoming regulations are causing the shipping lines to remain cautious against potential developments while some first-movers invest in a certain solution such as biofuels (biomthanol, Maersk or WalWil) or carbon capture technologies (the pilot test by Hapag Lloyd) expecting to stimulate supply and infrastructure availability. Ammonia is another popular option but the lack of insurance coverage is a big barrier in front of this fuel to attract investment besides the other hinders such as safety concerns, low maturity of engine technology, and lack of bunkering infrastructure.. The shipper demands for scope 3 emission reporting motivated the introduction of new services by shipping lines. At the moment, to meet the emission requirements of the regions they sail, a fuel mix is used by shipping lines where biofuels are available. On the occasion that a cargo is shipped with a vessel moving with a biofuel mix, the shippers are offered emission certificates. Greener fuels, in this case and for the moment, are being financed by the customers who would like to demonstrate the emission reduction performance in their supply chains.

Decarbonization of shipping is not a task that can be achieved by the shipping industry solely. It needs a close collaboration between energy providers, ports, inland terminals, policy makers, customers, ship builders and technology developers. Furthermore, the path to decarbonization will not be though a silver bullet but a balanced combination of technical and operational measures as well as the alternative fuels. All forces should be combined for a successful transition to net-zero in this industry.

2.2 Market development within wind-powered shipping

Wind propulsion in shipping is one of the current priorities for energy saving technologies and hence a very promising part of a shipping company's decarbonisation strategy. A review of up-to-date wind propulsion technologies (WPT) have been performed as part of the work in Orcelle Horizon WP4.1. The full review can be found in Appendix A, *"State of the Art Review of Wind Propulsion Technologies and Scenarios of alternative zero emission solutions for deep sea shipping".* Some highlights are available below.

2.2.1 Implementations of Wind Propulsion Technologies

Wind Propulsion Technologies are available in the market today, especially in the wind-assist category and there is a significant pipeline of viable and certified systems in late R&D and pre-market stages. As of August 2023, there were 30 large WPT equipped commercial vessels in operation across a range of segments and sizes, from VLCC/VLOC, other tanker & bulker sizes, RoRo, Ferry/Cruise, General Cargo & Fisheries along with eight ships that have received a notation of 'wind ready'. These vessels have a total of 63 rigs installed. These 30 vessels account for over 1.8 million tonnes of shipping (dwt for cargo, GT for RoRo/pax) with 445,000dwt 'wind-ready' and a further 16 ships (1.7 million dwt) awaiting installation and delivery by the end of Q1 2024 (IMO, 2024).

The pipeline of orders is also strengthening with 30+ additional vessels slated for delivery in 2024/25 including five 400GT+ primary wind vessels already under construction. EU market analysis (Nelissen et al, 2016) forecast up to 10,700 installed systems until 2030 on bulk carriers, tankers and container vessels, equivalent to savings of up to 7.5 Mt CO_2 in 2030. Added research indicated 37,000-40,000 vessels with wind propulsion installations by 2050 (assuming 50-100% GHG abatement) or 40-45% of the global fleet (IMO, 2024).

The main implementations in practice are so far (Werner et. al., 2023):

- *Flettner rotors* are rotating vertical cylinders driven by an electrical motor. When exposed to wind, the rotor generates a force perpendicular to the onset flow due to the Magnus effect, which can contribute to the ship's propulsion. In recent years, Flettner rotors were installed on Viking Grace (ferry), E-Ship 1 (RoRo), Maersk Pelican (tanker), Fehn Pollux (general cargo), Annika Braren (general cargo) and Copenhagen (ferry). Rotors were recently also fitted to deep-sea ships: Sea Zhoushan (Bulk) and SC Connector (RoRo).

- *Wing sails* are vertically arranged wings with or without flaps. Several developers lunched patented wing sail systems in recent years (e.g., Ayro of OceanWings, WindWings of BARTech/Yara Marine, Wisamo inflatable sails by Michelin, OceanBird of Alfawall, advanced in the Orcelle project). Among the prototypes with wing sails, as of today, is the 121m long RoRo cargo ship Canopée, delivered in December 2022. Its hybrid propulsion uses a combination of wing sails of Oceanwing type and traditional engines. The use of Canopée will ultimately halve the costs of shipping Ariane rocket parts from Europe to French Guyana and significantly reduce its environmental footprint. Also, in late 2022, the VLCC New Aden was delivered to China Merchant Energy Shipping, built by Dalian Shipbuilding Industry Co. and equipped with two pairs of new generation rigid wing sails, which were developed DSIC's R&D team, united CMES, CCS, Guangwei Composite Materials Co.
- *Suction wings* installed on for example Ankie (general cargo), Frisian Sea (general cargo), and La Naumon (general cargo). A suction wing is a vertical wing with a very thick profile. A fan installed inside the wing sucks air through the permeable surface of the wings trailing edge to prevent it from stalling. In that way it can provide a high lift coefficient (Ventifoil of Ecowind, Bound4Blue).
- *Soft sails,* Neoline (RoRo) and *kites* Beluga (Container), AirSea (RoRo) are less common and may have limited impact.

Above wind propulsion concepts may be categorized into seven main categories. There are substantial technical variations within these categories with over 30 technology providers and developers at present across the categories, see Table 1.

Table 1 Main Wind Technology Categories (*) (IMO, 2020)

Category	Description
Rotor	Rotating cylinders operated by low power motors. Magnus effect (air pressure difference on different sides of a spinning object) generates thrust
Hard sail	Wingsails, foils and JAMDA style rigs. Some rigs have solar panels for added ancillary power generation.
Suction wing	Non-rotating wing with vents/internal fan (other device) using boundary layer suction for max. Lift effect.
Kites	Dynamic or passive kites off the bow of the ship to assist propulsion or to generate a mixture of thrust and electrical energy.
Soft sails	Traditional canvas sail and new designs of Dynarig, etc.
Turbine	Marine adapted wind turbines to generate electrical energy or electrical energy/thrust combination.
Hull form	Redesign of ship's hulls to capture the power of the wind to generate thrust.
(*)*Source: International Windship Association, Dec. 2019*	

2.2.2 Technologies to be combined with wind propulsion systems

A wind-powered ship in commercial shipping, even if using wind as the main propulsion energy, is expected to be equipped with fueled, internal combustion machinery (or steam turbine) that will cover the needs of ship propulsion in case of emergencies and when wind conditions are not favorable. The engines of this machinery arrangement will be in general upgraded internal combustion engines fueled with low or zero emission fuels (alternative, green fuels) (Tay and Konovessis, 2023).

Alternative fuels which have been discussed in previous literature and could potentially be combined with wind propulsion systems include: biofuels, LNG, hydrogen fuel cells, methanol and ammonia. Multi-fuel (dual or even triple fuel) engines can operate using alternative fuels or a mixture of different fuels. LNG and methanol are the two fuels most commonly used in dual fuel marine engines that also burn conventional fuel oils.

In addition, other technologies are electric power, solar power and nuclear power.

2.2.3 ORCELLE WIND

The RoRo vessel *Orcelle Wind* will be the first newbuilt vessel adopting the wing sails developed by Oceanbird, and will be equipped by 6 Oceanbird wings. The vessel is a pure car and truck carrier and will be approximately 220 meter long, 40 meter wide and 70 meters in height above water. The size of the wings is 40 meters in height, and 14 meters in width. The ship is having a capacity for approx. 7,000 cars, but it will also be capable of carrying breakbulk, rolling equipment, also in the category of high and heavy goods.

The ambition is to commence sailing in early 2027. Besides air emissions reductions, underwater sound pollution will also be decreased. The Orcelle vessel would operate quietly in the water, fully protecting marine mammals' survival.

The vessel is designed for an optimal sailing speed of 10-13 knots, which is somewhat lower than today's operations on 14-16 knots. Depending on, for example, the operational profile and the weather conditions in the area of operations, the efficiency gains by using wind-propulsion will differ. The target is to reach an efficiency gain of 50 % compared to conventional vessels operating in regular trading.

See Figure 5 for a visualization of Orcelle Wind.

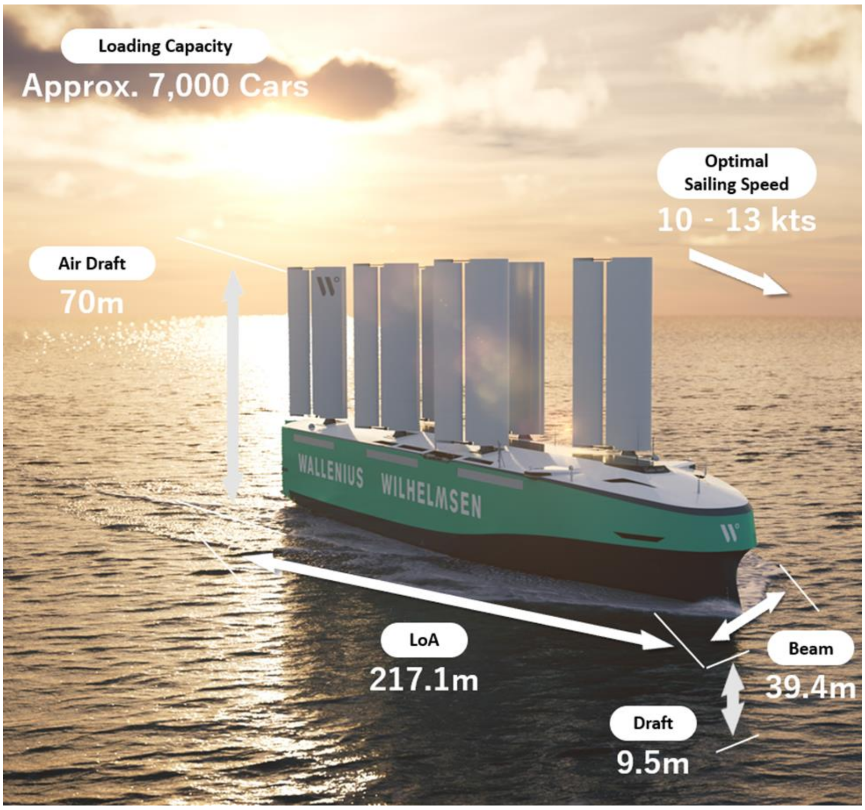


Figure 5 The specification of Orcelle Wind
Source: Illustration by Orcelle Horizon project

3 Macro-economic and market trends

The macro-economic and market trends include a general economic outlook on macro-level followed by a description of the development within global supply chains. Thereafter, the focus is on describing the maritime transportation and trends within the RoRo markets.

3.1 The general economic outlook

The recent reports released by different economic organizations indicate the persistence of moderate growth for the world economy. The estimated 3.1% increase in global GDP growth rate for 2023 is expected to remain at the same level in 2024 according to the recent World Economic Outlook Update by IMF (IMF, 2024). A slightly newer estimate shows relatively slower growth at 2.9% in 2024 and 3.0% in 2025 (OECD, 2024). Both of these projections indicate a growth rate below the historical (2000–19) annual average of 3.8 percent and still a cautious future for the world's economies.

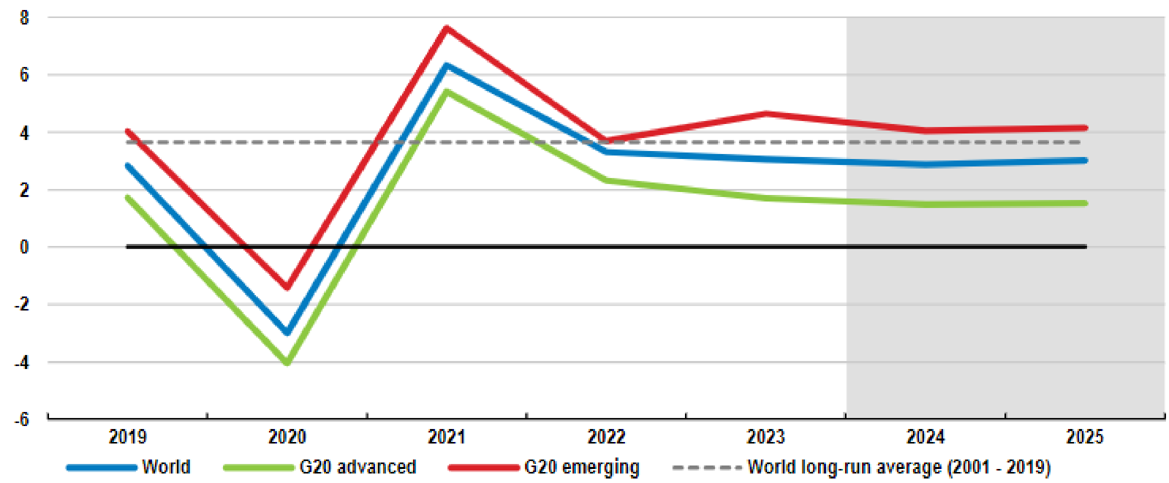


Figure 6 Real GDP growth % y-o-y
Note: Aggregates use moving nominal GDP weights at purchase power parties (PPPs)
Source: OECD Interim Economic Outlook 115 database

Global merchandise trade projections are similarly revised by the World Trade Organization (WTO, 2023). 1.7% was an already adjusted rate in April 2023 but the new estimate that came in the final quarter of 2023 now indicates only 0.8% growth in the volume of goods traded worldwide. The initial hopes were due to the recovery period after the pandemic particularly in China and the falling energy prices. However, the high inflation rates in the largest consumer markets such as the US and EU combined with the real estate market crisis in China acted as barriers for a quick rebound in global trade. Despite these negative trends, the expectations are higher in 2024 with a 3.3% increase.

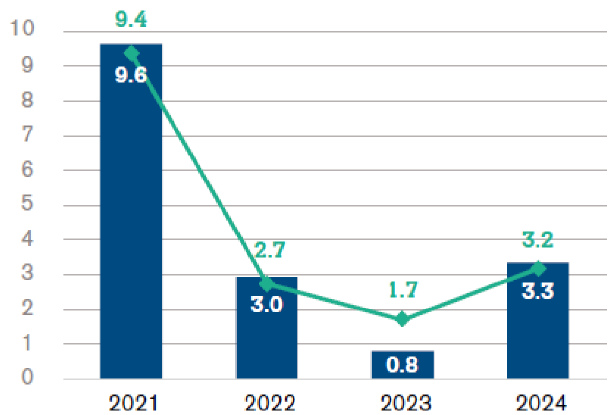


Figure 7 Merchandise trade volume growth

The decline in global trade volumes as well as value is observed more in certain product categories such as mining products, fuels, textiles and telecommunication equipment. It was partly balanced by a strong growth in passenger cars and automotive products which took a downturn during the last quarter of 2023. Despite the fall in merchandise trade, services trade remained resilient mostly due to post-Covid-19 trends.

3.2 Global supply chains

The decline in global merchandise trade and global GDP growth is not the same in all parts of the world. While US markets show slow but steady signs of growth, EU countries are expected to experience the carry over effects from the high exposure to the war in Ukraine as well as high inflation rates which hampered consumer spending. Asian markets on the other hand remained relatively resilient due to both strong domestic demand and government spending in infrastructure. Similar patterns were also observed in port throughput where the shipments to/from Chinese ports grew but shipments through European ports declined.

This trend is also visible in the Global Purchasing Managers Index (PMI) for the manufacturing industry. The major Eurozone countries indicated a contracting manufacturing industry based on their purchasing activity while most of the emerging markets exhibited expansion trends. The first two months of 2024 was no different but more reliable figures will come towards the year end. Such trends in the manufacturing industry indicate a low demand for merchandise in both business and consumer markets due to the low economic conditions.

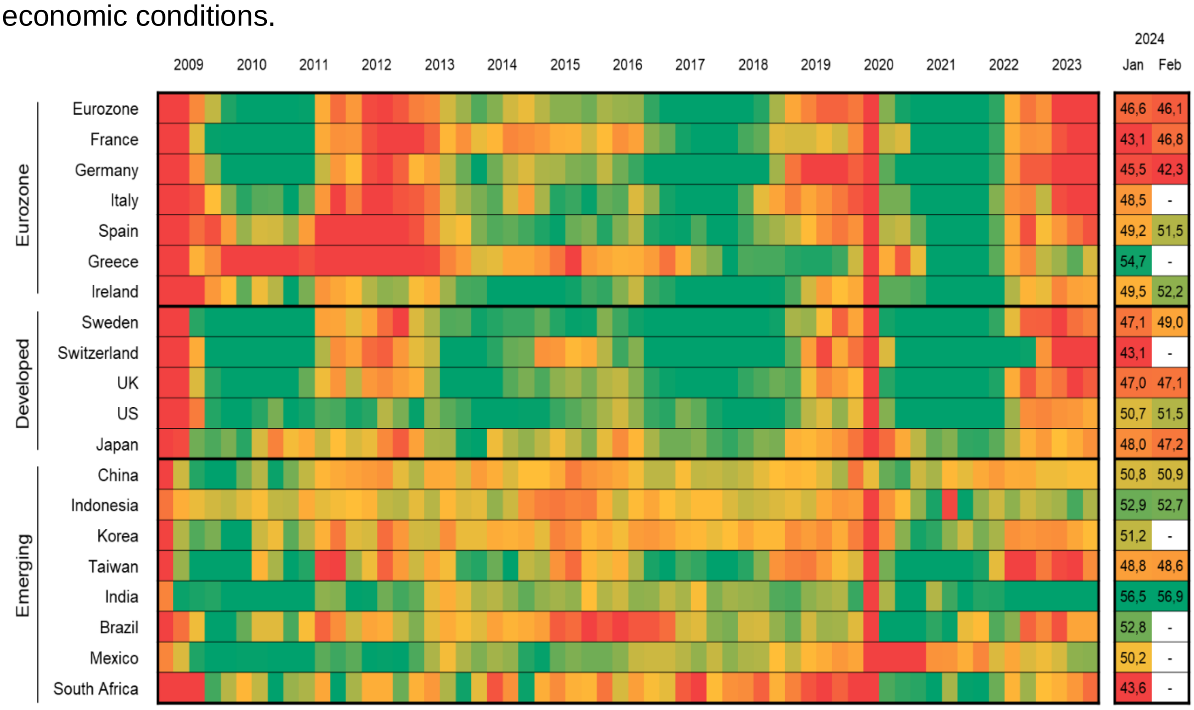


Figure 8 Global Purchasing Managers Index (PMI) for the manufacturing industry

A score of 5o indicates that economic activity in neither expanding nor contracting, above 50 indicated expansion. The heatmap colours range from red to yellow to green, where red is below 50, yellow is at 50 and green is above 50. Quarterly averages are shown except the two most recent monthly data points. Guide to the Markets- Europe. Data as of February 2024

Source: S&P Global J.P Morgan Asset Management

Regionalization has become a frequently used buzz word particularly during the aftermath of Russia's invasion of Ukraine. However, economic and political tensions between China and US have been going on even before that and some consequences can be observed now. Although there is still not adequate evidence for a backwards trend in globalization, there are some regional patterns in supply chain flows. Friend-shoring or the trade between politically aligned countries shows a significant increase although such trade does not take place only within close regions. On the other hand, non-tariff restrictive trade measures such as climate change-related measures are expected to stimulate policies to support domestic industries and reduce reliance on foreign supply chains. The combined effect from these policies might lead to a slowed-down global trade.

One trend which was observed among some large global supply chain actors is “China-Plus-One” trend where China remains as a strategic trade partner but another country is added as a sourcing base alternative. The most frequently observed “Plus-One”s are Vietnam, Taiwan, Mexico and EU countries. On the other hand, China has started to source domestically in an increasing pattern and diminished its dependence on imports of raw materials and parts. Another strategy is relocating manufacturing facilities closer to buyer markets where many China-based factories expand to Africa and Europe. All these trends indicate not a full-speed regionalization or back-shoring but an effort for building resilient and ‘friendly’ supply chains that operate within selected silos around the world. Such a strategy is not expected to reduce distances traveled but might add new busier routes than before and new combinations of transport modes depending on the points of origin and destination.

3.3 Maritime transportation

Seaborne trade is strictly coupled with the developments in global merchandise trade where a -0.4% contraction was observed in the total trade volume in 2022. This contraction is partly due to normalizing trade patterns following the radical and pandemic-triggered peak in 2021coupled with increased capacity and increased prices. The war in Ukraine, post-pandemic financial impacts on markets, inflation and rising interest rates altogether resulted in reduced confidence and stagnated demand in major world economies. The increased energy prices, particularly in coal and gas, impacted vulnerable households and exacerbated cost-of-living crisis. Although this contraction in seaborne trade volume is expected to increase in 2023 by 2.4% the 5-year average growth prospects are below the historical growth trend of 3% which was prevalent during the last three decades.

The relatively pessimistic forecast about global seaborne trade is caused by the combined effect of different forces. The uncertainty about trade patterns, conflicts and geopolitical crisis, persistent inflation in essential goods, policy measures tackling with inflation but putting a pressure on cost of living, housing crisis in large consumer markets, trade restrictions are among a few. Seaborne trade value indicates a positive trend but as the numbers show, this is not because of the volume, instead it is a result of high inflation.

Not all maritime transport branches are experiencing the same patterns though. Some segments are better off while others are struggling with capacity issues. Energy trade, for instance, is showing an upwards trend due to nations trying to secure energy supply and the increasing demand after the pandemic for stabilizing transport and manufacturing industries. On the contrary, containerized trade and dry bulk segments faced significant declines mostly due to the macroeconomic conditions. Containerized trade is expected to grow at a slow speed particularly because of the capacity imbalance. Large supply capacity is expected to enter the markets after 2024 while the demand is forecasted to remain modest which will lead to idling of vessels or demolition. Some changes in the main trade routes are also observed in the container segment. The historically busiest and the highly lucrative Trans-Pacific route still remains dominant. On the other hand, some intraregional routes exhibit resilience indicating a stable supply chain flow pattern. Intra-Asia flows as well as south-south trade between Africa and Latin America are the recently busy trade routes in containerized sailings. Spot freight rates dropped to unsustainable lows on most of the trade routes until the end of the year when a peak was observed due to the crisis situation at Red Sea. However, the upwards trend did not continue as the vessels were diverted to alternative routes and the freight differences were absorbable within the already low levels.

Although seaborne trade is not a stranger to disturbances such as strikes or natural disasters, disruptions have become a growing bottleneck in maritime transportation since the beginning of the pandemic. The ongoing geopolitical crises, trade restrictions, protectionist policies and consequences of climate crisis are causing major disturbances in trade flows. The low water levels in Panama Canal during the first quarter of 2024, caused long waiting times and restrictions for ships passing through. Any such disruption results in a surcharge addition to the final freight rate which is eventually reflected in finished goods prices. The inability to use the water route puts additional pressure on inland transportation in the USA where capacity is limited. The increasing demand for rail and road transport capacity is also pushing prices up.

Red Sea route and the Gulf of Aden is marked with a geopolitical disruption where the Houthis attack cargo ships as a response to the war situation in Gaza. Military measures could not prevent the attacks and majority of commercial vessels rerouted via Cape of Good Hope which adds two weeks to the transit time and associated costs. Global reliability levels which were hampered significantly during Covid-19 pandemic and the aftermath could not find the opportunity to recover. Reliability which is the main service dimension of liner shipping has been unable to meet pre-pandemic levels due to concurrent crisis at the chokepoints of seaborne shipping.

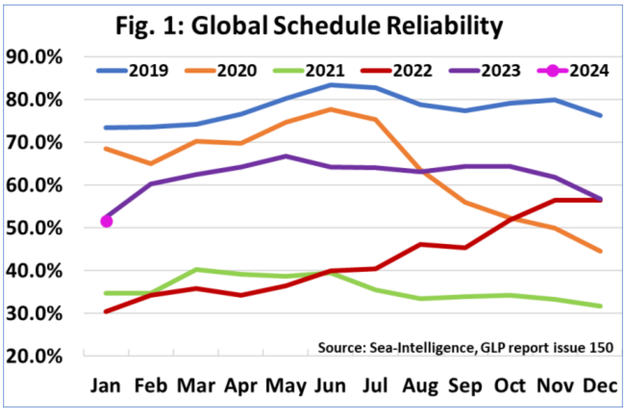


Figure 9 Global Schedule Reliability
Source: Sea intelligence GLP report 150

A longer transit time over Cape of Good Hope also reduces the available shipping capacity. Due to the low demand levels during the beginning of 2024, capacity was yet to become an issue but the low container freight levels have climbed up rapidly following the attacks as well as the charter rates for container ships because shipping lines had to inject additional capacity to meet the longer sailing times.The waterborne trade to and from Middle East is also disrupted and land bridges are built to secure trade flows. Such measures result in an increase in road transportation which reverses the modal shift trends and increases emissions as well as prices.

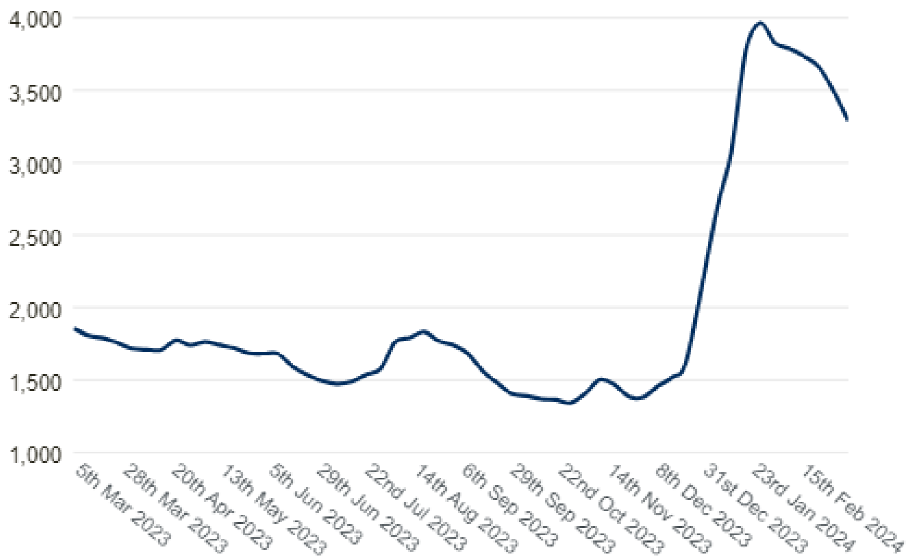


Figure 10 Drewry World Container Index (WCI) - 07 Mar 24 (US$/40ft)

It is not only the transit times and freight prices that are being affected by these disruptions. The decarbonization efforts of the industry are also hampered by these longer sailing distances and the higher speeds to meet transit times. According to an estimation by Sea Intelligence, the longer routes are causing the shipping emissions to increase between 31% to 66%, and each knot faster than economic speed is raising the emissions by 14%. Furthermore, to inject additional capacity, shipping lines add older and smaller vessels to their chartered capacity. These vessels have poorer energy efficiency performance and technical capacity to meet decarbonization targets. Altogether these impacts cause a backward trend in shipping decarbonization.

3.4 The car carrier industry trends (RoRo markets)

The RoRo and Pure Car Truck Carrier (PCTC) markets were historically going through low vessel order rates since 2016. Combined with high scrapping levels in 2020, the available capacity contracted significantly in 2022 leaving the market segment highly vulnerable to demand peaks and port congestion. The automotive industry was one of the first to react to the lockdowns and economic downturn at the beginning of the Covid-19 pandemic. Car makers stopped production and closed down their facilities. Hence, the excess scrapping of car carriers in 2020 was not unexpected. However, when the car makers restarted their operations and the demand for personal cars ramped up because of changing mobility preferences during the latter waves of the pandemic, there was not enough capacity in the market. The semiconductor crisis exacerbated the situation in automotive production, as all microchip producers were heavily engaged with their customers in electronics markets and the deliveries to automotive industry were delayed and reduced. This resulted in unfinished cars waiting at producer lots or at the docks of ports. Shortage of dock workers and truck drivers worsened the situation at major RoRo ports that suffered heavy congestion in 2022. The gap between supply and demand accompanied by port congestion caused a surge in car carrier rates, vessel charter rates and instability in service reliability levels.

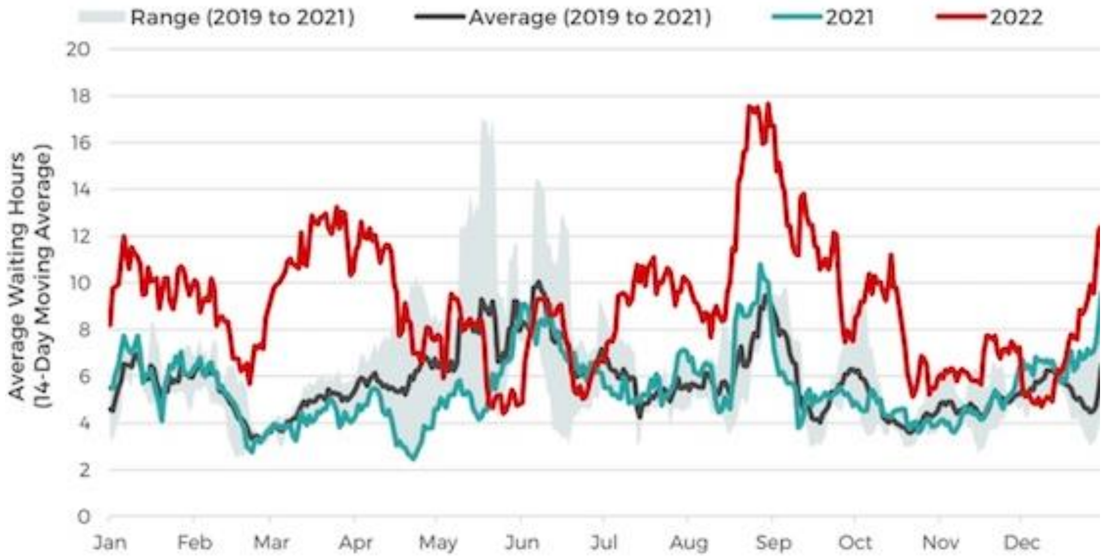


Figure 11 Average waiting hours for vehicle carriers at Northwest Europe in 2022 versus 2021, 2020 and 2019
Source: VesselsValue Jan 2023

On the demand side, China's vehicle export volumes increased 54% year on year with 3 million units as of December 2022. The leading market player was Tesla from its factory in Shanghai but strong competition came from Chinese brands such as Chery and BYD. Due to the lack of available carrier capacity, OEM led investments emerged in the market. The car makers from China, following the prosperous growth in the electric vehicle (EV) market, are developing car carrier construction bases in China and ordering their own vessels. Similarly, the large market players in the RoRo segment such as Grimaldi are also increasing their car carrier orders at Chinese shipyards.

Due to lack of capacity, a small share of finished automobiles were transported in containers and dedicated racks which triggered the interest from container carriers. Observing the demand increase in this segment, leading container carriers have started to enter RoRo and PCTC markets. Recently Cosco ordered four 7000 ceu PCTCs. CMA CGM and HMM are looking into chartering and building alternatives. In 2023and 2024 816.430 ceu was added to the orderbooks leading to a cumulative supply capacity of 4,2 million ceu by 2025 (estimated numbers, Clarkson & Wallenius Wilhelmsen Research). This increase in supply capacity is expected to push the freight rates down for RoRo and PCC markets.

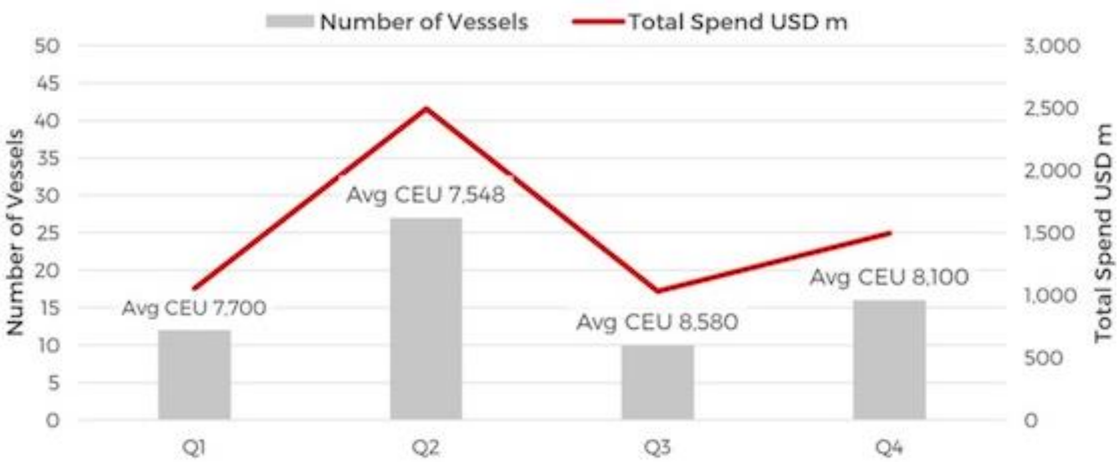


Figure 12 Vehicle carrier newbuild order by number of vessels, total spend (USD mil) and average ship size (CEU) in 2022
Source: VesselsValue Jan 2023

The global trade in this segment was driven by China in 2022 with global cargo miles increasing by 1.2% where China to global cargo miles increasing by 28%. The liner exports from Europe to North America, Far East and Middle East were impacted significantly due to the lack of space. Walllenius Wilhelmsen announced a complete booking stop to protect OEM contracts and improve schedule integrity which was hampered by chronic port congestion in Europe. The lucrativeness of long-haul trade from China to the rest of the world caused even more reduced capacity being deployed to intraregional trade in Europe - the shippers in the short-sea trades had to pay higher price premiums accordingly.

2023 figures are expected to be similar. Freight rates and charter rates will remain high due to the imbalance between supply and demand, reoccurring port congestion and the slower speed due to CII requirements besides others. Ship recycling in this segment will remain low while new-builds will enter the market gradually. The capacity is expected to be balanced in 2024 and 2025 with the delivery of new vessels. However, the extent of the decline in freight rates will be dependent on China's export demand and dominance in automotive markets. The estimated value of the global car carrier market is USD 10.4 billion in 2023 and this figure is expected to reach USD 12.94 billion in 2031 according to Data Bridge Market Research. The global sales numbers and estimations over a 10-year period for light vehicles are shown below in Figure 13. The growth of the market is closely coupled with the EV trade growth which has implications for ship sizes and design as well. EVs are heavier and wider than Internal Combustion Engine (ICE) units. Hence, more capacity is required to carry the same amount of units due to deadweight.

Average ship sizes have increased 14% in 2022 and are expected to increase further due to these demands. The developments in battery technology influences ship design significantly as it has implications for stowage for safety and fire risk. The BEV and PHEV production is expected to demonstrate a steady increase in their share of the global light vehicle production (Figure 14) which will require adjustments in car carrier ship design that can accommodate various types of vehicles.

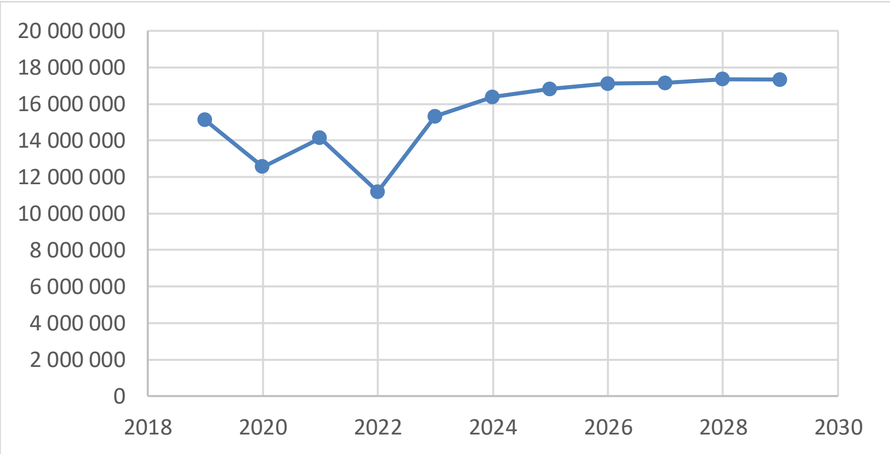


Figure 13 Number of vehicles sold.
Source: Developed based on S&P500 report & Wallenius Wilhelmsen Research

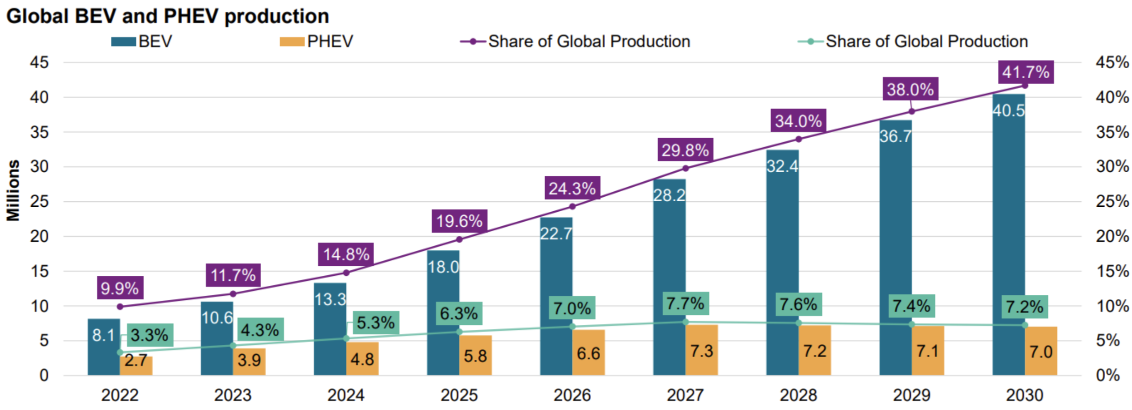


Figure 14 Global production overview - BEV and PHEV

BEV share reduced across horizon, legislative impacts and OEM strategy developments continue to be incorporated but trend remains in line. As of April 2024

Source: S&P Global Mobility, LVP+AP forecast March 2024

The production forecasts indicate an increasing trend as well but rather for Asian markets. The total production figures are expected to increase significantly over a 10-year period. However, the dominant markets of West Europe and North America are expected to stagnate while Asia (the combined production by China, Japan and South Korea) is expected to increase by appr. 50% when compared to 2019 production levels (Figure 15). On the other hand, new policy measures are introduced by the US and the EU in the form of high tax instruments to prevent Chinese EVs entering into these markets at lower prices. Such measures are expected to affect the price competition for EVs that are exported from Asia to US and EU markets.

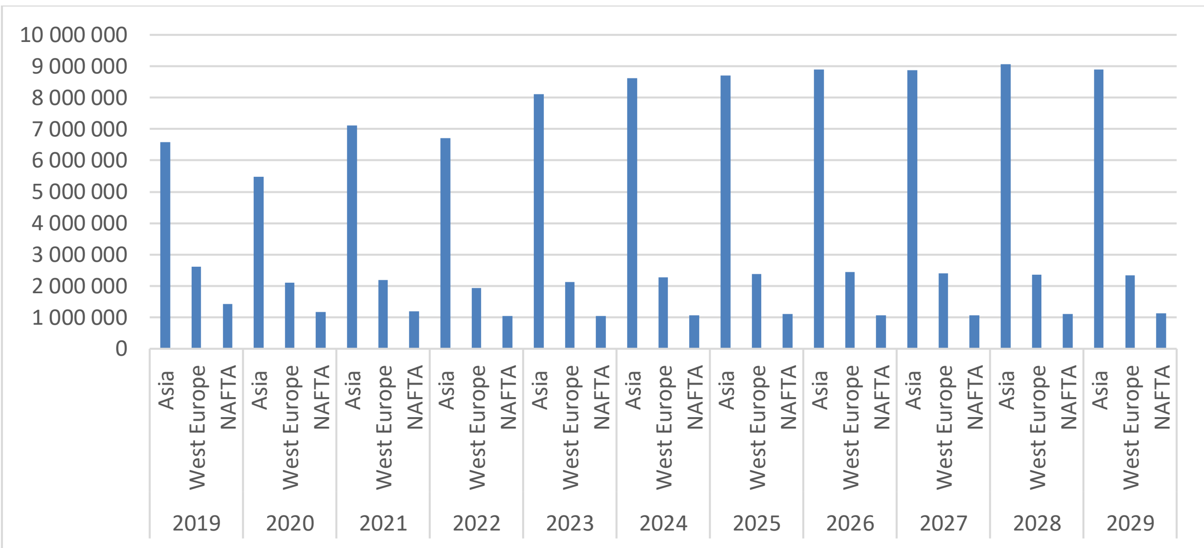


Figure 15 Number of light vehicles produced

Source: Developed based on S&P500 report & Wallenius Wilhelmsen Research

4 Operations

Below, we provide an overview of the different operational patterns in the varying shipping segments as well as a specific overview of the RoRo operations. How the operational pattern influence the wind-propulsion efficiency is discussed at the final part of this chapter.

4.1 A general overview of operational patterns in shipping[1]

Shipping connects the raw material markets to end markets via processing and manufacturing industries and this connection is composed of different shipping markets segments with different operating patterns. Raw material markets are composed of energy, mining, agriculture and forestry industries which are connected to processing and manufacturing industries mostly with dry and liquid bulk shipping. It is possible to use specialized shipping segments between these markets such as forest product carriers where special needs of the products are addressed with specialized operational patterns and ship design. From the manufacturing and processing industries to end user or consumer markets, the most widely used shipping segment is liner shipping, though again here some specialized segments are observed such as car carriers or LNG vessels.

The operational principles of different shipping segments are defined by the characteristics of shipment demands. The demand for shipping a certain product could be regular or irregular, large or small in consignment size, fast or slow in delivery speed, loose or packaged and require certain handling approaches such as vacuums or grabbers. In addition to that, parcel size distribution (PSD) is an important criteria that defines the type of shipping service that is needed to fulfill a certain shipment demand. PSD is the size of the product that is on average sold or bought by a merchant at a single consignment. This measure is dependent on three main things: (1) the average stock that is kept by the users (warehouse size, facility capacity etc.), (2) the draft at port of loading and port of discharge and (3) the economies of scale that is achieved by a larger vessel.

Once the demand characteristics are determined, the shipping service can take place under the three main merchant shipping segments: bulk shipping, liner shipping and specialized shipping. Bulk shipping is mostly characterized by cargo consignments that are over 2000-3000 tons. The individual consignments in this segment are large enough to fill a ship on their own and very homogeneous. The segment is divided into dry bulk and liquid bulk sub-segments. The former moves raw materials such as coal, iron ore, grain or other bulks such as sugar, scrap steel, cement and the like. The latter moves crude oil, petro-chemicals, vegetable oil and the like. The operating principles in this segment are characterized by fewer sailings over the year, approximately 6 sailings annually, relatively lower service levels required during sailing (unless an emergency occurs) and fewer labor on land side. Bulk segment operates with tramp shipping principles where the consignments are fixed on spot basis (unless there is a contract of affreightment for a series of shipments), there are no pre-defined routes as the ships call those ports where the goods are ready to be loaded and they berth to those ports where the goods are consigned for delivery. The prices are defined according to global spot rate indexes but also the contract between the seller, buyer and the shipping company.

On the other extreme, there is liner shipping where unitized cargo is moved mostly in containers, on pallets, in boxes or in break-bulk form. In this segment, the annual orders vary between 10.000 to 50.000 consignments which are characterized by smaller sizes that need to be consolidated with other similar but heterogeneous cargo. The consignments in this segment require speed, reliability and very high service levels. The majority of labor in this segment is working on the land-side at the shipping agencies of liner companies that are located all around the world. The unitized cargo is not only moved at sea but further logistics services and door-to-door delivery can be offered by the shipping agencies. The goods are moved

[1] A general overview of operational pattern in shipping is based on Stopford (2009)

on ships that operate on a regular basis (weekly or bi-weekly schedules) between pre-defined ports where hub and spoke network structures are used to achieve economies of scale. The freight rates depend on either monthly spot lists or long-term contracts between shippers and liner companies. The most common example of liner shipping is containerized cargo today.

Specialized shipping segment lies between the two extremes. The ships under this segment are designed to address the special needs of potential users. LNG or LPG vessels, live animal ships, forest product carriers, RoRo and pure car carriers are examples of ships operating in this segment. These require special investments in ship design as well as the port infrastructure at both ends because the cargo needs special handling most of the time. Some of these specialized segments operate on tramp basis such as the LNG or LPG vessels and some operate on liner basis such as the RoRo and pure car carrier segments.

4.2 Operational patterns in the RoRo segment

For the specific trades of rolling cargo suitable for RoRo shipping, the pure car and truck carriers serves the automotive sector including mainly vehicles such as cars, trucks and construction equipment on the global trades.

The shipping companies in this segment do typically have a global service in which the trade network reaches between the different continents, from/to Europe, Asia, North and South America and Oceania. As an example, Wallenius Wilhelmsen worldwide trade network is shown in Figure 16.

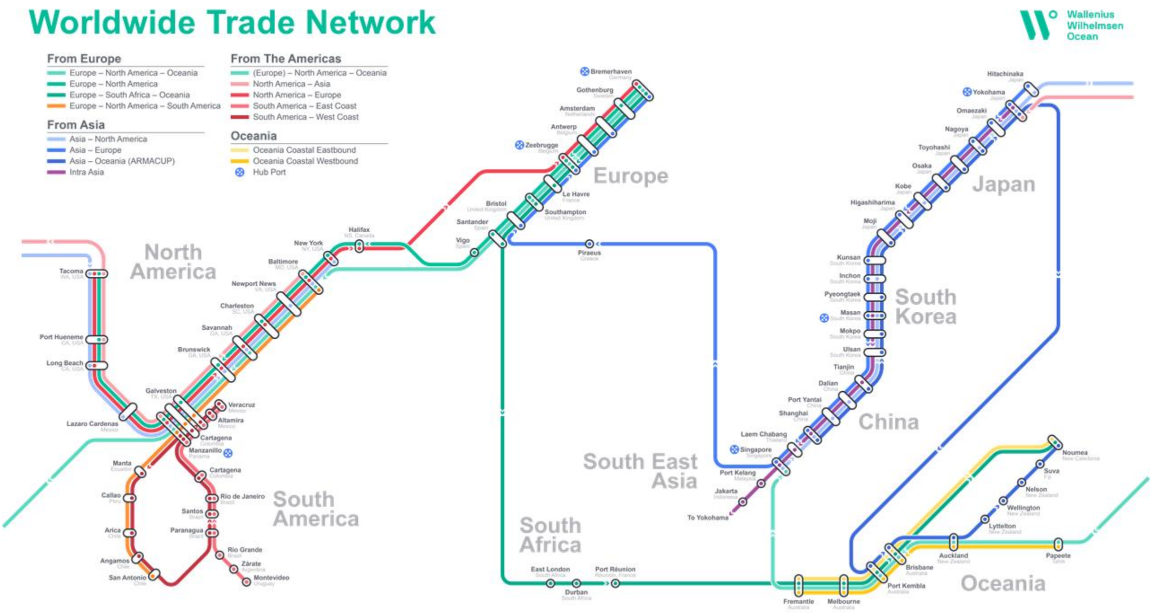


Figure 16 Wallenius Wilhelmsen Worldwide Trade Network
Source: Wallenius Wilhelmsen Ocean

There is a complex puzzle to plan the vessels in the fleet to meet the demand from the customers in the global trades. The supply of capacities in the fleet must be planned in the most optimum way to meet the demand. Around 125 vessels are operated in Wallenius Wilhelmsen's trades each with a capacity between 5 496 and 8 000 cars (RT43).

Wallenius Wilhelmsen especially put forward their tonnage coordinators as a critical team to plan their vessel movements in relation to their trades and demand from the customers (Hobbs, 2022). Since the supply of capacity on the market has been too small in relation to the customer demands the last years (after the pandemic), the situation has been extra challenging. The port congestions have been evident. The lack of capacity in several ports has been affected by, e.g. the import volumes stored at the port longer than expected. In interviews Wallenius Wilhelmsen mentions the fact that customers' port of departure has in some occasions been changed to another port with less congestion problems, in order to be able to load the volumes on the vessels in time.

For the tonnage coordinators there is a month-by-month plan allocating each vessel for the routes in the different trades based on the volume forecasts. However, adjustments are constantly made in order to meet the daily demand with their supply with the aim of reaching the best capacity utilization on the vessels, combining the different type of cargo, cars such as high and heavy goods. Delays on the scheduling can occur and may initiate updates of vessel allocation. This means that vessels in the fleet operate globally and are shifted between the different trades depending on the specific demand and outcome of the puzzling from the coordinators.

4.3 Operational concerns with wind-propulsion

The operational patterns of the vessel influence the performance in terms of energy savings from the wind propulsion technology. In previous studies examples of performance predictions based on different applications of wind propulsion is presented (e.g. IMO, 2024; EMSA, 2023; Werner et al., 2023).

There is no standardised method on how to predict the performance of a wind-powered vessel today (ABS, 2023a, Werner et al., 2023). There is a variation of approaches applied in studies available, in the same time as there is a strong development in developing standardised prediction approaches. Therefore, it is important to be aware of the potential uncertainties and the variations in the predictions as well as the reasons for why it is difficult to compare the results from different studies. Both in the Orcelle Horizon and in the sister project Optiwise (which creates a holistic design and control method to showcase the energy savings from wind-propulsion) there is a strong focus on the method development. In particular, Werner et al. (2023), highlights an overview of methods for predicting power savings, which includes different levels and combinations of aero- and hydrodynamic methods as well as machinery interaction and weather on route. These different levels could be differently applied weather it is an early idea stage or an advanced business case and performance expectation required. Further, there is also a need to verify the performance in real life (after retro-fit or new-building), in which procedures should be followed for such full scale verification tests.

Typical operational parameters influencing the performance are for example which geographical area(s) to operate in and their wind and weather conditions on the routes as well as the speed of operations (see e.g. Chou et al., 2021; Werner et al, 2023). Also, the WPTs can be applied of different type and number on a wide range of vessel types and size. In particular, Chou et al. (2021) highlight the environmental, on-board, and commercial factors that relates to the operations and influences the performance of using wind propulsion. Environmental factors is about the effect that can be reached by using the wind, which depends on the wind speed, wave height, and seasonal pattern of the weather. On-board factors are about how effectively the technology is operated, which depends on the route optimization applied, master's decision making as well as crew training. Commercial factors is about how the technology usage can comply with the commercial commitment, the trade pattern, trip duration, trip irregularity and port calls. All these areas are important to take into consideration when analysing the business case from an operational point of view.

For a vessel with wind propulsion operating in the RoRo-market, like Orcelle Wind, there are several operational conditions that will impact the wind-power performance and energy savings. Depending on which route to operate in, there will be differences in the energy-saving potential. In addition, operating between ports on coastal area will have a different saving profile than from operating on open sea. The speed will also make a difference for the power savings, creating a higher wind-propulsion rate if having a lower speed (10-13 knots) than the conventional vessel of approximately 16 knots. Further, to operate towards a specific estimated time of arrival (ETA) based on a specific speed and traditional route may not be as beneficial for the wind-propulsion rate as when optimising the route and speed based on the weather conditions. Hence, more flexible ETA could lead to higher energy savings.

As described in 4.2 above, there is today a high flexibility in the RoRo-market of how each vessel is planned for operation in relation to the whole trade network. It is difficult to predict the saving-potentials for a wind-powered vessel in such a dynamic setting, due to that various settings will have different saving potential. Therefore, a critical question is how to best include a wind-powered vessel in a fleet of services of the global trades? To get out the most of the savings potential the vessel could be directed towards promising steady routes in terms of e.g. weather conditions and volumes. Such further analysis will be of importance for the business case of Orcelle Wind.

5 Regulatory aspects

The EU has for a long time had several regulations in place for reductions of all kinds of emissions. It goes back to at least the 1970's with rules regarding the prevention of pollution from ships and new rules and regulations have then continuously been introduced. For example, rules regarding the reductions of Sulphur emissions and the introduction of ECA's i.e. Emission Control Areas that came into force 2010 and then later rules focusing on CO_2 /Green House Gas emissions such as the CII, EEXI, EU ETS and Fuel EU Maritime.

Below is a summary of the key developments in the field of EU environmental regulations from 2010 onwards that from the perspective of a ship owner/operator impact on their business/operations.

5.1 Sulphur Regulations

Sulphur regulations have played a crucial role in reducing sulphur emissions from ships and promoting cleaner maritime transport.

The Directive (EU) 2016/802 codified and repealed the existing EU legislation (Council Directive 1999/32/EC) related to reducing the sulphur content of certain liquid fuels. The aim was to reduce emissions of sulphur dioxide resulting from burning specific liquid fuels, thereby mitigating their harmful effects on health and the environment. The directive laid down maximum permitted sulphur content for various fuels:

- Heavy fuel oil and gas oil: EU countries were required to prohibit the use of heavy fuel oils with sulphur content exceeding 1% by mass and gas oils exceeding 0.1% by mass within their territories.
- Marine fuels: The directive incorporated changes from international law (Annex VI to the International Convention for the Prevention of Pollution from Ships, 1973) to introduce stricter sulphur limits for marine fuel in sulphur oxide emission control areas (SOx-ECAs). These areas include the Baltic and North Seas and the English Channel.
- As of July 1, 2010, the sulphur limit in SOx-ECAs was 1%.
- As of January 1, 2015, it further reduced to 0.1%.
- Outside SOx-ECAs, the sulphur limits were 3.5% until January 1, 2020, when they dropped to 0.5% globally (the global sulphur cap).
- Sustainable exhaust cleaning systems (scrubbers) could allow higher sulphur content if installed on ships.

The effects on the Maritime sector of these regulations have been significant. For example, stricter sulphur limits significantly reduced ship emissions' impact on human health and ensured a level playing field for ship operators worldwide. However, to comply with the new reduced limit shipowners have three main options:

1. Burn low sulphur bunker fuel oil (LSFO) instead of the current high sulphur fuel oil (HSFO).
2. Continue to burn HSFO and install a scrubber in the vessel's funnel to remove the sulphur before the exhaust is released into the atmosphere.
3. Switch from engines that burn traditional fuel oil to engines that burn alternatives, e.g. LNG or methanol instead. LNG and methanol exhaust contain almost zero sulphur content.

LSFO has been and still is significantly more expensive than HSFO. Installing a Scrubber is an expensive option as the equipment costs between USD 2 to 8 million per vessel. In addition to this an installation requires dry docking the ship which will take it out of service (and therefore off-hire) for 2-3 weeks. Also the maintenance cost of a Scrubber system is significant. Consequently, the installation and running cost of a scrubber system is very high.

In this context, it must be highlighted that installing a Scrubber is not an environmentally viable solution since it does not solve the problem with Sulphur emissions. It only moves the emissions from air into the oceans.

5.2 CO_2 and Decarbonization Regulations

There are a number of legislative measures aiming to reduce CO_2-emissions. To exemplify the “up-to-date” most important ones, as perceived from the shipping sector, some EU rules and regulations are summarized below.

5.2.1 EU Emissions Trading System (EU ETS) for Maritime Transport

The EU ETS is a cornerstone of the EU's policy to combat climate change and its key tool for reducing greenhouse gas emissions cost-effectively. It is the world's first major carbon market and remains the biggest one. The EU ETS, initially focused on land-based industries and was extended to maritime transport emissions in 2024. Shipping is gradually included in the EU ETS system for emissions of CO_2 as from 2024 (40% 2024, 70% 2025, 100% 2026).

The EU ETS in shipping applies to all ships above 5000 GT. For voyages from and to EU from outside EU - 50% of CO_2-emissions shall be accounted for and for intra EU voyages - 100% of the CO_2 emissions. From 2026 the system also includes GHG (Methane and N2O).

5.2.2 Energy Efficiency Existing Ship Index (EEXI)

EEXI is a one-time certification assessing the design, construction, and technical features of existing ships. It aims to improve energy efficiency and reduce emissions from ships. It is a measure introduced by IMO, agreed in the IMO strategy on Reduction of GHG emissions in 2018, and is mandatory for all ships from 1 January 2023. Each individual vessel, over 400 GT needs to calculate their EEXI. The calculated EEXI is compared to a “required Energy Efficiency Existing Ship Index” which is related to the Energy Efficiency Design Index (EEDI) baseline. The ship’s individual EEXI is required to meet the minimum energy efficiency standard (IMO, 2024).

5.2.3 Carbon Intensity Indicator (CII)

CII introduces an operational index applicable to all ships above 5000 GT (g CO_2 per DWT-nm) and shall be calculated annually for the first time in 2024 representing 2023 data.

The CII rating system rates vessels from A to E where A is “excellent”, C “acceptable” and D or E requires further actions and an improvement plan.

One of the goals with CII is to achieve a reduction in carbon intensity of 40% by 2030 compared to the 2008 level. The target is to reduce GHG emissions by improving vessels’ energy efficiency as well as introducing new technologies and low or zero-carbon fuels.

Examples of possible actions for complying/improving the CII rating

- ✓ Reduce speed
- ✓ Install fuel saving devices
- ✓ Regular hull/propeller cleaning
- ✓ Trim optimization
- ✓ Bio (drop-in) fuels

Example of consequences of the introduction of the CII

- ✓ Speed instructions – lowering the speed
- ✓ Risk of conflicts between owner and charterer
- ✓ Risk of losing certificates
- ✓ Impact on capacity and need for investments in new vessels

5.2.4 EU MRV Maritime Regulation

The EU MRV (Monitoring, Reporting, and Verification) Regulation requires shipping companies to report emissions data. It covers greenhouse gas emissions such as Carbon Dioxide (CO_2), Methane (CH_4), and Nitrous Oxide (N_2O) as of 2024 from ships during voyages to, from, and within EU ports. For a voyage to be covered by the EU MRV, at least one of the two ports of call of the voyage must be located in an EU territory, i.e. voyages into, within and out of the EU shall be reported.

5.2.5 Fuel EU Maritime

The EU has adopted the Fuel EU Maritime regulation to increase the share of renewable and low-carbon fuels in the fuel mix of international maritime transport in the EU.

FuelEU Maritime sets well-to-wake greenhouse gas (GHG) emission intensity requirements on energy used on board ships over 5000 GT trading in the EU and will be implemented from 1 January 2025.

The regulation also requires passenger and container ships to connect to onshore power supplies at major EU ports from 2030, when at berth for more than two hours. This will be extended to all ports with onshore power supply from 2035.

FuelEU Maritime sets requirements on annual average GHG intensity of energy used by ships trading in the EU or European Economic Area (EEA), measured as GHG emissions per energy unit (gCO_2e/MJ). GHG emissions are calculated from a well-to-wake perspective, including emissions related to extraction, cultivation, production and transportation of the fuel, in addition to emissions from energy used on board the ship.

5.3 Effects from the regulations – two examples

To exemplify the effects from the regulations, two examples related to EU ETS and CII is provided.

5.3.1 Example 1: Effects EU-ETS

To exemplify the effects from regulations, an example illustrates how the reduction of CO_2-emissions and EU-ETS impacts the fuel cost for a specific vessel. The vessel selected is a HERO-class vessel in the RoRo-fleet. For more information about the HERO-class, see Wallenius Wilhelmsen (2024).

Four different cases are compared for an Atlantic one-way voyage (Southampton-Halifax). The EU-ETS cost is based on 100% EU-ETS cost but with a 50% reduction due to out/in-bound EU voyages. The results are presented in Figure 17 as total cost per transported cargo unit (RT43) for one Atlantic crossing. The cases that are compared are as below:

1. Reference, Atlantic crossing in 16 knots with a HERO class vessel. An auxiliary power consumption of 800 kWe is assumed. The fuel calculation only includes the ocean leg of the trip and not the harbour part. Harbour time of 48h is included to illustrate the impact of speed reduction for total one-way voyages during a year.
2. Same as (1) but with a speed reduction that corresponds to a reduction of CO_2-emissions by 10%. This equals a speed reduction to 15.3 knots.
3. Same as (1) but now biofuel is blended with MGO to reach a CO_2-reduction of 10%. This requires a fuel blend that includes 11.1% biofuel (HVO100).
4. Same as (1) but with 50% reduced propulsion power due to installation of Wind Propulsion Units, this is a reference to Orcelle which shows a similar power reduction.

In (1),(3) & (4) are a total of 42.5 one way voyages possible during a calendar year. In (2) where the speed is reduced from 16 to 15.3 knots is the voyages reduced to 41.1 voyages/year.

In (2), (3) an (4) the EU-ETS cost is lower than (1). In (2), the lower EU-ETS cost is the same as in (3) when the same CO-emission reduction was achieved.

The use of HVO100 in (3) demonstrates the additional operational cost for the fuel mix in combination with the lower EU-ETS cost due to the reduction of CO_2-emissions.

The operational costs as well as the EU-ETS costs are much lower in (4) when introducing wind propulsion in this specific example. However, this should only be seen as a demonstrative example based on the general assumption of 50% efficiency. Further detailing of such calculations is required as a base for financial considerations, and with lower operational speed (10-13 knots is the design speed for Orcelle Wind). Simulations performed by Rise and Oceanbird, where the vessel is routed back and forth across the Atlantic over a 10-year period, show that Orcelle's energy reduction increases at lower speeds compared to a HERO vessel traveling at the same speed. The results are shown in the figure below.

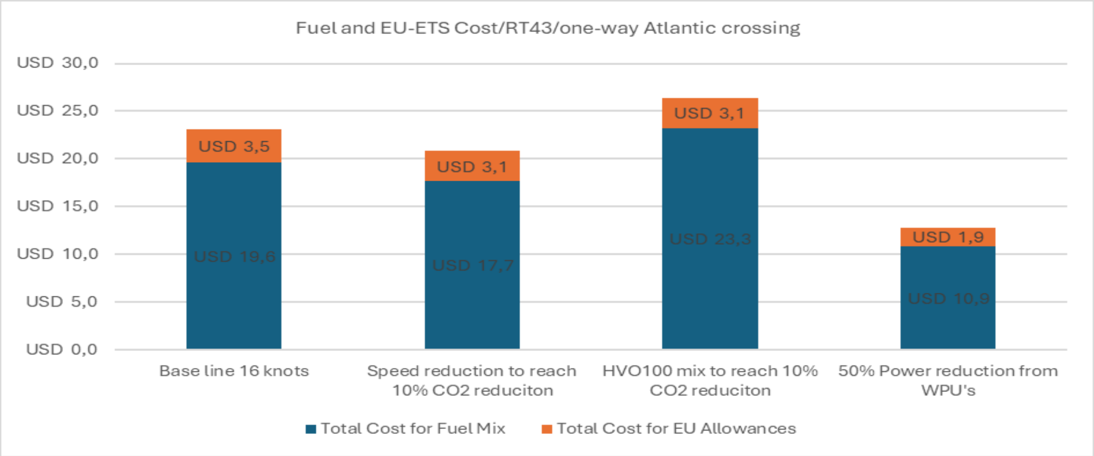


Figure 17 fuel and EU-ETS cost for four different cases per transported cargo unit on a one-way Atlantic voyage. Based on the following costs: MGO 745 $/ton, HVO100 1981 $/ton, EU-ETS allowance 83 $/ton.

5.3.2 Example 2: Effect on the tonnage capacity

Only a minority of the world fleet comply with the CII rating of C or better without having to take any measures. It is estimated that only 15% of the world fleet achieve C or better.

The CII regulation will therefore require ships to sail at lower speed and this will equal a loss of vessel capacity. How big the loss of capacity will depend on the speed reduction. In the above example the capacity loss equals 4%, when lowering the speed with 0,7 knots. Many ships would however need to reduce their speed more to achieve an acceptable rating.

To cover for the loss of capacity due to the lowered speed new vessels will be ordered. And if fleet sizes increase because individual ships are slow sailing, the CO_2-emissions will increase. The new regulations would reduce emissions for a single ship but would not automatically reduce emissions for the worldwide economy. However, the new vessels will most likely be better from an environmental point of view and have better CO_2-performance and therefore positive effects of the CO_2-emissions long term.

However, a recent study by Gerhart et al (2024) compares the effect from wind propulsion on CII reduction potential finding that for a 50 000 DWT Chemical Parcel Tanker equipped with 2 rotor sails would get a respite of around 5 yrs from being degraded to a D-rating. Those results are based on energy savings of around 7-13%. To achieve savings from wind-propulsion would in this case make it possible to buy enough time to wait for e-fuels and related infrastructure to get in place when influenced by the CII regulations.

6 Offering - Value proposition

In the context of shipping, the value proposition in the offer is the products and services that the shipping company offer towards their customers to meet their needs. Shipping is a central part in most global supply chains and is therefore producing a critical logistics service. A crucial question is, what is the value for the customer? The values in a logistics service traditionally center around the 7 Rs, which is: getting the Right product, in the Right quantity, in the Right condition, at the Right place, at the Right time, to the Right customer, at the Right price. In shipping, the most critical logistics parameters for the value proposition have traditionally centered around price, quality and lead time. However, times are changing and the interest for decarbonised and green transport options among both shipping companies and their customers has grown lately. Several shipping companies also grow their scope of service, to not only include the sea leg, but also including inland transportation to include the full range of door-to-door transport services.

The offer of future services could include wind propulsion as a base for the value proposition and as part of the green service. In Figure 18 questions of relevance for the value proposition is highlighted.

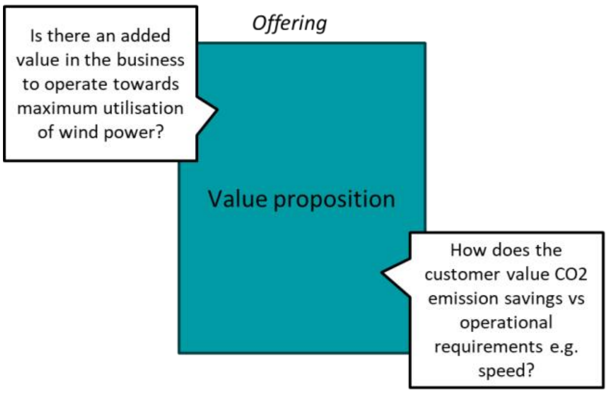


Figure 18 Questions of relevance for the building block Offering when introducing wind propulsion in the business

6.1 Motivations to greening the service

Green services in shipping refers to a service with less negative impact on the environment through less CO_2-emissions or more efficient use of resources. For several years, logistics and transport providers have given increased attention to environmental impact of operations. Meanwhile, the shipping industry has been relatively slow in its sustainability efforts, lagging behind due to e.g. its international character and difficulty to decarbonise.

There are many reasons for shipping companies to offer green services. A recent study found that the demand for green services is expected to increase due to new regulations, customer commitment, collaborative factors and economic benefits (Sisodia and Sundberg, 2024). While earlier financial incentives for using other than conventional fuels were previously lacking, there are now several policy instruments either already decided, under negotiation or discussed that can help drive the change to fossil free shipping, for example within the EU Fit for 55 (Jivén et al, 2023). Further, the pressure on companies to account for their emissions, also in their scope 3 emissions, is now more and more visible in among the shipping companies' customer base (see further details in chapter 8.1). To have a strengthened customer commitments is possible through the green service, for those customers that want to have totally green operations, including external logistics and transportation.

Another reason to offer green services is increased competitiveness and improved brand image. In fact, Tang and Gekara (2020) argue that shipping companies are more proactive and seeking to exceed mere compliance with regulations when motivated by meeting customer expectations. Martinsen (2014), for example, describes how it can be seen as a growth market to design transport solutions that have low CO_2-emissions for customers.

Further, there are also economic reasons for developing green services. To provide energy efficient services, with reduced fuel consumption lower the operational costs.

There are also risks associated with not offering green services. Shipping companies may be benchmarked against industry standards and competitors, and companies that fail to meet customers' sustainability expectations risk losing them to more sustainable competitors. Failing to meet to customer expectations may exclude shipping companies from securing tenders. Existing customers may opt for greener services offered by other shipping companies. If customers' needs for sustainability are neglected, it can lead to bad reputation for shipping companies and influence their profitability negatively.

Many transport-buying companies strive for reduced environmental impact, and green services can meet their needs. Raza and Woxenius (2023) report that environmental performance has become a key criterion when transport-buying companies award tenders. According to Sureeyatanapas et al. (2018), certifications such as the ISO 14000 series is also used by transport-buying companies in decisions on tenders. Sureeyatanapas et al. reported in 2018 that shipping customers asked for information about CO_2-emissions from their suppliers. And in 2021 all top-liner shipping companies had started to report on sustainability due to mounting pressure from customers and other stakeholders, according to Schramm (2021). A Swedish longitudinal survey report on the willingness from transport-buing companies to pay for green transport services comparing the years from 2012 up to 2022 (Styhre, 2023). The development and interest in green transportation is very clear and the last years a shift is seen in the willingness to pay a higher price for a transport service with less environmental impact. The expectations among shipping companies and transport buying companies are that environmental demands will continue to increase. In light of stricter expectations from downstream supply chain partners and end consumers to reduce their environmental impact, transport-buying companies have indeed started to pressure shipping companies to practice sustainability.

Still, there may be a different pace for the interest of green services in different markets (see also chapter 7). Among the shipping companies studied within the container and RoRo-segment by Sisodia and Sundberg (2024), it was highlighted that "customers often neglect the green service offer as it is considered too expensive".

6.2 Green services in shipping

In response to the customers' expectations regarding sustainability described above, shipping companies have adopted various sustainable initiatives. Greenhouse gas (GHG) emissions from the shipping industry mainly originates with the ships' fuels putting alternative fuels high on the agenda (Atilhan et al, 2021). Other initiatives include slow steaming, optimised routing and scheduling, the use of solar or wind power (Yuen et al., 2017; Christodoulou et al., 2019), optimised speeds, improved engine designs, hull coatings, the use of waste heat recovery systems and optimised hulls and propellers (Tang and Gekara, 2020).

It is still quite new for shipping companies to offer green services. In the study of Sisodia and Sundberg (2024) where shipping companies in the container and RoRo segments were interviewed, some of the shipping companies reported that they had been selling green services for a few years, while for others the green service offered was introduced alongside 2023 regulations. There were differences in shipping companies' maturity level regarding how long they had been offering green services (see Figure 19) and in how ambitious their long-term sustainability targets were (see Figure 20). Shipping companies who had been offering green services for a longer time, had a larger portfolio of green services, including both carbon reductions to customers and practices such as technological development. Regarding long-term sustainability targets, both Wallenius Wilhelmsen and Maersk had more aggressive targets regarding which year to achieve net zero emissions. Both of these aims ahead of IMO targets.

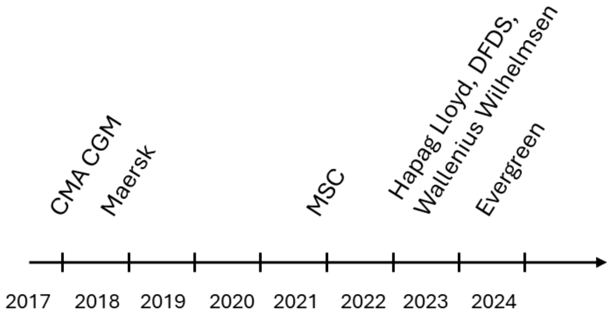


Figure 19 Time line for start of offering green services (based on Sisodia and Sundberg 2024)

Target: Net Zero Emissions

2040	2050
MAERSK	CMA CGM
Wallenius Wilhelmsen	MSC
	Hapag Lloyd
	Evergreen
	DFDS

Figure 20 Figure: Long-term sustainability targets (based on Sisodia and Sundberg 2024)

All shipping companies that Sisodia and Sundberg interviewed were found to have services to lower their emissions and reduce their impact on the environment. Table 2 provides an overview of the green services that shipping companies have introduced to reduce their emissions and reach their sustainability goals and that customer can contract for a separate cost. Internal carbon compensation refers to insetting according to the mass balancing concept, and is used because alternative fuels at the moment cannot be bunkered in all ports and therefore the alternative fuel used where possible within the shipping company's fleet. To ensure correct compensation, e.g. a customer paying for the use of alternative fuel while it is in fact not used on the specific route that customer uses, corresponding CO_2-emissions need to be calculated and verified properly. Transparency regarding emission calculations has been a critical factor for trust towards the customers and certificates are offered to confirm the amount of emissions saved by buying a green service. Finally, there is also external carbon compensation, also referred to as offsetting. Offsetting compensates for a fleet's emissions through external projects, such as planting a tree in Africa. It should be noted that carbon compensation does not have any effect on the shipping companies' own carbon reduction process. Apart from these services, it is widely discussed how a green corridor could be created. Several shipping companies look into creating a full green logistic solution door-to-door, e.g. with electrified road and/or rail transport on the inland side in combination with a green service on the sea leg.

In addition to the mentioned green services in below table, to reduce the carbon emissions in specific settings has been offered, e.g. in relation to the ZEMBA tender (COZEV, 2024), which is described further in 7.1.

Table 2 Overview of green shipping services (developed from Sisodia and Sundberg 2024)

Green service	Description	Examples
Internal carbon compensation	Alternative fuels e.g. LNG, Biofuels, Biodiesel, Green Methanol.	Reduced carbon services (biofuels) (Wallenius Wilhelmsen) Biofuel solution (MSC) Eco delivery (methanol, biofuels) (Maersk) ACT+ (LNG, biofuels) (CMA CGM) Insetting product (biofuels) (DFDS) Ship green (biofuels (Hapaq Lloyd)
Certificate of CO_2 emissions saved	Customers get a certificate confirming the amount of emissions saved by buying a green service. The emissions are calculated by the shipping companies and verified by a third party.	Ship Green declaration (biofuels) (Hapag Lloyd)
Emissions Tracking	Tracking the amount of emissions customers' for container/cargo, for example emissions dashboard used for monitoring CO_2-emissions.	Emissions dashboard (Maersk)
External carbon compensation	To compensate for climate impact customers are offered to pay a small amount of money for external projects (offsetting), such as water projects or planting trees.	ACT+ (CMA CGM) MSC

6.3 Services with wind-propulsion in shipping

As of early 2024, shipping companies using WPT include this technology as part of their efficiency improvements and/or their long-term decarbonization strategy, not specifically as a “stand-alone” green service. The number of vessels applying WPT is constantly growing, and in the review reported in Appendix A, more than 30 vessels operated with installed wind propulsion technologies as of early 2024.

For the RoRo-segment, only a few examples exist. One of the few pure RoRo vessels in ocean going operations applying wind propulsion today is the SC Connector, operating in the North Sea market with the assistance of two rotor sails that were retrofitted in beginning of 2021. A reduction of 25% of the fuel consumption was foreseen at installation. Sea-Cargo, the company operating the vessel, promotes the vessel on its webpage but in 2024 there were no specific service offerings for reduced emissions transport advertised (Sea Cargo, 2024).

Further, it is not as straight forward as with alternative fuels to include wind propulsion in the service offer. Firstly, the energy savings are varying depending on e.g., the weather conditions and the specific route sailed. It is of importance to have a process regarding how to validate and verify the emission reductions on the specific journeys. Secondly, since it is an efficiency measure which is part of the overall decarbonization strategy, to include it as a separate offer would pinpoint specific customer to pay for the emission reductions, while seeing it to contribute to the overall fleet efficiency and to lower the average emissions may benefit all customers.

Also, since we see several operational parameters influencing the savings, such as speed, route, ports to call and time window for ETA, there might be beneficial to adjust the operational pattern to maximise the utilization of wind power. The ships operate at different markets and will have varying possibilities to make such adjustments. In the RoRo-segment, and their liner service, there may be challenges in combining a fleet of traditional vessel with a new wind-powered vessel, if the new vessel has other operational pattern. How such adjusted service could align with the customers' needs are of importance to investigate for successful implementation and will be part of the next step in this project.

For future green services, Sisodia and Sundberg (2024) raise the need for shipping companies to benefit from stronger collaborations, both with customers, but also other shipping companies (alliances) and important partners (such as fuel suppliers). The focus should be on a larger exchange of information and knowledge that would allow for building developments together and trust between parties.

7 Customers' interest in decarbonized shipping

As mentioned in chapter 7 above, the customers of shipping companies (i.e. the cargo owners or the "transport-buyers"), have from a general point of view, traditionally valued price, quality, and lead time as a "typical shipping world competition". However, the shipping companies have started to notice the higher focus on decarbonization from the cargo owners' side, which is evident in several different forms.

The Customer section in the Business Model Canvas focus on which customers are targeted or reached and the relationships with them. In this chapter, the development and pressure from the customers are described in order to address the questions in Figure 21 that are of relevance when introducing wind propulsion.

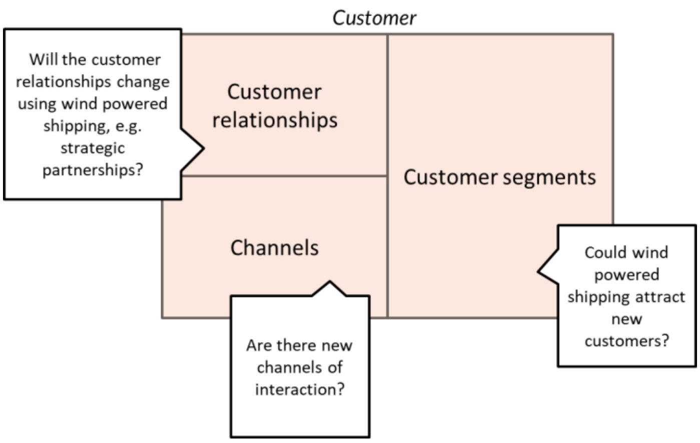


Figure 21 Questions of relevance for the building block Customer when introducing wind propulsion in the business

7.1 Global initiatives from cargo owners

One global initiative involving cargo owners on the global scale is the Science Based Targets Initiative that has a role in supporting the action from the private sector to achieve the 2015 Paris Agreements, halving the GHG emissions by 2030 and drop to net-zero by 2050. Up to now (June 2024), just above 8 700 companies have committed to set Science Based Targets (SBT) and almost 5 500 have approved targets (SBT, 2024). For the shipping companies themselves, their CO_2-emissions are within the scope 1, and for their customers, the emissions from the transport operations are within scope 3, which includes all indirect value chain emissions.

From the commitments of science-based targets it is visible that there is a difference in relation to the geographical areas. In general, companies with a base in Europe are represented to the largest extent, which can be compared to Asia (2nd), Northern America (3d) and further Oceania, Latin America and the Caribbean, Africa and MENA, see Figure 22.

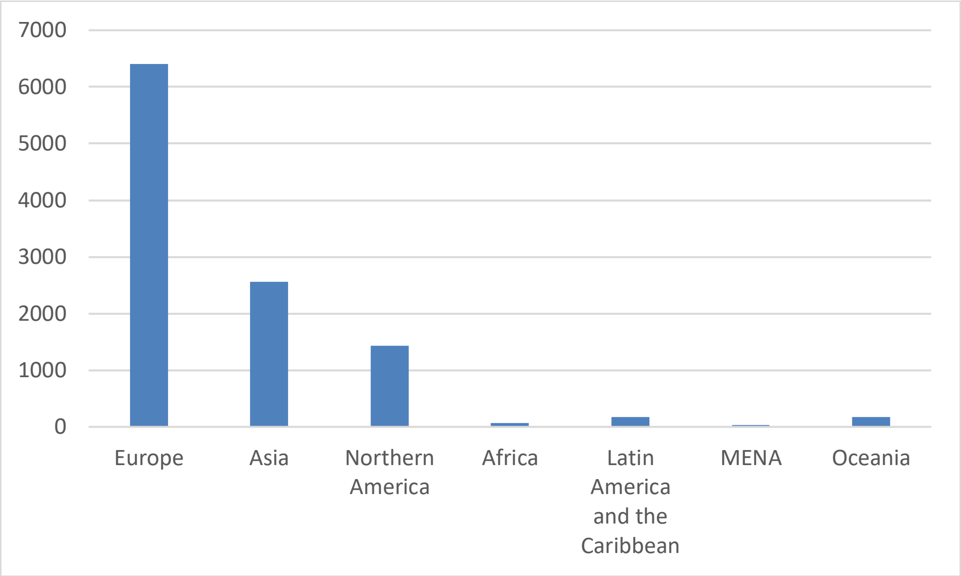


Figure 22 No of companies with approved targets in each region (figures from Science Based Target, June 2024)

It is also important to notice the differences in commitments comparing the goods segments. It is more visible that transport buyers of high valued goods, which normally is part of the downstream supply chain and more often uses containerized freight or RoRo options, is purchasing or demanding green freight options, than for example within the bulk segment. Also, those shipping segments are consolidating volumes from several cargo owners, and are operating to specific schedules in a type of linear service. The companies committed to Science Based Target within the automobile sector is reaching 452, and also, most companies are based in Europe, with Asia just behind in terms of number of companies committed.

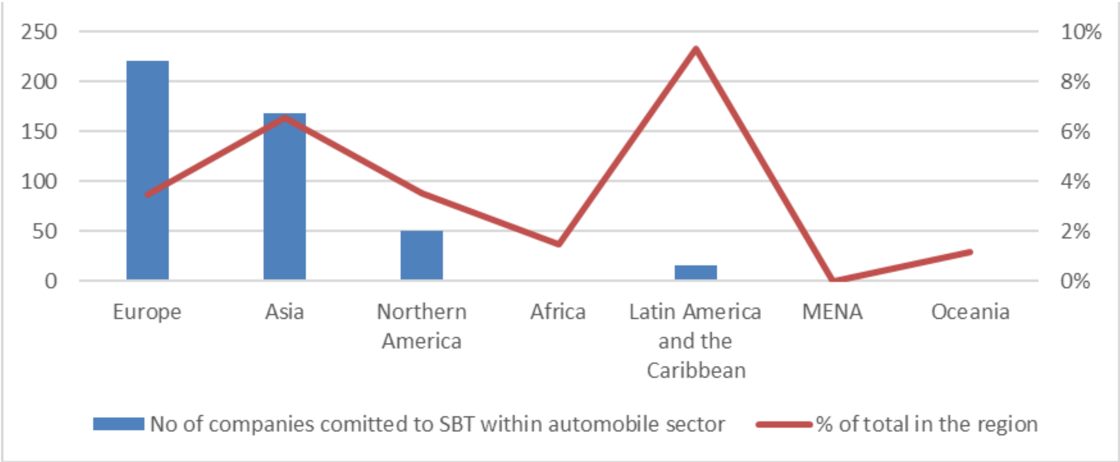


Figure 23 No of companies committed to SBT within the automobile sector

An initiative from customers, directed towards the shipping sector alone, is the Zero Emission Maritime Buyers Alliance (ZEMBA) launched by coZEV. ZEMBA has a mission to "accelerate commercial deployment of zero-emission shipping solutions, enable economies of scale for freight buyers and suppliers, and help cargo owners maximize emissions reduction potential beyond what any one freight buyer could accomplish alone" (COZEV, 2024). In April 2024, ZEMBA completed its first collective tender where over a dozen companies committed to purchase container freight on a route from Singapore to Rotterdam. The tender was won by Hapag-Lloyd, providing a service that will run on waste-based biomethane reducing over 90% emissions. This is an example of a new bidding process coming up, making it possible, not only to put higher pressure on the shipping companies from their customers, but facilitate the consolidation of a larger set of volumes dedicated for decarbonized shipping solutions.

Based on the European shipping market, Raza and Woxenius (2023) study the customer expectations of sustainable business practices. In their study they found that the shipping companies agree on the existing pressure from the customer side, i.e. in terms of using environmental impact as an important criterion in their choice of transport providers and to encourage or expect the implementation of environmental management practices and systems / to minimise greenhouse gas emissions or report the carbon footprint of the transport operations.

7.2 Customer pressure in the RoRo market

In a recent study, where seven global shipping companies in the container and RoRo market were interviewed, it was stressed that the shipping companies do see the increased interest for decarbonisation initiatives among their customers (Sisodia and Sundberg, 2024). Still, since the green services offered today at the market is more expensive than the regular shipping service, there are not many, just a few, companies that are prepared to pay the extra cost of the green service. However, the results show the belief from the shipping customers that the demand will strongly increase in the near future, where one reason is also the regulations coming into force, such as the EU ETS.

Another example of one large shipping customer, purchasing freight both within the container and RoRo-market, is Volvo Cars. In mid 2023 Volvo Cars announced being the first within the vehicle manufacturing industry, to ship car parts around the world using biodiesel, mainly derived from waste cooking oil (Volvo Cars, 2023). The agreement was a collaboration between Volvo Cars, Maersk, DB Schenker and Kuhne+Nagel and was calculated to reduce the CO_2-emissions by 84% using the mass-balancing approach, corresponding to 55 000 tonnes of CO_2/year (ibid).

As part of the EU Orcelle Wind discussions, Wallenius Wilhelmsen do confirm the strong pace in the interest of purchasing their green services in the RoRo segment. The uptake from mid 2023, when the first separate green offer came in place towards their customers, until now, show a strong commitment for decarbonisation initiatives. However, there is a large customer base in this specialised RoRo segment, ranging from large automotive OEMs (Original Equipment Manufacturer) to firms within construction, mining and agriculture equipment, and there is a variation of interest in reducing CO_2-emissions among them.

7.3 Collaboration with customers

As raised by Sisodia and Sundberg (2024) shipping companies may benefit from stronger collaborations with customers in the future. We already see such development in which deepened discussions around capacity, decarbonization strategies and green services.

To implement wind propulsion comes with high investments along with the energy savings potentials and lower fuel costs. To have the customers on-board for this new decarbonization journey may be of importance in order to lower the risk in the investment. We see strategic partnerships coming up also between shipping companies and customers, in which deepened discussions about the decarbonization strategies. Longer contracts may be of importance to get a more long-term and trusted relationship between the partners.

8 Infrastructure

Infrastructure required in the context of establishing a wind powered, “green”, shipping offering in the RoRo segment was considered from three main perspectives – the ship, the port, and the energy supply. As described previously, the development of the business case framework for wind-powered shipping is based on the Business Model Canvas. The *infrastructure* portion of this model defines the main resources, activities and partners required to create a value proposition for the customer desiring a green transport service. The *infrastructure* can be considered the main contributor to the investment cost structure of the offering. Infrastructure included in the model of a wind powered green ship business case included the following main categories:

Ship

- Renewable energy infrastructure (Sails, rotors, etc. and associated control systems; necessary ship systems to support the wind propulsor)
- Renewable fuel infrastructure (power source, on-board storage and supply systems, fuel transfer, safety, etc.)

Port

- Requirements to receive wind-powered ships (port navigation and considerations)
- Capacity in general

Energy Supply

- Infrastructure requirements at port for renewable fuels
- Infrastructure requirements for renewable electricity

Each of these main infrastructure categories are elaborated further in the following sub-sections in this chapter. The aspects of partners, activities, and resources as described in the business model are described for each of the categories. Relevant questions for the building block of Infrastructure when introducing wind propulsion in the business is highlighted in the figure below.

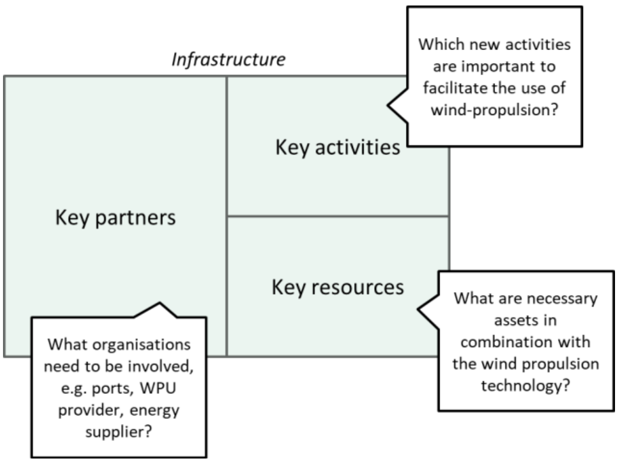


Figure 24 Questions of relevance for the building block Infrastructure when introducing wind propulsion in the business

8.1 Ship Infrastructure (Vessel development)

The ship infrastructure input to the business case model is based on the case of an ocean-going RoRo vessel with wind power technology serving as the primary energy source. Renewable fuels used in internal combustion engines will provide the additional energy needed for propulsion when wind power is insufficient, and as required for manoeuvring and safety.

A state of the art review of wind propulsion technologies and scenarios of alternative zero emission solutions for deep sea shipping was carried out by Alisafaki and Papanikolaou (2024) within Task 4.1 of the Orcelle project. Technologies for wind-powered and wind-assisted ships were identified, as were appropriate renewable fuel solutions that could be paired with the wind propulsion systems for a near zero emission shipping solution.

There were 30 large commercial ships equipped with wind propulsion technology (WPT) in service as of Q3 2023 (International Windship Association (IWSA), 2024). Six vessel types are represented, including RoRo vessels (IWSA, 2024). WPT can be considered as “wind assist” or “primary wind”. Within the Orcelle project and the development of the business model, the focus is on “primary wind”. As of early 2024 the seven RoRo cargo vessels in service with installed WPT were “wind assist”. Technologies used included rotor sails, flettner rotor, and wing sails (Alisafaki and Papanikolaou, 2024).

Creating a vessel needed to provide a near zero emission RoRo shipping service requires collaboration from key partners, completion of key activities, and a supply of key resources. Figure 25 provides an overview of the key partners, activities, and resources for creating the vessel infrastructure.

<table>
<tr>
<td rowspan="2">Key Partners:
• Vessel Owner
• Vessel Operator
• Shipyard and equipment providers
• Classification society
• Flag state (regulatory compliance)
• Insurer
• (Customer representation to determine demand and how to structure vessel)</td>
<td>Key Activities:
• Vessel design (systems approach, based on requirements, expected operational profile, etc. – includes sourcing of alternative energy and fuel technologies)
• Development of digital vessel model (in conjunction with design, and to be used for operation and weather routing, energy management)
• Risk Assessment (to show equivalent safety to conventional systems (for Class and Flag State))
• Vessel Construction
• Training: Vessel crew, “digital twin” support staff
• Certification of service environmental performance</td>
</tr>
<tr>
<td>Key resources:
• Financial – to cover development, design, construction, and operation costs
• Equipment (alternative energy solutions)
• Knowledgeable, trained staff and crew capable of working with the new systems and equipment</td>
</tr>
<tr>
<td colspan="2">Cost structure: Investment Costs/Capital costs for vessel and equipment; Operating costs (including differential cost for alternative fuels)</td>
</tr>
</table>

Figure 25 Key partners, activities, and resources needed to create a near zero emission primary wind propulsion vessel

Key activities are described as follows:

- Design of the vessel:
    - Wind propulsion technologies: Integration of WPT into vessel design from the initial design phase ensures fewer issues related to the interaction with the freeboard and drag from the hull, and rudder and drive train efficiencies can be optimised (IWSA, 2024). Other considerations include ensuring the ship’s structure can support the weight of the system and any additional forces that the ship may experience (ABS et al., 2023a). Potential for energy harvesting when

the wind is high can also be considered (IWSA, 2024), rigging can be optimally placed, and full integration with other on-board energy sources can be considered.

- Renewable alternative fuels currently used in commercial RoRo operations, and with engines available on the market, include biomethanol and liquefied bio methane. Only very small volumes of these fuels have been used as of 2024. Drop-in bio-fuel alternatives to conventional hydrocarbon fuels are also available. Ammonia and hydrogen fuels are still in the early stages of development with regards to trans-oceanic shipping and thus are not considered in this assessment of ocean-going RoRo vessels.
During the design phase fuel storage infrastructure and specific fuel systems associated with liquefied methane gas and methanol, in addition to energy storage such as batteries, can be optimally integrated with the wind propulsion technology.

- Development of digital vessel model: Amount of fuel savings and energy/power requirements from other on-board systems can be better assessed with a model where a range of routes, speeds, and weather conditions can be assessed. During operations the model enables weather routing and energy management during operations.

- Risk Assessment: Although wind has historically been used for propulsion for many years, application of the technology on modern commercial vessels is new. A vessel with WPT as primary propulsion will include some different hazards as compared to conventional propulsion. Safety regulations have not yet been fully developed for wind propulsion (ABS et al., 2023a). Thus, risk assessment studies, including hazard identification, will need to be carried out for the specific vessel design to ensure equivalent safety to conventional ships. Risk assessment is also required for the use of liquefied methane gas and methanol on board, according to the IMO's International Code of Safety for Ship Using Gases or Other Low-flashpoint Fuels (IGF Code). Any additional or different hazards from WPT combined with low-flashpoint fuels should be considered during the specific vessel risk assessment. For drop-in alternatives to conventional fuel oil, although the risks are very similar to conventional fuel oil operation, there may be impacts on the overall reliability of the equipment, depending on the type of biofuel and the blend (ABS et al., 2023b).

- Certification of "Green Service": Verifiable calculations of emissions reductions will be expected by most customers who are willing to pay extra for a "premium" green service or who are themselves providing the carbon footprint of their product. When using renewable fuels, the fuel life cycle "well to wake" should be considered. For the "well to tank" contribution, the International Sustainability and Carbon Certification (ISCC) body issues certificates of compliance with the European Renewable Energy Directive (RED II) directive after third party review of inputs and outputs of fuel production. The certificates are issued on a yearly basis. They confirm the origins of the input material and whether it qualifies as a waste, and state the GHG calculation option. The ISCC formed a "Technical Stakeholder Committee on Sustainable Marine Fuels" in 2023 in response to demand from within the shipping industry.

  To complete the "well to wake" assessment of the fuel, emissions from "tank to wake" could be calculated from fuel consumption figures together with emissions factors or by measuring actual emissions. For ships calling ports in Europe and the UK that are covered by the MRV (Monitoring, Reporting and Verification) regulations, reports of fuel use must be submitted and verified by a third party. These reports provide a verified indication of fuel consumption and GHG emissions. As of 1 January 2024 the MRV regulation requires reporting of three main greenhouse gases emissions from shipping - carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). Ships using WPT would thus have a verified record of fuel use and associated emissions as reported to the MRV. Reduced emissions from use of biofuels or blended fuels are also accounted for within the MRV scheme.

Regarding estimation of the fuel savings from wind propulsion technologies, ABS et al. (2023) noted that the variations between measured and estimated savings can be quite significant, and results are not always comparable. There are currently no standardised procedures for estimating energy savings of wind propulsion, although work is underway, with discussions at both the International Towing Tank Conference (ITTC) and the IMO regarding development of EEDI calculation procedures for ships using wind propulsion technologies. Different methods for estimating the fuel savings resulting from the use of wind assisted propulsion include numerical simulations and measurements (ABS et al., 2023a). To estimate annual fuel use reduction using Flettner rotors on the m/v Copenhagen, Werner and Nisbet (2023) used speed trial measurements, a voyage prediction tool, and statistical weather distribution.

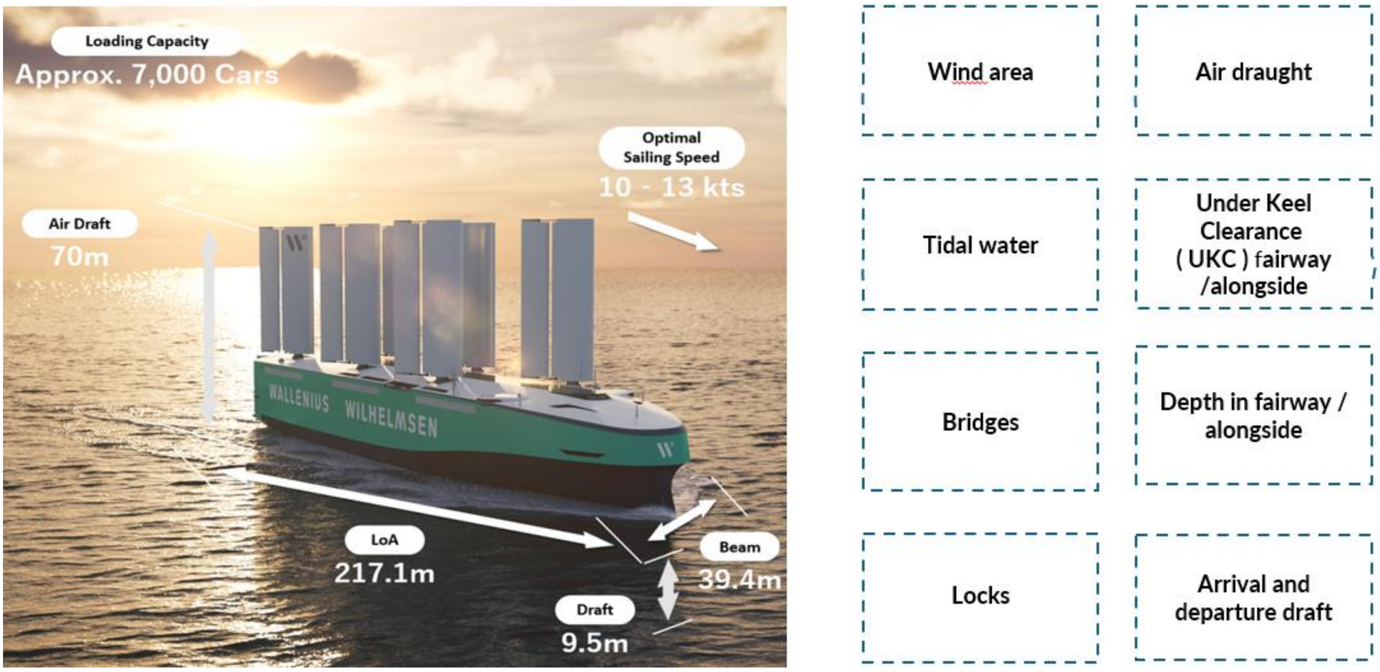
A key resource for creating a near zero emission primary wind propulsion vessel is financial capital. Investment costs and operating costs of this vessel type will differ from conventional vessels and must be set against the expected fuel savings in the case of the WPT and any additional income that is expected to result from a green service offering. Regarding WPT, most studies to date have focussed on possible fuel savings, without considering the possible premium that could result from the service. For example, a recent study for the European Maritime Safety Agency (EMSA) carried out by ABS et al. (2023a) modelled cost savings and economic benefits for installing WPT on different ship types. The investment cost part of the techno-economic model included capital expenditures for purchase and installation of the WPT and “one-off” costs for crew training. Operating costs included maintenance costs, extra crew member costs where considered applicable for the technology, and annual costs for voyage optimisation software or services. Potential reduction in service capacity in cases where voyage time was increased were also considered. Economic benefits cited in the study were fuel savings cost. For new builds, potential lower CAPEX costs were noted to be possible where the WPT resulted in lower installed engine power. The study found large variations in expected savings for different ship types and stated that there is a need for case-by-case analysis.

Opting to use renewable methanol or liquefied methane gas also impacts the financial resources needed for the green shipping solution. Capital costs for dual-fuel methanol engines and fuel storage and distribution systems were found to be about 36% higher than that of conventional fuel oil systems, while for LNG the costs were about 76% higher, according to a study by ABS et al. (2023b). An earlier analysis by Ellis and Tanneberger (2015) also found investment costs for LNG solutions to be higher than those for methanol.

For all renewable fuels considered, fuel costs will be the main difference in operating costs compared to conventional vessels and are difficult to predict due to uncertainties in regulations, technology development for alternative fuel production, and feedstock costs. These are further discussed in Section 9.3, which covers port infrastructure and fuel supply. Both methanol and liquefied methane gas engines and fuel supply systems are dual fuel, which brings more flexibility regarding future fuel costs as there remains the option to use drop-in renewable replacements for conventional fuel oil, should they be more easily available or at lower cost.

8.2 General port considerations

To understand the full scope and potential of a port, it's crucial to consider its various components, creating a comprehensive framework in which a ship's arrival can be viewed as part of an interconnected ecosystem. This includes not only the vessel itself, emphasizing the importance of a skilled crew and clear procedures during port entry, such as the use of enhanced pilot cards for better understanding of the ship's performance under different conditions and during manoeuvring, but also the harbour approach, and the Port Authority.



Figur 1 examples of static and dynamic factors affecting a vessel's port call

Static and dynamic factors significantly influence a vessel's approach to a port. These factors vary, with dynamic ones, for example, the vessel's draught and the impact of the lateral wind area of the vessel. On the other hand, static factors include, for example, the vessel's length, breadth, and air draught. Receiving accurate and timely nautical information from a port is crucial for an efficient approach. This includes understanding under keel clearance policies in both the fairway and at the berth, as well as acquiring details on depth, current wind conditions, and water levels within the approach and in the port. Route planning for a vessel may also involve adjusting arrival times to account for tides, bridges with specific opening schedules, and locks with allocated time slots.

To ensure a safe and efficient vessel port call, it is essential that the vessel has:

- Sufficient nautical information well in advance about a port, including access to accurate depth, berth, and port information. This guarantees compatibility between the vessel and the berth and provides the ship's master with a clear understanding of when it is safe to arrive or depart.
- Conditions exist for an effective exchange of information between ship and shore, including mandatory data for notifications and declarations to authorities. This will reduce the administrative burden onboard and result in a more optimized port stay.
- The right parties involved in the port call can complete their tasks quickly and efficiently through improved quality and availability of operational data. This includes planned times for arrival and departure (ETA/ETD) and estimated times for completion of cargo operations. It will also enable the ship's master to optimize the ship's speed and plan the crew's rest periods.

8.2.1 RoRo Terminal considerations

RoRo / Automotive terminals face specific challenges, particularly in managing volume fluctuations. Based on interviews with managers from automotive terminals we learned that terminals who handles car and H&H often experience larger volume variations compared to RoRo terminals, while both types of terminals may handle cars, RoRo terminals are specialized for wheeled cargo. In contrast, terminals for cars and

H&H are designed to accommodate a wider range of heavy and oversized cargo and often requiring customized storage and securing methods. Both export and import can be equally challenging, as production delays may require more storage space than initially planned. For instance, if a company manufactures between 1,000 and 1,500 cars per day, production delays can necessitate more storage space than the theoretically planned weekly volume.

Several factors, including production disruptions and delayed ships, can disturb planning. The automotive industry often plans for a steady production flow, but reality sometimes deviates from this plan. Furthermore, as mentioned in chapter 3, congestions in ports have been a challenge the last years, e.g. due to pandemic situation and lack of dock workers and truck drivers.

Also, the car manufacturing strategies in how to distribute their cars in their trades in relation to Build-To-Stock or Build-To-Order influence the need for storage. There are logistical challenges in both these approaches and new and hybrid approaches are discussed among practitioners (see e.g. Gopalakrishnan, 2024). A flexibility to adapt to changed market conditions or demand in an agile way is strived for. To have regional hubs with storage in terms of getting closer to the market towards the end customer is one potential solution, in which ports can act as a vehicle distribution center or a buffer point in their supply chains (Fredouet, 2022) . Also to add value by additional services, or production activities in the port terminals, as a postponement strategy in order to deal with demand uncertainties (ibid). Other activities could be adjust car configuration to adhere to national legal requirements, handling custom documentation etc.

Import and export flows are also affected by political decisions that can rapidly change the demand for cars. For example, taxes on electric cars in the EU can influence the volumes and trades. The global market for electric vehicles and other types of vehicles changes quickly due to political decisions and economic incentives, affecting the global volumes and the needs of storage in ports. Changes in political decisions can have significant consequences for storage requirements.

Figure 2 Zeebrugge terminal

Industries increasingly utilize port terminals as storage areas, leveraging their strategic locations and infrastructure. Port terminals can store a variety of goods, ranging from raw materials to finished products, providing a flexible solution for industries with varying storage needs. The benefits of using port terminals for storage include reduced transportation costs, streamlined logistics, and quicker access to shipping routes. However, this practice can negatively impact terminal capacity, leading to capacity challenges and less effective operations. (above figure is an example from the terminal in Zeebrugge.

Automotive terminals must be prepared to handle large volume variations. For instance, car importers plan for a throughput of about 30 days, while export cars are counted to stay a maximum of 10 days. Terminal space is expensive, necessitating efficient use of areas.

Ship transport not only handles cars but also H&H (Heavy and High) cargo, requiring specific equipment and areas. This poses a challenge for ports that must manage various types of cargo, including those needing special treatments like heat protection or wood treatment.

Future regulatory changes could affect capacity, especially regarding how electric cars are stored and handled due to fire risks. Terminals must be prepared for different fuel types and technologies that could influence space planning and management in the future. To manage these changes, it is important to have flexibility and the ability to quickly adapt to changes in the market and technology.

Flexibility in staffing is also a critical factor. A automotive terminal may need many employees one day and none the next. The difference between a RoRo terminal and a automotive terminal is that the RoRo terminal has more schedule-based staff, while the automotive terminal requires more flexibility.

Loading and unloading usually do not occur at night to avoid damage to the cars, which affects how staff and laytimes are planned. Wind restrictions can also affect ship arrivals and departures, which is another factor that must be considered.

Automotive terminals face many challenges and need to adapt to rapid changes in both the market and technology. Efficient use of space, staffing flexibility, and adaptability to political decisions are all critical factors in managing the complex needs of car ports.
The port's activeness with local agents, regional offices, and shipping lines management is crucial for optimizing terminal operations. By maintaining strong relationships and effective communication with all stakeholders, the terminal can ensure that everyone is synchronized and that the flow of goods is managed smoothly.

8.2.2 Port considerations for wind-powered vessels

Previous studies do highlight port considerations when operating a wind-powered vessel. Depending on the chosen technology as well the vessel type different concerns will be of importance.

An obvious limitation is the air draught of the technology, which will be restricted by bridges. The technologies installed on vessels today adds a height up to 35 meters (IMO, 2024). However, if installing a tilting function that is offered by most technology providers, an advantage will be reached in terms of not being limited to a larger air draught. This is of course both a technical and cost matter, since it can be restrictions on the vessel regarding if possible to install such a function. Also, depending on trading route of the vessel, different levels of criticalness regarding air draught limitations will exist. However, if not using tiltable devices, the additional load from the wind unit may impact how to manoeuvre the vessel to the quays when entering the port area which is a consideration that needs to be taken into account as well.

Further, the loading and onloading operation could interfere with the wind-propulsion technology, where there is a risk of damages (Mander, 2017). In particular, this is of relevance at vessel types where loading and unloading operations is performed from above. Also, in such occasions the wind-populsion units may need to be moved before handling the goods, which was the case in the study of a general dry cargo vessel and its installation of suction wings by Pllumi and Do Ly (2020).

For a RoRo-vessel like Orcelle Wind, where tiltable wings will be installed on top if the deck, there are no major concern related to the considerations of air draught or the loading and onloading operations, since they are operated by a separate ramp. However, since the aim of Orcelle wind is not only to have assistance from the wind propulsion but reach as high efficiency as possible, >50%, other factors may have implications for the port call. Such factors relate e.g. to how the operations are planned in best possible way from a wind-propulsion point of view, such as using the best route in relation to weather forecast, increasing the need for a larger ETA/ETD-window. A larger ETA/ETD-window would impact the port operations in terms of planning terminal operations, staff and available yard capacity. Also, a greater flexibility regarding ETA/ETD would impact the cargo owners logistics planning inland. Finally, another potential impact on the ports is based on the case if operations would be adjusted to include fewer port calls in the route compared to the conventional scheduling. This is an alternative that has been discussed within the Orcelle project Team, in order to utilise the vessel as much as possible on route and as little as possible in ports, which would also make it possible to keep the rotation time while reducing speed. Such adjustments would instead require a higher volume to be loaded/offloaded at one specific port call, which in turn would put a larger pressure on the yard capacity as well as the cargo owner's total distribution set up.

8.3 Alternative Fuel Infrastructure at Ports

To fully operate as a zero emissions vessel, a wind-powered car carrier must be able to bunker zero-emissions fuels for the on-board combustion engine used for providing the additional propulsion power needed. Today there is limited infrastructure at ports for the provision of alternative renewable fuels, but ports are actively working to develop bunkering guidelines and infrastructure. Ports are also working towards developing onshore power supply (OPS) for connection of vessels while at port.

The initial focus is on the renewable fuels that are being used in commercial shipping as of 2024 – methanol, liquified methane gas, and drop-in alternatives to conventional fuel oil. Methanol and liquefied methane gas are low flashpoint fuels with specific requirements regarding dual-fuel engines and on-board fuel storage and supply systems. For both of these fuels there are engines available on the market and renewable versions of the fuel that can be purchased (although currently at a price that is significantly higher than the price of the fossil fuel variant). There are also efforts to provide hydrogen for the short sea shipping market, but this is still in its infancy. Ammonia is also being considered but is at an early stage of development as well. Thus the development of the business model canvas and the description of key partners, activities and resources for fuel infrastructure was based on renewable methanol, renewable liquefied methane gas and drop-in alternatives to conventional fossil fuel oils.

Figure 26 provides an overview of the key partners, activities, and resources for creating the infrastructure necessary for supply of renewable fuels at ports.

Key Partners:

- Port Authority (to develop reference document with consultant as necessary)
- Bunker fuel provider (producer + bunker storage + bunker vessel) (may be two separate entities)
- Emergency Response Agency
- Environmental Agency as appropriate

Key Activities:

- Risk Assessment and develop guidelines (port + consultant + emergency response + bunker provider + receiving vessel)
- Training: Port personnel + bunker provider + emergency response
- Secure bunker supplier (contract). (Green fuel, blend, fossil variants)
- Build storage (if there is not nearby storage of the alternative fuel otherwise (for product use))

Key resources:

- Training facility and trainers
- Fuel storage facility
- Bunker vessel appropriate for the alternative fuel
- Staff and crew trained in handling the alternative fuel

Figure 26 Key partners, activities, and resources needed to create infrastructure for supply of renewable fuels at ports

Port authorities are a key partner for ensuring the availability of alternative fuels. Their role within the context of alternative fuel bunkering is to plan, provide space, and develop suitable regulation, as most are acting as landlords (RMI and Global Maritime Forum, 2024). Bunker fuel providers are also key actors within the port environment.

The development of alternative fuel infrastructure at ports within Europe is expected to increase as a result of adoption in April 2024 of EU directive (2023/1804) “on the deployment of alternative fuels infrastructure”. The objective of the Directive is to ensure the deployment of sufficient alternative fuels infrastructure in the European Union, for all modes of transport including shipping. The directive requires member states to ensure that an appropriate number of liquefied methane refuelling points are deployed at TEN-T core maritime ports to ensure adequate coverage, taking into consideration actual market demand. Member states are also required to draft national policy frameworks for development of alternative fuels and the deployment of relevant infrastructure, including planned measures in maritime ports for fuels such as hydrogen, ammonia, methanol, and electricity. The European Commission is also making funds available for port infrastructure – in February 2024 a call was launched to support recharging and refuelling points under the Connecting Europe Facility (CEF) funding instrument. For ports, this includes support for electricity and hydrogen supply, and methanol and ammonia bunkering facilities (European Commission, 2024).

Green shipping corridors are initiatives where a combination of public and private actions are focussed on supporting zero-emissions solutions along the designated trade routes. The Clydebank Declaration, signed by 21 countries in November 2021, signals the intent of the signatories to promote the develop of green shipping corridors (Talalasova, 2023). As of 2023, 30 green corridor initiatives have been announced around the world by various governments and industry stakeholders (Talalasova, 2023). The intent of the corridors is to test and deploy fuel, vessel, and infrastructure technology relevant to shipping decarbonisation in a coordinated way. The idea is that coordinated deployment should help reduce risk with early adoption. Routes with high impact and high feasibility are envisioned as the first green corridors. The increased cost of fuel is considered to be the biggest gap to be addressed, through various mechanisms available to governments, such as subsidies. Suggested value chain actions that would also contribute to reducing the cost gap include “green premia (cargo owners), operational efficiencies (shipping companies) and reduced port dues and other port side initiatives (ports)” (Talalasova, 2023).

A summary of the status of bunkering and provision of fuel for the main renewable fuels considered in this study of a zero emissions wind-powered roro vessel is as follows:

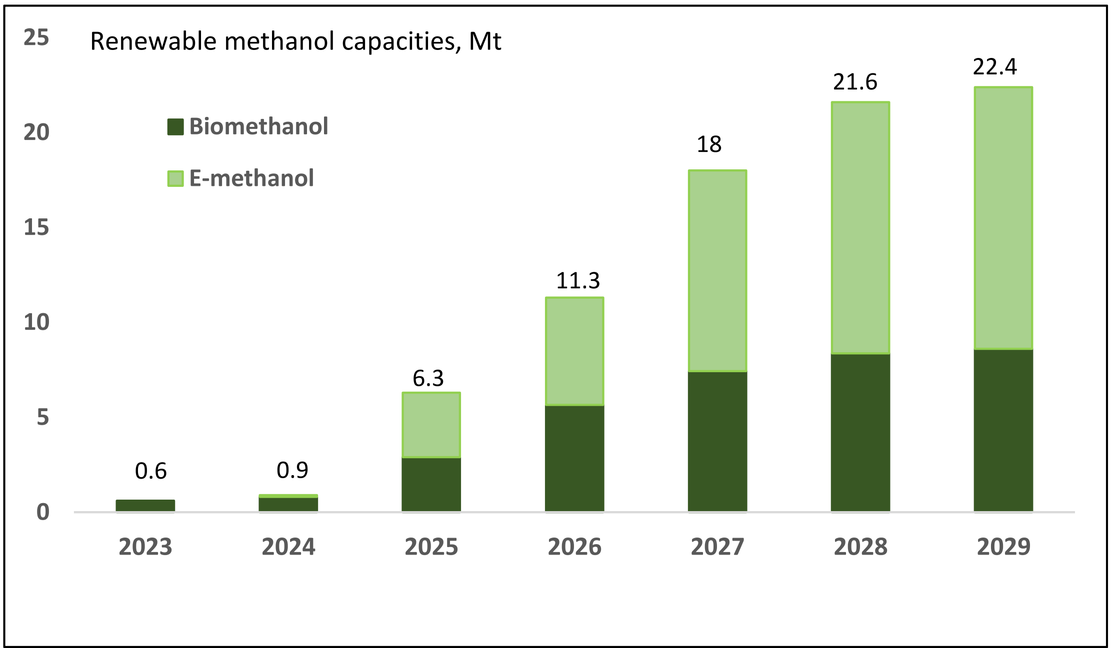
8.3.1 Methanol

As of April 2024 there were ten global ports offering methanol bunkering and a further 11 planning to establish capacity in the near term (RMI and Global Maritime Forum, 2024). Truck-to-ship, shore-to-ship, and barge-to-ship bunkering of methanol have all been successfully demonstrated (Ellis et al., 2021). Examples of selected bunker hubs and ports with recent experience of bunkering methanol are as follows:

- Port of Antwerp-Bruges: The *Ane Maersk* was bunkered with green methanol with a barge-to-ship transfer in April 2024 (Prevljak, 2024). Bunkering of 4300 tonnes of methanol was carried out simultaneously with cargo loading and unloading. This was the second barge-to-ship bunkering carried out at the Port of Antwerp-Bruges – the first was in July 2023. Port of Antwerp-Bruges launched a methanol-fuelled tugboat in May 2024 and this is bunkered by truck.
- Port of Rotterdam: The Port of Rotterdam was the first to demonstrate barge-to-ship bunkering of methanol in 2021 (Ellis et al., 2021). Europe’s first green methanol bunkering operation took place at the Port of Rotterdam in July 2023 (Riviera, 2023). Agreements are in place for regular bunkering of X-Press Feeders container ships with green methanol (Port of Rotterdam, 2023).
- Port of Singapore: Vessels bunkered with methanol at the Port of Singapore include the *Laura Maersk* (2023), *Stena Prosperous* (2024) and an Xpress Feeders containership bunkered with green methanol in May 2024 during a simultaneous bunkering and cargo operation (MPA, 2024). The Port of Singapore’s first dedicated methanol bunkering vessel was delivered at the end of 2023 (Labrut, 2023). The Maritime and Port Authority of Singapore (MPA) has stated that it is preparing to position Singapore as a hub for the supply of methanol (including green methanol) to the international and domestic shipping community (MPA, 2023).
- Port of Gothenburg: The *Stena Germanica*, which was converted to dual-fuel methanol operation in 2015, is bunkered regularly with truck-to-ship transfers, and was bunkered for the first time by ship at the Port of Gothenburg in January, 2023.
- Port of Houston: The *Stena Pro Marine* and *Stena Prosperous* were bunkered with barge-to-ship transfer of methanol at the Port of Houston in 2023 (Maritime Executive, 2023a).

Physical infrastructure required at ports for bunkering of methanol primarily includes fuel storage and a suitable bunker vessel. Adaptation of the existing oil storage and distribution infrastructure with relatively minor and inexpensive modifications is possible for methanol, whereas gaseous or cryogenic fuels require much more costly infrastructure (IRENA, 2021). Regarding bunkering, existing small chemical tankers have been used for bunkering trials, including those at the Port of Gothenburg (Rahman, 2023) and the Port of Rotterdam (Schuler, 2021). As demand grows dedicated methanol bunkering vessels are being ordered, such as described above for the Port of Singapore. Bunker supplier Bunker One signed a charter deal for a chemical tanker in 2023 which can provide methanol bunker fuel in the Gothenburg/Skaw area (Bunker One, 2023). In Rotterdam, OCI and Unibarge are retrofitting an existing vessel to dual fuel methanol operation, to be deployed in offering green methanol as bunker fuel (Hand, 2024).

Projected available methanol production capacities by year to 2029, based on announced start-up dates as of April 2024 are shown in Figure 27.



Source: GENA Solutions, www.genasolutions.com. Based on announced startup dates as of April 2024.

Figure 27 Projected renewable methanol capacities in metric tonnes, based on start-up dates and announcements as of May 2024 (adapted from Dolan, 2024, with data source cited as GENA Solutions (www.genasolutions.com)

The projected renewable methanol production capacities shown in Figure 27 do not include production at existing conventional methanol production facilities through the substitution of natural gas feedstock with biogas. Currently this is the source of the majority of renewable methanol used as ship fuel. For example Methanex provided biomethanol produced at their plant in Geismar, Louisiana for a “net zero” sailing of the chemical tanker *Cajun Sun* in 2023 (Maritime Executive, 2023b) from Geismar to Antwerp. Methanex produces biomethanol for customers on request and provides ISCC certificates showing feedstock origins for this premium product (Ellis et al., 2023). The green methanol provided for the maiden voyage of the *Ane Maersk* was also produced at a conventional methanol plant using biogas feedstock and a mass balance approach to produce green methanol certified in accordance with the EU Renewable Energy Directive (Maersk, 2023). GENA Solutions (2023) state that existing conventional methanol plants using biomethane feedstock and a mass balance approach can help meet the increasing demand for biomethanol. Thus decarbonisation of some existing methanol production plants and infrastructure may increase over time. The anticipated green premium that may be paid for renewable methanol compared to the availability and pricing of biomethane feedstock are considerations in the extent of how quickly this occurs (GENA Solutions, 2023).

Regarding location of new renewable methanol production capacities, Dolan (2024, based on GENA Solutions data) stated that China is expected to take the lead in the medium term to 2029, followed by Europe and then North America. China’s lead is due to the low cost of renewable electricity there, stemming from China’s lead in developing photovoltaics and solar energy (Dolan, 2024). A report by RMI and Global

Maritime Forum (2024) supports this justification, stating that areas with “good renewable resources, low capital costs, and access to hydrogen production support mechanisms” will be capable of producing e-methanol and e-ammonia “several times cheaper than other regions”. The cost of transporting these fuels is considered relatively insignificant compared to production costs, so that it is expected that ports with unfavourable conditions for fuel production will still be able to provide these fuels through importing them (RMI and Global Maritime Forum (2024).

In the potential case of limitations in availability of green methanol in the short term, the analysis by RMI and Global Maritime Forum (2024) predicts a possible concentration of supply at the world’s major bunkering hubs and in European ports, which will probably see increased demand for green fuels due to the FuelEU Maritime regulation and the EU ETS scheme.

Current and future production costs for the two main productions routes of renewable methanol – biomethanol and e-methanol – as forecast in a report by the International Renewable Energy Agency (IRENA and Methanol Institute, 2021) is shown in Figure 28.

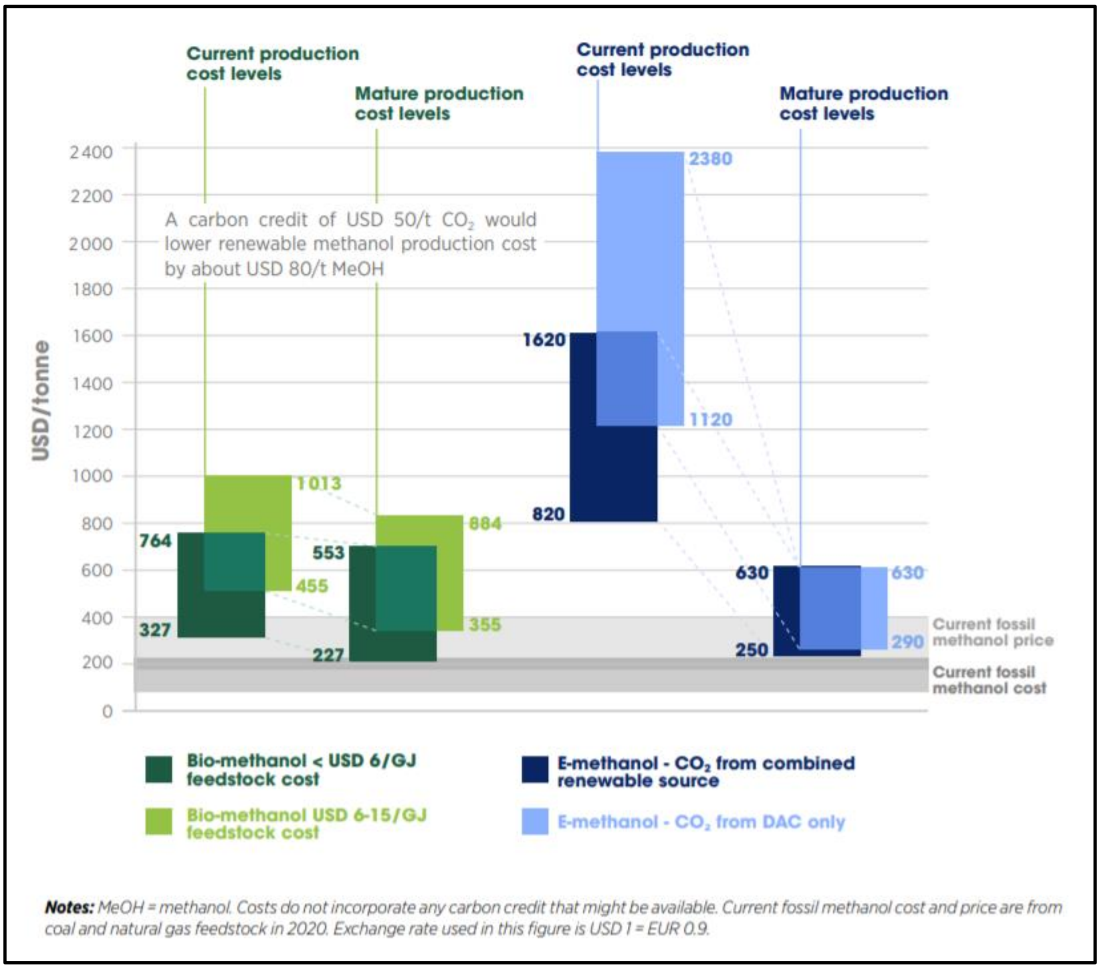


Figure 28 Current and future production costs of bio- and e-methanol (Reproduced from IRENA and Methanol Institute 2021, © IRENA)

Biomethanol is methanol produced from biomass feedstock, ranging from biogas to gasification of non-recyclable biological wastes (such as municipal waste or construction waste). It also includes methanol produced from the waste methanol stream from the kraft pulping process. E-methanol is produced from hydrogen generated by electrolysis of water, combined with captured CO_2-emissions and catalytically converted to methanol. For biomethanol, projected reduction of costs over time are expected to occur due to more mature production costs. For e-methanol dramatic costs reductions were predicted to occur due to more affordable renewable electricity and advancements in hydrolyser technology. The availability of future biogenic or renewable carbon sources is currently an uncertainty. Direct air capture (DAC) technologies are improving and costs have been decreasing so this is also a possibility. Important to note is that Figure 28 shows production costs rather than the price on the market. Additionally there will be competition for feedstocks such as biogas, which may also be used to produce liquefied biogas or be used for energy production on land, and for renewable electricity.

8.3.2 Liquefied Methane Gas

As of early 2024, there were 188 LNG bunkering facilities worldwide, with a further 82 under development (Bureau Veritas, 2024). Ship-to-ship bunkering of LNG has been conducted for many years, and as of the end of 2022 there were 40 LNG bunker vessels operating globally (Mandra, 2023). Bunkering of liquefied biogas has also taken place at selected ports in recent years, including the following:

- Port of Gothenburg: An LNG/liquefied biogas blend (10% renewable fuel) was bunkered ship-to-ship to the pure car/pure truck carrier *M/V Auto Energy* in 2020. This was claimed to be the first ship of its type to bunker renewable fuel of this type (Ship Technology, 2020).
- Port of Rotterdam: 2200 metric tonnes of liquefied biomethane was bunkered to the Hapag-Lloyd's *Brussels Express* container ship in April 2024 (Habibic, 2024). There had been one other previous instance of liquefied biomethane bunkering at the Port, in 2021, according to Port of Rotterdam bunkering statistics (Port of Rotterdam, 2024).
- Port of Singapore: Bio-LNG bunkering pilots are planned for 2024-2025 for a Singapore-Rotterdam green shipping corridor (Ship and Bunker, 2024).

Infrastructure in place for storage and bunkering of fossil feedstock LNG can also be used for renewable liquified methane gas liquefied biogas if it is available near the port or systems are in place for mass balance.

Regarding availability of renewable LMG, the LNG industry coalition group SEA-LNG claims that bio-LNG is available at close to 70 ports in Europe, North America, and Asia (SEA-LNG, 2023). The majority of the renewable LMG available today is bio-LNG that is produced from biogas, generated from feedstocks such as waste and residues, agricultural feedstocks (crop and plant residues, animal manure, energy crops, etc.), and landfill gas. E-LMG is made using renewable electricity and point source CO_2, although as of 2022 was not yet widely commercialized (Comer et al, 2022). In 2022, combined global biogas and biomethane production was more than 1.6 Exajoules (IEA, 2023). Europe is the base for more than half of this production, which has a mature industry with growing markets (IEA, 2023). This is followed by China, United States and India. Regional variations can be significant and development and support for the industry varies widely (IEA, 2023). Figure 29 shows the historic and predicted production of biogases by region and development.

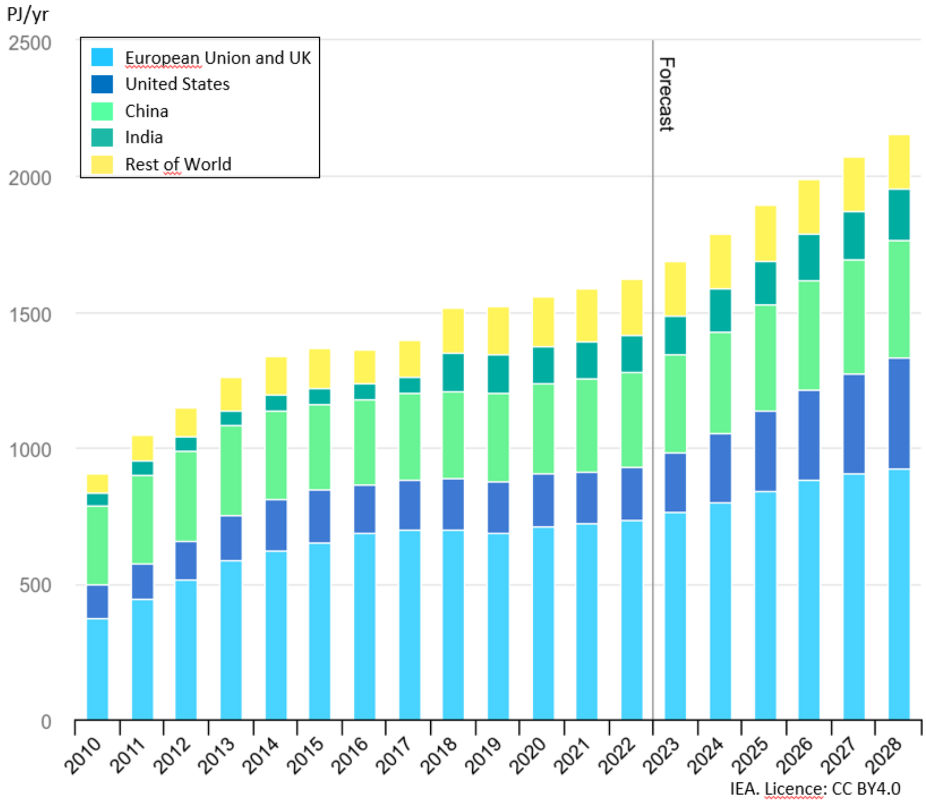


Figure 29 Global historical production and forecast of biogases, 2010-2028 (Source IEA, 2024)

The main use of biogas in Europe and the United States is for electricity and heat, while in China it is residential, commercial, and public service applications (IEA, 2023). Transportation fuel makes up only a small portion of use, but in Europe it consumes 20% of biomethane production and this is growing in many European countries (IEA, 2023). Under the EU RED II biomethane from biogenic residues and waste is considered an advanced biofuel. Thus although the production of biogas is increasing, there are also many competing uses. It can also be a feedstock for other renewable fuels such as for methanol production, as mentioned previously. The majority of the biogas produced is transported and used as compressed gas. The proportion of gas that is liquefied is quite small but growing. As of 2022 only five facilities that inject renewable LMG into the grid were found in Europe, according to a report by the ICCT (Comer et al., 2022). Liquefaction entails additional costs during processing and results in upstream emissions (Comer et al., 2022), but is necessary for use of the gas as fuel onboard ships as it reduces the storage space required.

Regarding production costs and prices of renewable LMG, the IEA (2023) notes that for biomethane feedstock, the production costs depend on feedstock, production scale, and operating costs. Liquefaction is an additional cost. Comer et al. (2022) state that bio LMG produced from landfill gas is the cheapest pathway in Europe, while that produced using biomethane derived from agricultural digesters is the most expensive. E-LMG production cost components include feedstock costs of renewable electricity and CO_2, plus capital investments in electrolyzer and methanation equipment (Comer et al., 2023). SEA-LNG (2023) states that the price of bio LMG is typically two to three times higher than that of conventional fossil LNG.

8.3.3 Drop-in bio-fuel and e-fuel alternatives to conventional hydrocarbon fuels

Drop-in biofuels are defined by the IEA as "liquid bio-hydrocarbons that are functionally equivalent to petroleum fuels and are fully compatible with existing petroleum infrastructure" (van Dyck et al., 2019). Thus the key challenge with using these fuels in shipping is more related to availability, price, and sustainability aspects of the fuel production rather than the provision of infrastructure on board ships or in ports. The amount of biofuels used by ships over 5000 gross tonnage, as submitted to the IMO Ship Fuel Oil Consumption database for 2021, was only 0.03%. Biofuels reported being used included B50 and B100 biofuels, HVO and Used Cooking Oil (IMO MEPC 2022).

Other transport sectors, primarily road, have a significant demand for biofuels both in Europe and globally. The IEA (2023) projects that biofuel demand will increase by 30% over the five-year period from 2023-2028. Emerging economies including Brazil, Indonesia, and India have introduced strong biofuel policies and this will drive demand. The United States and Europe are projected to expand their consumption of renewable diesel and biojet fuel over the period, with drivers in the EU including the Renewable Energy Directive III, which is aiming to double renewable energy use by 2030 (IEA, 2024). ABS et al. (2023b) states that projections for sustainable biomass vary considerably, and there are uncertainties due to technical and economic aspects as well as tightening of sustainability requirements. As of 2022 the production of biofuel was primarily based on biomass from crops, but there are sustainability concerns about these (ABS et al, 2023b). Thus there will be more pressure on other feedstocks such as wastes and residuals, which require more advanced processes to be used to produce “drop-in” fuel oil replacements, which would drive up the cost of production.

The IEA (2024) predicts costs for biodiesel-blend fuels will rise over the period 2023-2028 due to increased demand due to higher blending level requirements and increasing feedstock prices.

9 Financial considerations when implementing wind propulsion

From a business point of view, the financial considerations are commonly the first ones to focus on when assessing if wind-propulsion is of relevance as a decarbonisation or efficiency action for a specific vessel.

Since there are several examples of economic analysis of wind propulsion available in previous studies (see e.g. EMSA, 2023; Gerhart et al., 2021; Tillig et al. 2020 or Talluri et al., 2018) the focus in this report is not to go into detail in those, but rather to provide an overview and to set the financial considerations as a part of the business model in large. In the Business Model Canvas, one important financial part is related to the cost structure. The following questions are then relevant: Is there a cost focus or a value focus in the service? How important is it to produce this service at the lowest possible cost in relation to the value, e.g. the value that a green shipping service could provide towards the customers? And consequently, what difference on the cost structure would wind powered shipping lead to?

Further, the revenue streams may change if future green services include wind propulsion. The recently developed green services in shipping (see also 6.2), e.g., *Reduced carbon services by Wallenius Wilhelmsen, Biofuel solution by MSC* and *Eco delivery by Maersk*, makes it possible for customers to pay for their reduced carbon emissions through the insetting principle by using alternative fuels in the vessel fleet. Depending on how wind propulsion is included in the offer, the revenue may change, e.g. will it be offered as a separate offer similar to existing services, or integrated into the decarbonisation strategy as a whole, contributing to reduce the average fuel consumption and CO_2-emissions of the whole fleet?

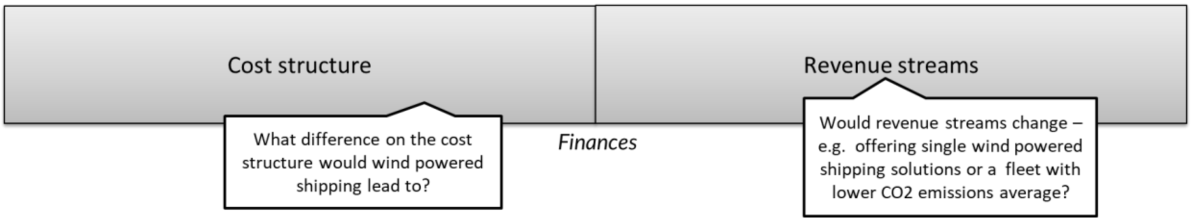


Figure 30 Questions of relevance for the building block Finances when introducing wind propulsion in the business

Normally CAPEX and OPEX are included in an economic assessments of wind propulsion. The CAPEX is the capital expenditure/asset cost of the technology which also includes the installation costs. OPEX is the operational expenditure and normally the fuel or energy cost is the part that is in most focus in the economic analysis of wind propulsion. Operational costs can further include crew costs, insurance, maintenance, management and administration. For a comparative analysis of different propulsion technologies the costs incurring due to the propulsion of the vessel is included. For wind propulsion installations it might also occur a one time cost for crew training, which Norsepower proves as an example, even though such costs are expected to be low in comparison with the other investment costs (EMSA, 2023).

Even if the costs related to the CAPEX of the technology has large uncertainties, and also, technology providers are reluctant in sharing such information officially, the recent study by EMSA (2023) do provide an overview of different WASP technologies CAPEX, One-off costs and OPEX as input to their economic analysis, see

Table 3.

Table 3 The cost indications for one a single wind propulsion unit 2021, depending on dimension. Source: EMSA, 2023

	WASP	Rotor sail		Suction wing		Hard sail		Kite	
	Costs (EUR 1,000)	min	max	min	max	min	max	min	max
CAPEX	Asset costs	560	1,050	200	900	438	876	340	2,345
	Installation costs (newbuild)	84	158	30	135	66	130	51	351
	Installation costs (retrofit)	140	263	50	225	109	219	85	586
One-off costs	Training	10	10	10	10	10	10	10	10
OPEX	Annual maintenance & repair	12	22	4	18	8	18	17	117
	Annual energy consumption WAPS	26	79	26	53	No data available			

As can be seen in the figures provided above, there is a large span between min and max asset cost of the technologies. The span indicates a large uncertainty and a wide range in the technology specifications. Since the development is strongly ongoing, there are new technologies (for example of wing sails) that are not yet on the market, and hence official figures are not shown yet.

As mentioned in chapter 4.3, there is not yet a standardised way of calculating the fuel savings. One of the most critical issues when assessing the potential of wind propulsion in a specific setting is therefore to be aware of the methods applied and also understand that it is not possible to compare figures from different studies without knowing more about the details in the calculations and assumptions. The performance predictions are dependent on so many variables that each case will most likely be unique.

One approach called SEAMAN Wings is presented by Gerhardt et al., 2021, shown in Figure 31. The power and fuel savings in the calculations are the results from the voyage simulations, which in turn rely on input from the ship performance model. The business case includes CAPEX and OPEX in which fuel price and legislative scenarios can be applied. From such calculations, financial information on the payback time for example can be derived. Also, the effect from different legislations, like EEXI, CII, Emission Trading Schemes can be calculated, or Net Present Value determined.

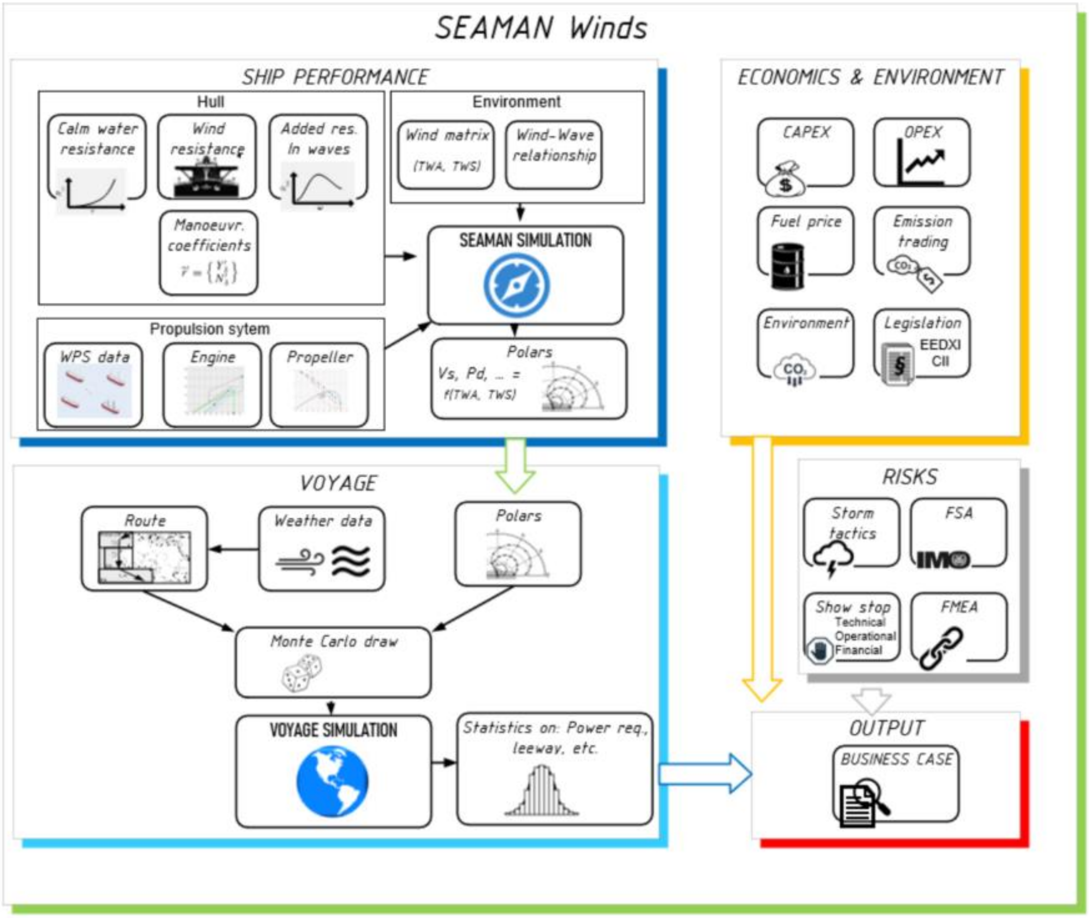


Figure 31 SEAMAN Winds, illustrating the blocks providing input to the economic assessments. Source: Gerhardt et al. 2021.

Financial uncertainties are mentioned in previous studies (e.g. Svanberg et al., 2023) as a barrier to the adoption of wind propulsion in shipping. Those uncertainties do relate to several of the above mentioned issues, such as an uncertainty in CAPEX, uncertainty in saving potential and uncertainty in fuel price. Performing scenario analysis will be necessary to understand how these different uncertainties would influence the business case.

Apart from those, another uncertainty is access to capital (Svanberg et al.). There are examples of subsidies provided, e.g. from EU funding, for investments like wind propulsion. But also, investors do put more and more priority to businesses having a forward thinking and sustainability mind-set. Green financing is emerging, e.g. through the Poseidon principle.

10 Resulting framework

When introducing a wind-powered RoRo-vessel, utilising wind as the primary energy source, there is a unique potential in building a value proposition that contributes to customers' future needs while also reaching a high energy saving potential from the technology.

The resulting framework is a structure to map the influences on the business case of wind-powered shipping, based on the "Business Model Canvas" layout. The purpose is to build a deeper understanding of the importance of different building blocks, where such understanding is of relevance to identify feasible strategies for the development of future business models of wind-powered shipping.

We propose to map influences in the area of regulations, macro-economic developments, market trends, commercial patterns and infrastructure, in line with the structure in Figure 32.

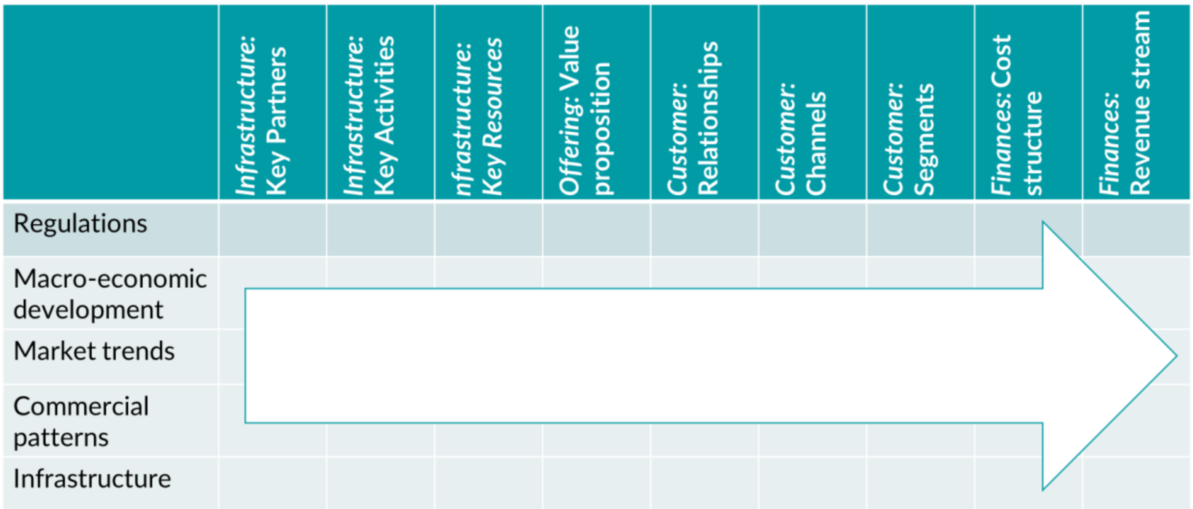


Figure 32 A structure to map the influences on the business case

10.1 Examples of influences on the business case

To exemplify the logic, a number of influencing factors (that have been described in chapter 2-9) is selected to demonstrate the mapping. These influencing areas relate to *Market - Demand vs Supply, Commercial – Offering vs Requirements* and *Infrastructure – Alternative fuels & Port considerations.* Each influencing factor is mapped to the building blocks of the Business model canvas in relation to where it influences it. The infrastructure block consists of Key partners, Key activities and Key resources. The Offering includes the Value proposition. The Customer includes the relationship, channels and segments. Finances includes the cost structure and the revenue stream.

Table 4 Examples of identified influences of external factors on the building blocks in the Business Model Canvas

	Infrastructure: Key Partners	*Infrastructure:* Key Activities	*nfrastructure:* Key Resources	*Offering:* Value proposition	*Customer:* Relationships	*Customer:* Channels	*Customer:* Segments	*Finances:* Cost structure	*Finances:* Revenue stream
Market - *Demand vs Supply*			X	X	X	X			X
Commercial – *Offering vs Requirements*	X	X		X	X		X		X
Infrastructure – *Alternative fuels & Port considerations*	X	X	X					X	

10.1.1 Example 1: Market

The first example concerns influence of market aspects, i.e. the balance between demand and supply. On the supply side, there have for many years before the pandemic been an over-capacity in the system with regards to available capacity onboard vessels. There were also low vessel order rates since 2016 of RoRo and Pure Car Truck Carriers. Then, in 2020 came the pandemic, and the automotive industry reacted quickly to lockdowns and closed down production. Shipping companies were influenced and scrapped vessels. As a result, the available capacity on the market became much lower.

However, there were also other reasons behind the shortage of capacity. China was driving global trade in 2022 and continued growth is expected from the whole Asian region. Similar as to what was the case in the container market, long-haul trade from Chine was very lucrative. With limited vessel capacity shipping companies prioritised this long-haul from Asia meaning that less capacity was deployed to lines within Europe and from Europe to e.g. North America and the Middle East.

To add to the problem, in 2022 there was port congestion, where cars stood for much longer in ports, and there were shortage of dock works and truck drivers on the inland leg which meant that cars were stood longer in ports.

The last two years (2022-2023) the supply was reported to be very tight in relation to the increased demand from the automotive sector (Kershaw, 2023). The tight supply made eventually shipping companies take different strategies on how to prioritise volumes, e.g. through reduced service and stop spot bookings, hence the offer towards their customers were changed. As a consequence of the tight supply, freight rates were going record high. With record high rates (and consequently increased revenue), RoRo-shipping companies have been able to plan for improvements of key resources in terms of more and newer (and potentially greener vessels) in their fleet.

The imbalance between supply and demand also led to instability in service reliability. Vehicle manufacturers found it difficult to find sufficient capacity to move their vehicles. They had to change the way that they planned and ordered capacity, so customers of shipping companies have become accustomed to lower flexibility in capacity. Longer lead time was accepted by manufacturers and getting capacity was much more important than the time it took to transport vehicles.

As a consequence, the dialogue between shipping companies and their customers have deepened. For example, since car manufacturers need to secure departures, discussions regarding available capacity have deepened. These relationships with customers are important when planning to introduce a wind powered vessel. In this way customers can be aware of developments, and also implications. For example, discussions regarding service requirements, such as potentially longer lead time and which ports such a vessel would service. It may also mean that customers are willing to commit to longer contracts, which tend to be positive when developing new solutions.

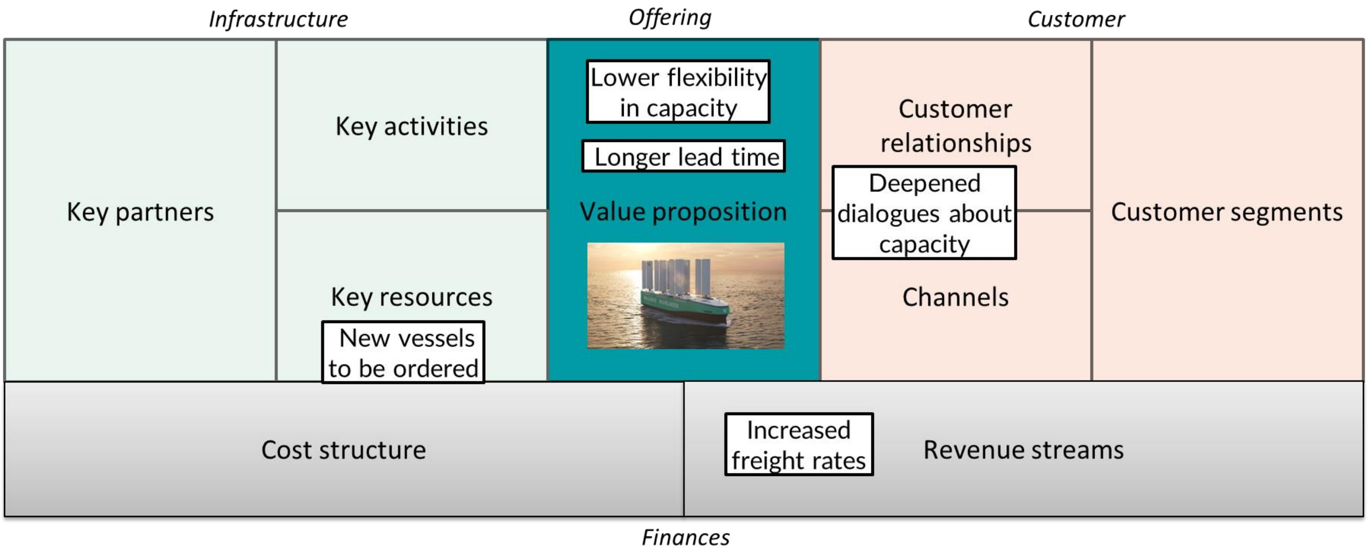


Figure 33 Influences of market factors exemplified

10.1.2 Example 2: Commercial

The second example is related to commercial aspects, offerings vs requirements. As been described earlier, there has been an increased focus on alternative fuels in the RoRo services. Wallenius Wilhelmsen announced in June 2023 their offers in sustainable biofuel supply. Apparently, the demand for such services exists and the focus on sustainability among the vehicle producers does increase. One such example is Volvo Cars announcing its willingness to pay more for reducing its carbon footprint through second generation biodiesel (Volvo, 2023). Hence, for specific customer segments, the new green offers do provide important value. However, the sustainability journey shipping companies now facing does require stronger collaboration with their customers. A higher trust between partners are needed for long-term agreements to support plans becoming action towards zero emission transport chains. Further, to meet these expectations on green operations from customers shipping companies are offering insetting where customers pay for the use of an alternative fuel while it is in fact used on another route. Here being able to transparently track and report on emissions is important. Shipping companies talk about providing certificates to customers confirming the amount of emissions saved by buying a green service. New relationships need to be established with partners that can provide such certificates and validate the calculations.

With an interest in green services from customers shipping companies should market their intentions with wind propulsion. They can target specific customer segments that are most interested in emission reductions. Marketing wind power may also attract new customers to specific shipping companies. Shipping companies also need to consider recent initiatives where cargo-owners collaborate in their work to reduce emissions from transport, such as ZEMBA (a first collaborative tender purchasing container freight between Singapore and Rotterdam). In that case the service that won will use waste-based biomethane. For shipping companies this has two implications: 1) that they need to consider such alliances and tenders as part of their customer relationships. And that consolidated and thereby larger volumes may facilitate the introduction of new solutions.

It should also be noted that while some customers are very interested in green shipping, other customers neglect it as it is considered too expensive. Not all customer segments are interested in green offers and shipping companies report a low willingness to pay on a general level. This means that shipping companies aiming for wind powered shipping need to segment their customers and identify which ones to target or not.

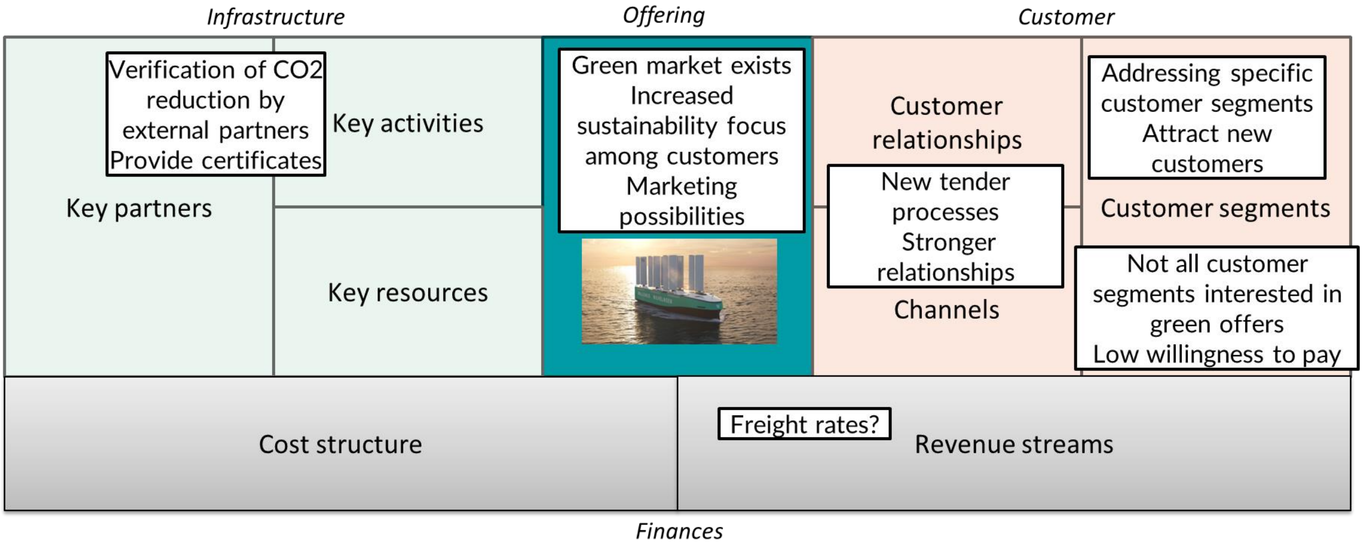


Figure 34 Influences of commercial factors exemplified

10.1.3 Example 3: Infrastructure

The third example concerns infrastructural aspects – alternative fuels and port considerations. First of all, wind propulsion reduces the need for alternative fuels. Alternative fuels are today more expensive leading to increased fuel costs. With wind-powered vessels need less alternative fuels compared to vessels only using alternative fuel that is positive for the cost structure of wind-powered vessels. To be able to offer a completely green service the wind propulsion needs to be complemented by an alternative fuel, and also, that the shipping companies need to make a choice regarding propulsion system in new vessels. Technology development and expected fuel price are key considerations affecting the selection of renewable fuel to be paired with wind propulsion technology for a near zero emission ship service. Renewable methanol, liquefied methane gas, and drop-in alternatives to fuel oils are the only fuels where there is off the shelf technology and demonstrated use in commercial ocean-going shipping. Volumes of the renewable fuels are currently low and costs are high, influencing the operational costs. When considering sailing routes and ports to call, fuel availability could also be a factor but many major ports have signalled readiness to supply these fuels as regulations and customer willingness to pay for green service increases the demand for renewables. Regulations such as the EU directive on the deployment of alternative fuel infrastructure and initiatives such as green shipping corridors are aimed at increasing the availability of alternative fuels at ports.

It is also important to consider the capacity available in ports for storing import and export cars. With limited bunkering possibilities initially, wind-powered vessels may call fewer ports possible meaning that they load and unload more in each of those ports.

Today vessels tend to be shifted between different geographical routes to optimize capacity utilization on the RoRo market. Allocation of vessels between routes is quite flexible and changes may even occur with quite short notice. This might be more difficult when introducing wind-propulsion given infrastructural limitations. In addition to bunkering possibilities, some routes have more energy-saving potential than others making them more interesting for wind propulsion. It may be that if only considering the wind-powered vessels these should be used in those routes with favourable weather conditions, volumes and bunkering possibilities. However, shipping lines operate a fleet of vessels and need to consider wind-powered vessels along side with the rest of their fleet.

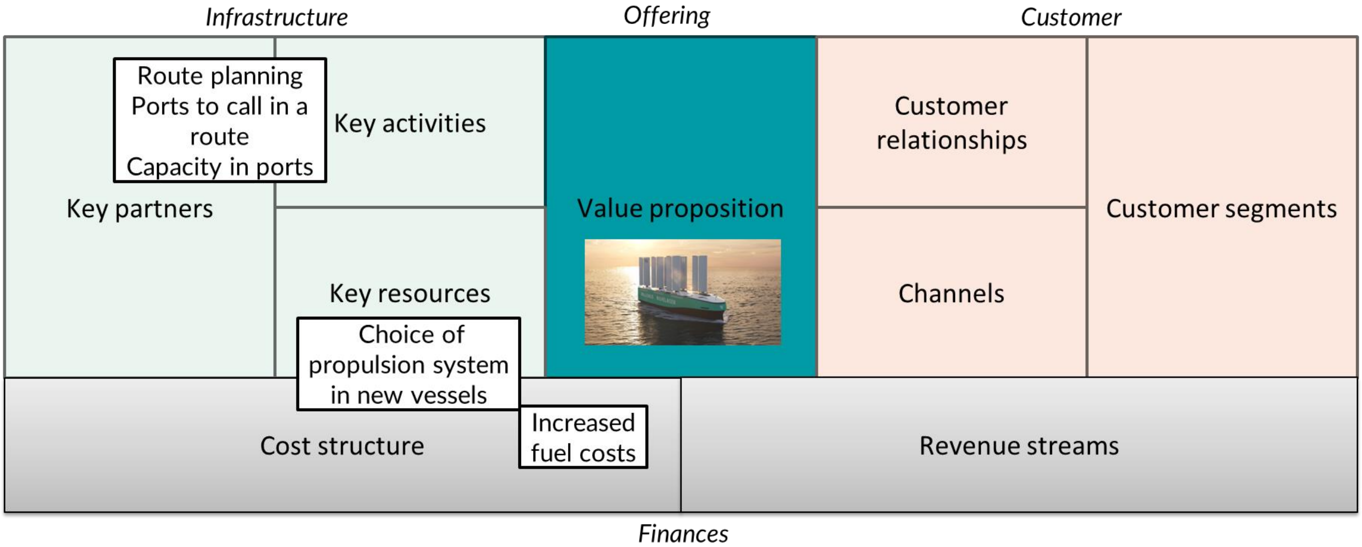


Figure 35 Influences of infrastructure factors exemplified

10.2 Further research

Further research is required to understand how different operational set ups (e.g. routes, speed, uncertainties in arrival time and volume) can benefit the CO_2-savings most in combination with reduced operational costs. Volume consolidation through fewer or selected ports could benefit the bunkering of alternative fuels while also reaching a reduction of operational costs. Although, such a strategy would put much pressure on the capacity in the ports as well as the cargo owners' adaptation possibilities in their inland logistics.

This report is the first step in identifying potential innovative business models in wind-powered shipping. In particular, a better understanding of the external factors' impact on the business case will assist shipping companies in designing their future commercial and operational set-up when using wind power as their primary energy source, where the operations in terms of speed, uncertainties in arrival time, routes and volumes strongly impact the CO_2-saving potential. The framework will be applied in the further work in the Orcelle Horizon project, for the specific case of the vessel Orcelle Wind.

11 References

ABS, CE Delft, & Arcsilea. (2023a). Potential of Wind-Assisted Propulsion for Shipping. Report prepared for the European Maritime Safety Agency. EMSA/Wind– 2023/2022 – 4837444.

ABS, CE Delft, & Arcsilea. (2023b). Update on potential of biofuels in shipping. Report prepared for the European Maritime Safety Agency. EMSA/Biofuels – 2023/2022 – 4837444 (updated version).

Alisafaki, A. & A. Papanikolaou (2024). State of the Art Review of wind propulsion technologies and scenarios of alternative zero emission solutions for deep sea shipping. Report carried out as part of Orcelle Task 4.1.

Atilhan, S., Park, S., El-Halwagi, M., Atilhan, M., Moore, M. & Nielsen R. (2021). Green hydrogen as an alternative fuel for the shipping industry, Current Opinion in Chemical Engineering.Volume 31

Balci, G. & Surucu-Balci, E. (2023). Green fuels in shipping face major challenges for 2050 net zero target, The Conversation, https://theconversation.com/green-fuels-in-shipping-face-major-challenges-for-2050-net-zero-target-211797, Accessed on 15/04/2024.

Bocken, N. M., Short, S. W., Rana, P., & Evans, S. (2014). A literature and practice review to develop sustainable business model archetypes. *Journal of Cleaner Production,* 65, 42–56.

Bunker One (2023). Bunker One Launches its First Methanol-Ready Bunker Tanker. Press Release. Available: https://bunkerone.com/insights/bunker-one-launches-its-first-methanol-ready-bunker-tanker

Bureau Veritas (2024). Are bunkering terminals keeping pace with the low-carbon transition? Available: https://marine-offshore.bureauveritas.com/magazine/are-bunkering-terminals-keeping-pace-low-carbon-transition

Chang, C-H. (2017). *How to Enhance Green Service and Green Product Innovation Performance? The Roles of Inward and Outward Capabilities.* Corporate Social Responsibility and Environmental Management. 25. 10.1002/csr.1469.

Chesbrough, H. (2010). Business model innovation: Opportunities and barriers. *Long Range Planning*, *43* (2-3), 354–363.

Chesbrough, H., & Rosenbloom, R. S. (2002). The role of the business model in capturing value from innovation: Evidence from xerox corporation's technology spin-off companies. *Industrial and Corporate Change*, 11 (3), 529–555.

Christodoulou, A., Gonzalez-Aregall, M., Linde, T., Vierth, I., & Cullinane, K. (2019). Targeting the reduction of shipping emissions to air. Maritime Business Review, 4(1), 16–30. https://doi.org/10.1108/MABR-08-2018-0030

Chou, T., Kosmas, V., Acciaro, M., & Renken, K. (2021). A comeback of wind power in shipping: An economic and operational review on the wind-assisted ship propulsion technology. *Sustainability*, *13*(4), 1880.

Cocca, S & Ganz, W. (2015). *Requirements for developing green services.* The Service Industries Journal. 35. 10.1080/02642069.2014.990002.

Comer, B., O'Malley, J., Osipova, L., & N. Pavlenko. (2022). Comparing the future demand for, supply of, and life-cycle emissions from bio, synthetic, and fossil LNG marine fuels in the European Union. Washington: International Council on Clean Transportation. Available: https://theicct.org/wp-content/uploads/2022/09/Renewable-LNG-Europe_report_FINAL.pdf

DNV (2022). Maritime Forecast to 2050. Energy Transition Outlook. Available at https://www.dnv.com/.

DNV (2024). https://www.dnv.com/news/maritime-decarbonization-efforts-propelled-as-orders-for-alternative-fueled-vessels-grow-251921/#:~:text=The%20latest%20stats%20from%20DNV's,neck%20with%20LNG%20(130), Accessed on 18/06/2024.

Dolan, G. (2024). Setting the Stage – Presentation at the FASTWATER Project Final Conference. 15 May 2024.Available: elink.clickdimensions.com/m/1/95463492/02-b24155-663e10ce6dad4867a5b3151e32caf6e8/1/79/a05fe0e4-5070-4baa-b47e-2ce1a1c7b709

Do Ly, K., & Pllumi, P. (2020). Influences on general dry cargo vessels' operation using ventifoils. Master thesis. Chalmers University of Technology.

Ellis, J. & K. Tanneberger (2015). Study on the use of ethyl and methyl alcohol as alternative fuels in shipping. Report prepared for the European Maritime Safety Agency (EMSA).

Ellis, J., Ólafsson, M., Olsson, T., Dolan, G., Yalcin, A., Jonkers, P., & M. Copin (2021). Methanol Supply, Bunkering Guidelines, and Infrastructure. FASTWATER Project Deliverable 7.1. Available: https://www.fastwater.eu/downloads

Ellis, J., & T. Olsson. (2023). Methanol Fuel Quality Recommendations. FASTWATER Project Deliverable Report D7.3. Available: https://www.fastwater.eu/downloads/deliverable-7-3-for-download-methanol-fuel-quality-recommendations

European Commission (2024). Commission makes EUR 1bn available for recharging and refuelling points under the Connecting Europe Facility (CEF). Available: https://transport.ec.europa.eu/news-events/news/commission-makes-eu1bn-available-recharging-and-refuelling-points-under-connecting-europe-facility-2024-02-29_en

European Commission (2024) https://climate.ec.europa.eu/eu-action/transport/reducing-emissions-shipping-sector_en, Accessed on 15/04/2024.

EC (2014). Directive 2014/94/EU of the European Parliament and of the Council of 22 October 2014 on the deployment of alternative fuels infrastructure Text with EEA relevance, Brussels: European Commission.

EC (2021). Regulation of the European Parliament and of the Council on the deployment of alternative fuels infrastructure, and repealing Directive 2014/94/EU of the European Parliament and of the Council, Brussels: European Commission.

EMSA (2023). Potential of wind-assisted propulsion for shipping. European Maritime Safety Agency.

Fredouet, C. H. (2022). The role of maritime poirts in the global supply chain networks of automotive OEMs. Supply Chain Management Review.

GENA Solutions (2023). Renewable and low-carbon methanol. GENA Solutions Oy: Lahti, Finland. Available: https://www.genasolutions.com/sustainability/2

Gerhardt, F., Werner, S., Hörteborn, A., Lundbäck, O., Nisbet, J. & Olsson, T. (2021). Horses for courses: How to select the "right" wind propulsion system and how to make the business case. In: Wind Propulsion Rina, London, UK.

Gerhardt, F., Kontos, S., Mazza, G. (2024). Wind propulsion for tankers? – An investigation into the CII reduction potential for ships operating on the spot market. Technical Conference: Managing CII and Associated Challenges, London, UK. The Royal Institution of Naval Architects.

Gopalakrishnan, D. (2024). The inventory tightrope in the automotive industry: Build-to-stock vs. build-to-order. www.thoughtworks.com. Published 9th May 2024.

Habibic, A. (2024). Hapag-Lloyd, Titan, and STX in 'largest' ship-to-ship bio-LNG bunkering operation. Offshore Energy. Available: https://www.offshore-energy.biz/hapag-lloyd-titan-and-stx-in-largest-ship-to-ship-bio-lng-bunkering-operation/

Hand, M. (2024). First methanol dual-fuel bunker barge to be deployed in Rotterdam. Seatrade Maritime News. Available: https://www.seatrade-maritime.com/sustainability-green-technology/first-methanol-dual-fuel-bunker-barge-be-deployed-rotterdam

Hobbs, D. (2022). Meet the tonnage coordinators who manage our fleet logistics. Tonnage coordinator team ensures vessels are optimally deployed for customer needs - Wallenius Wilhelmsen

ICC (2022) Fuelling the Fourth Propulsion Revolution: An Opportunity for All, https://www.ics-shipping.org/resource/fuelling-the-fourth-propulsion-revolution-an-opportunity-for-all-full-report/, Accessed on 15/04/2024.

IMF (2024) World Economic Outlook Update: Moderating Inflation and Steady Growth Open Path to Soft Landing, https://www.imf.org/en/Publications/WEO/Issues/2024/01/30/world-economic-outlook-update-january-2024, Accessed on 15/04/2024.

IMO (2020). MEPC 75/INF.26, Reduction of GHG Emissions From Ships - Wind propulsion solutions, Pre-session public release, Submitted by Comoros.

IMO MEPC (2022). Energy Efficiency of Ships – Report of fuel oil consumption data submitted to the IMO Ship Fuel Oil Consumption Database in GISIS (Reporting year: 2021). IMO: London. Accessed on 19/06/2024.

IMO (2023). IMO Strategy on Reduction of GHG Emissions from Ships, Available at: https://www.imo.org/en/OurWork/Environment/Pages/2023-IMO-Strategy-on-Reduction-of-GHG-Emissions-from-Ships.aspx#:~:text=The%202023%20IMO%20GHG%20Strategy%20envisages%2C%20in%20particular%2C%20a%20reduction,at%20least%2040%25%20by%202030 Accessed on 15/04/2024.

IMO (2024). Reduction of GHG emissions from ships – White paper on wind propulsion. Marine Environment Protection Committee, International Maritime Organization.

International Windship Association (IWSA). 2024. White paper on wind propulsion. Wind Propulsion: Zero-Emissions Energy Solution for Shipping. Submitted as MEPC 81/INF.39

IRENA (International Renewable Energy Agency) and Methanol Institute (2021). Innovation Outlook: Renewable Methanol. Report produced in partnership with the Methanol Institute. Available: https://www.irena.org/publications/2021/Jan/Innovation-Outlook-Renewable-Methanol [Accessed 20210128].

ITF (2018) Decarbonising Maritime Transport Pathways to zero-carbon shipping by 2035, https://www.itf-oecd.org/decarbonising-maritime-transport, Accessed on 15/04/2024.

Labrut, M. (2023). Singapore gets its first methanol bunkering vessel. Seatrade Maritime New. Available: https://www.seatrade-maritime.com/bunkering/singapore-gets-its-first-methanol-bunkering-vessel

Lüdeke-Freund, F., Gold, S., & Bocken, N. M. (2019). A review and typology of circular economy business model patterns. *Journal of Industrial Ecology*, *23* (1), 36–61.

Maersk, (2023). Maersk secures green methanol for maiden voyage of the world's first methanol-enabled container vessel. Available: https://www.maersk.com/news/articles/2023/06/13/maersk-secures-green-methanol

Mander, S. (2017). Slow steaming and a new dawn for wind propulsion: A multi-level analysis of two low carbon shipping transitions. Maritime Policy 2017, 75, 210–216.

Mandra, J.O. (2023). 185 global ports can bunker LNG. Offshore Energy. Available: https://www.offshore-energy.biz/185-global-ports-can-bunker-lng/

Maritime and Port Authority of Singapore. (2023). Expression of Interest (EOI) for the Supply of Methanol as a Marine Bunker Fuel in the Port of Singapore. Available: https://www.mpa.gov.sg/docs/mpalibraries/mpa-documents-files/sustainability-office/eoi-supply-methanol-marine-bunker-fuel.pdf?sfvrsn=31c26b63_0

Maritime and Port Authority of Singapore. (2024). Singapore is Ready for Methanol Bunkering for Container Vessels at Tuas Port with First Successful Simultaneous Methanol Bunkering and Cargo Operation. Available: https://www.mpa.gov.sg/media-centre/details/singapore-is-ready-for-methanol-bunkering-for-container-vessels-at-tuas-port-with-first-successful-simultaneous-methanol-bunkering-and-cargo-operation

Maritime Executive. (2023a). First US Gulf Barge-to-Ship Methanol Bunkering Completed in Houston. Available: https://maritime-executive.com/article/first-us-gulf-barge-to-ship-methanol-bunkering-completed-in-houston

Maritime Executive. (2023b). Methanex Conducts First Net-Zero, Biomethanol-Powered Voyage. Available: https://maritime-executive.com/article/methanex-conducts-first-net-zero-biomethanol-powered-voyage

Martinsen, U. (2014) Towards greener supply chains: inclusion of environmental activities in relationships between logistics service providers and shippers. Doctoral thesis, Linköping University

OECD (2024) OECD Economic Outlook, Interim Report February 2024: Strengthening the Foundations for Growth, https://www.oecd-ilibrary.org/sites/0fd73462-en/index.html?itemId=/content/publication/0fd73462-en&_csp_=7b8d5edea7570aac596749c5d775d56b&itemIGO=oecd&itemContentType=book#section-d1e412-28b1e449af, Accessed on 15/04/2024.

Osterwalder, A., & Pigneur, Y. (2010). *Business model generation: A handbook for visionaries, game changers, and challengers*. John Wiley & Sons.

Port of Rotterdam (2024). Bunker sales port of Rotterdam 2021-2024. Available: https://www.portofrotterdam.com/sites/default/files/2024-04/bunkersales-2021-2024.pdf

Prevljak, N. H. (2024). Methanol-powered Ane Maersk completes first bunkering in European waters. Offshore Energy. Available: https://www.offshore-energy.biz/methanol-powered-ane-maersk-completes-first-bunkering-in-european-waters/

Rahman, R. (2023).Port of Gothenburg completes landmark methanol bunkering. Port Technology International. Available: https://www.porttechnology.org/news/port-of-gothenburg-completes-landmark-methanol-bunkering/

Raza, Z., & Woxenius, J. (2023). Customer-driven sustainable business practices and their relationships with environmental and business performance—Insights from the European shipping industry. Business Strategy and the Environment, 32(8), 6138–6153.

Riviera News. (2023). Rotterdam sees first green methanol bunkering operation with arrival of Maersk box ship. Available: https://www.rivieramm.com/news-content-hub/news-content-hub/oci-global-conducts-green-methanol-of-maersk-ship-in-rotterdam-77572

RMI and Global Maritime Forum (2024). Oceans of Opportunity Supplying Green Methanol and Ammonia at Ports. Report prepared for the Zero-Emission Shipping Missing. Available: https://cms.globalmaritimeforum.org/wp-content/uploads/2024/04/Oceans-of-opportunity_supplying-green-methanol-and-ammonia-at-ports.pdf

Schaltegger, S., Hansen, E. G., & Lüdeke-Freund, F. (2016). *Business models for sustainability: Origins, present research, and future avenues*. Sage Publications Sage CA: Los Angeles, CA.

Schuler, M. (2021). First Barge-to-Ship Methanol Bunkering at Port of Rotterdam. G-captain. Available: https://gcaptain.com/first-barge-to-ship-methanol-bunkering-at-port-of-rotterdam/ [Accessed: 20210830].

Ship Technology. (2020). Gasum performs ship-to-ship LNG-LBG blend bunkering to cargo vessel.Available: https://www.ship-technology.com/company-news/gasum-lng-lbg-blend-bunkering/?cf-view

Stopford, M. (2009) *Maritime Economics*, 3rd Edition, Routledge: New York, NY.

Svanberg, M., Rogerson, S., Finnsgård, C., Kilicaslan & S., Santén, V. (2024). Technology adaption in hard-to-abate sectors; Enablers, drivers and barriers in maritime supply chains. CSCMP conference, Barcelona, June, 2024

S&P Global, JP Morgan Asset Management (2024) https://am.jpmorgan.com/content/dam/jpm-am-aem/global/en/insights/market-insights/guide-to-the-markets/mi-guide-to-the-markets-ce-en.pdf Accessed on 18 April 2024.

Talluri, L., Nalianda, D. K., & Giuliani, E. (2018). Techno economic and environmental assessment of Flettner rotors for marine propulsion. *Ocean engineering*, *154*, 1-15.

Tang, L., & Gekara, V. (2020). The importance of customer expectations: An analysis of CSR in container shipping. Journal of Business Ethics, 165(3), 383–393. https://doi.org/10.1007/s10551-018-4062-4

Tay & Konovessiss, (2023)._Sustainable energy propulsion system for sea transport to achieve United Nations sustainable development goals: a review, Discover Sustainability 4, 20 (2023).

Teece, D. J. (2010). Business models, business strategy and innovation. *Long Range Planning*, 43 (2-3), 172–194.

Tillig, F., Ringsberg, J. W., Psaraftis, H. N., & Zis, T. (2020). Reduced environmental impact of marine transport through speed reduction and wind assisted propulsion. *Transportation Research Part D: Transport and Environment*, *83*, 102380.

UNCTAD (2023a) Review of Maritime Transport. United Nations Publications.

UNCTAD (2023b) Global Trade Update. United Nations Publications.

van Dyk, S., Su, J., McMillan, J.D., and J.N. Saddler (2019). ”DROP-IN’ BIOFUELS: The key role that co-processing will plan in its production. IEA Bioenergy Task 39.

Volvo Cars (2023). The shipping news: Volvo Cars parts transported via CO_2-saving biodiesel

Wallenius Wilhelmsen Research (2024). Summary of market trends. Interviews and internal documentation. Wallenius Wilhelmsen[2].

Werner, S., Gerhardt, F., and Alterskjaer, A. (2023). “Performance Indicators for Wind Powered Ships: Towards an Industry Standard,” *8th Hull Performance & Insight Conference*.

Werner, S. and J. Nisbet. (2023). Speed trial and route analysis of m/v Copenhagen with Flettner rotor. SSPA: Göteborg. SSPA Report No. RE40201042-01-00-B. Available: https://vb.northsearegion.eu/public/files/repository/20230505141934_RE40201042-01-revBCopenhagen.pdf

WTO (2023) Global Trade Outlook and Statistics, October 2023 update. https://www.wto.org/english/res_e/booksp_e/gtos_updt_oct23_e.pdf, Accessed on 15/04/2024.

Yuen, K. F., Thai, V. V., & Wong, Y. D. (2017). Corporate social responsibility and classical competitive strategies of maritime transport firms: A contingency-fit perspective. Transportation Research Part A: Policy and Practice, 98, 1–13. https://doi.org/10.1016/j.tra.2017.01.020

Other web sources:

https://www.databridgemarketresearch.com/reports/global-car-carrier-market, Accessed on 15/04/2024.

https://www.metroshipping.co.uk/news/roro-car-carrier-market-attracting-container-shipping-lines/, Accessed on 15/04/2024.

https://www.hellenicshippingnews.com/vesselsvalue-vehicle-carrier-and-roro-full-year-review-2022/, Accessed on 15/04/2024.

https://airseas.com/en/wind-propulsion/, Accessed on 15/04/2024.

https://cars.usnews.com/cars-trucks/features/semiconductor-shortage, Accessed on 15/04/2024.

[2] Some of the internal data from Wallenius Wilhelmsen is based on Clarkson and S&P Global.