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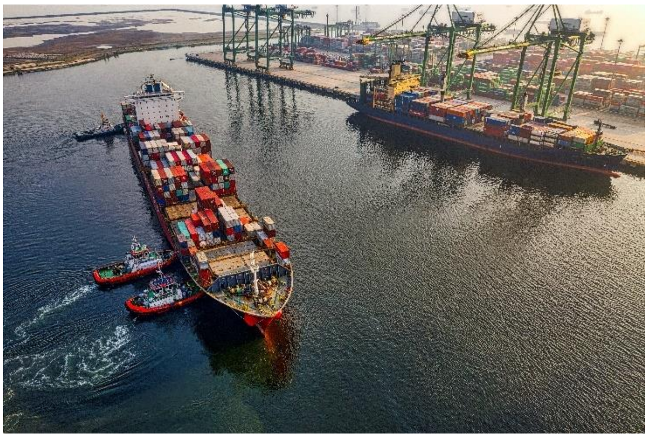
International shipping and emissions



In 2021, the UK's share of emissions from international shipping was formally included in the nation's sixth carbon budget. Although seen as a 'difficult to decarbonise' sector, it will now be required to contribute to the UK's net zero GHG emissions by 2050 target. This POSTnote examines the options for reducing emissions from international shipping activities and outlines the regulatory landscape of the sector.

Overview

- International shipping is responsible for 3% of global greenhouse gas (GHG) emissions.
- The sector is difficult to decarbonise owing to the long lifetime of ships, the complex network of actors in the sector and uncertainty around low-carbon technologies.
- Options are available for short-term reductions in GHG emissions but a transition to zero-emissions technologies will be required to fully decarbonise the sector.
- A number of zero-emissions fuels and drive systems are currently being developed.
- Emissions from international shipping are primarily regulated by the International Maritime Organization (IMO).
- The IMO's GHG targets are to be revised in 2023 and will need to be strengthened to meet the Paris Climate Agreement.

Background

Currently, 80% of global trade by volume and 95% of UK trade is transported by ship.[1,2] Of the global fleet of vessels, 97% are fuelled by heavy fuel oil (HFO) or marine diesel.[3] These are both fossil fuels that produce CO_2 and other air pollutants when burnt. Therefore, despite being one of the most energy- and cost-efficient modes of transport for international freight, the emissions from these vessels are directly linked to climate change as well as negative environmental and health effects.[4]

Shipping contributes significantly to the emission of harmful air pollutants such as SO_x, NO_x and particulate matter (PN 458).[5] Domestic and international regulations have controlled the emission of many of these gases from ships since the 1990s, though they remain a significant issue.[3,6–8] In contrast, GHG emissions from the sector have only been regulated in any form since 2013, with domestic and international discussions on decarbonisation accelerating in the last 5 years. GHG emissions from shipping are currently projected to grow by up to 50% by 2050, compared to 2018, as demand for seaborne trade rises.[3] As such, rapid action will be required to align the sector with international climate targets and the UK's own net zero goal.[9]

International shipping is generally recognised as being a 'difficult to decarbonise' sector due to a variety of technical and structural factors. Vessels are capital intensive and have an average lifespan of 20-30 years.[10,11] This results in low turnover within the fleet and hinders uptake of technologies without proven reliability. In addition, a large proportion of operators are small and medium-sized enterprises without the capital to invest in reducing emissions.[12] The sector is also highly fragmented, with a complex network of stakeholders involved in building, operating and chartering vessels.[13,14] The international nature of the sector means regulation is challenging and often requires the alignment of many states with diverse interests.[15]

Options for reducing emissions

The primary methods for reducing emissions are improvements in energy efficiency and the replacement of HFO and marine diesel with low- and zero-carbon alternatives.[5]

Improving the energy efficiency of shipping

Improvements in energy efficiency can deliver immediate reductions in fuel consumption and GHG emissions, without a significant impact on the capacity of the sector. Some measures are already mature and deployed to varying extents. From 2008–18 the global fleet is estimated to have reduced carbon intensity (carbon emissions per unit of transport work) by 30%, largely driven by optimisation of operating speeds and an increase in the size and capacity of new ships.[3,16] More effective

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use of existing and new technologies is estimated to offer further efficiency gains of 10-50% by 2050.[3,17–19]

Operational measures
Optimisation of vessel speeds can significantly reduce fuel consumption. Most commonly this involves operating at less than the maximum speed of a vessel (termed 'slow steaming'). For example, a 10% reduction in speed from the maximum can reduce fuel use by 19%.[20] Speed optimisation is already widely deployed and average operating speeds have decreased since 2012.[3] More effective use could deliver further fuel savings by up to 50% for some ships.[21] Weather routeing involves adjusting routes based on currents and weather conditions and can improve efficiency by as much as 5%.[22] Optimised maintenance of the hull, propeller and engine of a vessel could also reduce the fuel consumption of many vessels by up to 10%.[23,24] Optimising logistics to maximise loading of vessels, minimise voyages without cargo and promote practices like just-in-time arrival are estimated to offer efficiency improvements of up to 38%.[18] Operational data is increasingly collected and stored in a digital format. This is also likely to improve efficiency by facilitating data-sharing and coordination between ship operators, ports and other actors in the sector.[25]

Ship design
In addition to increasing the capacity of vessels, changes in vessel design can improve efficiency by reducing drag. Optimising the hull shape, use of coatings or air lubrication, and fitting of fins and ducts on the stern can provide incremental efficiency gains of 1-5%.[21,22,26,27] Onboard renewable energy generation (for example solar or waste-heat-recovery from exhaust gases) can also be used to supply heat and electricity onboard and decrease fuel consumption by 5-15%.[21,24,28]

Shore Power
Providing shoreside electricity allows ships to turn off their engines whilst in port (known as 'cold ironing'). Although emissions while in port are much lower than those produced during voyages, 60-90% of the emissions from ports are from the engines of docked ships.[29] As such, the greatest benefit of increased shore power is reducing air pollution around ports.[29–31] Ongoing projects at Orkney and Southampton represent the current extent of UK shore power but the technology is mature and deployed significantly in Europe and the US.[32–34] Some researchers suggest that uptake will require infrastructural development and/or regulatory changes to incentivise or mandate the connection of ports to the local grid and the plugging in of docked ships.[32] The Climate Change Committee (CCC) has recommended increased government investment in shore power infrastructure in UK ports.[35]

Wind-assisted Technologies (WATs)
A range of sails, wings and rotors are currently in development for use on purpose-built ships or as retrofits for existing ships. These technologies use wind propulsion to supplement engine power and reduce fuel consumption. There is a wide range of reported emissions savings as their effectiveness is highly dependent on various factors such as ship type or route.[36] Certain types of rotor are currently in commercial operation and provide fuel savings up to 10%.[37] Projections for wing sails and kites placed on bespoke ships show potential fuel savings of 15-50% when coupled with route optimisation.[38–41]

Barriers to improvements in energy efficiency
The structure of the shipping sector and the nature of contracts between shipbuilders, shipowners and charterers are a barrier to uptake of efficiency improving measures and technologies.[13] Financial and contractual limitations on the speed and route of voyages mean ship operators are often unable to use certain types of optimisation or cannot recoup investment in fuel-saving technologies.[36,42–44] Also, many of the options lack commercial scale demonstration, which creates uncertainty for ship owners on whether a technology will deliver a financial saving over a ship's lifetime.[36] This is compounded by the diversity of ships and operating conditions in the sector as the efficacy of many measures is dependent on these factors.[12]

Alternative fuels and drive systems
Improving efficiency can reduce emissions in the short term, but replacement of HFO and marine diesel with alternative fuels or drive systems will be required for shipping to realise zero or net zero GHG emissions. The main alternative fuels and drive systems are outlined below.

Liquified natural gas (LNG)
LNG is a carbon-based liquid fuel made by cooling natural gas to -162ºC. Burning LNG instead of HFO offers reductions of up to 30% in GHG emissions and 90-100% in emissions of air pollutants at the point of use.[45,46] However, if not properly contained across the supply chain, methane from unburnt LNG can escape into the atmosphere. Methane is a potent GHG (PN 480) and commentators have concerns this 'methane slip' might negate any GHG emissions benefits during burning.[47–49] The number of LNG-fuelled ships has grown in the last decade but remains low (less than 0.1% of the global fleet in 2021).[50,51] However, 10-20% of ships currently on order will use LNG and LNG refuelling facilities are now available at a third of European ports.[52] Some stakeholders support LNG as a 'transitional' fuel, capable of providing immediate and cost-effective reductions in emissions of GHGs and other pollutants.[53,54] Others argue that development of the LNG supply chain and infrastructure risks technological lock-in, assets becoming obsolete and delaying the transition to zero-emissions fuels.[48]

Biofuels
Different types of biofuels can be used as 'drop-in' alternatives to HFO, marine diesel and LNG without major infrastructural change or engine modifications. Biofuels are currently used as part of a fuel blend (with HFO) in many commercial vessels.[55–57] The production and use of biofuels are examined in PN 616 and PN 293. Estimates of the GHG emission reductions offered by biofuels in shipping cover a wide range (40-100% compared to HFO) and depend on various direct and indirect impacts of the supply chain, such as changes in land use.[55,58] Questions remain around the environmental impact of biofuels and the scalability of their production.[58,59] The CCC has advised that, due to supply limitations, biofuels should be prioritised for sectors with fewer alternative fuel options, such as aviation, but acknowledges them as a potential transitional fuel in shipping.[60]

Electrofuels
The production of carbon-based electrofuels such as e-methanol, e-LNG and e-diesel is described in PN 616. These synthetic fuels are attractive as a potentially carbon-neutral,

drop-in alternative to HFO, marine diesel and LNG. Their production is currently expensive and inefficient compared to competing alternative fuels. It also requires carbon capture and utilisation (POSTBrief 30) or direct air capture (DAC), which remain in the early stages of development.[16,61,62] As a result, these fuels are not currently carbon neutral and are unlikely to be commercially viable until the mid-to-late 2030s.[35,63] However, they remain the preference of many stakeholders due to their compatibility with existing vessels and infrastructure.[64]

Zero-carbon fuels
Hydrogen and ammonia have the potential to act as 'zero-carbon' alternatives to HFO, if produced sustainably. These fuels do not contain carbon and, when burnt, produce primarily water, in the case of hydrogen, or water and nitrogen, in the case of ammonia. The major production routes to sustainable hydrogen are the splitting of water using renewable electricity (green hydrogen) or 'steam reforming' of natural gas coupled with carbon capture and storage (blue hydrogen). Green or blue ammonia is made by combining nitrogen from the air with green or blue hydrogen, respectively. Green hydrogen and ammonia production are projected to be commercially viable at scale in the 2020s (PN 645). Their zero-carbon credentials as well as the low-cost and scalability of their production makes them the future fuel of choice for many stakeholders.[62,65–67]

However, liquid hydrogen and ammonia are both less energy dense than HFO, which means larger volumes of fuel are required for the same journeys (three and five times more for ammonia and hydrogen, respectively). Liquefaction of hydrogen also requires cooling to -252ºC, which is energy intensive and increases the cost of storage and transport. In contrast, liquid ammonia can be stored at -33ºC or under pressure at ambient temperatures.[20,68] Stakeholders who favour ammonia over hydrogen often refer to the higher energy density and relative ease of storage and transport as key factors.[16,63,69] Currently, ammonia is produced in large quantities and safely transported internationally despite being highly toxic and corrosive.[69] Nonetheless, use of ammonia as a fuel will require development of safety procedures and regulations to prevent exposure of humans and the environment.[65,70] Burning ammonia also releases substantial quantities of NO_x and N_2O, which are both air pollutants and GHGs, and pre-treatment of exhaust fumes would likely be required.[71] Neither ammonia nor hydrogen are a 'drop-in' alternative to HFO and will require new ship and engine designs or significant retrofitting of existing vessels.[71]

Fuel cells and batteries
Hydrogen or ammonia can both be used in fuel cells to generate electrical energy and emit only water or nitrogen and water, respectively. However, the cost of using a fuel cell is significantly more than using either as a combustion fuel and further technological innovation is likely required to make them economically competitive as a drive system in large ships.[20,72]

Batteries are a mature technology and currently allow the use of renewable electricity to power a number of small commercial vessels.[73,74] Current batteries are significantly below the energy density required to be used as the sole power source for deep-sea voyages and are only likely to be used in short-range vessels or as part of hybrid systems in the near future.[16,72]

Nuclear power
Vessels using nuclear power as their primary drive system could theoretically go their entire lifetime without refuelling and produce no direct emissions.[75] Small modular reactors (SMRs) are in service in the UK naval submarine fleet but are not commercially available at present (PN 580). There are generally seen to be many challenging environmental and socio-political barriers to the deployment of nuclear energy in commercial shipping.[19,20,76] The UK Government held a consultation in 2021 on updating UK law to reflect international standards on nuclear-powered merchant ships with a report due in 2022.[77]

Considerations for an effective transition
Stakeholders are debating which zero-emission technology is optimal, as well as the most effective way to transition towards domestic and international decarbonisation goals. This debate is made more complex as alternative fuels are likely to be more expensive, less energy dense and limited in supply during the initial scale up of production. Constructing a transition pathway that is economically viable and that aligns with GHG targets involves consideration of factors such as the short- and long-term availability of fuels, compatibility of fuel infrastructures, the retrofit-capability of ships, and the impact of assets becoming obsolete and early scrappage, among others.[17,66,78,79]

Projections for the international shipping industry point to a need for immediate reductions in emissions from the existing fleet as well as a rapid acceleration in the development of zero-emissions technologies and their supply chain infrastructures.[80] Some suggest a need for 34-45% reductions in absolute emissions or a 5% uptake of zero-emissions fuels by 2030 to align with the Paris Agreement goal of restricting warming to 1.5ºC and net zero by 2050.[9,66,81] The investment required from 2030–50 to decarbonise global shipping has been estimated at $1.2-1.6 trillion.[80] As a result, any strategy will need to drive substantial private investment as well as guiding a technological pathway towards decarbonisation.[82,83]

Regulatory landscape
Emissions from domestic shipping are the responsibility of national governments under the Paris Agreement. In contrast, international shipping is governed by the International Maritime Organization (IMO), a UN agency made up of 174 member states, including the UK. In recent years, the UK and EU have imposed policy actions to reduce their share of emissions from international shipping activities and some have questioned the IMO's remit for regulating emissions.[84]

International policy
The IMO's 2018 Initial GHG Strategy is the only internationally agreed target for GHG emissions from international shipping as these emissions were not explicitly included in the Paris Agreement. It aims for at least a 50% decrease in absolute emissions by 2050 and at least a 40% reduction in the carbon intensity of ships by 2030, both compared to 2008 levels.[85] These targets have been criticised by national governments, industry groups and researchers for a lack of ambition and a failure to align with the Paris Agreement goal of limiting warming to 1.5ºC.[9,86–88] In 2021, multiple nations, including the UK, called for the IMO to set a target of zero emissions by 2050 as well as stronger interim targets.[89,90]

The primary measures put in place by the IMO since 2013 have been a series of efficiency and intensity standards, with further measures to be enforced from 2023 (Box 1). These have been criticised for lacking stringency despite an estimated 30% decrease in carbon intensity across the global fleet from 2008–18.[3] The IMO plans to publish a revised GHG strategy in 2023 based on emissions data from its Data Collection System (DCS).[85] This strategy will include 'mid- and long-term' measures and a likely tightening of current GHG targets.[91] All proposed measures will be subject to the IMO's assessment for impacts on States, which especially aims to protect developing nations during the transition.[92] Discussions are ongoing at the IMO on the level of these revised targets and the use of technical and operational standards and/or market-based measures (MBMs) going forward. MBMs are financial measures aimed at driving uptake of emissions reduction options by placing an effective price on emissions. Broadly speaking, proposals for MBMs in shipping take the form of a simple emissions tax or levy, or an emissions trading scheme (ETS). Under an ETS, a limit would be placed on the total emissions from shipping activities covered by the scheme, and a price on emissions is established by trading emissions units on an open market. A range of stakeholders support some form of MBM in the sector, although the optimal carbon price and the use of the resulting revenues remains a topic of debate.[93–95]

Box 1: IMO regulations on GHG emissions

Enforced from 2013:

- Energy Efficiency Design Index (EEDI) – A compulsory energy efficiency standard placed on newly built ships.
- Ship Energy Efficiency Management Plan (SEEMP) – A plan to improve the operational efficiency of a ship through voluntary measures.[96]

To be enforced from 2023:

- Energy Efficiency Existing Ship Index (EEXI) – A compulsory energy efficiency standard on existing ships.
- Carbon Intensity Index (CII) – An annual rating placed on a ship based on the efficiency of its design and operation.
- SEEMP annual audit made compulsory for all ships.[97]

At COP26, 22 nations, including the UK, signed the Clydebank Declaration, committing to the creation of at least six zero-emissions shipping corridors by the mid-2020s.[98] Since 2018, many shipping companies and charterers have also committed to net zero GHG emissions by 2050.[99–102] In addition, a number of consortia of public and private bodies have been established to facilitate collaborative innovation and to align stakeholder groups with decarbonisation efforts (such as financiers and charterers).[103] Examples include the Zero-Emissions Shipping Mission, of which the UK Government is a core member, and initiatives by the Global Maritime Forum.[104–107]

EU policy

In 2021, the European Commission put forward the 'Fit for 55' policy package to be enforced from 2023 with the aim of reducing GHG emissions in the EU by 55% by 2030.[108,109] This proposal includes fuel standards mandating the use of an increasing percentage of low-carbon fuels over time in all ships (FuelEU Maritime), the introduction of international shipping into the EU Emissions Trading Scheme (EU ETS) and measures to promote shore power.[108] These regulations would cover ships and ports within the EU and 50% of emissions from voyages between EU and non-EU states, potentially extending to 100% if a global MBM is not in place by 2028.[110] Some stakeholders have questioned the efficacy of regional measures to affect an international sector such as shipping. Several corporate actors and nation states have pointed to the risk of warping the market or undermining the governing power of the IMO as well as the potential for 'carbon leakage' and shifting of freight to less efficient transport modes (such as road, rail or air) to negate any emissions savings.[111–116] In contrast, other corporate interests and many NGOs support the measures as a positive step in the absence of stricter measures from the IMO.[114,117,118] The IMO and EU strategies have both been criticised for failing to sufficiently accelerate development and uptake of zero-emissions fuels and infrastructure.[119]

UK policy

In April 2021, the UK Government announced the inclusion of international shipping and aviation emissions in the sixth carbon budget, in line with CCC advice.[35,120,121] As a result, from 2033 the UK's share of international shipping emissions will be included in its net zero GHG emissions by 2050 goal. The CCC identified 33% uptake of zero-carbon fuels in domestic ships by 2035 as a key milestone and has recommended policy actions to continue innovation and demonstration support for zero-carbon technologies and incentivise their deployment.[35] Many researchers have also advised the acceleration of similar domestic policy actions to enable the development of markets for zero-emissions marine fuels that can be scaled over time.[122]

The Department for Transport's Clean Maritime Plan (2019) and Transport Decarbonisation Plan (2021) outline the UK's desire to take a leading role in the decarbonisation of shipping and the substantial social and economic benefits it represents.[123–125] The Transport Decarbonisation Plan committed to consult on a 'Course to Zero' for domestic shipping in 2022, which will include indicative targets from 2030 and net zero as soon as is feasible.[124] The report also reaffirmed the UK Government's desire to press for acceleration of decarbonisation efforts at the IMO ahead of the 2023 GHG strategy revision. The following domestic policy actions have been enacted since 2019:

- Clean Maritime Demonstration Competition (CMDC) - £23 million provided to 55 green maritime innovation projects in 2021. Set for a second round in 2022.[126,127]
- Operation Zero – An industry coalition aimed at accelerating the decarbonisation of service vessels in the North Sea offshore wind sector.[128]
- Extension of the Renewable Transport Fuels Obligation (RTFO) to include incentives for use of renewable fuels of non-biological origin in domestic vessels, such as ammonia and hydrogen, to be enforced from 1 January 2022.[129]

Since 2019, the Government has also committed to the following actions:

- Consultations on steps to support shore power and a potential phase-out of the sale of new non-zero emissions domestic vessels.[124,130]
- Extension of the CMDC to an ongoing multiyear program.[130]
- To review the UK's Monitoring, Reporting and Verification system for GHG emissions from international shipping.[124]
- Exploring the establishment of a UK Shipping Office for Reducing Emissions (UKSHORE).[124]

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