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The decarbonisation of maritime transport: navigating between a global and EU approach

1. Introduction

Maritime transport accounts for ~3% of global anthropogenic greenhouse gases (GHGs), yet is not covered by the Paris Agreement objectives. Earlier this year, the sector's main regulator, the International Maritime Organisation (IMO) adopted a revised GHG strategy setting an enhanced common ambition to reach net-zero GHG emissions from international shipping close to 2050. The strategy also set indicative targets for 2030 (to reduce total annual GHG emissions from international shipping by at least 20%, striving for 30% compared to 2008) and 2040 (to reduce total annual GHG emissions from international shipping by at least 70%, striving for 80% compared to 2008). By 2025, IMO expects to finalize mid-term measures to achieve revised decarbonization objectives.

As of 2024, maritime transport emissions will be incorporated under the European Union cap-and-trade program – the Emissions Trading System (EU ETS).[1] As a result, shipping companies using European ports will have to monitor and report their emissions and purchase and surrender EU allowances (EUAs) for each tonne of reported carbon dioxide (CO_2) emissions. From 1 January 2026, this obligation will be extended to two short-lived GHGs – methane (CH_4) and nitrous oxide (N_2O). In parallel, the EU has finalised the Fit for 55 package legislation, including FuelEU maritime regulation, creating demand for alternative marine fuels[2] and the EU Methane regulation covering emissions from imported energy[3], including Liquefied Natural Gas (LNG).

These developments give rise to the following questions:

1) Are the IMO and EU regulatory frameworks complementary or contradictory?
2) Should the EU ETS be extended to other methane-relevant sectors in the EU?
3) What does it mean for the future of LNG as a marine fuel in Europe, given that additional LNG supplies are projected to come online after 2025[4]?

This paper aims to address these questions and is organised as follows. Section 2 presents an overview of the current decarbonisation approach at the IMO and the EU level. Section 3 analyses new obligations for the shipping companies under the EU ETS. Section 4 discusses the research questions. Section 5 presents conclusions and further research questions.

Maria Olczak, Research Fellow, OIES
Andris Piebalgs, Professor, Florence School of Regulation

2. The rise of shipping emissions and regulatory pressure to address them

Between 2012 and 2018 shipping emissions increased by 9.6%, from 977 million tonnes to 1076 million tonnes of CO_2e[1], driven by the rise in global maritime trade.[6] These GHGs are mostly carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). Carbon dioxide is the dominant source of shipping's climate impact accounting for 98% (91% if black carbon is included) of total GHG emissions from the sector calculated on a Global Warming Potential over 100-year time horizon (GWP_{100}). But methane (accounting for ~0.5%) is the fastest-growing GHG, with a 151-155% increase between 2012-2018, compared to a 5-9% increase in nitrous oxide emissions.[6]

About 90% of global trade is being carried on ships, making international transport a significant sector for global economy.[7] While the alternative marine fuels are slowly gaining traction, the majority of existing fleet runs on conventional fuels, e.g. Heavy Fuel Oil (HFO) and Marine Gas Oil (MGO),[8] resulting in GHG emissions and air pollution. But the voyage- and vessel- specific GHG emission levels depend of several factors including: the size and type of ships, their dead weight capacity, type of engines (main and auxiliary), the amount and type of fuel(s) consumed, the distances covered and operational mode. While the use of some fuels, such as LNG, offers lower emissions upon fuel combustion (including boil-off gas, BOG), their overall environmental benefit depends on reducing non-CO_2 emissions including methane emissions: unburnt methane from marine engines (methane slip), fugitive emissions (unintentional leaks, from specific components e.g. seals) and vented emissions (intentional release of methane).[9] The volume and share of methane may vary across the entire voyage, e.g. in case of an LNG carrier: LNG loading, laden voyage, LNG unloading and ballast voyage.

The International Maritime Organisation (IMO) projections show that without targeted policies, shipping emissions are likely to increase by up to 130% over 2008 levels by 2050.[6] These emissions are not accounted for in national GHG inventories and are not covered under the Paris Agreement. Under the United Nations Framework Convention on Climate Change (UNFCCC), Parties agreed to work through IMO to address these emissions. The legal basis for IMO's remit is the International Convention for the Prevention of Pollution from Ships (MARPOL) and the major decisions are taken at the IMO's Marine Environment Protection Committee (MEPC) forum. The IMO's current decarbonisation approach builds upon the 2018 initial GHG strategy combining an absolute emission reduction goal with energy efficiency objectives.[10] The Initial GHG Strategy has been criticised for falling short on its climate ambitions[11,12] and revised in 2023 to align with the Paris Agreement ambitions[13]:

- **a reduction in carbon intensity** of international shipping by at least 40% by 2030 compared to 2008 (baseline year in the Initial GHG Strategy)
- an **uptake of zero or near-zero GHG emission technologies**, fuels and/or energy sources to represent at least 5% striving for 10% of the energy used by international shipping by 2030
- GHG emissions from international shipping to reach **net zero** "by or around, i.e. close to, 2050, taking into account different national circumstances, whilst pursuing efforts towards phasing" with indicative checkpoints:
    - to reduce the total annual GHG emissions from international shipping by at least 20%, striving for 30%, **by 2030,** compared to 2008;
    - to reduce the total annual GHG emissions from international shipping by at least 70%, striving for 80%, **by 2040,** compared to 2008.

To meet these objectives, the Strategy suggests a combination of short-, mid- and long-term measures. The short-term measures focus on technical and operational actions to improve the energy efficiency of ships e.g. ship speed reduction (Table 1). Yet, energy efficiency measures are insufficient to meet the revised climate objectives, where the majority (64%) of the CO2 reduction is projected to be

[1] CO_2-equivalent emissions are presented using 100-year Global Warming Potential (GWP) values from the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5): 1 for CO_2, 28 for CH_4, and 265 for N_2O.[5]

achieved through the use of alternative marine fuels. The concerns about the global availability e.g. biomass-based fuels and high cost of such fuels compared with fossil fuels, has been the key barrier to a more widespread uptake of alternative fuels. Therefore, the medium-term candidate measures combine:

1) a technical element with a goal-based marine fuel standard regulating the phased reduction of the marine fuel's GHG intensity; and

2) an economic element, on the basis of the maritime GHG emissions pricing mechanism.

The IMO's new measures are expected to be adopted in 2025 and enter into force around mid-2027. The United Nations Conference on Trade and Development (UNCTAD) is working on the impact assessment for the adoption of GHG emissions pricing mechanism with the interim results to be published in March 2024 and final version expected in October 2024.

Table 1: The summary of the IMO short-term policies

POLICY MEASURE	SUMMARY	APPLICABLE TO	ENTRY INTO FORCE
Energy Efficiency Design Index (EEDI)	Ship design standard: introduced minimum energy efficiency level per capacity mile e.g. tonne mile for different types of ships	New-built ships	1/01/2013
Ship Energy Efficiency Management Plan (SEEMP)	Ship design/operation standard: ship-specific plan to improve the energy efficiency of a ship.	New-built and existing ships	1/01/2013
The Fuel Oil Consumption Data Collection System (DCS)	MRV: mandatory monitoring and reporting for fuel oil consumption of ships	All ships with IMO number, > 5,000 GT	1/01/2019
Energy Efficiency Existing Ship Index (EEXI)	Ship design standard: certification reflecting energy efficiency of a ship	Existing ships > 400 GT	1/01/2023
Carbon Intensity Indicator (CII)	Ship operation rating/standard: reflects operational energy efficiency of ships, builds upon IMO DCS (fuel consumption) and SEEMP (management tool)	Existing ships > 5,000 GT	1/01/2023

Source: Authors own elaboration based on: IMO (2023), Wissner et al. (2021). GT = gross tonnage.

While the EU represents one of the most prominent voices at the IMO forum, the Union has been increasingly disappointed with the slow progress of the IMO discussions and limited effectiveness of adopted policies.[14] In 2013, the Commission put forward a strategy proposing a gradual approach for including shipping in its overall target to reduce GHG emissions[14]:

1) the introduction of an MRV system for shipping (introduced in 2018),

2) setting intermediary reduction targets for the sector (the 2023 FuelEU maritime regulation setting GHG intensity targets for vessel operators) and

3) the adoption of market-based measures (MBMs) e.g. a Contribution based compensation Fund, a target based compensation fund or the EU Emissions Trading System (EU ETS).

In 2021, the EU proposed a number of measures targeting maritime transport under the Fit for 55 package with a view to achieve climate neutrality by 2050.[15] Shipping accounts for 3-4% of total EU GHG emissions and 13.5% of total transport-related emissions,[16] hence achieving the 2050 target will not be possible without reducing shipping emissions. But, the EU-related maritime emissions occur mostly on extra-EEA voyages, both incoming and outgoing (35% and 33% respectively),[16] highlighting the limited impact of a strategy addressing EU domestic emissions only. The EU approach to the decarbonization of shipping sector, building upon the 2013 strategy, is based on 3 pillars:

- the inclusion of maritime emissions in the EU Emissions Trading System (ETS): revised EU ETS directive = DIRECTIVE (EU) 2023/959[1], revised MRV regulation = REGULATION (EU) 2023/957[17]
- the increase in the share of renewable energy in the maritime sector: new FuelEU maritime Regulation[2], Revised Directive on Deployment of Alternative Fuels Infrastructure[18], Revised Renewable Energy Directive (REDIII)[19]
- the removal of exemptions for the intra-EU maritime transport sector, i.e. the revision of the Energy Taxation Directive[20] (not finalized yet).

The next section will focus on the first pillar of the EU's approach and present the major changes related to the inclusion of maritime emissions in the EU Emissions Trading System (ETS).

3. Inclusion of maritime emissions in the EU Emissions Trading System (ETS): the major changes

The EU Emissions Trading System (EU ETS) is a carbon market covering ~40% of the EU's total greenhouse emissions, mostly carbon dioxide (CO_2), but also nitrous oxide (N_2O) and perfluorocarbons (PFCs). It incorporates ~10,000 installations across several sectors i.e. the electricity and heat generation, energy-intensive industry sectors (oil refineries, steel mills, cement production), and domestic aviation. From 1 January 2024, the EU ETS will be extended to CO_2 emissions from large ships (≥5 000 gross tonnage, GT) entering EU ports, regardless of the flag they fly. From 1 January 2026, the ETS will also incorporate methane (CH_4) and nitrous oxide (N_2O) associated with shipping. The revised ETS and monitoring, reporting and verification (MRV) rules for shipping entered into force on 5 June 2023. They will be accompanied by a series of implementing and delegated acts specifying technical and operational issues e.g. reporting templates, which will be finalised by the end of 2023.

3.1 New obligations for shipping companies

Every year, shipping companies will have to monitor and report their emissions and purchase and surrender EU allowances (EUAs) for each tonne of reported CO_2eq emissions. All emissions data will be collected in accordance with the revised monitoring, reporting and verification (MRV) maritime regulation through the THETIS-MRV system managed by the European Maritime Safety Agency (EMSA).[21] To do so, each company will need to set up a Registry Account with an administering authority of a Member State.

All allowances will be allocated via auctions on the European Energy Exchange (EEX) and the companies can buy and sell them through secondary markets. There will be no free allowance allocation as was the case for industrial sectors due to the risk of carbon leakage. Yet, the surrender obligations for the maritime sector will be gradually phased in: 40% of allowances to be surrendered in 2025 (that is for 40% of emissions reported in 2024), 70% in 2026 and 100% (full price signal) from 2027 onwards. The companies already offsetting their emissions cannot use offset credits, e.g. carbon credits in the voluntary carbon market or certificates, for the EU ETS compliance.

The point of compliance is a shipping company defined as "shipowner or any other organisation or person, such as the manager or the bareboat charterer, that has assumed the responsibility for the operation of the ship from the shipowner" (article 3w, revised EU ETS Directive, 2023/959). The shipping company is responsible for emissions monitoring (EU MRV regulation) and for surrendering

allowances (EU ETS directive). In cases where contractual arrangements foresee that an entity other than the shipping company is responsible for the purchase of the fuel and/or the operation of the ship, the shipping company can seek reimbursement for the EUA surrendering costs. In practice, the companies involved (ship owner, charterer and operator) will need to develop new contractual clauses to pass on the costs related with EUA surrender and renegotiate existing contracts. The amount of GHGs will have commercial implications, hence the companies will need to find an agreement on the volume emitted and who covers this cost, underscoring the need for near real-time verified GHG emission data.[22]

The first test for the shipping companies will be on 30 September 2025. By then the companies will need to surrender (use) their first ETS allowances for CO_2 emissions reported in 2024.

3.2 Scope

Types of ships covered. The EU ETS will cover all large ships (≥5,000 GT) transporting passengers or cargo and large offshore ships (≥5,000 GT) as from 2027. The offshore ships will have to report their GHG emissions as of 1 January 2025. Similarly, offshore ships and general cargo ships below 5000 GT but not below 400 GT will be covered under the EU MRV Maritime Regulation as of 1 January 2025.

Geographical scope. The ETS will cover 100% of emissions occurring between two EU ports and when ships are within EU ports and only 50% of emissions from voyages starting outside of the EU (e.g. Shanghai to Rotterdam), or ending outside the EU (e.g. Rotterdam to Shanghai). The Commission will also establish a list of neighbouring container transhipment ports located outside the Union but less than 300 nautical miles from a port under the jurisdiction of a Member State by means of implementing acts (art. 3ga, point 2; Directive 2003/87/EC). By doing so, the EU intends to avoid contradictions with the ongoing discussions at the IMO level on the adoption of market-based measures and potential political backlash, after having to retreat on its proposal to extend EU ETS to international aviation back in 2013.[23]

GHGs covered. CO_2 emissions have been covered under the EU MRV since 2018 and the operators will have to surrender their allowances for CO_2 emitted in 2024. The timeline for non-CO_2 GHGs is longer with monitoring obligations starting on 1 January 2024 and surrender obligations from 1 January 2026. To account for different warming effect and life span of these GHGs – methane and nitrous oxide are more potent, but have shorter life span than CO_2 – the total emissions will be reported in tonnes CO_2 equivalent (CO_2eq). The reported amount of CH_4 and N_2O will be multiplied by their global warming potential over 100-year timescale (GWP-100), that is 28 and 265, respectively.[24] This approach is likely to result in more focus on the mitigation of non-CO_2 GHGs, e.g. the reduction of the methane slip.

Supply chain coverage. The ETS will cover tank-to-wake emissions only, that is emissions associated with burning or using a fuel, once the fuel is in the tank during the laden and ballast voyage. In contrast, well-to-wake approach will be used under the FuelEU maritime regulation[2], in line with the IMO Guidelines on life cycle GHG intensity of marine fuels (LCA Guidelines).[25] The volume of emissions will have direct financial implications for the companies, and hence the next section examines MRV provisions.

3.3 Monitoring, reporting and verification

Shipping companies are required to submit a monitoring plan for each of their ships to an independent accredited verifier. For ships falling within the scope of the ETS Directive, the monitoring plan must also be submitted to the administering authority responsible for approval, after it has been assessed by the verifier. Monitoring plans are submitted via the THETIS-MRV system.[21] The companies will need to update their monitoring plans, at least once per year, but also in certain situations, e.g. when new types of measuring devices, new sampling methods or analysis methods are applied.

The monitoring plan should specify which method is used for determination of GHGs. The companies can choose between the calculation approach (methods A, B and C) and measurement approach (D).[26] The calculation approach is based on default Emission Factors specified by the European Commission and includes: A) Bunker Delivery Note (BDN) and periodic stocktakes of fuel tanks, B) Bunker fuel tank

monitoring on board, C) Flow meters for applicable combustion processes. By contrast, method D involves direct greenhouse gas emissions measurement: greenhouse gas concentrations of the exhaust gas and the exhaust gas flow is directly measured and then multiplied to determine GHG flows in exhaust gas stacks (funnels). If method D is used, the monitoring plan should include the calibration methods applied and the uncertainty associated with the devices used. So far, shipping companies relied mostly on the calculation approach. Out of 13068 ships that reported their CO_2 emission via the THETIS-MRV for 2022, 51% (6636 ships) used method A, 29% (3726 ships) method B, 33% (4333 ships) method C, and none used direct emission monitoring (method D).[21]

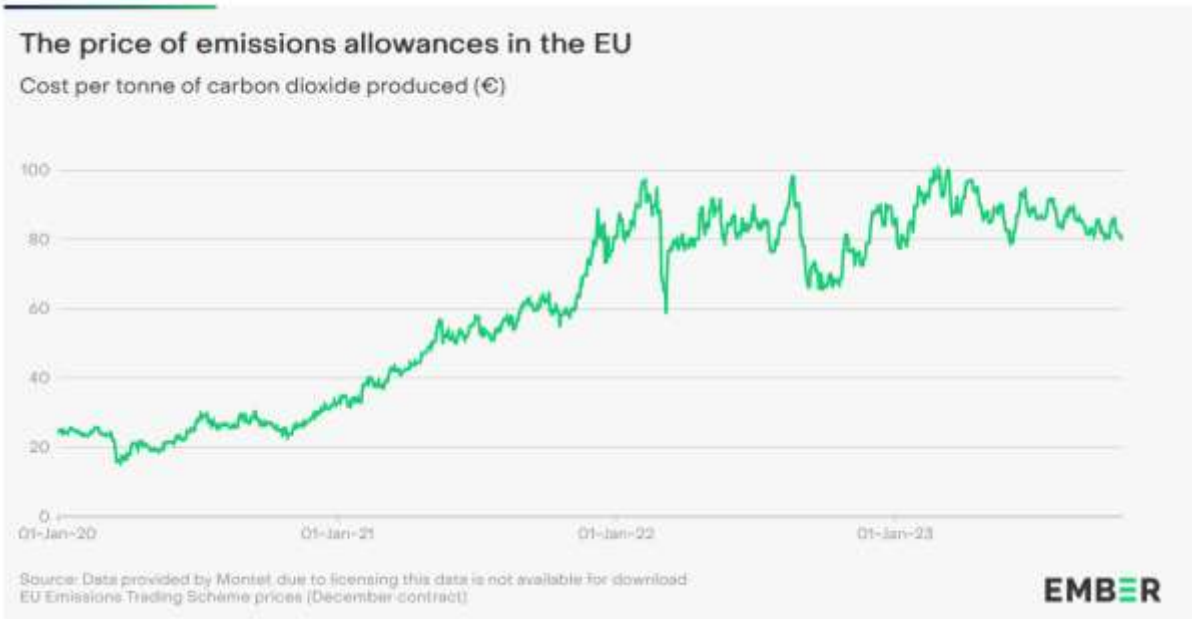
The monitoring plan and the emissions need to be verified by an independent verifier that is accredited by one of National Accreditation Bodies (NABs).[27] Companies can select any accredited verifier irrespective of the ship's flag or the place where the company and where the verification company is based.[28] However, the verifier must be independent from the company and impartial in carrying out its verification activities. Currently, the THETIS-MRV includes 19 verification companies, while in the LNG carrier segment (389 ships) the number of verifiers drops to 9.[21] Given the current verification capacity, the extension of ETS to new types of ships and GHGs puts into question the verifiers' ability to accurately verify the compliance of the shipping companies, e.g. an obligation to carry out site visits.[28]

Companies will be required to report total aggregated GHGs per ship and per company, it is still to be seen whether the GHG-specific emissions will be publicly available in the EU-THETIS database.[29] In case the operators fail to comply with the EU MRV Regulation for two consecutive periods, they will face the same penalties as for breaching the EU ETS directive, with a denied port access.

3.4. Compliance and enforcement

The ETS gives shipping companies the flexibility as to whether to reduce their emissions or to buy allowances. In the first ten months of 2023 the EUA prices averaged around €80 per tCO_2 (Figure 1).

Figure 1: The price of emissions allowances in the EU. Carbon Price Tracker 2023



Source: EMBER.[30]

Administering authorities in Member States will be primarily responsible for the enforcement of new ETS rules. However, the non-compliance with ETS obligations will have significant implications ranging from financial penalties to loss of entry to EU ports. Companies not complying with the EU ETS will face penalties including a €100 fine (inflation linked) per tonne of CO_2eq not surrendered. There is also a reputational risk for penalised companies, as their names will be publicly disclosed. Moreover, Member States may lay down additional penalties, provided they are effective, proportionate and dissuasive. If

a shipping company fails to comply with surrendering obligations for two or more consecutive reporting periods, each Member State is obliged to deny entry to the ship under the responsibility of the noncompliant company or to detain the ship, if a ship flies the flag of an EU Member State.

3.5 Revenues from the EU ETS auctions

In 2021, the total EU ETS auctioning revenues were estimated at €31 billion (bln).[31] Over 80% of the revenues, 25 bln, went directly to the Member States and the remaining 6 bln to the EU funding programmes – Innovation Fund and Modernisation Fund. The Member States decide how to spend the revenue, but they are obliged to use at least 50% for a broad range of climate- and energy-related purposes. The European Commission estimates that 20 million allowances (i.e. about €1.6 billion at €80/EUA) should be deployed up to 2030 via the Innovation Fund to support the decarbonisation of the maritime sector.[32] As this funding can be accessed by multiple sectors, maritime projects will compete with other sectors for the limited funding available under the Innovation Fund.[33]

4. The implications for shipping, methane mitigation and LNG

4.1 Shipping under growing decarbonisation pressure

Recent regulatory developments at the IMO and EU level have moved the maritime sector into the spotlight of global decarbonisation efforts. The level of ambition in the revised IMO GHG Strategy surpassed the expectations of IMO observer organisations, unlikely to happen without the EU challenging to IMO on carbon pricing scheme with its Fit for 55 measures.[34] The EU ETS has a direct and imminent regulatory and monetary impact, creating incentives for the European shipping companies to decarbonise and rewarding proactive operators who can credibly present the GHG emissions associated with their operations. Moreover, the FuelEU regulation is likely to increase the demand for alternative marine fuels, by increasing the reduction targets for the GHG intensity of energy used on board ships as from 1 January 2025 (2% below the reference value of 91.16 grams of CO_2e/MJ in 2025, 6% in 2030, 31% in 2040 and 80% in 2050) and introducing measures to encourage the use of renewable fuels of nonbiological origin (RFNBO). In contrast to the EU ETS, FuelEU regulation adopted well-to-wake approach. Decarbonisation has become one of the key challenges for the shipping industry and given new regulations are expected by 2030, an important question is how the regulatory landscape will evolve in the coming years. Will there be more regional fragmentation?

One of the key uncertainties up to 2030 is whether the IMO will adopt a consistent, comprehensive and stricter GHG regulations by 2030. The IMO targets, while providing a signal for the industry, are not legally binding, necessitating the adoption of binding policies. Bach and Hansen (2023) suggest that to play a more progressive role in climate change mitigation, the IMO needs to focus on: (1) capacity building within the IMO to regulate multiple and emerging technologies, (2) moving away from technical regulation towards new policy areas, e.g. R&D policies, and (3) building political consensus during negotiations.[12] Each task, on its own, is challenging, but it seems that the lack of consensus among the leading IMO Member States is the most important.

The EU played an important role in bringing decarbonisation and the use of market-based measures to the top of the IMO's agenda. The unilateral framework adopted by the EU is largely compatible with the IMO's policies and guidelines, e.g. Life Cycle Assessment Guidelines. While the EU was able to adopt its policies earlier, the revised IMO GHG strategy goes further in some aspects, e.g. the IMO targets are to be considered within the context of well-to-wake emissions, in contrast to the tank-to-wake approach under the EU ETS. The EU ETS Directive contains a review clause mandating the Commission to review the ETS Directive in case a global market-based measure is adopted at the IMO level "to ensure coherence between the implementation of the global market-based measure and the EU ETS, while avoiding any significant double burden." (Article 3gg, Directive (EU) 2023/959) It could potentially mean that the EU ETS will be superseded by the IMO's levy on GHG emissions as of 2027. But if the IMO does not adopt such measure by 2028 or if it will not be considered equivalent, the Commission can propose to further extend the surrender obligations from voyages starting outside of the EU currently covering a half of these emissions. This creates significant regulatory uncertainty for

the shipping companies and may increase tensions over the international impact of the EU climate policies.

In contrast to the Paris Agreement, which highlights a slow departure from the principle of common but differentiated responsibilities (CBDR), this remains one of the principles for the revised IMO GHG strategy. It has significant implications in the discussions on the medium-term measures, which are likely to disproportionately impact developing economies. Hence, political support for measures such as a global levy on maritime GHGs is conditional on the redistribution mechanism to compensate impacted countries. The EU ETS is not designed to work this way, as the majority of the ETS revenues are spent within the EU. Between 2013 and 2021, over 80% of revenues were used for domestic EU projects. In absolute terms, the amounts spent on projects at the international level have remained relatively unchanged (at €100-200 million per year) and were directed mostly to developing countries via multilateral funds and institutions.[31] Hence, the international instrument adopted by the IMO is considered more equitable by big ship-owner nations exerting significant influence over the IMO negotiations, such as China, Panama, Liberia and the Marshall Islands.[35] Given the international character of shipping, many influential voices at the IMO level, e.g. the US and the shipping industry also support a global IMO regulatory framework.

4.2 Contradictions in the EU methane policies

As of 2026, methane emissions will be regulated under two different policy instruments in the EU – market-based ETS and the EU Methane Regulation, covering emissions associated with the extraction, transportation and end-use of fossil fuels – oil, gas (pipeline and LNG) and coal. Both policies set out separate rules for Monitoring, Reporting and Verification (MRV) of methane emissions. This situation creates some inconsistencies as to how methane is regulated in the EU and with the EU ambitions outlined in the 2020 EU Methane Strategy, particularly with regard to emissions associated with energy imports. In particular: 1) which methane emissions are regulated and which are not, 2) how are methane emissions monitored, reported and verified, 3) which Global Warming Potential values are used to calculate CO_2e.

The first contradiction refers to the scope of policies. The proposed EU Methane Regulation applies to: i) oil and fossil gas upstream exploration and production, fossil gas gathering and processing; ii) gas transmission, distribution, underground storage and liquid gas (LNG) terminals operating with fossil and/or renewable (bio-or synthetic) methane. It implies that the regulation does not directly cover emissions associated with LNG shipping (art. 1), which are incorporated under the EU ETS. However, ETS covers mostly the emissions associated with the combustion of LNG, including methane slip. As a result, some LNG-related sources are likely to remain unregulated e.g. emissions arising during LNG loading and unloading, boil-off gas (BOG) emissions (if BOG is not routed as fuel via a fuel gas supply system or reliquefied onboard and reinjected in the cargo tanks) as well as fugitives and vents arising during the LNG shipping, unless they will be covered under the EU Methane Regulation's import requirements.[36] A recent study shows that noncontinuous sources associated with LNG loading/unloading can be a significant source of emissions.[37]

The second contradiction refers to the inconsistency in quantification and verification of methane emissions. The Methane Regulation places the focus on direct emission measurements, and measurement-based emission factors, in line with the OGMP2.0 Level 4 and 5 quantification. In contrast, the EU MRV Maritime Regulation is mostly based on a calculation-based approach and sets default emission factors (EFs) for the methane slip calculation, providing no incentives for choosing direct emission measurements instead of emission calculation. This discrepancy can be explained by the fact that CO_2 accounts for the vast majority (>90%) of emissions in shipping and these emissions can reasonably be calculated using engineering methods (by multiplying fuel consumption and CO_2 emission factors). The uncertainty in CO_2 calculations is much less pronounced relative to methane, which in turn constitutes a material GHG in the natural gas supply chain. However, these assumptions may not always be correct,[38] highlighting the necessity for more direct measurement studies to better understand shipping emissions profile[9] and raising questions over the uncertainty of methane estimations under the EU ETS, given the system's direct monetary impact. Moreover, while the

verification under with the MRV Maritime Regulation requires the verifiers to check if the operators comply with the EU MRV Maritime Regulation, the EU Methane Regulation places focus on the verification of emissions and adopted quantification approaches. The risk here is that methane emissions associated with LNG shipping will be reported under two different EU MRV regimes, undermining the EU efforts to provide more transparency on the GHG intensity of different gas supply chains.[39]

The last contradiction refers to the Global Warming Potential values used for CO_2e calculations. While the over 100 year horizon is consistently used under the Fit for 55 legislation, some differences exist in the choice of specific values. For example, methane emissions will be multiplied: by 25 under the FuelEU maritime regulation (as defined in Directive (EU) 2018/2001[19], paragraph 4 of Part C of Annex V) and by 28 under the EU ETS, based on the EU MRV maritime regulation and Delegated acts (as defined in Annex to Commission Delegated Regulation (EU) 2020/1044)[40].

Despite these contradictions, the inclusion of methane under the EU ETS may provide some lessons learned for other jurisdictions as to the effectiveness of market-based instruments in addressing methane emissions. Until now, market-based instruments and cap-and-trade programs in particular, have been used sparingly to address methane emissions, but the EU example could serve as a proof-of-concept for other jurisdictions developing domestic methane policies. Moreover, the EU ETS provides an example of how to regulate different GHGs under the same policy with non-CO_2 gases converted to an equivalent amount of CO_2 by using a global warming potential over 100-year horizon. Following this logic, the EU ETS can be subsequently extended to the waste sector e.g. landfills, but will first require agreement on MRV principles e.g. monitoring frequency and approaches, in the solid waste context[41] and a better understanding of methane emissions from wastewater treatment plants.[42]

4.3 The cost of compliance and the impact on LNG

The ETS data management services company, OceanScore, estimated the EU ETS compliance cost, based on 82.7m EU Allowances which would have been needed for voyages to from and between European ports in 2022, at €6.5bn, assuming the price of €78 per EUA/tCO_2.[43] This would have translated into the average cost of complying with the EU ETS by 2024 standards amounting to about 3.25% of the freight cost, according to Argus.[44] While it creates a "significant financial exposure" for the shipping industry, the reason for concern is not necessarily the ETS compliance cost itself, but rather ETS price volatility alongside the risk of non-compliance fines.[44] In theory, shipowners could seek reimbursement by the entity responsible for the fuel purchase and/or the ship's operation under the EU ETS rules. Yet, it is still not clear how it will work in practice and some shipowners have already declared their plans to pass the costs over to ship charterers.

The risk is even higher for ships emitting methane and nitrous oxide. As these emissions will be multiplied by 28 and 265, respectively, to calculate CO_2e. Shipping companies with LNG-fuelled vessels in their fleet will need to pay more attention to robust monitoring, reporting and verification of their GHG emissions. While LNG has been presented as an alternative due to lower CO_2 emissions upon combustion, the new EU shipping regulations create a certain disadvantage for LNG. The industry related to LNG shipping is already responding to this challenge by investing in: larger and more efficient fleet, 2 stroke engines characterised by lower methane slip, as well as onboard reliquefaction units to deal with BOG and increasingly looking into future technologies like Carbon Capture and Storage (CCS).[45] It is still to be seen if it will be sufficient to maintain the uptake of LNG as a marine fuel on an upward trend, and how regulatory changes in Europe may impact LNG ship order book. For instance, over the coming five years, the global LNG carrier fleet is projected to add 303 vessels to the 615 vessels existing in 2022.[45] Regulatory changes in Europe and the revised IMO GHG strategy (still lacking binding IMO policies implementing mid-term measures) may not necessarily reverse, but are likely to reduce the growth in the LNG carrier fleet going forward. For the existing fleet, the regulation may widen the price differential between vessels using different propulsion systems, as charterers will be likely to demand more efficient technologies.[45]

Moreover, significant regional differences exist as to how different regions and countries are looking at the role of the LNG in shipping in 2040-2050 perspective. For instance, Malaysia set a target to increase the share of LNG in marine transport from 0% in 2018 to 25% in 2040 with an intention to become a regional LNG bunkering hub.[46] Japan sees an essential role for LNG, alongside hydrogen and ammonia to decarbonise shipping industry, as part of its Long-Term Climate Strategy.[47] In the light of regulatory uncertainty, limited supply and infrastructure for alternative marine fuels, the competition for renewable energy with other sectors e.g. aviation and projected decrease in LNG prices after 2025, the shipping companies are preparing their fleets to run on multiple families of fuels, e.g. suggesting more wide-spread use of dual-fuel and tri-fuel engine designs.[48] More and more shipping companies are exploring the possibilities of using alternative marine fuels such as methanol, ammonia or hydrogen. However, there is as risk that a number of dual-fuel vessels, e.g. using methanol in dual-fuel engine, may actually continue to run on conventional fuels, as a ship orderbook is not always a perfect fuel demand forecast.[49]

5. Conclusions and further research questions

International maritime transport, responsible for almost 3% of global GHGs, has been one of the last major sectors not covered by decarbonisation policies. But recent regulatory changes at IMO and EU level make decarbonisation one of the major challenges for the shipping industry. As of the 1st of January 2024, shipping emissions will be incorporated under the EU cap-and-trade program – the EU ETS. This paper reflects on the key implications for shipping, methane mitigation and LNG as a marine fuel.

The effectiveness of the EU ETS extension and other Fit for 55 measures, e.g. FuelEU regulation should be closely followed by the LNG industry. Shipping companies with LNG-fuelled vessels in their fleet will need to pay more attention to robust monitoring, reporting and verification of their GHG emissions, energy efficiency measures, e.g. wind assisted propulsion systems, and methane slip reduction. This may become a commercial advantage, especially in the context of new LNG supplies coming to the market post-2025, likely to increase competition between LNG suppliers and the demand for accurate assessment of their supply chain emissions.

Finally, while this paper provides an overview of the key issues and tensions related to the decarbonisation policies for shipping, our future research will focus on the following more specific questions:

1) What changes are necessary to better align the EU MRV maritime regulation and EU methane regulation to provide more consistent approach for methane monitoring, reporting and verification in the EU?
2) How should various parties in the shipping business establish compliance mechanisms and plan for the future?
3) What strategies are there for the LNG suppliers to remain competitive in Europe and how are the major EU LNG suppliers responding to the EU decarbonisation policies?

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