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Targeting the reduction of shipping emissions to air

A global review and taxonomy of policies, incentives and measures

Anastasia Christodoulou and Marta Gonzalez-Aregall
Business Administration, Goteborgs Universitet Handelshogskolan, Goteborg, Sweden

Tobias Linde and Inge Vierth
Statens Vag och Transportforkningsinstitut, Stockholm, Sweden, and

Kevin Cullinane
Business Administration, Goteborgs Universitet Handelshogskolan, Goteborg, Sweden

Abstract

Purpose – The purpose of this paper is to identify and classify the various initiatives developed and implemented across the globe for the abatement of maritime air emissions.

Design/methodology/approach – In this paper, an extensive survey of various sources was conducted, including the official reports of international and regional institutions, government policy documents, port authority websites, classification society pages, private firms' sites and the academic literature. The initiatives were then categorized in accordance with the classification of the Swedish Environmental Protection Agency and analyzed using the SPSS Statistics software to give some insight into their frequencies and the interrelationships between them.

Findings – This exploratory review resulted in the establishment of a comprehensive global database of initiatives encouraged by the whole range of shipping stakeholders and decision-makers for the reduction of shipping air emissions. According to the findings, economic incentives that provide motivation for the adoption of less environmentally damaging practices are the most commonly used initiative, followed by infrastructure investments and informative policies.

Research limitations/implications – The results provide implications for further research that include an in-depth analysis of ports' policies, as well as an evaluation of initiatives applied on a large scale to map their emissions reduction potential for shipping.

Originality/value – The main contribution of this paper is the identification and analysis of all the diverse initiatives implemented globally in a comprehensive way and its dealing with air pollution from shipping as a whole.

Keywords Shipping, Policies, Incentives, Abatement measures, Maritime air emissions

Paper type Research paper

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Introduction

Shipping is essential for the growth of international trade, carrying more than 90 per cent of global trade in volume. From this perspective, it is fortunate that shipping is the most energy-efficient mode of transport and, as such, is often held to be the least environmentally damaging mode of long-distance freight transport. This and its other benefits in comparison to other modes are identified by López-Navarro (2013) and Styhre *et al.* (2014). It is for this reason that a number of EU transport policies, for example, are aimed at incentivising a modal switch for freight from land to water (European Commission, 2011), even though the benefits of such a modal switch are not categorical in every case (Ng, 2009; Baindur and Viegas, 2011; Douet and Cappuccilli, 2011; Tzannatos *et al.*, 2014). This general policy direction is reflected in many similar regional and national policies on a worldwide basis.

The abatement of maritime air emissions[1] has become an issue of major concern during the past few decades, as some of these emissions have significant impacts upon human health (like NOx and PM), while others contribute to global warming and climate change (like CO_2) (Cullinane and Cullinane, 2013; Corbett *et al.*, 2007). In 2012, international shipping accounted for 2.2 per cent of global CO_2 emissions (Smith *et al.*, 2014). However, CO_2 emissions from shipping are forecast to increase by 50 per cent by 2050, as international shipping has not been included in any international agreement for combating climate change, such as the Kyoto Protocol or the Paris Agreement (UNCTAD, 2015). On the other hand, the demand for shipping is forecast to increase considerably in the future (Smith *et al.*, 2014; UNCTAD, 2015). The growing concern of general society and the maritime community more specifically for reducing shipping emissions to air has resulted in the development and adoption of various measures, policies and incentives targeting the achievement of this goal by a range of different actors, from inter-governmental organizations to regional and national public institutions and private associations.

First, the main inter-governmental administration is the International Maritime Organization (IMO). It is responsible for the regulation of air pollution and greenhouse gas (GHG) emissions from international shipping and has adopted some technical and operational measures targeting the reduction of either local air pollutants (SOx, NOx, PM) or GHG emissions by including them within Annex VI of its MARPOL Convention[2] (IMO, 1998, 2003). These mandatory policy instruments incorporate a range of different regulations relating to, for example, the establishment of sulphur emission control areas that set specific fuel oil sulphur limits for vessels operating in specific areas which have lobbied for such regulation; comprehensive NOx standards for vessels constructed after 2011; the Energy Efficiency Design Index (EEDI) requiring a minimum energy efficiency level per capacity mile for vessels built after 2012; the Ship Energy Efficiency Management Plan (SEEMP) that establishes a mechanism for the improvement of the operational energy efficiency improvement of a ship, as well as the data collection system for the fuel consumption of ships. The IMO has also discussed developing some market-based instruments, such as a levy on marine fuels sold and a global CO_2 emissions trading scheme, that might provide incentives to the shipping industry for compliance with these regulations (IMO, 2010).

Second, apart from the IMO regulations, the European Union (EU) has adopted directives for the abatement of shipping emissions within its territorial waters. In this regard, the EU Directive 2012/33/EU sets a maximum sulphur content of 0.5 per cent for fuel used within the exclusive economic zones of EU member countries which lie outside the European Emission Control Areas (ECAs) and a maximum sulphur content of 0.1 per cent for fuels used at berth in EU ports (EU, 2012). Additionally, Member States are required to build liquefied natural gas (LNG) refuelling points in all maritime and inland waterway ports and

install infrastructure for shore-side electricity supply by the end of 2025 (EU, 2014; Directive 2014/94/EU). The most recent EU Regulation 2015/757 requires ship owners and operators to annually monitor, report and verify CO_2 emissions for vessels larger than 5,000 gross tonnage calling at any EU and EFTA[3] (Norway and Iceland) port (EU, 2015).

Finally, in addition to these regulations adopted by inter-governmental organizations, various national strategies have dealt with the reduction of maritime air emissions by imposing compulsory measures or promoting voluntary initiatives. At port level, there is a wide variety of policies and incentives adopted for rewarding "cleaner" vessels and stimulating the employment of technical innovations and better operational practices. There are also various initiatives taken by private stakeholders, either large shippers that aim at the improved environmental performance of the maritime leg of their logistics chains or shipowners that are proactive in greening their operations.

Despite the various initiatives taken by different stakeholders, the global reduction of air emissions from ships has been quite slow and the desired environmental results have not been achieved (Smith *et al.*, 2014). This implies that the results from the practical implementation of the various measures, policy instruments and incentives need to be analyzed and evaluated to identify those with the greatest potential for reducing maritime air emissions.

Up until now, all these diverse policies, incentives and measures have not been identified and analyzed together in a comprehensive way and it is this research gap that this paper aims to fill. The majority of previous studies have focussed on the evaluation of the environmental effectiveness and feasibility of specific individual initiatives or have targeted the abatement of particular maritime emissions. Therefore, there is a dearth of scientific studies addressing the reduction of air pollution from shipping as a whole and examining the various mandatory measures, policies and voluntary incentives implemented globally. This paper reports on the establishment of a comprehensive global database of measures, policy instruments and incentives that target the reduction of shipping air emissions and which have been adopted in in the period from 2008 to 2018. Developing this database also entails classifying the various initiatives on the basis of specific features that they share. The taxonomy of initiatives developed in this paper will enable the identification of specific case studies of these incentives across the globe and assist in the evaluation of the level of success achieved in their practical implementation, as well as the identification of the best performing packages of policies and incentives for the achievement of further reductions in maritime air emissions. The main contribution of this paper lies with the identification and analysis of all the diverse policies, incentives and measures implemented globally in a comprehensive manner, as well as its dealing with air pollution from shipping as a whole.

Policies, incentives and measures targeting the reduction of maritime air emissions

There have been various efforts to review the various technical, operational and market-based measures, policies and incentives implemented worldwide for targeting the abatement of air pollution from ships. However, most of them have only a limited scope, focussing either on specific types of measures (e.g. technical), particular geographical areas (e.g. ports) or individual policies (e.g. vessel speed reduction). None of them has dealt with air emissions from shipping as a whole; most of the studies have been divided into combating local air pollutants (such as SOx, NOx and PM) or GHG emissions that have a global impact.

Several studies have focussed on the GHG emissions reduction potential of technical and operational measures, as well as their cost of implementation (Bouman *et al.*, 2017; Miola *et al.*, 2011; Johnson *et al.*, 2013; Smith *et al.*, 2014; Kontovas and Psaraftis, 2011;

Goulielmos *et al.*, 2011; Eide *et al.*, 2009; Giziakis and Christodoulou, 2009). According to Smith *et al.* (2014), energy efficiency measures alone could reduce the CO_2 emissions from ships by somewhere between 40 and 60 per cent, while Bouman *et al.* (2017) point out that "no single measure is sufficient to achieve meaningful GHG reductions". However, a combination of measures, policies and regulations could lead to a reduction in GHG emissions by more than 75 per cent by 2050. Johnson *et al.* (2013) compare the SEEMP with the ISO 14001 (Environmental Management Systems) and the ISM (International Safety Management) Code and conclude that the effectiveness of the SEEMP appears rather disappointing, as it seems to lack essential elements affecting its effective implementation. Moreover, Kontovas and Psaraftis (2011) undertook an evaluation of operational models and policies for the reduction of emissions along the maritime intermodal container chain, focussing on reduced port service time and the prompt berthing of vessels upon arrival. Finally, approaches targeting the improvement of the operational efficiency of shipping, like the utilization of the hub-and-spoke and load centre concepts, the maximization of the size of the ship to take advantage of economies of scale, the improvement of the logistics systems and the enhancement of port efficiency have also been examined (Cullinane and Cullinane, 2013; Wang and Cullinane, 2006; Cullinane and Khanna, 1999).

Furthermore, the need for efficient market-based incentives and policy instruments that would "encourage" investment in innovative abatement technologies or the employment of alternative fuels in the shipping industry has been mentioned in various studies (Shi, 2016; Wan *et al.*, 2018; Psaraftis, 2012; Giziakis and Christodoulou, 2012). Specifically, Wan *et al.* (2018) made an evaluation of the progress of technical, operational and market-based policies for the abatement of GHG emissions from shipping. According to their findings, a market-based approach is necessary to address the environmental impact of shipping. They argued that while slow steaming is by far the most efficient operational measure for the reduction of fuel consumption, because of the already slow speeds currently implemented in practice, it is likely to have only limited emission reduction potential unless the market improves and average speeds increase. Wan *et al.* (2018) also suggested that a performance-based index can be ambiguous and, therefore, permits the avoidance of deep emission reductions. The CO_2 emission reduction potential of slow steaming was also "supported" by Cariou (2011) in combination with a market-based instrument – a tax levy or a cap-and-trade system – that would keep bunker prices at a given level. In this regard, Kosmas and Acciaro (2017) supported the assertion that bunker levy schemes could internalize the external cost of GHG emissions from shipping, but that the allocation of the costs arising from the enforcement of the levy between shipowners and shippers depends on the market conditions, the freight rates and the level of capacity utilization. The prospects and benefits from the implementation of a cap-and-trade system for the reduction of SOx and NOx in the Northern European ECA was analyzed by Nikopoulou *et al.* (2013), while the potential impacts of such a scheme on the organization of containerized shipping lines and European ports were pointed out by Franc and Sutto (2014).

In addition, the potential of individual measures to reduce maritime air emissions at ports has been evaluated by several authors. First, Zis *et al.* (2014) made an evaluation of cold ironing and speed reduction policies to reduce ship emissions near ports, while Ahl *et al.* (2017) investigated the effects of financial incentives on vessel speed reduction using the empirical data from the implementation of these incentives through the Port of Long Beach Green Flag Incentive Programme. Second, the findings of Maersk shipping that reducing speeds by 20 per cent leads to fuel consumption savings of 40 per cent and CO_2 emission reductions of about 7 per cent were reported by Cullinane (2012). Third, Winnes *et al.* (2015) examined the emissions reduction potential of different kinds of measures – alternative fuel,

ship design and operation – for diverse types of vessels and parts of the port area. According to their findings, GHG emissions from ships are expected to increase significantly by 2030 and operational measures seem to have the greatest environmental impact. Finally, the potential installation of onshore power supply (OPS) in medium-sized ports with several small berths was examined by Innes and Monios (2018) based on the case of Aberdeen. The authors focussed on the feasibility of installing this technology and concluded that the need to have individual OPS units for each small berth and the necessary installation of the onboard technology for several vessels are the main challenges that should be addressed when medium-sized ports consider investing in OPS.

Several authors have investigated the maritime air emissions reduction potential to be derived from the use of alternative fuels. Brynolf *et al.* (2014) made an environmental assessment of potential marine fuels – LNG, liquefied biogas, methanol and bio-methanol – and concluded that, although the use of all these fuels would significantly improve the overall environmental impact of shipping, GHG emissions could only be reduced by a transition to the use of liquefied biogas and bio-methanol. The use of biofuels is indicated as a possible measure that could reduce the contribution of shipping to global warming and climate change, even though having negative effects on other shipping emissions (Bengtsson *et al.*, 2012).

Methodology

As referred to above, the scope of this paper is the identification and classification of the policies, incentives and measures that have been implemented across the globe and are related to the abatement of air emissions from shipping. To identify the full range of policies, incentives and measures that have been adopted for the reduction of shipping air emissions, an extensive survey of various sources was conducted during late 2017 and early 2018. Official reports of international and regional institutions (like the IMO and the EU), government policy documents, port authority websites, classification society pages, private firms' sites and the academic literature are included in our research. This exploratory review resulted in the establishment of a comprehensive global database of measures, policy instruments and initiatives proposed and encouraged by the whole range of shipping stakeholders and decision-makers – intergovernmental organizations, public authorities, private firms and the research community – for the reduction of shipping air emissions.

A total of 249 initiatives were identified in this database, which were then categorized with regard to

- their "nature", the category and subcategory of measures under which they fall (e.g. economic, fee etc.);
- their geographical level of application;
- the continent where the organization is located;
- the sector (public or private) of the organization; and
- the specific type of the organization.

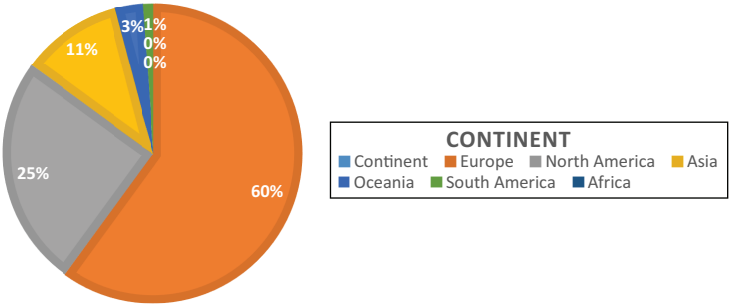
The proposed categorization was developed in accordance with the classification of the Swedish Environmental Protection Agency to serve as a basis for the further detailed analysis and evaluation of policy instruments and incentives with maritime emission reduction potential. After their categorization, the initiatives were analyzed using the SPSS Statistics software to give some insight into their frequencies and the interrelationships between them.

Results

Organization profile of the institutions that have adopted measures, policies and incentives with maritime emission reduction potential

The first step in the analysis was the identification and analysis of the organization profile of the various institutions that have developed and adopted policies and measures targeting shipping air emissions. The sector, type and geographical level of the identified organizations are shown in Figures 1, to 3. The analysis of these elements provides some valuable information on the organizations that have been most active in combating air pollution from shipping. As can be seen in Figure 2, the public sector has developed the vast majority of initiatives for the reduction of maritime air emissions (84 per cent), which is an expected outcome, as the administrative bodies responsible for the regulation of the shipping emissions in any geographical level are mainly public authorities (inter-governmental organizations, governmental agencies and port authorities).

Another interesting finding is the fact that almost half of the initiatives (47.6 per cent) were implemented by port administrations, followed by governmental agencies and inter-governmental organizations (Figure 3). The inter-governmental institutions involved in the abatement of maritime air emissions are the IMO, which is responsible for the regulation of the whole maritime sector and the EU that has imposed some directives at regional level.



Source: Own elaboration

Figure 1.
Geographical location of the organizations

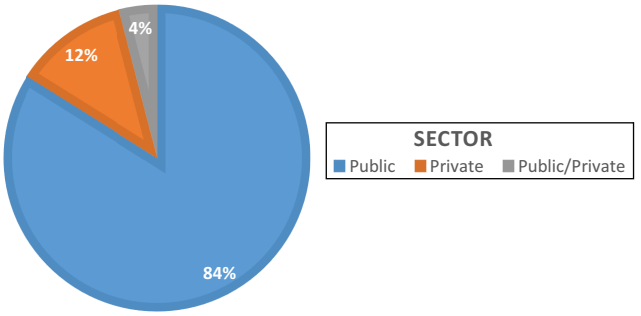


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Figure 2.
Sector of the organizations

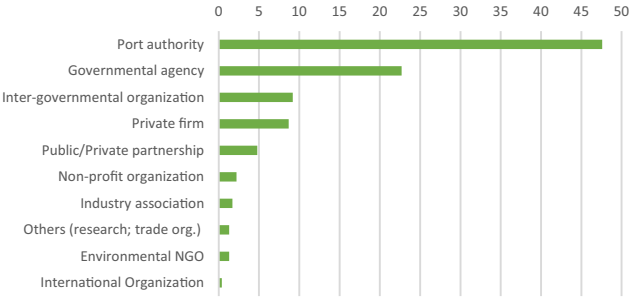


Figure 3.
Type of the organizations

Source: Own elaboration

From a geographical perspective, Europe is the region where the majority of measures, policies and incentives have been developed and adopted (60 per cent), followed by North America and Asia (Figure 1). The generally stricter regulatory framework in Europe and the growing concern about environmental issues could explain this.

In Figure 4, the predominant role of European port authorities in adopting policies for the reduction of maritime air emissions is clear. This can be explained by the increasing interest of European ports in reducing the air pollution from ships in port waters. According to the European Sea Port Organization (ESPO, 2016), the importance of the majority of port environmental issues for the European Ports has remained relatively stable over the past 20 years. However, air quality and energy consumption have become major priorities for European ports, as they seek to improve their carbon footprint and comply with the recent relevant directives and regulations. Additionally, North American governmental agencies and port authorities have also been active in combating shipping air emissions. A relevant example of such an initiative is the RECLAIM (Regional Clean Air Incentives Market)

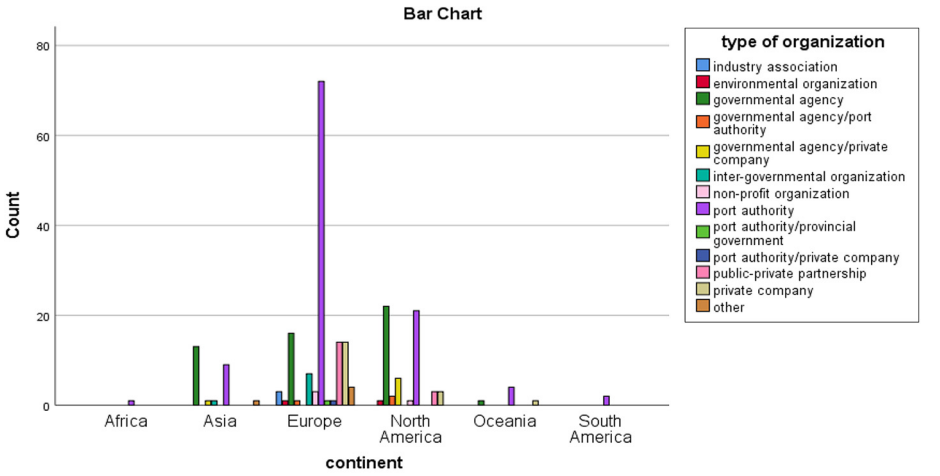


Figure 4.
Continent and type of organization

Source: Own elaboration

programme, adopted in 1994 by the state of California, that establishes a regional emission trading scheme. Since 2001, emission reduction credits from marine sources can be used in the RECLAIM trading programme, and this has led to the modification of ships' engines that has been effectively paid for by funds from stationary land-based sources of air emissions that are required to offset any emissions they produce in excess of those allowed under RECLAIM. Finally, several countries in Asia have also developed national strategies targeting the air pollution of ships. The Green Ship Programme of Singapore is an example of a national initiative. The programme encourages Singapore-flagged ships to reduce CO2 and SOx emissions by offering a reduction of Initial Registration Fees and a rebate on Annual Tonnage Tax to qualified Singapore-flagged ships.

Identification of measures, policies and incentives targeting the abatement of maritime air emissions

After the analysis of the organization profile of the institutions, the various measures, policies and incentives adopted worldwide were categorized into five groups according to their "nature": administrative, economic, informative, research and infrastructure (Figure 5). As can be seen in Figure 5, almost half of the initiatives (48 per cent) are economic incentives that provide motivation for the adoption of less environmentally damaging practices and "encourage" either investment in innovative abatement technologies or the employment of alternative fuels in the shipping industry. Economic incentives are followed by infrastructure investments (18 per cent) that mainly include the building of LNG refuelling points in ports to promote the use of LNG as a fuel for ships, building a network of alternative fuel infrastructure and the installation of OPS that would result in significant emissions reductions as vessels could turn off their auxiliary engines and use shore-side electricity for their activities while at berth. Administrative policies occupy the third place (15 per cent) and encompass the mandatory policy instruments and regulations targeting shipping air emissions.

To have an overall picture of the measures and incentives most commonly used, the identified initiatives were further classified into several sub-categories (Table I). According to Table I, the most popular economic incentive for the abatement of maritime air emissions is the provision of discounts at ports (85 cases). These discounts mainly refer to the environmentally differentiated port dues offered to vessels that have a high ESI (Environmental Ship Index)[4] score and a Green Award Certification[5], use approved scrubber technology or burn clean fuels (fuels with low sulphur content) or have reduced NOx emissions after relevant technical adjustments.

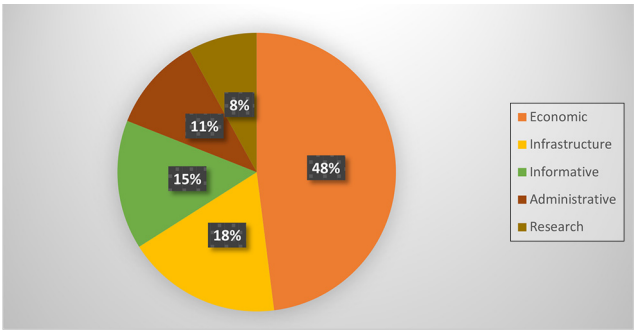


Figure 5.
Categorization of measures, policies and incentives

Administrative	38	Economic	119	Informative	29	Research	20	Infrastructure	43
Legislation	6	Fee	1	Eco-labelling	20	Development	2	Infrastructure investment	43
Limit	12	Penalties	1	Advising	9	Technique evaluation	18		
Agreement	2	Grant	17						
Inspection	4	Discount	85						
Technical requirements	10	Tax	2						
Environmental classification	4	Tax deduction	2						
		Subsidies	5						
		Reimbursement	2						
		Trade with emission allowances	4						

Source: Own elaboration

Table I.
Sub-categories of measures, policies and incentives

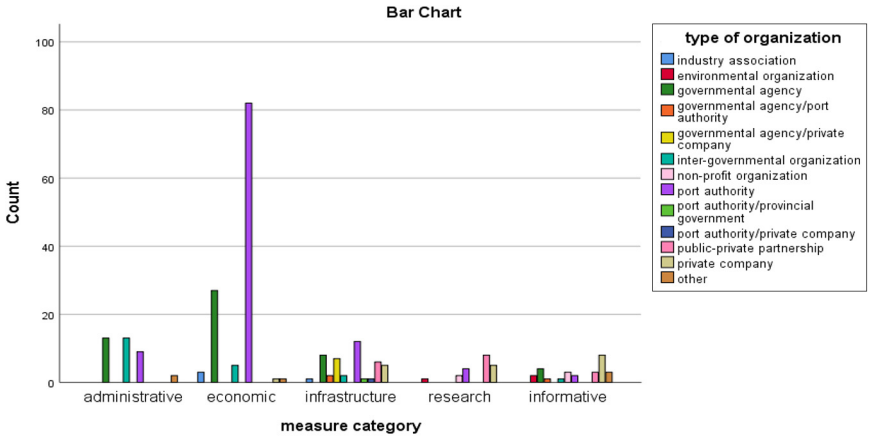
However, they can also be related to good operational practices, like slow steaming. An example is the Green Flag Incentive Programme of the Port of Long Beach that provides incentives for continued observance of the voluntary vessel speed reduction programme by asking vessel operators to slow down to 12 knots or less within 40 nm of Point Fermin (near the entrance to the Harbour).

After the infrastructure investments (43 cases), eco-labelling is a quite popular informative policy targeting shipping air emissions (20 cases), mostly adopted by private firms and organizations. An example of eco-labelling is the CSI (Clean Shipping Index), an industry driven labelling system for the environmental performance of ships and shipping companies that covers six different parameters: SOx, NOx, CO2, PM, chemicals and water and waste. A commonly used research initiative is technique evaluation/testing (18 cases), mostly implemented by private firms to "test" possible mechanisms that could improve their energy efficiency performance. Among the administrative measures, the enforcement of emissions limits represents the most usual policy instrument (12 cases).

Inter-relationships between categories of measures, geographical level of application and type of institutions

After the classification of measures, policies and incentives into categories and sub-categories, they were analyzed in relation to their geographical level of application and the type of organization that adopted them. This analysis could provide some additional information on the kind of policies and incentives that the various relative institutions develop and implement, as well as highlight the focus of their actions. In Figure 6, we can see that the administrative policies – one of the categories of initiatives – have been largely implemented by governmental agencies and inter-governmental organizations, which is an expected outcome because of the regulatory and policy-making role of these public institutions. In contrast, private firms and public–private partnerships have developed some research and informative measures – different categories of initiatives – that can improve their technical and operational performance and offer them a competitive advantage in the shipping market.

Port authorities and governmental agencies have both applied economic incentives – the most popular category of initiatives – for the abatement of maritime air emissions. However,



Source: Own elaboration

Figure 6.
Category of measure and type of the organization

these incentives are quite different, as port authorities mainly offer discounts to the "cleaner" vessels rewarding them for their good environmental performance, while national strategies often provide grants to incentivize investment in innovative abatement technologies or the employment of alternative fuels in the shipping industry. An example is the Green Technology Programme in Singapore that encourages local maritime companies to develop and adopt green technologies providing a grant of up to 50 per cent of total qualifying costs to co-fund the development and adoption of green technological solutions/systems.

Infrastructure investments – another category of initiatives – have been supported by the whole range of institutions. However, their approaches represent great differentiation, as governmental and inter-governmental organizations have developed the regulatory framework for the adoption of these investments, while port authorities and the private sector have been active in applying these infrastructure investments. Many European ports have already built LNG refuelling points and installed OPS as a result of the adoption of the EU Directive 2014/94/EU that requires them to implement these infrastructure investments by the end of 2025.

Finally, we examined the relation among the various categories of measures, policies and incentives and their geographical level of application to have an image of the policies that are mostly used at international, regional, national or local level. As can be seen in Figure 7, policies implemented globally belong in all categories, which can be explained by the diversity of regulations adopted by the IMO. The development of international eco-labelling initiatives (like the ESI or the CSI) explains the increased number of international informative policies. Coming to regional measures, the large number of administrative policies is related to EU regulations, as well as the sulphur emission control areas, established by the IMO, where stricter fuel sulphur standards are applied.

Initiatives at national level are dominated by economic incentives that mainly include subsidies and grants offered by governmental agencies for the promotion of investments in innovative abatement technologies or the employment of alternative fuels in the shipping industry. The majority of local initiatives are economic incentives and infrastructure investments. These measures are mostly implemented by port authorities and are related to the provision of discounts to "cleaner" vessels and the installation of OPS and LNG

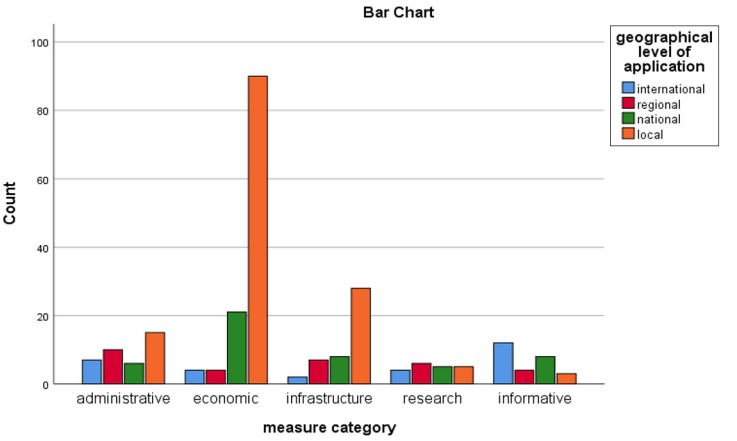


Figure 7.
Category of measure and geographical level of application

Source: Own elaboration

refuelling points. The administrative policies applied at local level refer to regulations that cover specific ports. An example is the "Air Pollution Control (Ocean Going Vessels) (Fuel at Berth)" Regulation in Hong Kong. With effect from July 2015, ocean going vessels are required to switch to fuel with sulphur content not exceeding 0.5 per cent while berthing. The Hong Kong Government will also impose a 0.50 per cent fuel sulphur limit for all vessels entering waters under its jurisdiction from the beginning of 2019.

Discussion and conclusions

The abatement of maritime air emissions has become an issue of major concern during the past few decades, resulting in the development and adoption of various measures, policies and incentives targeting the reduction of these emissions by a range of different actors, from inter-governmental organizations to national, regional, public institutions and private associations. Throughout this paper, we established a comprehensive global database of all types of initiatives that target the reduction of shipping air emissions implemented globally in the period from 2008 till 2018 and then classified them on the basis of specific features that they share. Apart from the classification of the various initiatives, we analyzed the organizational profiles of the institutions that have adopted and implemented these policies to give some insight into the organizations that have been most active in combating air pollution and GHG emissions from shipping.

According to our results, Europe is the region where the majority of measures, policies and incentives have been developed and adopted, followed by North America and Asia, while almost half of the initiatives were implemented by port administrations, followed by governmental agencies and inter-governmental organizations. European port authorities have played a predominant role in addressing shipping air emissions by adopting various economic incentives, administrative policies and infrastructure investments. This can be explained by the stricter regulatory framework in Europe and the increased interest of the European ports in air quality and energy consumption issues, putting them high in their environmental agenda and taking their own initiatives that go beyond regulatory requirements.

Economic incentives that provide motivation for the adoption of less environmentally damaging practices and "encourage" investment in innovative abatement technologies or the employment of alternative fuels in the shipping industry are the most commonly used

initiatives for the reduction of maritime air emissions. These incentives are mainly applied by port authorities in the form of discounts – "environmentally differentiated port dues" – offered to "cleaner" vessels with good environmental performance. This finding verifies the need for efficient economic incentives that will be implemented in combination with technical and operational measures already mentioned in previous studies (Cariou, 2011; Wan *et al.*, 2018). While the majority of environmentally differentiated port dues are related to the use of "clean" fuel and reduced NOx emissions, there are also financial incentives rewarding good operational practices, like slow steaming. The effects of such incentives on vessel speed reduction were investigated by Ahl *et al.* (2017) on the basis of empirical data derived from the Port of Long Beach Green Flag Incentive Programme. According to Wan *et al.* (2018), while slow steaming is by far the most efficient operational measure for the reduction of fuel consumption, it is likely to have only limited emission reduction potential, because of the already slow speeds currently implemented in practice, unless the market improves and average speeds increase.

Infrastructure investments represent another popular category of measures for the reduction of air pollution from ships and these have been supported by the whole range of institutions. This category includes the building of LNG refuelling points in ports to promote the use of LNG and building a network of alternative fuel infrastructure, as well as the installation of OPS that would result in significant emissions reductions as vessels could turn off their auxiliary engines and use shore-side electricity for their activities while at berth. The significant improvement of the overall environmental impact of shipping by the potential use of LNG as a maritime fuel was supported by Brynolf *et al.* (2014), while Zis *et al.* (2014) highlighted the effects of OPS for the reduction of ship emissions near ports.

The regulations and mandatory measures for the abatement of maritime air emissions consist of the third category of initiatives, the "administrative" policies. The effectiveness of these policies, developed mainly by policy-making inter-governmental organizations and governmental agencies, was evaluated by Bouman *et al.* (2017), who pointed out that "no single measure is sufficient to achieve meaningful GHG reductions", but a combination of measures, policies and regulations could lead to a reduction in GHG emissions by more than 75 per cent by 2050. More specifically, Bazari and Longva (2011) estimated the CO2 emissions reduction potential from the mandatory introduction of EEDI and SEEMP, testing various scenarios of implementation. The "Informative" and "research" initiatives form the categories of measures mostly implemented by private firms and public-private partnerships and often concern eco-labelling and technical evaluation that can help them improve their technical and operational performance and also provide them with a competitive advantage in the shipping market.

The main contribution of this paper is the identification and analysis of all the diverse policies, incentives and measures implemented globally in a comprehensive way and its dealing with air pollution from shipping as a whole. The taxonomy of initiatives developed in this paper will enable the identification of specific case studies of these incentives across the globe and assist in the evaluation of the level of success achieved in their practical implementation, as well as the identification of the best performing packages of policies and incentives for the achievement of further reductions in maritime air emissions.

The results provide implications for further research that could include an in-depth analysis of port policies for the reduction of maritime air emissions, as well as an evaluation of initiatives applied on a large scale – like the electrification of vessels, the use of alternative fuels, slow steaming etc. – to map their emissions reduction potential for shipping.

Notes

1. Shipping emissions mainly comprise: Carbon Dioxide (CO_2), Oxides of Sulphur (SOx), Oxides of Nitrogen (NOx), Volatile Organic Compounds (VOCs), Ozone (O_3) and Particulate Matter (PM).
2. The International Convention for the Prevention of Pollution from Ships (MARPOL) is the main international convention covering prevention of pollution of the marine environment by ships from operational or accidental causes.
3. The European Free Trade Association (EFTA) is the intergovernmental organisation of Iceland, Liechtenstein, Norway and Switzerland. It was set up in 1960 by its then seven Member States for the promotion of free trade and economic integration between its members.
4. ESI (Environmental Ship Index) is a voluntary system, designed to improve the environmental performance of sea going vessels, that gives a numerical representation of the environmental performance of ships regarding air pollutants and CO2. ESI scores NOx and SOx emissions directly and proportionally and gives a fixed bonus for documentation and management of energy efficiency.
5. Green Award certifies ships that are extra clean and extra safe. The Green Award Requirements address issues related to quality, safety, environment and technical areas related to the ship and the ship manager's office. The most recent update of the Green Award requirements covers, for example, the Monitoring of Ship Exhaust Emissions and the Marpol NOx emission limits.

References

Ahl, C., Frey, E. and Steimetz, S. (2017), "The effects of financial incentives on vessel speed reduction: evidence from the port of Long Beach Green Fag Incentive Program", *Maritime Economics and Logistics*, Vol. 19 No. 4, pp. 601-618.

Baindur, D. and Viegas, J. (2011), "Challenges to implementing motorways of the sea concept – lessons from the past", *Maritime Policy and Management*, Vol. 38 No. 7, pp. 673-690.

Bazari, Z. and Longva, T. (2011), "Assessment of Imo mandated energy efficiency measures for international shipping", MEPC 61/INF.2, International Maritime Organisation, London.

Bengtsson, S., Fridell, E. and Andersson, K. (2012), "Environmental assessment of two pathways towards the use of biofuels in shipping", *Energy Policy*, Vol. 44, pp. 451-463.

Bouman, E.A., Lindstad, E., Rialland, A.I. and Strømman, A.H. (2017), "State-of-the-art technologies, measures, and potential for reducing GHG emissions from shipping – a review", *Transportation Research Part D: Transport and Environment*, Vol. 52, pp. 408-421.

Brynolf, S., Magnusson, M., Fridell, E. and Andersson, K. (2014), "Compliance possibilities for the future ECA regulations through the use of abatement technologies or change of fuels", *Transportation Research Part D: Transport and Environment*, Vol. 28, pp. 6-18.

Cariou, P. (2011), "Is slow steaming a sustainable means of reducing CO2 emissions from container shipping?", *Transportation Research Part D: Transport and Environment*, Vol. 16 No. 3, pp. 260-264.

Corbett, J.J., Winebrake, J.J., Green, E.H., Kasibhatla, P., Eyring, V. and Lauer, A. (2007), "Mortality from ship emissions: a global assessment", *Environmental Science and Technology*, Vol. 41, Vol. 2, pp. 8512-8518.

Cullinane, K.P.B. (2012), "An international dimension: shipping", in Chapman, L. and Ryley, T. (Eds), *Transport and Climate Change, Transport and Sustainability, Series*, Emerald Publishing, Bingley, pp. 65-104.

Cullinane, K.P.B. and Cullinane, S.L. (2013), "Atmospheric emissions from shipping: the need for regulation and approaches to compliance", *Transport Reviews*, Vol. 33 No. 4, pp. 377-401.

Cullinane, K.P.B. and Khanna, M. (1999), "Economies of scale in large container ships", *Journal of Transport Economics and Policy*, Vol. 33 No. 2, pp. 185-208.

Douet, M. and Cappuccilli, J.F. (2011), "A review of short sea shipping policy in the European Union", *Journal of Transport Geography*, Vol. 19 No. 4, pp. 968-976.

Eide, M.S., Endresen, Ø., Skjong, R., Longva, T. and Alvik, S. (2009), "Cost-effectiveness assessment of CO2 reducing measures in shipping", *Maritime Policy and Management*, Vol. 36, pp. 367-384.

European Commission (2011), "White paper", Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system, COM(2011) 144 final, Brussels.

European Sea Port Organization (ESPO), (2016), "European port industry sustainability report 2016", available at: www.waterborne.eu/media/10488/european-port-industry-sust-rep-2016.pdf (accessed 12 January 2018).

European Union (EU) (2012), "Directive 2012/33/EU of the European Parliament and of the Council of 21 November 2012 amending Council Directive 1999/32/EC as regards the sulphur content of marine fuels", available at: http://data.europa.eu/eli/dir/2012/33/oj (accessed 12 January 2018).

European Union (EU) (2014), "Directive 2014/94/EU of the European Parliament and of the Council of 22 October 2014 on the deployment of alternative fuels infrastructure", available at: http://data.europa.eu/eli/dir/2014/94/oj (accessed 12 January 2018).

European Union (EU) (2015), "Regulation (EU) 2015/757 of the European Parliament and of the Council of 29 April 2015 on the monitoring, reporting and verification of carbon dioxide emissions from maritime transport, and amending directive 2009/16/EC", available at: http://data.europa.eu/eli/reg/2015/757/oj (accessed 12 January 2018).

Franc, P. and Sutto, L. (2014), "Impact analysis on shipping lines and European ports of a cap- and-trade system on CO2 emissions in maritime transport", *Maritime Policy and Management*, Vol. 41, pp. 61-78.

Goulielmos, A., Giziakis, C. and Christodoulou, A. (2011), "A future regulatory framework for CO2 emissions of shipping in the Mediterranean area", *International Journal of Euro–Mediterranean Studies*, Vol. 4 No. 1, pp. 39-60.

Giziakis, C. and Christodoulou, A. (2009), "Climate change and marine industry", paper presented at the International Association of Maritime Economists Conference, Copenhagen, 24-26 June.

Giziakis, C. and Christodoulou, A. (2012), "Environmental awareness and practice concerning maritime air emissions: the case of the Greek shipping industry", *Maritime Policy and Management*, Vol. 39 No. 3, pp. 353-368.

IMO (1998), *The Protocol of 1997 to Amend MARPOL 73/78: Annex VI of MARPOL 73/78*, International Maritime Organisation, London, ISBN 9280160893.

IMO (2003), "Resolution A.963 (23), Imo policies and practices related to the reduction of greenhouse gas emissions from ships", Adopted on 5 December, London.

IMO (2010), "Full report of the work undertaken by the expert group on feasibility study and impact assessment of possible market-based measures", MEPC 61/INF.2, International Maritime Organisation, London.

Innes, A. and Monios, J. (2018), "Identifying the unique challenges of installing cold ironing at small and medium ports – the case of Aberdeen", *Transportation Research Part D: Transport and Environment*, Vol. 6, pp. 298-313.

Johnson, H., Johansson, M., Andersson, K. and Södahl, B. (2013), "Will the ship energy efficiency management plan reduce CO2 emissions? A comparison with ISO 50001 and the ISM code", *Maritime Policy and Management*, Vol. 40, pp. 177-190.

Kontovas, C. and Psaraftis, H.N. (2011), "Reduction of emissions along the maritime intermodal container chain: operational models and policies", *Maritime Policy and Management*, Vol. 38, pp. 451-469.

Kosmas, V. and Acciaro, M. (2017), "Bunker levy schemes for greenhouse gas (GHG) emission reduction in international shipping", *Transportation Research Part D: Transport and Environment*, Vol. 57, pp. 195-206.

López-Navarro, M.A. (2013), "Unaccompanied transport as a strategy for international road hauliers in Ro-Ro short sea shipping", *Maritime Economics and Logistics*, Vol. 15 No. 3, pp. 374-394.

Miola, A., Marra, M. and Ciuffo, B. (2011), "Designing a climate change policy for the international maritime transport sector: market-based measures and technological options for global and regional policy actions", *Energy Policy*, Vol. 39 No. 9, pp. 5490-5498.

Ng, A.K.Y. (2009), "Competitiveness of short sea shipping and the role of port: the case of North Europe", *Maritime Policy and Management*, Vol. 36 No. 4, pp. 337-352.

Nikopoulou, Z., Cullinane, K.P.B. and Jensen, A. (2013), "The role of a cap and trade market in reducing NOx and SOx emissions: prospects and benefits for ships within the Northern European ECA", *Proceedings of the Institution of Mechanical Engineers, Part M: Journal of Engineering for the Maritime Environment*, Vol. 227 No. 2, pp. 136-154.

Psaraftis, H.N. (2012), "Market-based measures for greenhouse gas emissions from ships: a review", *WMU Journal of Maritime Affairs*, Vol. 11 No. 2, pp. 211-232.

Shi, Y. (2016), "Reducing greenhouse gas emissions from international shipping: is it time to consider market-based measures?", *Marine Policy*, Vol. 64, pp. 123-134.

Smith, T.W.P., Jalkanen, J.P., Anderson, B.A., Corbett, J., Faber, J., Hanayama, S., O'Keeffe, E., Parker, S., Johansson, L., Aldous, L., Raucci, C., Traut, M., Ettinger, S., Nelissen, D., Lee, D.S., Ng, S., Agrawal, A., Winebrake, J.J., Hoen, M., Chesworth, S. and Pandey, A. (2014), *Third Imo GHG Study 2014*, International Maritime Organization (IMO), London.

Styhre, L., Roso, V., Bergqvist, R., Woxenius, J. and Lumsden, K. (2014), *Development of the Short Sea Shuttle Concept*, IVL Swedish Environmental Research Institute Ltd, Gothenburg.

Tzannatos, E., Papadimitriou, S. and Katsouli, A. (2014), "The cost of modal shift: a short sea shipping service compared to its road alternative in Greece", *European Transport*, Vol. 56 No. 2, pp. 1-20.

UNCTAD (2015), *Review of Maritime Transport 2015*, UNCTAD, Geneva.

Wan, Z., el Makhloufi, A., Chen, Y. and Tang, J. (2018), "Decarbonizing the international shipping industry: solutions and policy recommendations", *Marine Pollution Bulletin*, Vol. 126, pp. 428-435.

Wang, T.F. and Cullinane, K.P.B. (2006), "The efficiency of European container terminals and implications for supply chain management", *Maritime Economics and Logistics*, Vol. 8 No. 1, pp. 82-99.

Winnes, H., Styhre, L. and Fridell, E. (2015), "Reducing GHG emissions from ships in port areas", *Research in Transportation Business and Management*, Vol. 17, pp. 73-82.

Zis, T., North, R.J., Angeloudis, P., Ochieng, W.Y. and Bell, M.G.H. (2014), "Evaluation of cold ironing and speed reduction policies to reduce ship emissions near and at ports", *Maritime Economics and Logistics*, Vol. 16, pp. 371-398.

Corresponding author
Anastasia Christodoulou can be contacted at: anastasia.christodoulou@gu.se