REDUCING THE MARITIME SECTOR'S CONTRIBUTION TO CLIMATE CHANGE AND AIR POLLUTION

Identification of Market Failures and other Barriers to the Commercial Deployment of Emission Reduction Options.

A Report for the Department for Transport

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1 EXECUTIVE SUMMARY

Shipping[1] is currently responsible for 3.4% of the UK's overall greenhouse gas (GHG) emissions and it emits a range of pollutants that are harmful to human health (DfT, 2019). National and international commitments have been made to reduce emissions. Fulfilling these commitments requires the widespread adoption of abatement options and changes in behaviour.

However, take-up of these options is hampered by the existence of market failures and other barriers. This means deployment is slower than would be ideal from a social perspective and emission reduction ambitions could be jeopardised. Government intervention may therefore be needed to address some of these barriers to unlock commercial deployment of cost-effective abatement options.

This report offers a framework for considering market failures and other barriers in this context. Firstly, a typology is defined, which provides a way to classify the range of barriers that are hindering the commercial deployment of abatement options. Secondly, an indicative qualitative assessment of the relative magnitude of each barrier is compiled.

This report finds that the most notable barriers to uptake are:

- Negative externalities;
- Split incentives to invest;
- Imperfect information on abatement options;
- Imperfect information flows between owners and charterers;
- Existing infrastructure and onboard technologies; and
- Inter-organisational co-ordination failures.

There are other barriers which may be relatively smaller in size, but intervention may still be a proportionate way to increase the uptake of options. These are:

- The cost of capital;
- Hidden costs of investing;
- Existing policy;
- Market operations;
- Intra-organisational co-ordination failures;
- Bounded rationality; and
- Myopic outlook.

[1] Both international and domestic.

2 INTRODUCTION

A wide range of technological, operational and behavioural abatement options, alongside alternative low carbon fuels and energy supplies, are currently available. Most are to some extent already being used, or at least seriously considered, by the maritime sector. However, take-up of these options is hampered by the existence of market failures and other barriers. This means deployment is slower than would be ideal from a social perspective, with the effect that national and international emission reduction ambitions could be jeopardised. Understanding the nature of these barriers and the extent to which they could hinder the deployment of abatement options is therefore important.

This report provides a framework for categorising these market failures and other barriers based on a review of available evidence. It then provides a qualitative assessment of the extent to which they hinder commercial deployment and considers how this may change over time.

The structure is as follows:

- **Context** for the maritime sector is provided, which helps to illustrate why market failures and barriers may exist.
- **A typology of barriers** is defined, which can be used to consider the range of barriers and market failures. Each of the barriers and market failures considered in this report is assigned to a category within the typology.
- **Criteria to assess the barriers** are then set out. These can be used to compare the barriers on a consistent and qualitative basis and provide a relative indication of the extent to which each barrier may hinder commercial deployment of an abatement option.
- **Qualitative assessment of the barriers** is provided. Each market failure and barrier is described individually, along with the corresponding assessment of the challenge it poses for commercial deployment.
- **Conclusions** about the most notable barriers are then summarised.

Published evidence has been used to inform the assessment, both relating to the maritime sector and other sectors where relevant. Where appropriate, potential government interventions that could be used to address the barriers are noted, though not considered in detail.

2.1 Sector context

The UK’s maritime sector is a complex system of multiple parties that interact to facilitate the movement of goods and passengers into, out of and within the UK by sea. The challenge for the sector is how it can undertake its activities in an environmentally sustainable and commercially viable way.

Maritime activity in the UK is substantial:

- There were 51 major ports in the UK in 2017, 42 of which handled more than 1 million tonnes of cargo (DfT, 2018a).

- Total freight handled at UK ports was 482 million tonnes in 2017. Approximately 20% of this was domestic and the remainder was international (DfT, 2018a).
- At the end of 2017 there were 354[2] UK-registered trading vessels of 500 gross tonnes and over (DfT, 2018b).
- The total number of sea passengers in 2017 on UK domestic routes was 44 million and the equivalent figure for international routes was 21.5 million (DfT, 2018c).

The maritime sector's participants do not exist in isolation. They continually interact with each other and interface with other sectors.

Shipping[3] is currently responsible for 3.4% of the UK's overall greenhouse gas (GHG) emissions. In 2016, international shipping bunkers were responsible for 59% of the UK's CO_2 emissions from shipping (DfT, 2019). Shipping also generates emissions of several pollutants harmful to human health. In 2016 domestic shipping[4] accounted for 11% of the UK's total domestic nitrogen oxide (NO_x) emissions, 2% of particulate matter (primary $PM_{2.5}$) emissions and 7% of sulphur dioxide (SO_2) emissions (DfT, 2019).

The costs of these environmental impacts are felt by wider society yet will only be reduced if action is taken by the sector to deploy abatement options effectively.

There is an established body of evidence which suggests that abatement options are not being implemented due to the existence of market failures and other barriers faced by the maritime sector. Other sectors which are attempting to reduce emissions, such as buildings (Frontier Economics, 2015), manufacturing (Trianni et al., 2012) and road transport (Vernon and Meiier, 2012), encounter similar issues. The barriers need to be understood and addressed appropriately if commercial deployment of abatement options is to be effective. The nature of these barriers is explored in more detail in the next section.

[2] Excluding passenger ships.

[3] Both international and domestic.

[4] Ships that start and end their journey in the UK.

3 TYPOLOGY OF BARRIERS

3.1 Framework

Based on a review of the available evidence, this section offers a framework which groups barriers into one of five categories. This framework – or typology – provides a way to capture the range of barriers which are hindering the commercial deployment of abatement options. The typology is shown in Figure 1.

Figure 1 Typology of market failures and barriers relevant to the commercial deployment of maritime abatement options

Source: Frontier and UMAS based on review of evidence.

- **Economic** barriers: There are a variety of economic barriers which hinder take-up of abatement options in shipping. These factors can be divided into market failures and other economic barriers (Sorrell et al., 2004).
  - **Market failures**[5] occur when markets operate inefficiently, meaning that it is possible to improve society’s welfare by altering the way in which goods are produced or consumed (Krugman and Wells, 2012). For example, in shipping, typical market failures might relate to the availability of good information about the range of cost-effective abatement options. Inadequate (or ‘imperfect’) information could lead to decisions which do not deliver the best outcome for society.

    In addition, shipping emissions (GHGs and air pollutants) impose costs on society that the sector itself does not have to bear (e.g. the costs to human health associated with air pollutant emissions) (Brown, 2001). This is known as a negative externality. The party purchasing and consuming the fuel, and therefore who is responsible for the emissions (the ship operator/owner), does not bear all the costs of those emissions and therefore purchases and

[5] All market failures within the shipping industry which are affecting the deployment of abatement options are included within this sub-category.

consumes too much. Without intervention to address this over-consumption, the sector would not take those harmful wider effects into account when making its operational decisions.

Market failures can also occur due to split incentives: ships are often owned by one set of organisations and leased to others to operate them. The incentives for owners to invest in abatement options which reduce emissions (e.g. by increasing energy efficiency) are minimal given that it may be the operator (and wider society) that would benefit from lower energy use (IEA, 2007; Rehmatulla, 2014; Faber et al., 2012).

Government intervention could help address these market failures, though consideration of the appropriate intervention would need to carefully balance the costs of intervention with the benefits (Fisher and Rothkopf, 1989; Jaffe and Stavins, 1994; Brown, 2001).

- **Non-market failures** refer to other economic barriers that contribute to the slow diffusion and adoption of abatement options but do not constitute market failures. These often relate to the practical way markets work.

  For example, investing in certain types of abatement options could require a shipping firm to borrow significant amounts of capital. Depending on the nature of the firm and its size or perceived riskiness (from the lender’s perspective), borrowing those funds could be costly relative to what is affordable and therefore reduce the attractiveness of investing in an abatement option. These issues do not necessarily reflect a fundamental flaw in the market but do affect how markets operate (Brown, 2001).

- **Structural** barriers relate to particular features of the shipping industry. These issues relate specifically to current practices and infrastructure prevalent in the maritime context. Specifically, existing infrastructure in ports and shipyards may act as a lock-in that hampers change from the current status quo, given its long lifetime. For example, handling of cargo in ports by cranes can conflict with wind propulsion technologies which require high masts (Rehmatulla, et al., 2017). In addition, current contract design may incentivise certain types of behaviour which is not consistent with some abatement options. For example, currently, charterers may be penalised if they arrive late at destination ports, which could limit the scope for slow steaming (Rehmatulla, 2014). Finally, vessels themselves have long lifespans, which can mean that existing designs and technologies persist even when new options are available (EEA, 2017).
- **Policy/regulatory** barriers refer to government intervention that can directly or indirectly hinder the uptake of abatement options (Fenton and Kanda, 2016; Rehmatulla et al., 2016).[6] These interventions may, in some circumstances, prevent the ability to achieve an outcome that maximises benefits for society. This could be because national governments implement policy (such as subsidies of fossil fuels[7]) that seek to achieve one objective (e.g. economic growth) but inadvertently have an adverse consequence for the ability to achieve another objective (Ni, 2015).

[6] It is also possible that in certain circumstances a lack of government intervention could act as a barrier to commercial deployment of abatement options. However, in this report these instances are considered elsewhere in the typology, specifically the market failures section.

[7] See OECD (2018) for further details.

- **Organisational** barriers arise from the ways in which organisations are structured and how they interact with each other. For example, shipping companies will consist of many actors with different, sometimes conflicting, objectives (Thollander and Palm, 2013). A finance director could be in favour of implementing a cost-effective abatement option due to the possibility of long-term savings. However, the operations director in the same firm may be against this change as they seek to minimise short-term disruption (Thollander et al., 2010).

  These issues are based on insights from organisational theory and relate to power and culture within organisations (Thollander et al., 2010). As such, they may apply to organisations in all industries and will not necessarily be limited to the maritime context in which they are considered here.
- **Behavioural** barriers relate to the decision-making processes of individuals. These barriers are grounded in psychology, which provides insights into how biases can systematically lead to deviations in so-called ‘rational’ judgement.

The barriers and sub-groups will not always operate in isolation. In reality, the various barriers which hamper uptake will interact and potentially exacerbate each other.

3.2 Criteria for assessing the barriers

A comparative assessment of the nature of the barriers can be carried out by defining assessment criteria. Against these criteria, an indicative qualitative assessment of the relative magnitude of each barrier can be carried out, based on published evidence. This indicates the relative strength of each barrier to uptake, and therefore the potential benefit from addressing the barrier.

Criteria proposed for the assessment are described in Figure 2 .

Figure 2 Criteria for qualitatively assessing the barriers

Size of impact	Description
High impact	Uptake is unlikely to increase materially from today’s levels unless the barrier is addressed.
Medium impact	Uptake could increase to some extent from today’s levels over time but would be more rapid and wide-scale if the barrier is addressed.
Low impact	Uptake likely to increase on its own but addressing barrier will allow more widespread and rapid uptake.

Source: Frontier / UMAS

4 ASSESSMENT OF THE BARRIERS

Figure 3 lists subcategories of each barrier under the five typologies defined in Figure 1 above. The qualitative assessment of the impact of the barriers is summarised in the table, with each barrier discussed in detail in the text that follows.

Figure 3 Barrier categorisation

Barrier typology	Barrier subcategory	Impact of barrier
Economic	Negative externalities	High
Economic	Split incentives to invest	High
Economic	Imperfect information on abatement options	High
Economic	Imperfect information between owners and charters	High
Economic	Variation in characteristics	Low
Economic	Cost of capital	Medium
Economic	Hidden costs of investing (capacity reductions etc.)	Medium
Structural	Existing infrastructure and onboard technologies	High
Structural	Long life of existing assets	Low
Structural	Market operations	Medium
Policy / regulatory	Existing policy	Medium
Policy / regulatory	Regulatory constraints	Low
Organisational	Intra-organisational co-ordination failures	Medium
Organisational	Inter-organisational co-ordination failures	High
Behavioural	Bounded rationality	Medium
Behavioural	Myopic outlook	Medium

Source: Frontier / UMAS

The following relative assessment of individual barriers is necessarily qualitative and based on best available evidence. Quantifying the precise scale of barriers is not feasible. Statistics and evidence are provided where possible to provide some sense of magnitude and prevalence for the barriers.

The nature and importance of barriers could evolve over time. For example, information issues may in some cases be transitory until knowledge and information disseminate.

The purpose of the assessment is not to suggest that all barriers should be addressed, as the benefits of doing so may be outweighed by the costs. This would need to be considered on a case by case basis.

4.1 Economic barriers: market failures

The qualitative assessment suggests the following:

- **Negative externalities** associated with emissions of GHGs and air pollutants from the consumption of fuels constitute a market failure. This is because the party purchasing and consuming the fuel, and therefore who is responsible for the emissions (the ship operator/owner), does not bear the costs of those emissions as they accrue to society in the form of health impacts, climate change, etc. Ship owners and operators will only invest in abatement options when they appear to be cost effective from their point of view, i.e. based on the price they pay for fuel and the benefit they personally derive from it. At present, fuel prices do not fully reflect the negative environmental effects associated with their consumption (Brown, 2001) or the associated economic and public health risks. Shipping continues to produce a range of GHG emissions and air pollutants which have a negative environmental impact (Smith et al., 2014; Olmer et al., 2017). This is also the case for other sectors, such as freight and transport, where there is strong evidence of negative externalities (Maibach et al., 2008; Ranaiefar and Regan, 2011; Inderwildi and King, 2012; Demir et al., 2015).

  Therefore, from a social point of view there will be an over-consumption of fuel and an under-investment in potential abatement options. Uptake of abatement options would therefore be expected to increase if fuel prices fully reflected the full costs to society because there would be a greater incentive to minimise these costs.

  This barrier will affect all possible abatement options as it fundamentally influences the perceived cost effectiveness of any possible abatement option. As a result, the classification of this barrier is **HIGH**. Without intervention, uptake of all abatement options is likely to be considerably slower and may not be adequate for certain options, relative to the best outcome for society. It would be possible for government intervention to address this barrier. Intervention could, for example, require that fuel prices are set such that they better reflect their true social cost. It could also be re-designed where appropriate. For example, in the UK, tax relief can be claimed currently on heavy oils (diesel or light oil (petrol)) used during a sea voyage, therefore implying an incentive to use these fuels despite the social costs of their emissions.[8]

- **Split incentives to invest[9]** can occur when the costs of investing in an abatement option are incurred by one party but the benefits accrue to another (IEA, 2007). Ship owners are generally responsible for making investments in new technology as they own the capital asset i.e. the ship. However, they may not realise all of the associated benefits, such as lower fuel costs, because under certain types of contract it is the charterer that pays for the fuel. Therefore, cost-effective abatement options may not be invested in (Faber et al., 2012; Rehmatulla, 2014).

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[8] https://www.gov.uk/guidance/fuel-duty-reliefs

[9] This is a variant of the 'principal-agent problem' whereby one agent is responsible for making decisions on behalf of, or that impact on, another entity.

Charterers may also be deterred from making investments themselves. Even if they are able to make investments, their incentive to do so will be less than if they owned the vessel themselves. This is because any investment would only benefit them while they are leasing the ship. Future charterers of the ship would then enjoy the benefits of the investment made by the current charterer.

The same issue arises in the rented housing sector where previous research has suggested landlords have a lower incentive to invest in energy efficiency options because it is the tenant, rather than the landlord, that benefits from lower fuel bills (Frontier, 2015).

Within the shipping industry, the importance of this split in incentives depends on the type of contracts used, the length of those contracts and the extent to which charterers are willing to reward owners for their investments in, for example, energy-efficient technologies (Rehmatulla et al., 2017). Existing evidence shows that the charter rates earned by owners of more efficient ships do not fully reflect the cost of the investment in abatement options (Agnolucci et al., 2014, Prakash et al., 2016, Adland et al., 2017).

The pervasiveness of this barrier is influenced by the particular chartering arrangements. In the time charter market, a charterer pays the daily fuel bill and the daily charter rate. However, under a voyage charter the owner is responsible for fuel costs and is paid a lump sum by the charterer (Rehmatulla, 2014). The split incentive issue is likely to be more relevant under time charter arrangements as the fuel costs are not directly met by the owner.

Rehmatulla (2014) and Pirrong (1993) present analysis of the two key sectors, wetbulk and drybulk. Rehmatulla (2014) shows that, on average in the wetbulk sector, 20% of the fleet is on time charter compared to 60% of the drybulk fleet. This suggests that the split incentives could be more prevalent in the drybulk sector. However, there are other factors that should also be examined, for example ownership profiles and average duration (Stott, 2014).

This issue is likely to apply primarily to technological abatement options which require an upfront capital investment. While, operational decisions such as route optimisation, speed reduction and weather routing, may not require similar levels of investment from the ship owner, they could still be prone to these so-called 'principal-agent problems' which hinder their uptake. For example, contracts may include clauses requiring that cargo must be delivered as soon as practically possible, and sometimes changing speed means they could be in breach of contract or incur penalties/damages (Rehmatulla and Smith, 2015a).

This barrier is classified as **HIGH** impact. This is because time chartering arrangements are common across the maritime sector.

Government intervention could have some role to play in mitigating this barrier. For example, the government could incentivise the use of longer contracts between charterers and owners, which could reduce the impact of this barrier. Alternatively, national governments could collectively introduce a shipping policy similar to that applied for the Housing Green Deal.[10] This gave homeowners, landlords and tenants the opportunity to pay for energy-efficient home improvements via savings on energy bills. Importantly, the resulting debt

[10] https://www.gov.uk/green-deal-energy-saving-measures

burden of any investment stayed with the property rather than an individual, which helped to overcome the issue identified above.

- **Imperfect information on abatement options** can also cause a market failure (Golove and Eto, 1996). Ship owners will make their investment decisions using the information that is available to them. In some cases, this information may be unavailable or insufficient. This could in turn lead to decisions that are not in the owners' best interests (Maddox Consulting, 2012).

  For example, it may be that independent performance data relating to new technologies is lacking or that price and compatibility information for a sustainable fuel is unavailable (Faber et al., 2011). This in turn can lead to high uncertainty and prevent ship owners from investing.

  The lack of verifiable performance data causes an information gap which in turn leads to a market failure (Stern and Aronson, 1984). Again, this issue is likely to apply primarily to abatement options which require the installation of a new technology, as opposed to operational abatement options.

  The classification of this barrier is **HIGH**. Currently, there is a systemic lack of independent information on the performance of existing technologies and alternative fuels. To address these information gaps, government could potentially commission third-party testing of new technologies' effectiveness and undertake knowledge gathering and dissemination exercises for other options.

- **Imperfect information flows between a ship's owner and the charterer** can also contribute to a market failure. Ship owners will generally be better informed relative to charterers regarding the current efficiency of their fleet. Owners could then misrepresent the fuel efficiency to potential charterers to make their fleet seem more attractive (Veenstra and Dalen, 2011). This asymmetry in information could lead to mistrust between charterers and owners. This in turn could diminish the willingness of the charterer to pay a premium for a more fuel-efficient vessel (Agnolucci et al., 2014; Adland et al., 2017) as they struggle to differentiate between more- and less-efficient vessels. As a result, owners could be less confident that they will be rewarded for making investments.

  The classification of this barrier is **HIGH**. Potential government interventions could include incentivising the sharing of standardised and verifiable performance-monitoring information with charterers. This would make the fuel efficiency of vessels more transparent. Government could also mandate ship owners to make the performance-monitoring data publicly available if they wished to operate from UK ports. Energy performance certificates in the housing sector work in the same way.[11]

4.2 Economic barriers: non-market failures

The qualitative assessment suggests the following:

- The **different characteristics** of vessel owners' and operators' business models, as well as different types of ships in use, can also influence take-up of abatement options. There are multiple different ship types, ship sizes, operating

[11] Further information is available here: https://www.gov.uk/buy-sell-your-home/energy-performance-certificates

routes and styles of contract in place. All of these factors can play a role in determining whether a particular abatement option is cost effective for a specific vessel or company (Sweeney, 1993).

A technology may be cost effective, on average, for a group of vessels. However, that group will be managed by individual owners and operators. Some of these owners and operators may pursue abatement options, while others will find these options not to be cost effective (Rehmatulla and Smith, 2015b).

This could potentially apply to multiple abatement options as fleet characteristics could affect the extent to which an option is cost effective or not.

The classification of this barrier is **LOW**. For the market to provide such options, a new technology will have to be proven effective across a sufficiently significant sub-section of the maritime industry, which itself is known to be heterogeneous. Every abatement option does not need to apply to every company or vessel.

The options for government intervention to address this barrier are likely to be relatively limited. Uptake of specific options will always be varied due to the heterogeneity evident in the sector. One option would be for the government to incentivise the standardisation of vessel types or contract styles, for example. This would help to limit the variation in characteristics referred to above. However, any such standardisation would require careful consideration as there may be associated costs.

- The **cost of capital** is an important consideration when investing in a new abatement option (Sorrell et al., 2004). If the cost of accessing capital is high (i.e. a high interest rate is charged) then this may affect the extent to which the benefits to the investor exceed the costs. This is often an issue for smaller organisations for whom borrowing money is often perceived by lenders to be more risky, especially if they do not have a long track record to inform their credit worthiness (Schleich and Grubber, 2008).

  This barrier is most likely to affect those options with a large upfront cost that will likely necessitate borrowing. The assessment classification of this barrier is **MEDIUM**. Borrowing costs are likely to pose a significant barrier for certain segments of the market. For example, within any sector the financial structure of firms and their ability to access capital could be related to firm size (Chittenden et al., 1996). If private sector financing is prohibitively expensive for some ship owners, government could provide subsidised loans. Innovation loans are being used in other sectors currently by UK Research and Innovation.[12]

- **Hidden costs** of pursuing abatement options can also hamper deployment. Hidden costs refer to additional expenses associated with abatement options beyond the initial outlay (Koomey and Sanstad, 1994). These hidden costs could mean that certain abatement options which appear at first to be cost effective are not implemented. Hidden costs could include:
  - Opportunity costs associated with reduced capacity for cargo (Lloyd's Register and UMAS, 2017). For example, switching to alternative fuel types

[12] https://www.gov.uk/guidance/innovation-loans-general-guidance-for-applicants

can require the introduction of specially designed tanks. These tanks take up additional space and reduce the available area for carrying goods.

- Technology lifecycle costs which arise as a result of ongoing maintenance and upgrades of new technology (Golove and Eto, 1996).
- Cost of time and resources spent selecting and implementing an appropriate abatement option (Sorrell et al., 2000).
- Training costs to upskill the workforce so that they can operate new technologies (Golove and Eto, 1996).

Hein and Blok (1995) investigated the composition and magnitude of transaction costs arising as a result of energy efficiency investments. The authors carried out interviews with 12 large energy-intensive industrial firms from a variety of sectors.[13] Their analysis revealed that the transaction costs of energy efficiency improvement measures are estimated to be around 3-8% of the investment.

The classification of this barrier is **MEDIUM**. Again, smaller firms are likely to be affected by this barrier to a greater extent than larger firms. Larger firms can spread the costs of selecting an abatement option across a larger fleet and may be less sensitive to overall costs (Faber et al., 2011).

Government could provide financial support, for example, in the form of subsidised public sector loans, as discussed above. This support need not be limited to loans exclusively.

4.3 Structural barriers

The qualitative assessment suggests the following:

- **Existing infrastructure and onboard technologies** can act as a lock-in to the introduction of new/green operations or abatement technologies. Therefore, certain abatement options may not be adopted due to the fact that ports and shipyards are currently configured in a certain way. This configuration may not be compatible with some abatement options.

  For example, current cargo handling by cranes can be incompatible with some wind propulsion technologies which require high masts (Rehmatulla et al., 2017). In general, ports currently struggle to provide access to alternative fuel sources that require different infrastructure, such as hydrogen and methanol, due to the associated new infrastructure requirements. The infrastructure required for liquefied natural gas (LNG) is more widely available and under development globally but is still limited in relation to the total number ports (DNV GL, 2018).

  The classification of this barrier is **HIGH**. The development of infrastructure to support the uptake of abatement options is likely to vary by the abatement option under consideration, along with the characteristics of the port location and market segment. Some areas will develop faster than others, and some abatement options will only be feasible at some ports, with others needing significant infrastructure investment.

[13] Metal, chemical, food and beverage and textile sectors.

Some alternative fuels, like hydrogen and LNG, are expected to be severely affected by structural barriers (IEA, 2013). Use of shore power when at berth is also likely to be affected by this barrier as significant investment is required in order to provide plug-in facilities at port. Without changes to existing infrastructure, the uptake of these options could be very limited. It is also important to consider that changes to infrastructure will need to be widespread and consistent. If there is a difference in the infrastructure offered at certain ports, then ships which feature abatement options could be restricted in terms of which routes they operate. This in turn could hinder investment and uptake of these options by ship operators.

Government could potentially play a co-ordinating role in assisting the shift from existing infrastructure to new facilities that would support the deployment of abatement options. For example, government could consider the case for offering financial support to ports that may not otherwise invest due to uncertainty regarding future demand which may not be sufficient to reach minimum efficient scale. Alternatively, government setting a clear policy direction for shipping fuels could provide more certainty and mitigate some of the risk of investment.

- Take-up of abatement options may be delayed due to the **long life of existing assets**. Vessels typically have long lifespans of perhaps several decades. Current designs and associated technologies are therefore locked into the longer term. It may, to some extent, be possible to overcome this issue by retrofitting abatement options to existing vessels (EEA, 2017). However, some retrofits are only feasible when a ship is already undergoing large-scale maintenance. This typically occurs at regular five-year intervals (Faber et al., 2011).

  This could be exacerbated by the current oversupply of ships, which corresponded to around one-quarter of the world fleet in 2015 (ITF, 2017). This could slow the rate of turnover and replacement of existing inefficient stock as there is less demand for the construction of new vessels.

  This issue is expected to be most acute for abatement options which require substantial alterations to ship design. More minor alterations are likely to be easier to implement and other operational options, such as voyage optimisation, may require no change to vessel design at all.

  The classification of this barrier is **LOW**. Even with existing oversupply issues, new vessels are still being constructed. These new builds can incorporate the abatement options with the greatest potential to comply with regulatory and economic pressures (HSH Nordbank, 2013).

  Government could, however, work with other countries to set standards around mandatory technologies that must be included in new vessels. Also, government could put in place incentives to encourage new-build ships to incorporate retrofitting capabilities.

- **Current market operations** in the shipping sector can act as a non-tangible structural barrier. These issues reflect the way the market currently works and how participants go about business.

This could include contractual arrangements. For example, currently, charterers can face penalties for late arrival at destination ports.[14] This may mean that slow steaming is not a viable option commercially (Rehmatulla and Smith, 2015a).

As a result, without intervention, it is likely that the uptake of some abatement options, such as slow steaming, is significantly hampered by current practices. The classification of this barrier is therefore **MEDIUM**. It is possible that government could encourage the sector to move away from certain established contractual behaviours that are currently acting as a barrier. This could include caps on late arrival charges. However, government intervention in commercial contracts may be difficult.

4.4 Policy/regulatory barriers

The qualitative assessment suggests the following:

- Current **policy** may inadvertently encourage continued use of existing technology due to a favourable tax regime or subsidies. This could make new, more energy-efficient technologies or sustainable fuels relatively less cost effective. For example, OECD analysis has shown that fossil fuel subsidies across all sectors in OECD countries and partner economies totalled $151-249 billion annually over the 2010-16 period (OECD, 2018). There is currently tax relief for fossil fuels used in marine voyages in the UK, giving further incentive for the use of these fuels.[15] This could limit the uptake of certain abatement options.

  The classification of this barrier is **MEDIUM**. The sector has long-established regulatory regimes that favour fossil-fuelled vessels. The International Maritime Organization’s Energy Efficiency Design Index[16] aims to promote the use of more energy-efficient equipment and engines. However, the regulations assume that vessels will be powered by conventional fossil fuels, which is not consistent with potential zero emission options.

  As this barrier directly relates to current (domestic) government activity there is scope for intervention. Any decision to alter policy will require the government to compare the relative costs and benefits of change.

- **Regulatory constraints** could also reduce the speed of uptake in some circumstances. This could occur because some regulations can have different objectives, such as safety, rather than solely being focused on emissions abatement.

  For example, alternative fuels require development of fuel-specific safety standards. The International Maritime Organization Code of Safety for Ships using Gases or other Low-Flashpoint Fuels[17] is one of the international

[14] This is known as ‘demurrage’ in the shipping sector.

[15] https://www.gov.uk/government/publications/excise-notice-263-marine-voyages-excise-duty-relief-for-mineral-hydrocarbon-oil/notice-263-marine-voyages-excise-duty-relief-for-mineral-hydrocarbon-oil

Notice 263: marine voyages – relief from fuel duty

[16] http://www.imo.org/en/ourwork/environment/pollutionprevention/airpollution/pages/technical-and-operational-measures.aspx

[17] IMO International Code of Safety for Ships using Gases or other Low-Flashpoint Fuels (IGF Code); MSC.391(95), in force since 2017-01-01., DNV GL Recommended Practice RP – G105 on the development

regulations in place to make LNG a safe option for ships. These regulations reconcile safety issues with the desire to address environmental concerns of ship SO_x and NO_x emissions (Xu et al., 2015). Equivalent standards do not exist for other alternative fuels, which can act as a barrier. Other alternative fuels like hydrogen have to follow the ‘alternative design’ principle. Under this approach, each ship design will have an individual process to be approved by the vessel’s flag state for operation, adding cost, time and risk to the certification process (DNV GL, 2018).[18] Additionally, there can be uncertainty in engine manufacturer warranty provisions for engines running on alternative fuels (Ecofys, 2012). Engine manufacturers could be a key stakeholder in setting new fuel standards to overcome this potential barrier.

The classification of this barrier is **MEDIUM**. Government could, in theory, modify the current regulatory constraints that are in place and help to coordinate changes in fuel and vessel standards and certifications at the international level. It could be feasible that for some low carbon marine fuels (hydrogen, ammonia and, previously, LNG) the safety concerns could be addressed through sufficient risk assessment, correct procedures and technological solutions, following the same path that was developed for LNG (Wang and Notteboom, 2013). However, this process would take time and could also hamper uptake. Any decision to alter regulatory constraints would require the government to compare the relative costs and benefits of change.

4.5 Organisational barriers

The qualitative assessment suggests the following:

- **Intra-organisational co-ordination failures** could reduce the uptake of abatement options. These issues occur because companies that are active in the shipping sector consist of many actors with different, sometimes conflicting, objectives (Thollander and Palm, 2013).

  The interests of one employee or department may be in conflict with those of others. For example, a finance director could be in favour of implementing a cost-effective abatement option due to the possibility of long-term savings. However, the operations director in the same firm may be against this change as they seek to minimise short-term disruption (Thollander et al., 2010).

  In addition, different employees within a firm may also have different levels of awareness regarding the existence of abatement options. Emissions abatement and environmental awareness have not traditionally been high priorities in the shipping sector (Faber et al., 2012). While these attitudes have changed somewhat, it still may be the case that some senior decision makers are not well informed.

  The impact of these intra-organisational co-ordination failures will not be limited to specific abatement options, as they could relate to any decision-making processes within an organisation.

and operation of liquified natural gas bunkering facilities, ISO technical specification for supply of liquified natural gas as fuel to ships (ISO TS 18683).

[18] https://www.dnvgl.com/maritime/publications/alternative-fuel-assessment-download.html
Page 16 – International Regulations and Class Rules.

The classification of this barrier is **MEDIUM**. Conflicting interests of actors occur in some form in all organisations. The shipping sector is characterised by specific rules and hierarchies, which could lead to conflict regarding the implementation of major changes (EEA, 2017). This could significantly affect deployment within the industry.

Government intervention could, for example, encourage the sector to recognise that these issues exist and help to disseminate best-practice governance procedures.

- **Inter-organisational co-ordination failures** can also play a role in hindering the uptake of abatement options. Organisations active in the shipping sector do not make decisions in isolation. In the UK, ship owners, shipyards and ports are all interdependent commercial entities.

  Existing evidence (EEA, 2017) refers to a 'chicken and egg' problem whereby no ship owner wants to invest in abatement options, such as alternative fuel technologies, until other actors, such as ports, put in place the supporting infrastructure. However, ports may not want to invest in the supporting infrastructure until the demand can be credibly demonstrated. This affected the development of LNG-bunkering infrastructure in northern Europe where uptake of LNG was hindered by the lack of bunkering facilities linked to uncertainty of future demand (Aronietis et al., 2016).

  The impact of these inter-organisational co-ordination failures will be apparent in relation to all abatement options which involve significant interaction between different parties in the shipping sector for their delivery. As described above, switching to alternative fuels will fall into this category, as would cold ironing and port-related behavioural change.

  The classification of this barrier is **HIGH**. Uptake of certain abatement options requires complementary developments across multiple industry segments. Without intervention, these actions are not likely and deployment could be significantly impacted (EEA, 2017). These co-ordination issues could be partially overcome if governments, trade bodies or international representative groups could organise, promote and facilitate the diffusion of alternative technologies, especially through an inter-governmental body like the International Maritime Organisation.

4.6 Behavioural barriers

The qualitative assessment suggests the following:

- When individuals make decisions, they may rely on a range of factors to inform them – and some may not be evidence based. This is because individuals cannot always incorporate all available information into their thinking when making complex trade-offs. Instead, individuals may rely on established heuristics or rules of thumb to simplify decision processes. This is known as **bounded rationality** (Stern and Aronson, 1984).

  These heuristics could be used when individuals are making investment decisions. Ship owners who are deciding between competing technology options may be subject to a number of biases (Faber et al., 2012). For example, they may opt to pursue the solution that is most readily accessible or familiar (i.e. apply the ‘availability’ heuristic) even if this option is not optimal for them or society.

Behavioural barriers primarily relate to the way in which people think, evaluate and act upon information. As a result, they have the potential to affect deployment of all solutions.

The classification of this barrier is **MEDIUM**. Abatement options will continue to be deployed in the presence of bounded rationality. However, biased decision-making processes could lead to sub-optimal investment decisions, which in turn could lead to significantly slower take-up of certain solutions.

Government will not be able to eliminate the issue of bounded rationality. However, it may be possible to reduce the magnitude of this barrier’s impact by simplifying the decision processes of ship owners. This could be achieved by providing clear, accessible information such as best-practice guidelines. Alternatively, government could introduce new policies (such as a mandatory review of abatement options within shipping companies) that could assist decision-making by switching the default position.

- Individuals and organisations may also suffer from a **short-term outlook**. Certain types of new technology may only become cost effective years after installation. These options could be disregarded if decision makers are more focused on short-term cost savings (Thollander et al., 2010; HSH Nordbank, 2013).

  This short-term viewpoint could be compounded by an overall status quo bias. This inertia comes about due to habit and established routines and leads to the endurance of a ‘stable state’ (Kahneman et al., 1991). In addition, the shipping industry’s culture is conservative and risk averse, which could also affect how participants approach investment decisions (Rehmatulla et al., 2017).

  The classification of this barrier is **MEDIUM**. It is difficult to precisely determine the extent to which this barrier is currently hampering deployment of abatement options. However, it is likely to vary within different parts of the sector and could significantly affect certain technological abatement options. Specifically, those options which require an upfront capital investment may be impacted by this barrier as these options are likely to take some time before they become cost effective and therefore require a long-term outlook. As above, government-subsidised finance could help to overcome this barrier by allowing certain investments to become cost effective earlier. In addition, the publication of additional information on the long-term value of abatement options by government could help to shift companies away from the status quo.

5 CONCLUSION

Shipping is responsible for a substantial proportion of the UK’s GHG emissions and contributes significantly to regional and local air quality issues. National and international commitments have been made to reduce emissions. Fulfilling these commitments requires the widespread adoption of abatement options and changes in behaviour.

However, take-up of these options is hampered by the existence of market failures and other barriers. This means deployment is slower than would be ideal from a social perspective, and emission reduction ambitions could be jeopardised. Government intervention may therefore be needed to address some of these barriers to unlock commercial deployment of cost-effective abatement options.

This report offers a framework for considering market failures and barriers to reducing shipping emissions. It finds that the most notable barriers to uptake are:

- Negative externalities;
- Split incentives to invest;
- Imperfect information on abatement options;
- Imperfect information between owners and charterers;
- Existing infrastructure and onboard technologies; and
- Inter-organisational co-ordination failures.

However, there are other barriers noted as ‘medium’ where intervention may be a proportionate way to increase the uptake of options. These are:

- The cost of capital;
- Hidden costs of investing;
- Current policy;
- Market operations;
- Intra-organisational co-ordination failures;
- Bounded rationality; and
- Myopic outlook.

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