Global maritime carbon footprint: EU policy diffusion

Deliverable D3.7: Discussion papers on the impact on the EU's main partners dealing with the respective dimensions (Paper 3)

Michael Petroni, Climate Analytics

Andrzej Ancygier, Climate Analytics

WP: 3.2

Discussion paper, final version

30.04.2023

Document information	
Project name:	4i-TRACTION
Project title:	Transformative Policies for a Climate-neutral European Union (4i-TRACTION)
Project number:	101003884
Duration	June 2021 – May 2024
Deliverable:	D3.7 Five discussion papers on the impact on the EU's main partners dealing with the respective dimensions (Paper 3)
Work Package:	WP3: International dimension: Lessons learned and future prospects
Work Package leader:	Climate Analytics
Task:	Task 3.2: Assessing the global impact of EU's climate action
Responsible author(s):	Michael Petroni, Andrzej Ancygier, Olivia Waterton; Climate Analytics
Peer reviewed by / on	Reviewer 1: Jasper Faber; CE Delft; 04/2023 Reviewer 2: Lau Blaxekjær; Global Maritime Forum; 04/2023
Planned delivery date:	30/04/2023
Actual delivery date:	28/04/2023

Dissemination level of this report	
PU	Public

Suggested citation

Petroni, Michael; Ancygier, Andrzej; Waterton, Olivia (2023): Global maritime carbon footprint: EU policy diffusion. Climate Analytics. Berlin.

Acknowledgements

The opinions reflected in this publication are those of the authors and the 4i-Traction consortium, they do not purport to reflect the opinions or views of the Global Maritime Forum and the Getting to Zero Coalition as external reviewers of this publication.

The information and views set out in this report are those of the author(s) and do not necessarily reflect the official opinion of the European Union. Neither the European Union institutions and bodies nor any person acting on their behalf may be held responsible for the use which may be made of the information contained therein.

Disclaimer

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 101003884.

Content

List of tables

List of figures

Abbreviations

CfD	Contracts for Difference
EC	European Commission
ETS	Emissions Trading Scheme
GHG	Greenhouse Gases
HFO	Heavy Fuel Oil
HFOe	Heavy Fuel Oil equivalent
IMO	International Maritime Organisation
LDC	Least Developed Countries
MBM	Market Based Measures
MEPC	Marine Environment Protection Committee
MS	Member State
RLF	Renewable and Low Carbon Fuels
RFNBO	Renewable Fuels of Non-Biological Origin
SIDS	Small Island Developing States
SZEF	Scalable Zero Emission Fuels
TtW	Tank-to-Wake
WtW	Well-to-Wake

1. Introduction

In its European Climate Law, the European Union (EU) has committed to a legally binding goal of reaching climate neutrality by 2050. With the launch of the Fit-for-55 package in July 2021, and additional policy initiatives proposed in the framework of REPowerEU in May 2022, the EU has provided a decarbonisation roadmap.

The Fit-for-55 Package includes maritime regulations, making the EU the first regulator globally to introduce legally binding measures directly aimed at reducing emissions from the international maritime shipping sector.

Policy diffusion is where policies adopted by one country are influenced or affected by other countries' policies. This may happen as a result of learning, competition, coercion and emulation (Gilardi & Wasserfallen, 2019). Policy diffusion here is identified as either the (1) adoption of similar policy tools to those developed by the EU, (2) development of policies by third countries' authorities that in turn will support reaching the objectives of EU policies, and (3) diffusion of benefits such as cooperation, capacity building and finance to non-EU countries.

The EU's decision to develop and implement a shipping regulation presents an opportunity to become a global leader on shipping policies by presenting practices which could be replicated by third countries. With this in mind, the aim of this report is to assess how the impact of climate action in the EU could potentially influence policy decisions that could result in greater ambition for emission reductions in the international sector and non-EU countries, with key consideration towards ensuring an equitable transition.

To this end, the report seeks to address two overarching questions; (1) How could the ambition set by the EU policy proposals have flow through effects for emissions and impacts in third counties? and (2), how can the EU facilitate policy diffusion to support third countries' maritime emissions reductions through its own policy approaches and available international mechanisms?

For this purpose, we examine key elements of EU ETS expansion to the maritime sector and the FuelEU Maritime proposals. We identify key countries in the maritime sector, and of importance to the EU, in which EU policies could impact and/or be replicated. We examine what the impacts these changes will have for third countries.

This assessment was conducted by compiling and analysing existing literature to extract key lessons learned with specific consideration for capacity building and cooperation in the context of an equitable transition. Based on this assessment and a workshop with relevant experts in the field, several recommendations are put forward.

1.1 Context and background

In 2018, the Greenhouse Gas (GHG) emissions in the shipping sector grew to 1076 $MtCO_2e$, a roughly 36% increase from 2008 emission levels of 794 $MtCO_2e$. Emissions in the sector are projected to continue growing with a projected increase of 90-130% by 2050 compared to 2008 levels (IMO, 2020a). Shipping transport constitutes about 80% of global trade, and shipping emissions account for almost 3% of global GHG emissions, with about 99% of those emissions generated from the fuel combustion on vessels (UNCTAD, 2022a).

About 18% of these emissions emerge from vessels (regardless of flag state) calling at European Economic Area (EEA) ports (European Parliament, 2022; Søgaard, & Blaxekjær, Lau, 2022). In 2019, the EU's domestic and international shipping accounted for 154 $MtCO_2e$ (14%) of the EU's transport emissions. Carbon dioxide emissions from extra-EEA voyages represented 62% of emissions of EU related shipping, with 32% from internal EU voyages and 6% from vessels at berth in EEA ports (European Commission, 2021b).

The importance of maritime shipping to global trade has shown an increasing trend in the recent years, however some projections show that this growth will slow down in the future. Regulatory and policy measures required to support further action to decarbonise the sector include operational and technical approaches such as increasing energy efficiency of vessels, digitalisation of logistics, speed optimisation and the rapid uptake of scalable zero emission fuels (SZEFs) as fast as possible (Dong et al., 2022; Krantz, Randall et al., 2023; Vidović et al., 2023). Decarbonising the maritime sector will also require enabling policies to advance and accelerate investment in SZEFs, vessels, and infrastructure (Søgaard, & Blaxekjær, Lau, 2022). Such a transition will have varying impacts for different states, particularly vulnerable countries such as Small Island Developing States (SIDS) and Least Developed States (LDCs), many of which are heavily reliant on maritime trade, and therefore key consideration to an equitable transition must be manifest in policy design.

Alternative fuels to drive emission reductions in the sector include green ammonia, hydrogen, methanol and synthetic fuels derived from renewable energy sources and battery storage (GMF, 2021). Green hydrogen has high scalability potential and globally, the push for hydrogen production adds to its potential. There are no commercially available vessels at present for ammonia powered vessels (DNV, 2022; Faber, Kleijn, et al., 2021), but the first dual-fuel ammonia ships are expected to be delivered between 2025 and 2030 (Mærsk Mc-Kinney, 2022a). Projects investing further into the development of fuel production, on-board ship technology and bunkering infrastructure to support zero emission fuels have increased between 2016 and 2022 (**Table 1**). The majority of these are located in Europe, followed by Asia and North America (GMF, 2021; Kilemo, Heidi et al., 2022). Methanol appears to be the most likely immediate zero emission solution (provided it is sourced from renewable energy sources) as the fuel is compatible with existing on-board engines (IRENA, 2021).

Table 1: Number of zero emission fuel related projects globally in 2022.

Project	Hydrogen	Ammonia	Methanol
On-board ship technology	~45	~40	~26
Bunkering infrastructure	~22	~12	~2
Fuel Production	~47	~24	~10

Source: (Kilemo, Heidi et al., 2022)

Since at present, zero emission fuels are more costly than their fossil fuel counterparts, without policy and regulatory intervention the industry is unlikely to make the necessary technological and operational changes to their fleets (IEA, 2021; IMO, 2020a; Smith, 2022). The existing IMO policy measures are not in line with 1.5°C compatible emission reduction pathways. An assessment by the Climate Action Tracker rates the shipping sector's 2030 target as highly insufficient, as it is consistent with warming between 3°C and 4°C (Climate Action Tracker, 2022). By the end of 2023, the IMO will agree to, and subsequently adopt, a strategy which is expected to have more ambitious targets, while also negotiating new mid-term measures to achieve them.

In 2022, about 30% of the world's ships were owned by EU companies. In comparison, Chinese (including Hong Kong) and Taiwanese companies account for 20%, while Japan 12% and the U.S. a mere 3% (UNCTAD, 2022b). With almost a third of the global fleet owned by EU shipping companies, the EU has significant influence over the sector.

Five of the EU's thirteen legislative proposals in the framework of the "Fit for 55" package have measures that will result in emissions reductions from the maritime sectors directly from the revision of the EU ETS and FuelEU Maritime Regulation, and indirectly though the Alternative Fuel Infrastructure Directive (AFIR), revision of the EU Taxation Directive and, the revision of the Renewable Energy Directive (RED III).

FuelEU Maritime creates the demand and sets a trajectory for zero emission fuels. The EU ETS intends to provide economic incentives to shift to cleaner fuels and technologies and supports the transition through recycling of revenue. Additionally, the revised Renewable Energy Directive creates the supply of these fuels to match the demand, while the Alternative Fuel Infrastructure Regulation regulates the infrastructure needed. Measures proposed within these documents address several interconnected challenges facing the maritime sector.

2. Proposed EU decarbonisation policies for maritime sector

The Commission's proposals for the FuelEU Maritime Regulation and amendment of the EU ETS directive have been formally adopted in the early 2023. Both pieces of legislation apply a "technology neutral" approach, giving shipping companies flexibility on how they must achieve their fleet-wide emission reduction targets. In this section we briefly examine the key elements of the EU's ETS directive amendment in terms of its impact on the maritime sector, and FuelEU Maritime regulation, and analyse their impacts based on: (i) potential emission reductions, and (ii) impacts on non-EU countries including (iia) administrative burden, (iib) competitiveness, (iic) finance and (iid) compatibility with existing policy mechanisms.

2.1 FuelEU Maritime Regulation

Policy description and recent developments

The FuelEU Maritime Regulation sets fuels standards that aim to increase the uptake of alternative fuels used by vessels greater than 5000GT in size. The proposal sets out binding emissions reduction targets for GHG intensity in maritime fuels. The targets will increase in stringency over five year intervals starting with 2% reduction in 2025, 6% in 2030, 11% in 2035 and 75% by 2050. Additionally, a compliance mechanism applies a penalty to ship owners unable to achieve the target GHG intensity reductions of their fleets set by FuelEU Maritime (European Commission, 2021b). The revenues generated will be directed towards maritime decarbonisation projects (European Council, 2023).

The Regulation regulates well-to-wake (WtW) emissions and covers carbon dioxide, methane, and nitrous oxide. Additionally, the proposal introduces an obligation to vessels and ports to use onshore power when at berth in ports for cargo and passenger ships from 2030. The FuelEU Maritime Regulation fuel standards will apply to all vessels interacting with European Economic Area (EEA) ports, regardless of flag state and so in this regard, the regulation is non-discriminatory to any state (European Commission, 2021b).

Strength of measures:

The proposal makes two important inclusions to ensure broader emission coverage. First, the well-to-wake (WtW) scope ensures that life cycle emissions of marine fuels, which includes upstream emission from land use, are accounted for (Mærsk Mc-Kinney, 2022b). Secondly, the regulation includes methane and nitrous oxides among the GHGs covered. The inclusion of methane is of particular importance due to significant emissions resulting from methane slippage (Wissner & Cames, 2022). This should make LNG less attractive in the long run. The increasing

stringency of GHG intensity reduction targets over time provides a clear signal to industry about the long-term regulatory approach. Given the clear regulatory signal, shipping companies have already started taking steps to decarbonise their operations, to ensure long term compliance or risk losing access to EU ports and market.

Regulatory shortcomings of measures:

By focusing only on emissions intensity reduction targets, without mandated quotas for the uptake of specific zero carbon fuels (IEA, 2022), the proposal weakens the incentive for necessary volume of alternative fuels, allowing ship operators to prioritising low hanging fruit measures such as improving energy efficiency, speed optimisation, and what the regulations consider as "low carbon fuels". This includes LNG, which cannot be considered as a low carbon transition fuel as it is still a fossil fuel with high lifecycle GHG emissions (Wissner & Cames, 2022).

Furthermore, the initial GHG intensity reduction targets (2% by 2025 and 6% by 2030) are too low to illicit the rapid response needs to scale up zero carbon fuels (Transport & Environment, 2022a). As a result, the FuelEU Maritime Regulation is likely to encourage uptake of other fossil fuels like LNG. Replacing one fossil fuel with another will not lead to the decarbonisation of the sector. Given the average lifespan of vessels (around 30 years), this could represent a long-term lock-in investment that jeopardises the necessary sectoral emission reductions this decade (Nelissen et al., 2022). The lack of stringency in targets and penalties will likely not be sufficient to incentivise the necessary level of renewable fuel and technology development needed before 2030. Given that at present cheaper LNG and biofuels can deliver on the GHG reductions required by 2025 and 2030, the demand for RNFBOs is greatly diminished (Faber, Meijer, et al., 2022).

Lastly, the penalty-based compliance mechanisms, while a critical element, does not set high enough financial penalties to deter non-compliance. With the large financial capacity of major shipping companies will not disincentive them enough to make their fleet's emissions intensity reductions (Transport & Environment, 2022a). These are major limiting factors to emission reduction potential.

Impacts on third countries

As targets become more stringent, vessels interacting with EEA ports will increasingly need to source zero emission fuels over time, including from third countries that comply with fuel certification (European Commission, 2021b). However, planning to do so requires action in the short and medium terms. With the eventual higher costs for shipping companies to bunker in European ports, companies may choose to bunker outside the EU, potentially global maritime fuelling and routing logistics (Faber, van den Berg, et al., 2021). Shifts in maritime trade and logistics may fuel tensions with or between third countries over changes in competitiveness associated with increasing trade costs (ECSA & ICS, 2020).

Winners and losers in the bunkering trade can be based on a country's ability to transition their bunkering fuel production. This may create added pressure for major bunkering hub nations to make initial investments to supply the transition global fleet with zero emission fuels or risk losing their supremacy in sector to other port states taking the lead and potentially becoming new major bunkering hubs. For example, currently Singapore and Fujairah (United Arab Emirates) currently do not yet have any ammonia or methanol storage port facilities (Faber, Kleijn, et al., 2021). Vulnerable countries such as Small Island Developing States (SIDS) and Least Developed Countries (LDCs), which are heavily reliant on maritime trade, would pose greater socio-economic impacts through increasing trade costs and cost of living (Kotzampasakis, 2022). At the same time, the requirements introduced in the FuelEU Maritime Regulation may accelerate shift towards renewable fuel in countries with the capacity and ability to do so. However, some countries may also see an increase uptake of lower carbon intensity fossil fuels such as LNG and LPG as transition fuels (Christodoulou & Cullinane, 2022), fuels which are not aligned with 1.5ºC compatible decarbonisation pathways.

2.2 Expanding the EU ETS to maritime sector

The EU ETS expansion to the maritime sector is the first attempt in the world to cover maritime sector emissions by a carbon pricing mechanism. The ETS works on the basis of the cap-and-trade principle. By requiring shipping companies, including charterers, of container and passenger ships over 5000 GT (gross tonnage) to purchase emissions allowances corresponding to their emissions, it will increase the competitiveness of zero and "low carbon" [1] alternatives (DNV, 2023; European Commission, 2021c, 2022a), once the price of carbon is high enough to make maritime fossil fuels more expensive.

The regulation covers Tank-to-Wake (TtW) emissions and carbon dioxide, methane, and nitrous oxide gases. There will be a gradual increase in volume of emissions covered by the EU ETS, from 40% of the maritime emissions in 2024, 70% in 2025 and 100% in 2026. Allowances will have to be surrendered by September 30th of the following year. The emissions covered by the expansion of the EU ETS will cover carbon dioxide, methane and nitrous oxide, and include:

- 100% of emissions from intra-EU voyages (voyages between any two or more EEA ports)
- 50% of emissions from international voyages to and from an EEA port and a third country.

While the EU ETS will apply only to vessels larger than 5000GT, the reform of the EU ETS requires monitoring of emissions also from smaller vessel being general cargo and offshore service vessels following review in 2026 (DNV, 2023).

[1] The language used for "low carbon" is reflective of what is used in the Commission Proposal. Additionally, zero emission fuels under the Commission definition in the Revised Renewable Energy Directive (RED III) include advanced biofuels and biogas, renewable fuels from non-biological origin (RFNBO) and recycled carbon fuels (DNV, 2023; European Commission, 2022b).

To help operators meet the requirements resulting from the expansion of the EU ETS coverage, the Innovation Fund will be allocated with additional resources resulting from the sale of 20 million emissions allowances (Council of the EU, 2022). At the current price of over 90 EUR/allowances this would result in over 1.8 bn EUR (Prosertek, 2022), that must be dedicated to decarbonising shipping activities in addition to any funding that member states (MSs) wish to allocate from national budgets.

It has been estimated that the total emission coverage of maritime emission under the ETS would be 583 $MtCO_2e$ between 2023 and 2030 (Transport & Environment, 2022b).

Strength of measures:

One major strength of the policy is that from 2026 there will be no free allowances to shipping companies, ensuring that fossil fuels are not indirectly subsidised. Another strength of the regulation is that beyond carbon dioxide it also includes methane and nitrous oxide, which will be phased into the MRV reporting system from 2024 and into the EU ETS by 2026. This means that until 2026 only carbon dioxide will be traded. In future reviews of the directive, the EU will consider expanding the EU ETS coverage to emissions representing the full life cycle of fuels.

Lastly, safeguards were introduced for future reviews to ensure the ETS will be combined to operate with any future international market-based measure (MBMs) developed through the IMO, ensuring continuous geopolitical progress and more effective and robust emission reductions for the international shipping sector.

Regulatory shortcomings of policy

The EU ETS maritime component includes several elements that reduced the impact of the measure. Firstly, the 50:50 geographic scope will omit a significant amount of emissions from consideration (Transport & Environment, 2022c). Also, contrary to the FuelEU Maritime Regulation, which reflects WtW emissions when assessing the emissions intensity of the fuel, the reform of the EU ETS only covers tank-to-wake (TtW) emissions. This limits the transition potential for upstream decarbonisation processes. As a result, this could theoretically allow grey hydrogen or fuels derived from it (e.g. ammonia or methanol) to be used and undermines truly zero emission fuel transition (Wissner & Cames, 2022). The phase in of gas coverage to include methane and nitrous oxide while positive, will only be accounted for after 2027, which means methane slippage emissions are unaccounted for until then.

The EU ETS design could pose a risk to carbon leakage through evasion of EEA ports and pursuant shipping shift to neighbouring non-EEA transhipment hubs (such as in the Mediterranean) where vessels would berth at transhipment ports outside the EEA to avoid applying the 50% emission coverage of the full voyage. This could test the limits of ports' capacity to deal with the increased traffic entering neighbouring third countries, in turn affecting the logistics of maritime trade. This

would undermine the purpose of the directive and possibly even result in increased emissions through additional shipping distances (Lagouvardou & Psaraftis, 2022; Nelissen et al., 2022; Pons et al., 2021). The likelihood of avoidance is dependent on several factors (emission price, costs of non-EEA ports vs EEA port calls, transhipment costs and long initial and final voyages to or from EEA ports), which would determine whether avoidance makes financial sense for shipping companies (Faber, Leestemaker, et al., 2022). For some shipping lines it may be beneficial but not for all, a fact which will become more evident with time. Additionally, the risk is lowered by the fact that many neighbouring non-EEA ports lack the capacity to accommodate an increase in transhipment needs, reducing the risk of port evasion. In addition to the 50% emission of short leg voyages from neighbouring non-EEA transhipment ports to EEA ports, the ETS will also apply an additional coverage 50% emissions of the voyage to that non-EEA ports located 300 nautical miles from an EEA port. To avoid uncertainties, the EU will publish a list of these non-EEA transhipment ports (European Parliament, 2022; Hagberg, 2022).

Impacts on third countries

On the basis of added administrative impact and compatibility with existing policy mechanisms, the maritime EU ETS will follow the existing framework set under the EU MRV system which has already been in force since 2018 and which third countries and shipping companies have already had time to familiarise themselves with the documentation of carbon dioxide emissions from vessels interacting with EEA ports (IMO, 2020a). However, the additional verification processes that may come with the EU ETS, which may generate administrative burden for Small and Medium Enterprises (ECSA & ICS, 2020) and may add delays to logistical capacity of third country ports.

In the short term, the initial higher cost of zero emission fuels may drive up transport costs from container shipping and cruise liners, which be transferred onto the consumer. In the long-term, when the ETS carbon price is higher than the fossil fuel price variability, the EU ETS will increase the cost competitiveness of alternative zero emission fuels. This could make fossil fuel-operated maritime transport costlier for some countries and shipping companies operating outside of the EU (Kotzampasakis, 2022; Pons et al., 2021). The impact to SIDS and LDCs will be greater where there is direct trade between these countries and the EU. While most SIDS and LDCS do not currently host any major bunkering hubs (Singapore being one major exception), the impact of increasing fuel prices may be mitigated if ships bunker alternative fuels elsewhere. However, certain infrastructure improvement would still be required to supply renewable onshore electricity in ports, which in turn would incur additional costs for LDCs and SIDS.

2.3 Ambition gap and discussion

In advancing regulation to decarbonise shipping at a regional level, the EU has provided a strong policy signal to the maritime industry. This foresight can be considered as an advantage to EU shipping industry – one that would have ripple effects across the globe.

The phase out of free allowance allocation is a major lesson learned for the EU in its designing of the maritime ETS. Without mandating full surrender of allowances and ringfencing revenues specifically back into maritime decarbonisation efforts, there will be a missed opportunity for driving investment in the decarbonisation of the sector. Furthermore, states and companies may otherwise put revenues into ineffective carbon offsetting projects to account for their emissions instead facilitating necessary decarbonisation action in the sector (European Parliament, 2022; Wissner & Cames, 2022).

Even with the weaknesses of the FuelEU Maritime Regulation and amendments of the EU ETS referring to the maritime sector, these two pieces of legislation have prompted a response from industry to be compliant with the new EU obligations and potentially move the dial in the right direction at international level prompting international market-based measures (MBMs) and fuel standards.

The revenues being generated under the EU ETS, even with a 50:50 geographic scope, covers trade with non-EEA port countries. Despite this partial coverage of transport from third countries, there is no mechanism in which these countries can benefit from the EU-centralised funds raised through revenues, to assist in their own maritime decarbonisation efforts (Parker et al., 2021). While some countries may be capable of developing their own domestic emissions trading schemes to charge for the other 50% and generate revenues themselves, most countries, especially SIDS and LDCs, may not have the capacity to do so. To avoid any negative repercussions to SIDS and LDCs from being left behind regional policy measures, equity must be built into the design from the beginning.

3. Mechanisms of diffusion

In this section we examine the possible drivers of diffusion for the EU policies in maritime sector by first examining impact of the EU's policies on other regions. This is followed with an assessment of how and why the EU pushed forward to regulate its shipping emissions instead of waiting for more ambitious emission reduction policies to being adopted by the IMO. On this basis we formulate recommendations on how emissions reduction in the global maritime carbon footprint can be accelerated.

Studies show that in order to be aligned with the Paris Agreement temperature goal, the share of scalable zero emission fuels (SZEFs) must reach 5% of the global share of international shipping fuel mix, or 15% for domestic shipping, by 2030 (Baresic, Rojon, et al., 2022a; DNV, 2022; Pandej et al., 2022). Subsequent benchmarks for international shipping will require 27% share of SZEFs by 2036, 93% by 2046 and 100% by 2050 (Osterkamp et al., 2021). To put this into context, this 5% SZEFs share would require substituting fuel energy demand by roughly 20 Mt HFOe (Smith, Shaw, & Roberts, 2022).

To accelerate emissions reduction in the maritime sector the EU may have an impact on emissions reduction framework at a global level in two ways. Firstly, the EU's expansion of the EU ETS to maritime sector may prompt the IMO to move forward with an agreement to a combination of policy measures of which should include a global market-based measure (MBM) regulation at the MEPC80[2] session in 2023. Secondly, if a global MBM system is not adopted, the emergence of several regional carbon pricing systems may be prompted following the EU's own initiative. The adoption of regional carbon trading hubs may occur in the Asia-Pacific region, with China, Japan and the Rep. of Korea already having some form of cap-and-trade system in place but not extended to shipping (ICAP, 2022).

Box 1: Existing case of EU policy diffusion in maritime sector - EU MRV to IMO DCS

The case for the EU's role as a driver of development of a more ambitious emissions reduction mechanism in the maritime sector builds on the success the EU has had in the past with the EU MRV regulation. The EU had initial intentions of developing a global monitoring system for shipping emissions communicated as early as 2009 but with subsequent failures to reach consensus through the IMO framework. With the growing urgency to address the issue of climate change, in 2013 the EU began procedures for EU MRV regulation, eventually being adopted in 2018. The EU MRV was introduced to monitor and report on carbon dioxide emissions from vessels voyaging to and from the EU, with the subsequent gradual long-term intentions to define emission reduction targets and facilitate the introduction of MBMs (Adamowicz, 2022). Following this the IMO in 2016 initiated the steps for the eventual adoption of the global Data Collection System (DCS) for reporting on ship fuel oil consumption (Wissner & Cames, 2022). The push from the IMO to adopt the DCS was promoted to avoid having a fragmented regulatory framework on GHG emission reductions. Considering this, the EU has demonstrated how its pollical influence and its position as a key player in the global shipping sector has worked to advance regulatory framework advancing emissions reduction.

3.1 Impact of the EU's policies on other regions

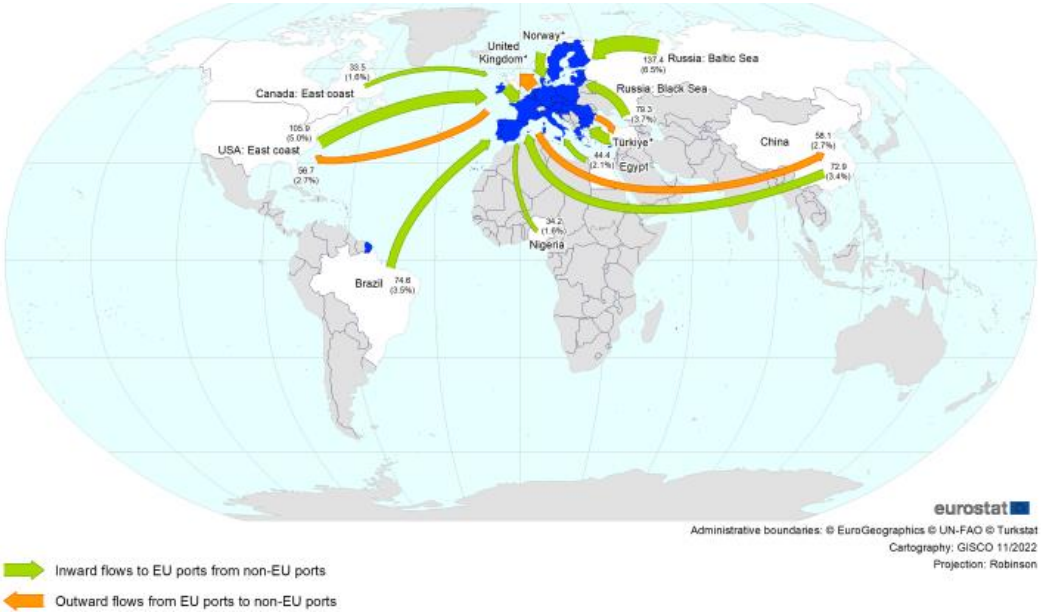
Geographic prioritisation of key strategic areas and maritime players may provide key insight into where policy diffusion and equitable transition efforts can be given further attention by policymakers. One study estimates the expansion of the EU ETS coverage to include maritime emissions will have an impact on 100 third country 'flag states', representing 67% of fleet participating in the EEA trade. An estimated 60% of the EU ETS maritime revenues will be generated from voyages with third countries. Between 2,000 to 2,500 companies will be affected with half located in non-EU/EEA countries (ECSA & ICS, 2020). The volume of freight passing between EU and third country ports along deep-sea routes shows that China, U.S., Canada, Brazil,

[2] The International Maritime Organisation's Marine Environment Protection Committee 80th Session

and Nigeria are critical to EU trade and therefore to external decarbonisation interest for the EU (**Figure 1**).

Figure 1: Extra-EU flows of freight handled in main ports with third countries in 2021.

Gross weight of freight in million tonnes and percentage share.



Source: (European Commission, 2021a; Eurostat, 2022)

With the magnitude of maritime trade flowing through developed countries and China, domestic regulatory and financing policy action aimed towards zero emission shipping efforts can cover a significant burden of cost to decarbonise the sector. The EU, US, UK and China combined, account for 40% of voyage emissions to and from these countries but have regulatory coverage of 84% of the global fleet calling at their ports. This means that shipping companies would accelerate further technology development and uptake by shipping companies (Transport & Environment, 2022b). Developing domestic decarbonisation policies much of the administrative and regulatory burden would fall on developed rather developing countries. Ports will play a crucial role in decarbonisation of the maritime sector due to their role as hubs for distributing alternative fuels. This concerns especially the major bunkering hubs in the world, such as Singapore, Fujairah (UAE), Rotterdam (the Netherlands), Hong Kong (China) and Busan (Rep. of Korea) (European Commission, 2021b; IRENA, 2021).

Assessing which countries have existing understanding and experience with similar policy tools employed by the EU can be useful in understanding their potential ability to adopt similar policies as well as their capability in dealing with knock-on implementation effects of the EU proposals. As of February 2023, there were 39 national or sub-national carbon pricing initiatives already being implemented, scheduled or under construction (World Bank, 2022). Selected countries

relevant to the EU and global maritime, that may likely be impacted by the EU's maritime legislation (ECSA & ICS, 2020, 2021; European Commission, 2021b) are outlined in **Table 2**, also highlighting their experience with ETS systems and financial incentives supporting emission reductions actions at port level. Energy demand of bunkering fuels between countries provides an indicator of the quantity of zero emission hydrogen derived fuels (green hydrogen, ammonia and methanol) that could substitute fossil fuels in the maritime sector (Smith, Shaw, & Roberts, 2022). For EEA ports as a whole, the potential energy demand is estimated to 5.5 MtHFOe that can be substituted for hydrogen derived fuels, with the potential application to 5,271 vessels. This ranks the EU third in the world after China (6.6 MtHFOe) and Japan (6 MtHFOe) (UMAS & UCL, 2022).

Table 2: Third countries of importance to shipping to the EU and their current experience with similar and other policy tools.

Region	Country	Energy Demand (kt HFOe)[1]	Vessels (No.)[2]	Significance to EU shipping[3]	ETS[4]	Financial incentives[5]
Asia	China	6581	4629	MTP, MBH, MSB	Yes	No
Asia	Singapore	772	664	MBH	No	Yes
Asia	Japan	6046	3598	MTP, MSB	UD	Yes
Asia	Rep. Korea	1695	2315	MTP, MSB	Yes	Yes
Middle east	UAE	302	220	MBH	No	No
Middle east	Saudi Arabia	244	184	MBH	No	No
Europe	Turkïye	485	665	NEP	UD	Indirect - EU
N. America	USA	3192	1508	MTP	Partial	Yes
N. America	Canada	806	738	MTP	Yes	Yes
S. America	Panama	NA	NA	MBH	No	No
S. America	Brazil	1765	679	MTP	Yes	Yes
Africa	Morocco	59	112	NEP	No	No
Africa	Nigeria	NA	NA	MTP	UD	No

MTP: Major Trade Partner; MBH: Major Bunkering Hub; NEP: Neighbouring External Port; Major Ship Builder: MSB. UD: Under Development. Sources: [1] (UMAS & UCL, 2022); [2] (ECSA & ICS, 2020; UNCTAD, 2022b); [3] (European Commission, 2021a); [4] (Camargo-Díaz et al., 2022; ICAP, 2022); [5] (Environmental Ship Index, 2022).

From the countries identified in **Table 2**, China, Japan and Rep. of Korea have the potential to realise significant change to the global fuel transition due to their high energy demand in the maritime sector (6.6 MtHFOe, 6 MtHFOe and 1.7 MtHFOe, respectively) and vast fleet sizes (4,629; 3,598 and 1,695, respectively). While Singapore is a major bunkering hub their own fleet size is relatively small and therefore also the potential energy demand shift compared to other Asian countries. Furthermore, China and Rep. of Korea have an experience in ETS mechanisms in other sectors, while Japan is currently in the process of developing their ETS mechanism development (Toft Valuer, 2022; Yum et al., 2022). Japan and Rep. of Korea have introduced financial incentives at port level for their shipping sector (Environmental Ship Index, 2022).

These countries have expressed concerns with the EU ETS regional approach to regulating international maritime shipping, preferring to have a standardised international system (DNV, n.d.). However, some indications suggest that China at least is following the EU's developments closely to possibly replicate the EU's approach (Chambers, 2021; Fang-Ting Cheng, 2020). In this case, on option towards bridging two regional ETS mechanisms would require bilateral cooperation to address challenges of compatibility ETS systems where shipping activities overlap.

Policy diffusion of carbon pricing mechanisms to different countries can be facilitated through proper linkage design mechanisms between the different national or regional systems. Linkage design must accommodate compatibility of several design elements such as legal basis, MRV system, political feasibility, price management mechanism, market liquidity, coverage, carbon leakage, offset rules and allowance allocation (Fang-Ting Cheng, 2020; Pan et al., 2021). Previous attempts by the EU to link its emissions trading scheme to other national systems such as those of Switzerland and Australia turned out to be challenging.

The UAE and Saudi Arabia dominate the bunkering fuel supply for the Middle East, and both have a sizeable potential shift in energy demand to hydrogen derived fuels, (0.3 MtHFOe and 0.2 MtHFOe respectively), to transition to hydrogen derived fuels combined with existing projects to boost hydrogen production in their countries. However, neither have carbon trading schemes. While seemingly no direct maritime decarbonisation financial incentives are in place, Saudi Arabia is investing in green hydrogen development projects (Government of Saudi Arabia, 2022).

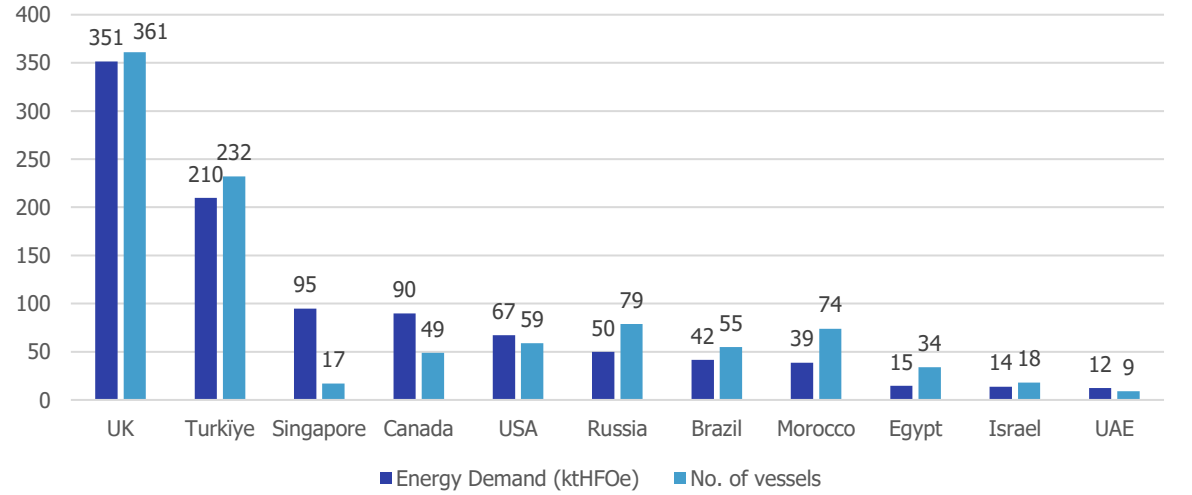
The US ranks fourth after the EU in the potential to shift 3.2 MtHFOe to zero emission fuels, accounting for 1508 vessels. At the same, the US has followed in the EU's footsteps by adopting new legalisation, the 'Clean Shipping Act', in July 2022, that establishes carbon intensity fuel standards for fuels used in certain vessels (U.S. Government, 2022).

Figure 2 shows the largest opportunities to substitute the equivalent volumes of hydrogen-derived fuels required to cover demand for fossil fuels (HFOe) and vessels between the EEA and third countries. The largest bilateral potential to substitute energy demand to hydrogen derived fuels between EEA ports (i.e. EU and Norway) will be with neighbouring countries (UMAS & UCL, 2022). Due to the high connectivity between ports and frequency of voyages, with the added factor of transhipment hubs located outside the EU, neighbouring UK and Turkīye possess the largest potential to transition fuels and ships compared to all countries globally. Russia, Morocco,

Egypt and Israel show lower energy demand needs with EEA ports, but still ranking within the top ten globally.

In relation to long distance potential for deep-sea trade, Singapore, Canada, the US and Brazil will be key partners as they are key trade partners for the EU with high port connectivity. Potential energy demand shift potential with China, Japan and South Korea rank relatively low, likely due to the lack of direct connectivity with the EEA ports. Singapore and UAE could in this case absorb much of the potential energy demand needs to facilitate trade between EEA ports and Fareast countries.

Figure 2: Top country pairing opportunities for potential fuel energy demand and number of vessels shift between EEA and non-EEA countries.



Source: Data from (UMAS & UCL, 2022)

In order to meet the EU's hydrogen fuel demand, as part of the RePowerEU initiative, by 2030 the EU will seek to accelerate hydrogen production to produce 10Mt of green hydrogen and import and additional 10Mt (European Commission, 2023). Given the high demand pairing between the EU and its neighbouring countries the EU's accelerated fuel transition may have spill over effects such as neighbouring non-EEA ports to absorb the EU supply of zero emission fuels, neighbouring non-EEA to access potential funding opportunity with the EU under regional cooperation or new partnerships agreements with neighbouring countries to further develop green hydrogen-based fuel production and capacity.

3.2 Policy diffusion through the IMO framework

The IMO is the body responsible for creating regulatory framework for the international maritime shipping sector. The present Initial GHG Strategy (2018) aims to cut shipping emissions by 50% by 2050 and till now has introduced three main short-term measures aimed at increasing the

energy efficiency of ships. These measures include the Ship Energy Efficiency Management Plan (SEEMP), the Energy Efficiency design Index (EEDI) and the Carbon Intensity Index (CII, which came into force at the start of 2023) (IMO, 2018).

As of February 2023, except for the EU ETS, there is no other emissions trading mechanism covering emissions from maritime sector. Over the years there have been several proposals submitted to the IMO for variants of carbon pricing which can be generally categorised into a GHG levy, global ETS and a regional ETS (such as the EU) but have yet to be adopted (Cullinane & Yang, 2022; Psaraftis et al., 2021). NGOs and industry alike have hailed the EU's expansion of carbon trading to the maritime sector as a necessary step in the right direction. The industry is in general agreement that a global solution is preferred through the IMO (Cotton, Stephen et al., 2022; Toft Valuer, 2022).

In 2018, the IMO launched its GHG reduction strategy laying a series measures and an emission reduction target of only aimed at 50% by 2050 compared to 2008 levels (IEA, 2021; IMO, 2018). Discussions during the Marine Environment Protection Committee's (MEPC) 79 Session in December 2022 showed increased interest from the majority of the IMO member states to increase the emission reduction target to net zero by 2050. Much of the negotiations have taken place during early 2023 and an a decision for an agreement on whether or not to adopt proposals for mid-term measures (including a global MBM and GHG Fuel Standard) will be decided at the MEPC80 session in July 2023 followed by any subsequent adoption of measures (Smith, Shaw, & Bonello, 2022).

GHG levies, have long been the preferred approach by SIDS (with Marshall Islands being a vocal proponent) especially at a global level, particularly for the greater equity considerations towards financing associated with them (Marshall Islands & Solomon Islands, 2022; Smith, Shaw, & Bonello, 2022). Furthermore, the IMO is considering a similar global equivalent of the FuelEU Maritime in the form of a GHG Fuel Standard (GFS) setting standards for green fuels as proposed by the EU member states at IMO (Austria et al., 2022) but this is not yet guaranteed.

In 2020, the MEPC adopted resolution MEPC.327(75) to encourage member states to develop national action plans that will initiate shipping decarbonisation at national level (IMO, 2020b). Significant funding will be required to implement and operationalise such plans, particularly for SIDS and LDCs (Chai et al., 2022). To date seven countries[3] have published National Action Plans (NAPs) since 2019 to address domestic maritime decarbonisation (IMO, 2022). Indirectly, developed countries enacting NAPs can support the equitable transition in which dedicated policies can accelerate development of new zero emission technologies thereby lowering costs through the spill-over of these technologies and fuels to third countries, avoiding learning curve costs (Baresic, Rojon, et al., 2022b).

[3] Finland, Norway, U.K., Japan, India, Singapore and Marshall Islands.

3.3 Clydebank Declaration: green shipping corridors

Since COP26 a total of 24 states signed[4] the Clydebank Declaration of "green shipping corridors' along specific shipping routes between two or more ports that would fast track zero emission shipping. The declaration requires signatories to develop and facilitate partnerships with ports, operators and other stakeholders to develop green corridors by addressing technical, economic and regulatory aspects on a port, route and systematic level (GMF, 2021). Figure 2 below shows the network of proposed routes and hubs to be developed.

By 2026, there should be more than six major deep-sea routes in operation. The signatory countries involved should have policies in place to accelerate the scaling up of SZEF, with at least 20 ports able to supply zero emission fuels for at least 200 vessels by 2030. These objectives aim to achieve an overall goal of enabling at least 5% zero emission fuels in the maritime fuel mix by 2030 (GMF, 2022a, 2022b).

As of February 2023, under the Clydebank Declaration, 21 initiatives have been announced in conjunction with over 100 stakeholders across sectors (government, ports and industry) (GMF, 2022a). During the MEPC 79 session in 2022, it was proposed that green shipping corridors be regulated by IMO, but it did not garner the support needed. It was decided that as an option for voluntary actions that states can take pertaining to collaboration with ports and through National Action Plans (Smith, Shaw, & Bonello, 2022).

During the expert workshop there was a consensus that green shipping corridors present an opportunity for the EU to diffuse global maritime decarbonisation benefits by means of cooperation and facilitate deployment of alternative fuels. With the adoption of the FuelEU Maritime Regulation and expansion of the EU ETS to the maritime sector, the EU will fast track decarbonisation of its domestic and international maritime sector faster than the global progress. Projections show that China, Europe and North America, respectively, will be the largest producers of clean hydrogen by 2050 accounting for 60% of global demand (Hydrogen Council & McKinsey & Company, 2021). Projections by the Commission on future fuel mix resulting from the FuelEU Maritime and other support policies in the basket of measures envisage that renewable and low carbon fuels (RLFs) would make up 5.5 - 13.5% of the shipping fuel mix by 2030 and 86 - 88% by 2050 (European Commission, 2021b).

[4] Non-EU member states: Australia, Canada, Chile, Costa Rica, Fiji, Japan, Marshall Islands, Morocco, New Zealand, Norway, Palau, Singapore, UK and the U.S. EU Member States: Belgium, Denmark, Finland, France, Germany, Ireland, Italy, Netherlands, Spain and Sweden.

Figure 3: Map of current planned Green Shipping Corridors.

Source: (GMF, 2022a)

There are several shallow water green corridors proposed that would operate within the EU/EEA waters in which the intra-voyage scope of the FuelEU Maritime and the EU ETS regulations could support achieving the objectives of the green corridors. A quantitative analysis on scoping and identification of different corridors globally, based on impact and feasibility, found that the Europe – Asia route has the highest carbon footprint (GMF, 2021).

The international deep-sea routes proposed so far under the green shipping corridors initiative of importance to international connections for the EU, include the Rotterdam to Singapore (Asia), the Antwerp to Montreal (North America) (GMF, 2022a) and more recently the EU and South Africa corridor for iron-ore (GMF, 2023). With the fuel energy demand pairing between Europe to Singapore at 95 ktHFOe (UMAS & UCL, 2022), this connection represents the largest potential fuel shift for the EU with long distance (i.e. non-neighbouring) partners.

Green Shipping Corridors can help boost diffusion of the ambition set by the expansion of the EU ETS to the maritime sector and FuelEU Regulation and encourage other third countries to adopt similar policies to allow for some compatibility in easing logistical challenges (assuming a global solution through the IMO is still not achieved).

3.4 Financing and an equitable transition

The global investment requirements for transitioning the shipping sector to complete (100%) decarbonisation by 2050 is estimated to be between 8-28 USD bn/yr for onboard vessel investments and between 28-90 USD bn/yr for fuel infrastructure annually between 2022 and

2050 (DNV, 2022). Another study estimated that to reach 100% decarbonisation of the sector at a global level, the total investment requirements would total 1-1.4 USD trillion by 2050.

Carbon pricing measures taken at a global level under a full decarbonisation scenario could mobilise 40 to 80 USD bln/yr annually or a total generation 1-2 trillion USD by 2050 (Baresic, Palmer, et al., 2022). This approach has long been pushed for by SIDS, The Marshall Islands (also holding one of the largest flag state registries), Solomon Islands and Tuvalu, have long been promoting MBMs as a means of enabling an equitable transition through the revenues generated (Marshall Islands et al., 2022).

As in other areas of decarbonisation, equitable transition is one of the key sticking points in the negotiations. During the MEPC 79 meeting in December 2022 at IMO, just and equitable transition was referred to several times in proposals and interventions. Generally, equitable transition in the maritime sector is referred to as:

"*a transition that increases equity between states – including a transition that is procedurally fair, equitable in relation to maritime mitigation (opportunities for research, development and deployment of new fuels and technologies are available to all), and equitable in relation to climate impacts (recognising responsibility of the shipping industry for climate impacts)*" (Smith, Shaw, & Bonello, 2022).

The need for an equitable transition is centre around a moral imperative that many vulnerable countries are suffering from the impacts of climate change largely caused by historic emissions from developed countries (Shaw et al., 2022).

Positions put forward by Pacific SIDS to the MEPC argue for a global GHG levy with 51% of the revenues be directed to SIDS and LDCs, while opposing a global ETS system. SIDS have suggested that revenues from the expansion of the EU ETS should be used to increase equity and contribute to fair share under the CBDR principle (Clean Shipping Coalition, 2021; Marshall Islands et al., 2022). This approach will help close the gap for the distributed adoption of new innovative technologies and fuels, using a relatively small amount of EU ETS revenues to support green shipping corridors (GMF, 2023).

The impact to SIDS and LDCs may be exacerbated by policy diffusion, as regions adopt a fragmented patchwork of regional market-based mechanisms, such as the EU ETS, if the outcome of the 2023 MEPC 80 session at IMO does not result in some agreement for a global market-based measure. In this case, the Global South may have little to no influence over the specifics of sectoral transition, regulation and how revenues from MBMs but may still be "forced" to comply if continuing business in these regions or countries.

Additionally, Global South countries could risk falling further behind in the global green technology and innovation race (UNCTAD, 2023), as there could be little to no technology transfer under a fragmented regulation patchwork system. Developing countries and their companies will face increased uncertainty, increased trade costs and general costs of doing business.

The EU ETS (or MBMs in general) can be used to address this through Contracts-for-Difference (CfDs). The potential revenue generated by the EU ETS at a carbon price of 87€/t, this would result in total proceeds of 9 bln EUR annually, while the cost of implementing CfD would amount to only 1.2 bln annually by 2030 (Pandej et al., 2022). CfD programmes can be implemented to offset the fuel cost different and support vessel and fuel infrastructure developments along green shipping corridors with developing countries. It was calculated that using half of the revenues generated through the maritime EU ETS would be sufficient to transition 715 vessels to run of green ammonia (Pandej et al., 2022).

Other than ringfencing MBM revenues back into the maritime sector to accelerate further decarbonisation, a portion of revenues can also be used to support an equitable transition by channelling carbon finance to climate vulnerable countries (such as SIDS and LDCs). Such support can be earmarked to finance climate mitigation and adaption measures, maritime decarbonisation projects and/or to support the implementation and function of measures (EU or international) such as MBMs and fuel standards, reducing the burden of increased cost of shipping. This would include financing administrative and enforcement activities. While in the long-term move from fossil fuels to zero carbon alternatives will reduce the costs and volatility, in the short and midterm, the major challenge will be large price gap between initial high costs of zero emission fuels and cheaper fossil fuels.

In 2016, the EC cooperated with the IMO to develop Maritime Technology Cooperation Centres (MTCCs) around the world[5] to support the diffusion on port energy efficiency assessments, port vessel equipment for solar power and stablishing data collection systems. Other than provide technical assistance and capacity building, the Centres promote the uptake of low carbon technologies to LDCs and SIDS. This diffusion was supported through the provision of financing and capacity building seminar. At COP27, the EU announced providing additional 10 million EUR to facilitate and support port side efficiency measures (DG MOVE & European Commission, 2022). MTCCs can be one such mechanism to diffuse either policy capacity building, cooperation and financing with vulnerable countries.

4. Conclusions and recommendations

The decision of the EU to regulate shipping emissions outside the IMO framework may have two main consequences. Firstly, it has accelerated action at IMO to move forward with the development and adoption of a global MBM and GHG fuel standards, as suggested by experts in the field. Secondly, it may encourage other countries to follow suit by adopting their domestic policy action, as has been the case in the US with the Clean Shipping Act (U.S. Government,

[5] Shanghai (China), Nairobi (Kenya), Fiji, Trinidad and Tobago, and Panama.

2022). The expansion of the EU ETS to the maritime sector can serve as a template for other countries to adopt similar carbon pricing mechanisms for their domestic emissions.

While the EU can be considered as the first mover in taking regional action to decarbonise global shipping emissions, it is evident that to be successful in its goal it needs to increase ambition in its proposals to tighten any loopholes inadvertently prolonging any further use of fossil fuels. Cooperation with other countries will be crucial to promote a global approach, for which there seems to be growing convergence at the IMO.

Both, the literature and experts agree that carbon pricing is crucial for the global decarbonisation of shipping, by closing the cost competitive gap with fossil fuels and accelerate the uptake of alternative fuels – but it cannot exist as a standalone measure. Subsidising zero emission fuel through research and development, scaling up and deployment is also a necessity (Baresic, Palmer, et al., 2022; Mærsk Mc-Kinney, 2021).

Simultaneously, the EU needs to continue fostering bilateral cooperation with key stakeholders and partners globally. The EU can work with other key players such as China, the U.S. and Singapore to increase ambition on regional regulatory approaches that can result in truly knock-on effect for the uptake of zero emission fuels and vessels, globally and in this decade. Working with its neighbours will be necessary to avoid port evasion. By promoting equitable transition, the EU can ensure that the negative impacts and the potential backlash against its own policies can be mitigated especially by vulnerable nations, particularly SIDS and LDCs.

On the basis of literature review and dialogue during a dedicated workshop, the following recommendations have been compiled to support the direction needed for further development of policy diffusion, enabling greater transformative change to lower the global maritime carbon footprint:

- In its policies, the EU need to avoid creating conditions that may drive switching from oil to other fossil fuels (such as LNG). Given the average lifespan of vessels, this would result in long-term carbon lock in. Instead, a transition to zero-carbon fuels should be promoted through more stringent reduction targets, and setting mandated targets for the uptake of zero emission fuels.

- The EU's policies would need to increase the level stringency of its non-compliance penalties, particularly on the size of the monetary penalty, to act as a stronger economic deterrent for shipping companies.

- The EU should use green shipping corridors to identify and facilitate key partnerships with third countries and in this way fast-track decarbonisation along major shipping routes. As highlighted in this paper, partnerships with key players that have high potential to shift to zero emission fuels such as the US, China, Japan and Singapore should be explored further. Additionally, the EU can use a relatively small amounts of the revenues generated through the EU ETS to support the developed of green shipping corridors, which in turn

can be used to support financing green zero emission shipping transitions in developing third countries.

- At a regional level, the EU would need to give due consideration to development of zero emission bunkering, ships and ports in neighbouring countries. In the case of the UK, effort should be directed towards harmonising joint efforts. For other neighbouring partners, particularly Turkïye, Egypt and Morocco, higher levels of cooperation would be needed for financing the development of skills and capacity to accommodate the necessary infrastructure and services associated with zero emission fuels. Partnerships to develop hydrogen-based fuel productions with these neighbouring countries can help address the zero emission fuel production needs as part of the EU Hydrogen Strategy.

- Working towards an 'equitable transition' through financial support, capacity building and cooperation should be given greater emphasis. For this purpose, the EU can use a portion of revenues generated from the EU ETS to support the maritime decarbonisation in third countries, especially vulnerable LDCs and SIDS. The Contacts for Differences (CfDs) approach should be explored further as one such mechanism to implement the EU's fair share contributions in the sector.

- The EU needs to continue scaling up its engagement with international partners at the IMO to develop global measures for maritime decarbonisation policies especially around global fuel standards and MBMs. If such measures are not adopted at international level through the IMO, then additional provisions should be taken at EU level to ensure that necessary support is provided to vulnerable SIDS and LDCs to ensure they are not excluded from the fuel, technology and bunkering transition of the maritime sector.

Overall, it should be stressed that despite some weaknesses, the adoption of the FuelEU Maritime Regulation and expansion of the EU ETS to include the shipping sector are steps in the right direction. As these measures are implemented in practice, the IMO should take the opportunity and facilitate introduction of a global emissions reduction measures and complementary policies, including the deployment of zero emissions fuels. In addition, SIDS and LDCs should be supported in their emissions reduction efforts by the EU in cooperation with other major players.

5. References

Adamowicz, M. (2022). Decarbonisation of maritime transport – European Union measures as an inspiration for global solutions? *Marine Policy*, *145*. https://doi.org/10.1016/J.MARPOL.2022.105085

Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, & European Commission. (2022). *Further development of the proposal for a GHG Fuel Standard* (ISWG-GHG 13/4/7). IMO.

Baresic, D., Palmer, K., Smith, T., Rehmatulla, N., Taylor, J., Saucedo, A., Kapur, D. A., Bonello, J.-M., Shaw, A., & Perico, C. (2022). *Climate action in shipping: Progress towards Shipping's 2030 Breakthrough*. Getting to Zero Coalition. www.lr.org

Baresic, D., Rojon, I., Shaw, A., & Rehmatulla, N. (2022a). *Closing the Gap: An Overview of the Policy Options to Close the Competitiveness Gap and Enable an Equitable Zero-Emission Fuel Transition in Shipping*. www.u-mas.co.uk

Baresic, D., Rojon, I., Shaw, A., & Rehmatulla, N. (2022b). *Closing the Gap: An Overview of the Policy Options to Close the Competitiveness Gap and Enable an Equitable Zero-Emission Fuel Transition in Shipping*. www.u-mas.co.uk

Camargo-Díaz, C. P., Paipa-Sanabria, E., Zapata-Cortes, J. A., Aguirre-Restrepo, Y., & Quiñones-Bolaños, E. E. (2022). A Review of Economic Incentives to Promote Decarbonization Alternatives in Maritime and Inland Waterway Transport Modes. *Sustainability*, *14*(21), 14405. https://doi.org/10.3390/su142114405

Chai, K.-H., NG, S.-H., Ng, E., & Yueh-Lin, L. (2022). Dual Actions: National and Route-Based Plans to Tackle GHG Emissions from International Shipping. *Global Centre for Maritime Decarbonisation*. https://www.gcformd.org/gcmdpapers

Chambers, S. (2021). China looks at adding shipping to the world's largest emissions trading scheme—Splash247. *Splash*. https://splash247.com/china-looks-at-adding-shipping-to-the-worlds-largest-emissions-trading-scheme/

Christodoulou, A., & Cullinane, K. (2022). Potential alternative fuel pathways for compliance with the 'FuelEU Maritime Initiative.' *Transportation Research Part D: Transport and Environment*, *112*, 103492. https://doi.org/10.1016/J.TRD.2022.103492

Clean Shipping Coalition. (2021). Reduction of GHG emissions from ships: Principles for market-based measures. *International Maritime Organization*, *MEPC 77/7/17*.

Climate Action Tracker. (2022). *International Shipping*. https://climateactiontracker.org/sectors/shipping/

Cotton, Stephen, Englert, Dominik, Hemmingsen, Claus, Højgaard, Bjørn, Humphreys, Martin, Bach Nielsen, Rasmus, Nixon, Jeremy, Saverys, Alexander, Takahashi, Masahiro, Smith, Tristan, Blaxekjær, Lau, & Sindenvall Jegou, Ingrid. (2022). *Shipping's urgent need for Paris-aligned regulation* [Insight Brief]. GMF, Getting to Zero Coalition. https://cms.globalmaritimeforum.org/wp-content/uploads/2022/11/Insight-brief_Shippings-urgent-need-for-Paris-aligned-regulation.pdf

Council of the EU. (2022). *"Fit for 55": Council and Parliament reach provisional deal on EU emissions trading system and the Social Climate Fund*. https://www.consilium.europa.eu/en/press/press-releases/2022/12/18/fit-for-55-council-and-parliament-reach-provisional-deal-on-eu-emissions-trading-system-and-the-social-climate-fund/

Cullinane, K., & Yang, J. (2022). Evaluating the Costs of Decarbonizing the Shipping Industry: A Review of the Literature. *Journal of Marine Science and Engineering*, *10*(7). https://doi.org/10.3390/jmse10070946

DG MOVE & European Commission. (2022). *Decarbonising international shipping: European Commission provides additional 10 million euro*. https://transport.ec.europa.eu/news/decarbonising-international-shipping-european-commission-provides-additional-10-million-euro-2022-11-15_en

DNV. (n.d.). *Decarbonize shipping regional developments: Asia Pacific region*. Retrieved January 23, 2023, from https://www.dnv.com/maritime/hub/decarbonize-shipping/key-drivers/regulations/regional-developments/asia.html

DNV. (2022). *Maritime Forecast 2050*.

DNV. (2023). *EU ETS: Preliminary agreement to include shipping in the EU's Emission Trading System from 2024*. DNV. https://www.dnv.com/news/eu-ets-preliminary-agreement-to-include-shipping-in-the-eu-s-emission-trading-system-from-2024-238068

Dong, J., Zeng, J., Yang, Y., & Wang, H. (2022). A review of law and policy on decarbonization of shipping. *Frontiers in Marine Science*, *9*. https://doi.org/10.3389/fmars.2022.1076352

ECSA & ICS. (2020). *Implications of application of the EU Emissions Trading System (ETS) to international shipping, and potential benefits of alternative Market-Based Measures (MBMs)*. www.ecsa.eu

ECSA & ICS. (2021). *FuelEU Maritime—Avoiding Unintended Consequences: Efficacy and implications of potential measures, including new EU fuel standards, to help decarbonise international shipping*.

Environmental Ship Index. (2022). *ESI Incentives*. https://www.environmentalshipindex.org/ports

European Commission. (2021a). *Commission Staff Working Document: 2020 Annual Report form the European Commission on CO2 emissions from maritime transport*.

European Commission. (2021b). *Commission staff working document Impact Assessment accompanying the Proposal for a Regulation of the European Parliament and of the Council on the use of renewable and low carbon fuels in maritime transport*.

European Commission. (2021c). *Proposal for a Directive of the European Parliament and the of the Council amending Directive 2003/87/EC establishing a system for greenhouse gas emission allowance trading within the Union, Decision (EU) 2015/1814 concerning the establishment and operation of a market stability reserve for the Union greenhouse gas emission trading scheme and Regulation (EU) 2015/757. 2021/0211 (COD)*. https://ec.europa.eu/info/sites/default/files/revision-eu-ets_with-annex_en_0.pdf

European Commission. (2022a). *Press release: "Fit for 55": Council and Parliament reach provisional deal on EU emissions trading system and the Social Climate Fund*. https://www.consilium.europa.eu/en/press/press-releases/2022/12/18/fit-for-55-council-and-parliament-reach-provisional-deal-on-eu-emissions-trading-system-and-the-social-climate-fund/

European Commission. (2022b). *Proposal for a Directive of the European Parliament and the Council amending Directive (EU) 2018/2001 on the promotion of the use of energy from renewable sources, Directive 2010/31/EU on the energy performance of buildings and Directive 2012/27/EU on energy efficiency*. https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52022PC0222

European Commission. (2023). *Hydrogen*. Energy - European Commission. https://energy.ec.europa.eu/topics/energy-systems-integration/hydrogen_en

European Council. (2023). *FuelEU Maritime initiative: Provisional agreement to decarbonise the maritime sector*. https://www.consilium.europa.eu/en/press/press-releases/2023/03/23/fueleu-maritime-initiative-provisional-agreement-to-decarbonise-the-maritime-sector/

European Parliament. (2022). *Opinion of the Committee on the Environment, Public Health and Food Safety for the Committee on Transport and Tourism on the proposal for a regulation of the European Parliament and of the Council on the use of renewable and low-carbon fuels in maritime transport and amending Directive 2009/16/EC*.

Eurostat. (2022). *Maritime freight and vessels statistics*. Maritime Freight and Vessels Statistics. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Maritime_freight_and_vessels_statistics&oldid=550240#Most_EU_maritime_freight_transport_is_with_extra-EU_partners

Faber, J., Kleijn, A., Király, J., & Geuns, M. van. (2021). *Impacts of FuelEU Maritime on the Dutch maritime sector*. CE Delft.

Faber, J., Leestemaker, L., & van den Berg, R. (2022). *Maritime shipping and EU ETS. An assessment of the possibilities to evade ETS costs*. CE Delft. https://cedelft.eu/publications/maritime-shipping-and-eu-ets-an-assessment-of-the-possibilities-to-evade-ets-costs/

Faber, J., Meijer, C., Nelissen, D., & van den Toorn. (2022). *Fit for 55 and 2030 milestones for maritime shipping: A pathway towards 2050* (22.220125.144). CE Delft.

Faber, J., van den Berg, R., & Leestemaker, L. (2021). *The impacts of the ETD proposals on shipping and bunkering*. CE Delft. https://cedelft.eu/publications/the-impacts-of-the-etd-proposals-on-shipping-and-bunkering/

Fang-Ting Cheng. (2020). Policy Diffusion of the Emission Trading Scheme in China: Progress and Prospects. *Chinese Business Review*, *19*(4). https://doi.org/10.17265/1537-1506/2020.04.001

Gilardi, F., & Wasserfallen, F. (2019). The politics of policy diffusion. *European Journal of Political Research Rr : Rr-Rr*. https://doi.org/10.1111/1475-6765.12326

GMF. (2021). *The Next Wave Green Corridors: A special report for the Getting to Zero Coalition*. https://www.globalmaritimeforum.org/publications/the-next-wave-green-corridors

GMF. (2022a). *Annual Progress Report on Green Shipping Corridors*.

GMF. (2022b). *Green Corridors: Definitions and Approaches*.

GMF. (2023). *Maritime, mining, steel, and energy industry leaders join forces to develop first-ever concept for a green corridor between South Africa and Europe*. https://www.globalmaritimeforum.org/press/maritime-mining-steel-and-energy-industry-leaders-join-forces-to-develop-first-ever-concept-for-a-green-corridor-between-south-africa-and-europe

Government of Saudi Arabia. (2022). *Saudi & Middle East Green Initiatives*. Saudi & Middle East Green Initiatives. https://www.greeninitiatives.gov.sa/about-sgi/sgi-targets/reducing-emissions/reduce-carbon-emissions

Hagberg, H. (2022). *Maritime transportation will be included in the EU ETS from 2024 | Advokatfirmaet Thommessen*. Thommessen. https://www.thommessen.no/en/news/maritime-transportation-included-in-the-eu-ets

Hydrogen Council & McKinsey & Company. (2021). *Hydrogen for Net-Zero: A critical cost-competitive energy vector*.

ICAP. (2022). *EU Emissions Trading System for buildings and road transport—International Carbon Action Partnership*. https://icapcarbonaction.com/en/ets/eu-emissions-trading-system-buildings-and-road-transport

IEA. (2021). *Energy Technology Perspectives 2020*. www.iea.org/t&c/

IEA. (2022). *International Shipping*. https://www.iea.org/reports/international-shipping

IMO. (2018). *Initial GHG Strategy on reduction of emission from ships* (MEPC.304). IMO.

IMO. (2020a). *Fourth IMO GHG Study 2020*. https://www.imo.org/en/OurWork/Environment/Pages/Fourth-IMO-Greenhouse-Gas-Study-2020.aspx

IMO. (2020b). Resolution MEPC.327(75): Encouragement of member states to develop and submit voluntary national action plans to address GHG emissions from ships. In *MEPC 75/18: Vol. Resolution MEPC.327…*.

IMO. (2022). *National Action Plans*. https://www.imo.org/en/OurWork/Environment/Pages/RELEVANT-NATIONAL-ACTION-PLANS-AND-STRATEGIES.aspx

IRENA. (2021). *A pathway to decarbonise the shipping sector by 2050*. www.irena.org

Kilemo, Heidi, Montegomery, Robert, & Leitão, Ana Madalena. (2022). *Mapping of zero emission pilots and demonstration projections* (Third Edition). GMF, Getting to Zero Coalition. https://www.globalmaritimeforum.org/content/2022/03/Mapping-of-zero-emission-pilots-and-demonstration-projects_third-edition.pdf

Kotzampasakis, M. (2022). Intercontinental shipping in the European Union emissions trading system: A 'fifty–fifty' alignment with the law of the sea and international climate law? *Review of European, Comparative and International Environmental Law*. https://doi.org/10.1111/reel.12485

Krantz, Randall, Laffineur, Ludovic, & Faber, Lena. (2023). *Short-Term Action Opportunities*. GMF. https://www.globalmaritimeforum.org/news/short-term-action-opportunities

Lagouvardou, S., & Psaraftis, H. N. (2022). Implications of the EU Emissions Trading System (ETS) on European container routes: A carbon leakage case study. *Maritime Transport Research*, *3*, 100059. https://doi.org/10.1016/j.martra.2022.100059

Mærsk Mc-Kinney. (2021). *Options paper on Market-Based Measures*. Mærsk Mc-Kinney Møller Centre for Zero Carbon Shipping. https://www.zerocarbonshipping.com/publications/options-paper-on-market-based-measures/

Mærsk Mc-Kinney. (2022a). *FuelEU & ETS analysis: What can the industry learn and adopt from regional regulations? Deep-diving on two EU regulatory proposals for the maritime industry*. Mærsk Mc-Kinney Møller Centre for Zero Carbon Shipping. https://www.zerocarbonshipping.com/publications/fueleu-ets-analysis-what-can-the-industry-learn-and-adopt-from-regional-regulations/

Mærsk Mc-Kinney. (2022b). *Maritime Decarbonization Strategy 2022*. Mærsk Mc-Kinney Møller Centre for Zero Carbon Shipping. https://www.zerocarbonshipping.com/publications/maritime-decarbonization-strategy/

Marshall Islands & Solomon Islands. (2022). *Proposal for a GHG levy as a component in a basket of measures* (ISWG-GHG 13/4/11). IMO.

Marshall Islands, Solomon Islands, & Tuvalu. (2022). *Enabling and equitable transition* (ISWG-GHG 12/3/6; Consideration of Concrete Proposals for Mid- and Long-Term Measures and Associated Impact Assessments in the Context of Phase I of the Work Plan as Well as the Proposal to Establish an International Maritime Research Board). IMO.

Nelissen, D., Kleijn, A., & Faber, J. (2022). *FuelEU Maritime and EU ETS Sound incentives for the fuel choice?* CE Delft. https://cedelft.eu/publications/fueleu-maritime-and-eu-ets/

Osterkamp, P., Smith, T., & Kasper, S. (2021). *Five percent zero emission fuels by 2030 needed for Paris-aligned shipping decarbonization*. UMAS, Getting to Zero Coalition.

Pan, C., Shrestha, A. K., Wang, G., Innes, J. L., Wang, K. X., Li, N., Li, J., He, Y., Sheng, C., & Niles, J. O. (2021). A linkage framework for the china national emission trading system (CETS): Insight from key global carbon markets. *Sustainability (Switzerland)*, *13*(13). https://doi.org/10.3390/su13137459

Pandej, A., Sagaard, K., Blaxekjær, L., Spiegelenberg, F., & Montgomery, R. (2022). *How EU Contracts for Differences can support zero emission fuels*. GMF, Getting to Zero Coalition.

Parker, S., Shaw, A., Rojon, I., & Smith, T. (2021). Harnessing the EU ETS to reduce international shipping emissions Assessing the effectiveness of the proposed policy inclusion of shipping in the EU ETS to

reduce international shipping emissions. In *Environmental Defense Fund Europe*. UMAS. www.u-mas.co.uk

Pons, A., Martin, C., Andrew, E., Finney, H., Kwon, H., Millard, K., Budaragina, M., Scarbrough, T., Siskos, P., De Vita, A., Paroussos, L., Charalambidis, I., Tsiropoulos, I., & Mavrouli, E. (2021). *Study on EU ETS for maritime transport and possible alternative options of combinations to reduce greenhouse gas emissions Final Report*. https://doi.org/10.2834/27271

Prosertek. (2022). *EU ETS, financing for decarbonisation of the maritime sector*. https://prosertek.com/en/blog/eu-ets-financing-decarbonisation-maritime-sector/

Psaraftis, H. N., Zis, T., & Lagouvardou, S. (2021). A comparative evaluation of market based measures for shipping decarbonization. *Maritime Transport Research*, *2*, 100019. https://doi.org/10.1016/J.MARTRA.2021.100019

Shaw, D. A., Blaxekjær, Lau, Spiegelenberg, Femke, & Leitão, Ana Madalena. (2022). *Decarbonizing shipping while ensuring an equitable transition* [Insight Brief]. GMF, Getting to Zero Coalition.

Smith, T. (2022). *Aligning with 1.5 degrees: Managing the risks and opportunities for shipping and the companies in its value chain*. UMAS, Getting to Zero Coalition.

Smith, T., Shaw, A., & Bonello, J.-M. (2022). *An overview of the discussions from IMO ISWG-GHG 13 & MEPC 79*. UMAS. www.u-mas.co.uk

Smith, T., Shaw, A., & Roberts, A. (2022). *Green Shipping Corridors: Opportunity Identification: A data-based approach to evaluating potential corridors, and an initial case study of the Clydebank Declaration signatories*. UMAS, Getting to Zero Coalition. www.u-mas.co.uk.

Søgaard, & Blaxekjær, Lau. (2022). *How the EU can catalyze the global transition to zero emission shipping and the green hydrogen economy*. Getting to Zero Coalition.

Toft Valuer, I. (2022). Industry welcomes ETS quotas: "We have been waiting for this moment for four years." *Shipping Watch*. https://shippingwatch.com/regulation/article14741095.ece

Transport & Environment. (2022a). *FuelEU Maritime: T&E analysis and recommendations How to drive the uptake of sustainable fuels in European shipping*. www.transportenvironment.org

Transport & Environment. (2022b). *Less is more: Regional shipping policy and global decarbonisation*. https://www.transportenvironment.org/wp-content/uploads/2021/10/Briefing-paper-NDCs-legal-advice-Aviatio

Transport & Environment. (2022c). *Lost at sea: EU States' €20 billion giveaway to the shipping industry Analysis of European institutions' shipping ETS positions Transport & Environment Further information*. Transport & Environment.

UMAS & UCL. (2022). *Green Corridors Opportunities by Country Pairings Dataset*.

UNCTAD. (2022a). *Review of Maritime Transport 2022*. https://shop.un.org/

UNCTAD. (2022b). *UNCTADSTAT - Share of the world merchant fleet value by country of beneficial ownership, annual*. https://unctadstat.unctad.org/wds/TableViewer/tableView.aspx?ReportId=190216

UNCTAD. (2023). *Technology and Innovation Report 2023* (UNCTAD/TIR/2022 and Corr.1). https://unctad.org/publication/technology-and-innovation-report-2023

U.S. Government. (2022). H.R.8336—Clean Shipping Act. *117th Congress*.

Vidović, T., Šimunović, J., Radica, G., & Penga, Ž. (2023). Systematic Overview of Newly Available Technologies in the Green Maritime Sector. *Energies*, *16*(2), Article 2. https://doi.org/10.3390/en16020641

Wissner, N., & Cames, M. (2022). *Briefing on the proposal to integrate maritime transport in the EU ETS*. www.oeko.de

World Bank. (2022). *Carbon Pricing Dashboard | Up-to-date overview of carbon pricing initiatives*. https://carbonpricingdashboard.worldbank.org/map_data

Yum, J., Rose, M., Healy, G., Santos, A., Bui, T., & Kang, H. (2022). *Korea's Green Shipping Pathways: The Korean Shipping Landscape and Policy Recommendations for Ocean-Climate Leadership in Shipping*.

About the project

4i-TRACTION – innovation, investment, infrastructure and sector integration:
TRAnsformative policies for a ClimaTe-neutral European UnION

To achieve climate neutrality by 2050, EU policy will have to be reoriented – from incremental towards structural change. As expressed in the European Green Deal, the challenge is to initiate the necessary transformation to climate neutrality in the coming years, while enhancing competitiveness, productivity, employment.

To mobilise the creative, financial and political resources, the EU also needs a governance framework that facilitates cross-sectoral policy integration and that allows citizens, public and private stakeholders to participate in the process and to own the results. The 4i-TRACTION project analyses how this can be done.

Project partners

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement **No. 101003884**.