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Lessons Learned during the COVID-19 Pandemic and the Need to Promote Ship Energy Efficiency

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Abstract: The COVID-19 pandemic significantly impacted the way we do business and trade. As a result of the pandemic, a variety of stakeholders in the maritime sector have been adversely affected; nevertheless, they adapted successfully to the new circumstances and learned how to make the necessary compromises. The purpose of this study is to examine the status of ships' energy efficiency during the pandemic. It is hypothesized that the pandemic has strengthened barriers to ship energy efficiency, and shipping decarbonization has not been a priority for stakeholders throughout the pandemic. To examine this hypothesis, by conducting a literature review and utilizing the barrier models, the energy efficiency barriers were revisited through the lens of the COVID-19 pandemic. The established focus group assessed the impact of the pandemic on these barriers. The pandemic revealed the vulnerability of shipping's energy efficiency, and a majority of barriers were strengthened as a result. A number of factors have contributed to the marginal decarbonization of shipping during the pandemic period, including inadequate and lenient energy regulations (policy gap), economic crisis within shipping companies (low freight rates and a decline in charter markets), and extremely low fuel prices.

Keywords: COVID-19 pandemic; energy efficiency; energy policies; fuel price; shipping industry



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1. Introduction

Acting as the backbone of world trade, approximately 80–90% of goods and raw materials are served by the international shipping industry. Its capacity to transfer goods and materials from the point where they are produced to where they will be ultimately consumed literally underpins the modern way of life [1]. Since shipping plays such an important role in global trade, a great deal of research has been conducted in order to improve its safety and efficiency. The shipping industry, on the other hand, is exposed to many external factors, such as the global economy, geopolitical events, and the energy market. With its unprecedented speed and scale, the COVID-19 pandemic revealed vulnerabilities in the shipping industry, which is one of the main pillars of international trade. The global decline in demand for goods, which was the direct result of lockdowns and other restrictive measures that were part of the necessary response to the coronavirus implications, created negative effects on all major sectors of shipping. Globalization patterns are clearly remodeled and a shift towards regional trade is recently noted; the global supply chain has been reshaped and new consumption styles have emerged. With its black swan characteristics and high uncertainties, the pandemic clearly obscured the future outlook for international trade and health [2].

UNCTAD reported that the recession caused by the pandemic was as severe as the Great Depression of the 1930s [3]. It is therefore not a coincidence that the United Nations predicted a 3.2 percent shrinkage in the world economy in their mid-2020 report [4].

Furthermore, UNCTAD predicted a 4.1 percent decline in international maritime trade in 2020 [5]. In April 2020, UNCTAD estimated that 10 percent of the global vessel-carrying capacity was laid up [5], and at the same time, three million TEUs were removed from Asia-Europe and the transpacific as a result of blank sailing due to trade shrinkage [6]. The result of reviewing 41 European port transactions showed only 7 ports have not experienced blank sailings and the other 34 ports have experienced the hardest hit due to blank sailings [7]. Reportedly, the tanker order book was at a historical low of 8% of the fleet in October 2020 [8], and there might be no more new orders for cruise vessels till 2025 [9]. It is also interesting to note that “Yara International has paused further construction of its much anticipated all-electric autonomous vessel MV Yara Birkeland as a result of the COVID-19 pandemic” [10]. Millefiori et al. [11], by utilizing the AIS data and introducing a new notion which is called the “maritime mobility index” could show the unprecedented drop in maritime mobility due to the pandemic.

All the shreds of evidence mentioned above are about shipping logistics, shipping market, maritime and world trade, and ship building. The ships’ energy efficiency during the pandemic period, however was not investigated in any report or news. One of the main reasons for the neglect of ship energy efficiency during this period could be the absence of a gauge and benchmarking mechanism able to indicate the changes in CO₂ emissions instantly (without waiting for the next GHG study report), like the other statistical indicators in other aspects mentioned above.

This study aims to investigate the impact of the COVID-19 pandemic on the ship energy efficiency (EE). Introducing a quantitative gauge to measure the impact of the pandemic on the ship EE is not practicable and this study will present an overall qualitative image to capture and demonstrate these impacts. In shipping daily routines, there are various hindering features against the ship EE. These barriers themselves could be under the influence of multidimensional external factors. For instance, a great deal of sensitivity to global events is evident in the fuel price, which is one of the most influential factors on ship EE. During the pandemic, a sharp decline in fuel prices was observed. Even though the low fuel prices during the pandemic were in favor of the global economy, however, climate change and global warming are critical concerns that cannot be ignored. Under pandemic pressure and supply chain disruption, many energy efficiency practices in the shipping and port operations, as well as in the ship–port interface were undermined.

This study hypothesizes that the pandemic had strengthened barriers to ship energy efficiency, and shipping decarbonization had not been a priority for stakeholders during the pandemic. By using the barrier models, this study attempts to investigate the impact of the COVID-19 pandemic on ship energy efficiency and provides an overview of how the pandemic affected the EE barriers.

2. Materials and Methods

To explore the impacts of the recent pandemic on ship EE, this study has utilized the barrier models. Discussion of industrial EE in academic literature began in the 1970s, but the use of barrier models became more prevalent in the late 1990s [12–14] and later on, discussions and deployments of barrier models in academic literature gained momentum [15–17]. Based on the barrier models created by scholars in other industrial sectors, maritime experts have applied these models to the EE in shipping in the 2010s [18–20]. Barrier models can act as a guide in the exploration and categorization of barriers in the literature review process.

In this direction, an extensive literature review was performed at the very beginning to construct a list of energy efficiency barriers in shipping. The next step was the formation of a focus group comprised of researchers in the field of maritime energy management to improve/finalize the barrier model and then examine all the barriers individually, and in detail, in light of the impact of the pandemic.

In validation of barriers and estimation of the level of pandemic impacts on them (major/minor/no effect), different criteria were considered, including global trade, ship-

ping trends, fuel price, IMO 2020 Sulphur cap, logistic disruption, irregularities in port and shipyards operation, and difficulties related to the seafarers' working conditions during the pandemic. To examine the various barriers, numerous publications and news stories reflecting the conditions of the shipping market and operation in the peak period of the pandemic (mostly in 2020) were analyzed and relevant examples are discussed in Section 4.

3. Results

To create a comprehensive list of barriers, an extensive review of studies was conducted in order to demonstrate the different dimensions of the barriers hindering energy efficiency in shipping. Table 1 shows the outcome of this literature review. In the next step, through the establishment of a relevant focus group and by receiving necessary input and feedback, the level of impact of the COVID-19 pandemic on each individual barrier was investigated. The associated results are shown in Table 1.

Table 1. Barriers to ship energy efficiency and impact of pandemic.

Barriers' Cluster		Praxis in Shipping and References		Impact of COVID-19 Pandemic	
Economic barriers	Market barriers	Heterogeneity	High diversity in ship types, sizes, and operation [18,19,21–32].	No effect	
		Financial barriers	Risk	1. External risk including: global economic trends impacted by external events like COVID-19 pandemic [21,23,24,32–36], and fuel price fluctuation [18–21,23,24,28,32–39]. 2. Business risk related to the shipping cycles [19–21,23,28,33,34,36,37,40]. 3. Technical risk, e.g., doubt about claimed fuel reduction [19,24,34,37,41,42].	Major
			Hidden cost	Transaction cost [18,23,29–32,34,36,38,41,43]—Training cost [19,26]—Unexpected operation cost [24,34,36]—Costs related to the contract and tendering process [19,23,34,36]—Opportunity cost [19,23,24,26,29–32,34,36,44,45].	Major
			Access to capital	Insufficient company's internal fund [26,32,33,41,42,45]—Failure of bankers in recognition of vessel energy projects [46].	Major
		Priority in investment	Short term strategy in investment [26,37]—Incorrect company's appraisal rules for investment [19,21,23,37,41].	Major	
	Slim organization	High transaction costs for small companies [19,31,34,36]—Lack of credit to receive fund from banks [43,46].	Major		
	Market failures	Information barriers	Imperfect information	Inaccurate information [19,21,23,32,33]—Lack of information [18–20,22,23,32,33,37]—Source of information [18,19,21,23,24,28,31,33,35,41,43,47]—Improper form of information [19,21,24,30]—Lack of knowledge diffusion [35,42].	Minor
			Asymmetric information	Adverse selection [18,19,21,24,29,30,32,36,48]—Principle agent problem and moral hazard [18,19,22,24,29,30,32,33,41].	No effect
		Split incentive	Contractual conditions like ship speed and arrival time [49–51]—Conflict of interest in energy efficiency investment [19,20,22–26,28,30–32,34,35,37–39,41]—Ship selling [20,23,27,28,31,32,34,37,39,41]—Third party management [19,20,29,52].	Major	

Table 1. Cont.

Barriers' Cluster		Praxis in Shipping and References	Impact of COVID-19 Pandemic	
Non-economic barriers	Organizational barriers	Power	Energy efficiency and energy management are not in priority [19,21,26,34].	Major
		Culture	Environmental values are not institutionalized in the organizational body of shipping companies [18,19,21,29].	No effect
		Ineffective energy management	Inefficient SEEMP implementation [53,54]—Lack of energy management system [18,43,54]—Inefficient monitoring [43,52,55]—Inefficient ship–shore communication [19,43,55,56].	Minor
		Decision-making difficulties	Predominance of financial considerations over technical and operational issues [57]—The gap between operators and decision-makers [18,19,29,56]—Lack of experts and knowledgeable managers [18,19,41].	Major
	Behavioral barriers	Inertia and lack of commitment to CSR	Resistance to change at both management and operational levels [21,39,53,58].	Minor
		Bounded rationality	Decision-making based on the rule of thumb and not by accurate analyzing process [18,19,21,23,24,26,29–31].	Major
		Lack of awareness, training, and guidelines	Ship staff need more awareness-raising activities and training courses relevant to the energy management [19,25,46,52,53,58].	No effect
		Lack of knowledge	Lack of technical knowledge to operate new energy efficiency technologies [19,21,24,25,47].	No effect
	Policy barriers	Insufficient & ineffective regulations	Current energy regulations (SEEMP and EEDI) are not sufficient to reach the ambitious targets [18,25,27,52,54,55]—High flexibility in the current energy regulation [35,57].	No effect
		Complex process of legislation	Slow pace of policymaking in the IMO [22,40,59]—Heterogeneity in shipping segments' operation profile [60].	No effect
		Energy efficiency practices in conflict with other regulations	e.g., the optimization of trim and ballast could conflict with ballast water management regulations [20]—Hull cleaning in conflict with biofouling regulations [19,20,28,41].	No effect

Table 1. Cont.

Barriers' Cluster		Praxis in Shipping and References		Impact of COVID-19 Pandemic
Non-economic barriers	Technical barriers	Immatureness of technologies	Doubt in technical performance [19,20,23,24,28,32–34,37,39,41,47,61]—Complexity of the measures [19,37,41,47,61].	No effect
		Incompatibility between EE measures	Uncertainties in the utilization of a combination of efficiency measures and practices [19,30,42,55,60].	No effect
		Contradiction between EE measures/practices and operation	Conflict between ship operational considerations and energy efficiency practices [19,28].	No effect
		Inactivity of technology providers	Lack of motivation due to less demand for energy efficiency technologies mostly as a result of low fuel prices [41,44].	Major
		Inertia	Resistance to change in ports and shipyards' management [19,23,26,27,39,41,55].	Major

Table 1 presents a list of the barriers preventing ship EE, as well as the possible impact of the global pandemic on these barriers. The majority of barriers have been identified as being affected by COVID-19, particularly those related to financial and decision-making issues. This could be an early response to our hypothesis that the barriers to ship EE have been strengthened during the pandemic period. The policy barriers and those barriers related to pure technical matters as well as knowledge of the ship and shore staff about the energy efficiency could be perceived as not to be under the influence of COVID-19. Section 4 discusses in detail each category of the barriers and how they are affected by pandemics.

The literature review revealed that the majority of the studies discussing the barriers to energy efficiency follow a common language under normal conditions of the global trade and shipping market. On the other hand, the published reports and news reflecting the shipping situation during the pandemic have shown an unprecedented shock wave to the supply chain. Therefore, we decided to explicitly add the hindering factors undermining the supply chain efficiency at the end of Section 4 (see Section 4.4).

4. Impacts of COVID-19 Pandemic on Energy Efficiency Barriers

This section contains explanations of barriers based on the literature review and discussion of the impact of the pandemic on these barriers based on focus group arguments.

4.1. Market Barriers

4.1.1. Heterogeneity (No Effect)

Heterogeneity refers to the fact that ships of different types, sizes, and operational profiles will not respond to a single cost-effective EE technology or practice in the same way [18,19,22,23,25,31,32]. Heterogeneity is an inherent characteristic of shipping and in result, economic and commercial changes due to, for instance, pandemics or economic recessions, have little effect on it.

4.1.2. Financial Barriers

Financial Risk (Major Impact)

The risk of investment in energy efficiency has been a chronic concern for a wide range of industries. The shipping economy is highly dependent on market cycles and fuel price fluctuations [23,24,32,33,35,36], and the impact of the COVID-19 pandemic on these factors could significantly increase investment risk. The fuel price has a key role in the calculation of NPV, ROI, and payback period utilized in the process of project risk assessment, economic feasibility study, and life cycle assessment. Fuel price is essentially under the influence of different factors like upcoming regulations, global oil price, world trade, and shipping demand [18,23,28,32,37–39]. In the wake of the COVID-19 pandemic, world trade was significantly reduced, and oil prices plunged precipitously as a result of the economic downturn.

Even though the Sox scrubber is not an energy efficiency measure, however, because of its relation with the type of fuel consumed onboard and for demonstrating the importance of fuel price in the project's feasibility study, the flow of scrubber installation under the pandemic circumstances is discussed. IMO's 2020 Sulphur cap and consequent pressure on ship-owners to install Sox scrubbers or use VLSFO is an example of new regulation imposing a new regime on the bunker market and the shipping industry. The refineries' ability to meet the VLSFO demand after 1 January 2020 as well as shipyards' capacity to retrofit scrubbers were the main concerns in this regard.

Global and seaborne trade were affected by COVID-19, which resulted in a dramatic decrease in bunker prices. During the peak of the pandemic, fuel prices for VLSFO and IFO380 declined from 685 US\$/mt and 375 US\$/mt in January 2020 to 212 US\$/mt and 157 US\$/mt respectively by the end of April 2020 [62]. It is very remarkable that the coincidence of the pandemic with the enforcement date of the Sulphur cap could dampen the predicted price increase for VLSFO. According to S&P Global [63], the price of VLSFO

(0.5% Sulphur) in April 2020 (post-IMO 2020) was almost half of the HSFO (3.5% Sulphur) in April 2019 (pre-IMO 2020).

Some ship-owners postponed the scrubber installation following the drop in the price difference between HSFO and VLSFO from USD 300 per ton predicted before the pandemic to USD 60 during the pandemic [64]. Similar to the scrubber issue, energy efficiency projects may have no economic rationalization under pandemic impact and the related low fuel price situation.

Hidden Cost (Major Impact)

Improving energy efficiency in shipping companies necessitates having some rough predictions of hidden costs. Transaction cost is a major part of the hidden costs and includes organizational transaction cost and market transaction cost [18]. Organizational transaction cost is corresponding to the budget for the establishment of the energy management system, infrastructure like IT (Information Technology), energy management department, monitoring mechanism like data collection system, and upholding of this structure [18,19]. On the other hand, market transaction cost includes the cost associated with research and development (R&D), and charges for gathering, analyzing, and application of information [19,23,34,41].

Under the pandemic situation, R&D and research centers, shipyards, classification societies, agencies, and logistic firms were working with their partial capacities complying with social distancing and hygiene protocols. Access to these stakeholders' services was more challenging and expensive in comparison to the pre-pandemic situation.

Assume a shipping company intended to install a Mewis duct on a vessel. The laboratory which was supposed to do the technical feasibility study such as CFD simulation, or testing the ship model in a towing tank might not have enough manpower to complete the study on time. Considering the manufacturing of the Mewis duct in other yards and shipment of the parts to the destination yard for installation on the vessel, the logistic chain in this process has been sluggish under the pandemic effect, and booking time for retrofit at a dock was problematic. On the other hand, the class surveyor who should approve the final installation, had difficulties reaching the location. On the company side, they had to watch for opportunity cost because of the extended off-hire time [24,37] due to less manpower in the repair yards. In all likelihood, these are some hidden costs that if a shipping company be aware of them, will not attempt for efficiency improvement under a pandemic and in low fuel price circumstances.

Access to Capital and Priority in Investment (Major Impact)

Usually, energy efficiency projects do not rank high on the list of top priorities in the company's investment plan [19,23,37,41]. It was particularly challenging to implement energy efficiency projects under pandemic conditions, when companies were merely thinking about survival and a safe transition from the crisis. Due to the coincidence of the pandemic with other emerging regulations, such as ballast water management and Sulphur cap, shipping companies, especially small ones with limited economic resilience were unable to dedicate enough capital to invest in energy efficiency. During the pandemic, managers prioritized the installation of ballast water treatment plants and Sox scrubbers over energy efficiency measures. Compliance with regulations always comes before voluntary carbon footprint mitigation (idea by focus group).

4.1.3. Slim Organization (Major Impact)

Small shipping companies with a very limited economic resilience are very dependent on the daily ship trade and freight rate. We observed an unprecedented reduction in seaborne trade and freight rate during the pandemic [65,66]. Meanwhile, these small companies do not benefit economies of scale, and as a result, the transaction costs [19,31,34,36] and retrofit expenses [25,43] are very high for them.

4.2. Market Failure

4.2.1. Imperfect Information (Minor Impact)

The availability of accurate, valid, and accessible data regarding technical features of an energy efficiency project is crucial to evaluate the performance of the energy efficiency measure throughout the entire process from technical feasibility studies by research centers and laboratories to the final stage of installation and trial [20,22,23,26,29–33,35,36,38,41]. During the pandemic, representatives of shipping companies and third parties acting on their behalf were unable to attend research centers to supervise trials and obtain data directly. Similarly, the same restrictions prevented the company's R&D representative, energy auditor, or technical superintendent to attend the dry dock during the installation and testing of energy efficiency measures.

4.2.2. Asymmetric Information (No Effect)

There are two possible forms of asymmetric information: Adverse selection and principal-agent problem. Adverse selection occurs when the selected and installed EE measure does not offer the best possible option because the technology provider does not provide the required information [19,23,29,32,36]. Principal-agent problem rooted in moral hazard refers to circumstances in which the incorrect information is intentionally provided [19,24,29,30,32,33,41]. There was no evidence that the pandemic had an impact on this barrier according to the focus group.

4.2.3. Split Incentive (Major Impact)

Split incentives have been identified as one of the major barriers to energy efficiency in shipping, as well as many other sectors. As an analogy to the landlord–tenant conflict in energy efficiency investments, in the shipping industry, it corresponds to the owner–charterer conflict [19,20,24–26,30–32,35,38,39,41,48]. As a result of the COVID-19 pandemic, the split incentive could be viewed as more related to matters such as sailing speed, re-routing, and lay-up strategies. While shipowners consider the slow steaming practice to absorb the overcapacity of their fleet, charterers may intend higher speed for more cargo shipment per unit of time and to be the beneficiary of low fuel price and probable demurrage compensation in case of delay in berthing at ports [50,51].

Another big source of conflict between shipowners and charterers in the pandemic era was the lay-up strategy and the recovery cost. According to Riviera [67], an owner of a product tanker in May 2020 at the peak of the pandemic claimed that 12% of the clean trading product tanker fleet had been working in storage. Riviera [68] reported that there are around 4000 platform supply vessels and anchor handling tugs in the global fleet, and around 1000 of them have been laid up and inactive due to the pandemic and low oil prices. There have been reports of a large number of oil tankers and cruise ships anchored in the tropical waters of the Persian Gulf, Philippines, and United States, and one can imagine that the roughness of the hull and propeller would increase substantially over a few weeks [69]. Several issues arose during the pandemic regarding who should be responsible for cleaning the hull and ensuring energy efficiency, which lay-up strategy (hot, warm, or cold) is the most effective for each type of vessel, and who should be responsible for the cost of lay-up reactivation? [70].

4.3. Non-Economic Barriers

4.3.1. Organizational Barriers

Power (Major Impact)

Lack of power as a barrier to energy efficiency refers to a situation in shipping companies when the energy efficiency is not treated as a significant issue [19,26,34]. Focus group provided another viewpoint to this barrier, indicating that the energy efficiency objectives of the energy management (or technical) department are not those of other departments in a shipping company, such as operation, commercial, and chartering. During the pandemic period, the main focus of managers was primarily on chartering status of the ship and freight rate, which contributed significantly to the strengthening of this barrier.

Culture (No Effect)

In view of the fact that organizational behaviors are rooted in the cultural values of an organization, and an organization must adhere to its cultural values, surrounding conditions should not be used to justify deviation from this cultural strategy. This principle suggests that this barrier should not be affected by the pandemic. However, if a shipping company deviates from its environmental pledge to reduce its carbon footprint during the pandemic, it might also happen under other scenarios.

Less Productive Energy Management (Minor Impact)

It was unlikely for shipping companies to invest in energy management during the pandemic, when revenues were significantly reduced. In this case, it was not feasible to establish the energy management system from scratch with a high cost to build up infrastructures, and even if the system was already established, maintaining it efficiently and operationally was very challenging and costly. While managers were scrambling to provide safe transit from the pandemic period, they failed to consider the possibility of rejuvenating the fleet as part of the company policy to reduce the age and CO₂ emissions of the fleet. Furthermore, energy efficiency projects, which were primarily retrofitting in nature, followed the same pattern as new construction, and the results of the economic feasibility studies could not justify them as profitable plans due to low fuel prices and the lengthy payback period associated with them. In the same manner, periodic maintenance of ships was mostly delayed during the pandemic as a result of the lockdown and the impossibility for shipyard workers to return to routine work. Based on Clarkson Research Services (CRS), cited by Riviera [64], repair activities dropped by 20% in the period of January to May 2020.

Taking a different approach, recently, we have frequently resorted to solutions like “social distancing”, “online meetings”, and “remote inspections”, which are gaining popularity and are becoming dominant in daily routines in shipping. However, a key component of performance monitoring is the development and maintenance of the IT system, which necessitates IT specialists physically attending vessels on a regular basis, and this was too costly and sometimes impossible during the pandemic. Similarly and due to travel restrictions, it was not possible to send energy auditors and technical superintendents onboard ships to supervise the implementation of the SEEMP, and managers did not prioritize this task.

Decision-Making Difficulties (Major Impact)

The decision-making process plays an important role in sustainable management. Making the right decisions at the right time could help save a company in a crisis and elevate the company in the aftermath. During the pandemic, shipping managers have faced enormous challenges such as fleet overcapacity, unchartered vessels, low freight rates, ship inspections and certification, crew change, planning and implementation of training courses, and on-time delivery of required services like spare parts, provision, etc. The combination of these difficulties with the challenges involved in complying with new regulations such as ballast water management and the IMO 2020 Sulphur cap made the situation more complex. This situation could result in the adoption of decisions that lead to a series of superficial procedures with little or no impact on energy efficiency.

4.3.2. Behavioural Barriers

Inertia and Lack of Commitment to CSR (Minor Impact)

At the forefront of implementing energy efficiency practices onboard ships, seafarers play an important role in enhancing the efficiency of the vessels. In this regard, various studies have highlighted the resistance of operators to change when it comes to adopting and utilizing new energy efficiency practices, technologies, and monitoring equipment [39,53,58]. Very primary activities like routine maintenance of machinery, cutting the unnecessary energy consumer onboard, and changing the mindset by simple alterations

in daily routines can save a high amount of energy, however, this requires motivated and fresh-minded seafarers.

According to UNCTAD [5], 150,000 seafarers were to be changed over to ensure safe operation onboard and prevention of fatigue during the pandemic. Under the impact of the pandemic, many seafarers were stranded at sea due to restrictions on air flights, visa issuance, port protocols [65], and joining/signing-off procedures. In many cases, the seafarers' contracts had expired, but they were not able to return to their homeland and only had to watch their families struggling with the COVID-19 disease from a distance. This frustrating situation posed a significant threat to operational safety, and clearly, energy efficiency might not be a priority for seafarers.

The problem of inertia could be attributed to the shore managers as well. Managers with less commitment to corporate social responsibility have difficulties in changing their mindset to alter their strategic vision toward more efficient shipping [19]. Considering the impact of the pandemic, managers' inflexibility in incorporating energy efficiency into their macro and long-term strategies may be exacerbated.

Bounded Rationality (Major Impact)

The concept of bounded rationality refers to decisions made under conditions of uncertainty, insufficient information, and time constraints [19,24,26,29–31]. The pandemic resulted in high uncertainties [66], not only for maritime trade but also for the macroeconomic landscape. Under these circumstances, without any certainty in the oil price, future geopolitical concerns, and availability of the COVID-19 vaccine, any decision regarding investment in energy efficiency projects in shipping has been risky and based on bounded rationality.

Lack of Awareness, Training, and Guidelines/Lack of Knowledge (No Effect)

In general, this barrier refers to lack of technical knowledge and skills for operating energy efficiency measures [19,21,24,25], or in a broader sense, lack of awareness of energy efficiency concepts among seafarers [20,41,43]. This barrier did not appear to have been significantly affected by the pandemic, according to the focus group.

4.3.3. Policy Barriers (No Effect)

During the pandemic, the IMO sessions were conducted virtually, and by ignoring the minor effects of online sessions, it is assumed that the pandemic had no essential impact on the policymaking process and those barriers in the way of policymaking were persisting in the pre-pandemic situation. By adopting the draft of the energy efficiency short-term measures in November 2020 through MEPC 75, the IMO demonstrated an uninterrupted policymaking process.

4.3.4. Technical Barriers

Immaturity of Technologies (No Effect)

Doubt in maturity of an EE measure could act as a barrier for its deployment, as an immature technology can compromise the safety of seafarers and ships or affect the quality of shipping service [19,21,24,37,45,61]. On the other hand, the performance of an immature technology is in the veil of ambiguities [24,34,41,42]. As this barrier is inherent to the technology, no impact of the pandemic can be attributed to it.

Incompatibility between EE Measures/Practices (No Effect)

Possible examples of this barrier could be a contradiction between slow steaming and waste heat recovery system [20], and a contradiction between slow steaming and self-polishing coating [20,41,55]. The pandemic cannot affect this barrier in any way.

Contradiction between EE Measures/Practices and Ship Operation (No Effect)

It is sometimes difficult to take full advantage of the potential of an EE measure or practice due to ship operational features. For instance, the effectiveness of wind technology

is greater on ships that travel at a slower speed [22,25], or some restrictions in cargo operations due to wind sails on deck [24–26,35,39,55] could be highlighted. Events such as the COVID-19 pandemic could not have an impact on this barrier.

Inactivity of Technology Providers (Major Impact)

As a rule of thumb in the business, the level of production is in direct relation to demand. Accordingly, companies providing energy efficiency measures for ships could become demotivated by the frustrating level of deployment of their products onboard vessels. Under economic recession circumstances like the pandemic period, while shipping companies earn detracted revenue, under uncertain market and low fuel prices, investment in energy efficiency has no economic rationalization. Aside from the limitations imposed by the pandemic, research centers might also face difficulties in securing research funds, installation, and trial process at shipyards, and communicating with shipping companies, classification societies, and insurance companies.

Inertia in Port and Shipyards' Management (Major Impact)

The role of port infrastructure in shipping decarbonization may be discussed in areas such as alternative fuel bunkering arrangements, cold ironing, digitalization of port activities and supply chains, deployment of renewable energy technologies, and the use of energy efficient equipment in cargo handling [71]. Nevertheless, the willingness of the port management to implement these measures is crucial. Essentially, willingness is something that transcends economic conditions, as evidenced by the fact that in the economic prosperity season with a high volume of cargo transactions in ports, there is still a high resistance to adopting energy-efficient approaches. The pandemic impact on ports has harmed the willingness to engage in green port activities. Due to the reduced number of port calls and cargo transactions during the pandemic [65], the port's income was considerably reduced. Blank sailing as a prevalent practice resulted in many ports being excluded from the supply chain [5] leading to a modal shift, and as a result, ports had to offer higher discounts on their dues or increase the period for payback of arrears [72].

In the same way as ports, shipyards throughout the pandemic period were unable to implement fundamental changes in greening their procedures and equipment. The shipyards are expected to perform some corrective actions in their routine manufacturing processes in order to complete the energy efficiency retrofit works on vessels [19,23,26,41,55] that under pandemic circumstances with few orders regarding energy efficiency projects and less manpower might be viewed as being irrational. When shipyards encounter high levels of inertia to improve their efficiency during normal economic conditions, they may easily justify this resistance to change through a pandemic.

4.4. Impacts of the Pandemic on the Supply Chain (Major Impact)

Ship–port interfaces play a crucial role in enhancing shipping energy efficiency. On the other hand, the port–hinterland relationship must be addressed to realize its effect on shipping efficiency. The deterioration of the supply chain and global dislocation of both the supply and demand ends caused by the pandemic could affect ship energy efficiency.

As a result of the pandemic, many best practices in shipping efficiency have been disrupted, including virtual arrival, voyage and ship capacity planning, optimal routing, and slow steaming. Due to a drop in world trade and, consequently, port transactions [65,66], running mega-sized vessels was not profitable unless by practicing the blank sailing. Blank sailing by very large vessels has pointed some ports to be set aside from the supply chain and, in case they receive some call, they face a high volume of cargo at once with operational restraints in cargo handling and warehousing at ports as well as hinterland distribution [73]. During the pandemic, many cancellations by both shippers and carriers at the last moment without the usual notice periods have adversely affected the voyage and capacity planning [74]. By presenting information regarding ship capacity into and out of ports, clipper data [75] has been able to study the impact of blank sailing in relation

to port size. Another impact of the pandemic has been the cancellation of work shifts at ports due to the reduced traffic, sometimes without informing the inland shippers on time [5]. Furthermore, there was an imbalance in global distribution of empty containers, notably, the deficit in Europe due to the accumulation of containers at Chinese ports [76]. Reportedly, during the pandemic, the optimal routing, for instance, passing through the Suez Canal, has been replaced by sailing around the Cape of Good Hope. In this case, the cost of transit via the Suez Canal and low fuel price were drivers for re-routing [5,77], irrespective of the considerable increase in CO₂ emissions. Likewise, when the low fuel price can offer enticing sailing speed, the slow steaming practice could be overlooked.

5. Approaches and Recommendations for a Viable Ship Energy Efficiency

According to many maritime experts, shipping has demonstrated necessary flexibility during the pandemic. Recently, the appropriate adaptation has been observed, and best practices have been presented and implemented in a variety of maritime sectors. Training institutes in cooperation with IT companies have invested in e-learning and, reportedly, more ships have established electronic training platforms [78]. “Classification societies made allowances, including special survey deferrals ranging from three to six months” [64], and pioneer classes provided the necessary infrastructure to conduct remote surveys [78]. DNV GL opened a new operational center for remote surveys with a record of 300 undertaken surveys per week after February 2020 [79]. The first remote SIRE (Ship Inspection Report) inspection for an LNG carrier was conducted in September 2020 [80].

It should also be noted that the human element is a priority in the guidelines provided by maritime stakeholders, administrations, and authorities standing out [81]. In June 2020, the Maritime and Port Authority of Singapore (MPA) designated an accommodation vessel to establish a safe corridor to facilitate the overdue crew changes [82]. In late March 2020, a cruise ship has been remotely piloted passing through the Suez Canal using escort tugs to prevent the spread of coronavirus [83]. SSPA in Sweden as one of the world’s leading maritime research centers has tested the live streaming of Towing Tank tests in some projects and they believe that it can be a good alternative in the future [84]. These are some examples regarding shipping response to the restrictions created by the pandemic, but what about energy efficiency in the pandemic period?

The survival of the shipping economy during the pandemic, up to a high extent, has been owing to low fuel prices. In response, all stakeholders involved in shipping have to take proper actions toward energy efficiency. The following could be some approaches in this direction.

5.1. Need for More Stringent and Goal-Based Energy Efficiency Regulations

Current energy efficiency regulations, particularly those pertaining to ship operation, are extremely flexible [35,54] and provide optional elements without guaranteeing results. SEEMP does not require shipping companies to set goals or conduct energy audits, and even the EEOI which serves as the only KPI for measuring ship operational efficiency is voluntary [54]. One of the consequences of these non-decisive and non-preventive regulations is the unregulated speed of ships. Due to very low fuel prices, best practices in green ship operation, such as slow steaming and efficient routing, were neglected during the pandemic.

The IMO has adopted the GHG strategy intended to address these vulnerabilities in the current energy efficiency regulations, with the implementation of short-term measures beginning on 1 January 2023. As a result, existing ships built before 2013 will be subject to the EEXI standard, which is equivalent to the phase one of EEDI. SEEMP will incorporate a clear statement regarding the methodology and target for CO₂ reduction, and will be evaluated on a regular basis. Furthermore, the collection of data and the calculation of the CII will become mandatory to rate vessels from A to E in an effort to increase vessel efficiency transparency.

5.2. A Fair MBM in Favor of Both World Trade and the Environment

Many maritime experts view MBM as the ultimate policy solution to decarbonizing shipping. Global trade, in particular the economies of developing countries, may be adversely affected by MBM schemes that leverage fuel prices to increase shipping energy efficiency. As a result of low tax rates, there will be a less responsive scheme without satisfactory reductions in CO₂ emissions, while high tax rates will result in modal shifts and reduced competitiveness for developing countries. Assuming the future MBM is a bunker levy, the most suitable option could be a price-based mechanism where the tax rate is inversely proportional to the fuel price [54]. When the fuel price is high, the fuel tax will be reduced to protect the world trade, while when the fuel price is low (e.g., in case of the pandemic), the fuel tax will be increased in order to preserve motivation for green ship operation [54]. This option allows effective decarbonization while protecting the world's trade at the same time.

5.3. R&D Fund

To achieve the ambitious decarbonization targets in shipping, R&D activities based in universities and research centers are the most promising initiatives. Utilizing the renewable source of energy and alternative fuels are long-term measures in the recent IMO GHG strategy and research centers have invested a lot in this field. A greater and faster independence of shipping from fossil fuels can reduce the vulnerability of decarbonization in this industry to external events such as the COVID-19 pandemic. The provision of fiscal support to research and development activities may enable researchers to achieve their research objectives to a greater extent and in a more timely manner. The R&D Fund proposal submitted to IMO at the end of 2019 could be an appropriate approach to providing this monetary support [85].

5.4. Digitalization

Despite all its undesirable consequences, the pandemic played a significant role in the development of the digitalization of shipping. Through greater transparency and facilitating the flow of information through digital platforms, most of the deficiencies discussed in Section 4.4 about the supply chain deterioration can be moderated. Moreover, many of the mitigation measures adopted by the shipping industry in response to the pandemic, such as e-learning platforms, online surveys, and remote pilotage, are based on ICT and digitalization. It is possible to enhance and promote energy efficiency practices such as slow steaming, virtual arrival, voyage and capacity planning, and optimal routing through digital platforms tailored for maritime applications, such as electronic trade documentation, collaborative decision-making at ports, sea traffic management, and ship real-time monitoring.

5.5. Establishment of ERT (Emergency Response Team) at IMO

As a proactive measure, it may be appropriate to establish an Emergency Response Team at the highest level of IMO to respond properly and timely to the unexpected events occurring at overwhelming speeds and immense scales, such as the COVID-19 pandemic and the explosion in the port of Beirut. ERT members may represent leading and steering maritime organizations, such as BIMCO, ICS, and IAPH. With the aid of a detailed risk assessment, the ERT is capable of providing guidelines and best practices at the right time, and providing information about the latest developments through circulars. As an example, these unified guidelines would cover crew changes, vessel surveys, piloting, lay-up strategies, and any additional considerations for charter parties during the pandemic.

6. Conclusions

An examination of the barriers to energy efficiency through the lens of the COVID-19 pandemic, and an evaluation of recent news and mitigation activities undertaken by the maritime community and related stakeholders, may reveal that the transition to the post-pandemic era is based mainly on a short-term strategy, and the chronic lesions of global

warming and climate change have been overlooked. The COVID-19 pandemic has clearly shown the vulnerability of the wider ship's energy efficiency issue. The analysis of barriers to ship energy efficiency in this study confirms that these barriers have been strengthened under impact of the pandemic. Inadequate and lenient energy regulations (policy gap), economic crisis within shipping companies (low freight rates and a decline in charter markets), and extremely low fuel prices have been contributing factors to undermining the decarbonization of shipping during the pandemic. The development of digitalization in supply chain and ship/port management coupled with more stringent energy policies and a transparent MBM scheme can protect the process of ship energy efficiency from external factors such as the COVID-19 pandemic.

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Abbreviations

AIS	Automatic Identification System
BIMCO	Baltic and International Maritime Council
CFD	Computational Fluid Dynamics
CII	Carbon Intensity Indicator
CSR	Corporate Social Responsibility
DNV GL	Det Norske Veritas and Germanischer Lloyd
EE	Energy Efficiency
EEDI	Energy Efficiency Design Index
EEOI	Energy Efficiency Operational Indicator
EEXI	Energy Efficiency Existing Ship Index
GHG	Green House GAS
HSFO	High Sulphur Fuel Oil
IAPH	International Association of Ports and Harbors
ICS	International Chamber of Shipping
IMO	International Maritime Organization
KPI	Key Performance Indicator
MBM	Market Based Measure
MEPC	Marine Environment Protection Committee
NPV	Net Positive Value
ROI	Return of Investment
SEEMP	Ship Energy Efficiency Management Plan
TEU	Twenty-Foot Equivalent
UNCTAD	United Nations Conference on Trade and Development
VLSFO	Very Low Sulphur Fuel Oil

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