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Sustainable Shipping and Environment of the Baltic Sea region

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Report on policy evaluation and tradeoffs

The objective of this report is to provide a socio-economic assessment for the evaluation of policy options that have the potential to reduce environmental pressures from shipping in the Baltic Sea and move towards policy objectives especially on EU and global level. The report describes the assessment of 20 selected policy options that focus on different environmental pressures from shipping: GHG and air pollutant emissions (SO_X, NO_X, PM), water emissions (including invasive species and water pollutants such as heavy metals), underwater noise and physical impacts. The assessment includes different steps of stakeholder engagement process. The evaluation is based on a developed multidimensional assessment framework which includes eight assessment criteria (political implementability, acceptance & feasibility, scientific knowledge & uncertainty, technological & innovation potential, environmental and health outcomes, efficiency, distributional effects, synergies & tradeoffs). As part of the policy options' assessment, their potential effect on different environmental pressures and on human health and ecosystem services such as commercial fishing or recreation and tourism is analysed. The result is a semi-quantitative and participatory multi-criteria assessment.

'Promoting biocide-free anti-fouling paint and alternatives' and 'Promoting use of renewable fuels and energy sources' were the top two options in this ranking, followed by the options 'Stricter regulation of scrubber water', 'Promoting shore power in ports' and 'Promoting low emission fossil fuels'. Four of the five highest ranked policy options are rather targeting on financial support and funding of research, pilot testing and market uptake, thriving for change through the promotion of environmentally beneficial behaviour. 'Regulating shipping speed', 'Promoting vessel scrapping' and 'Excluding the noisiest ships' were ranked at the low end of all 20 policy options. More research is needed to gain knowledge about underwater noise. Sea grass protection could play a bigger role, when new marine infrastructure is planned and built.

Some assessed policy options have an integrative potential covering several policy targets, environmental pressures and components of human well being, e.g. 'Electric driven ships' are reducing GHG emissions and as well noise emissions and water emissions such as oil spills or 'The promotion of renewables' for example does not only curb CO_2 emissions, but also other (air) pollutants which harm human health and the coastal environment, including NO_X, SO_X or particulate matter. At the same time, such measures can have systemic effects. If shipping speed would be lowered at the same or increasing demand, more ships would be necessary to transport the same amount of goods, which would compensate the benefits partially or totally. Other adverse systemic effects, for example from 'promoting renewables', could occur at land where e.g. biofuels are produced.

When assessing shipping policies, it is evident that there are still low "hanging fruits", which would have considerable impacts at low costs, for example 'promoting low emission fossil fuels', for which infrastructure is already available in many ports. Other policies are effective, but require considerable efforts of policy making. For example 'promoting shore power' or 'integrating biocidal release rates into river management plans or marine strategies'. Some policies do not only require changes of policy schemes or new institutions, but a paradigm shift, which includes shipping into international

up to global agreements. This applies to introducing a carbon tax, an emission trading scheme or including shipping into the UNFCCC process.

Policy mixes should take into consideration synergies between different options reaching policy objectives, e.g. direct funding of alternative fuels (in ports and at sea) and improvements on energy efficiency or differentiated fee systems in ports can accompany an introduction phase of a maritime emission trading scheme or a CO_2-tax. Promoting existing biocide-free antifouling paints and research alternative paints could prepare or accompany the 'Strengthening of reduced limits for the biocidal release rate of anti-fouling paint' wich was assessed as the option with the highest environmental and health outcomes.

The choice for the implementation of a certain instrument should take into consideration the general advantages and disadvantages of an instrument. Additionally, it is highly relevant what are the actual policy objectives in the concrete situation, what is the policy and socio-economic framework for implementation, the geographic level, the mainly targeted pressure of the instrument, etc. Depending on the situation, not only high prioritized policy options should be considered, also instruments in mid-range of the ranking can be suitable, if implemented in combination with other instruments to compensate weaknesses.

1 Introduction

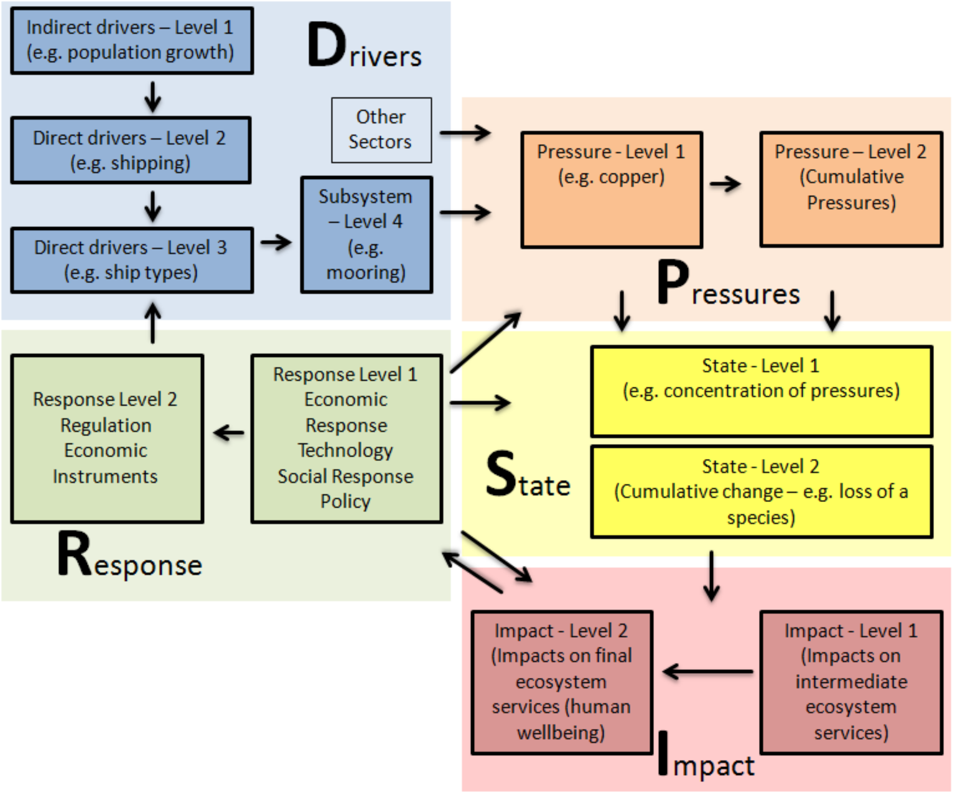
The objective of this report is to provide a socio-economic assessment for the evaluation of policy options that have the potential to reduce environmental pressures from shipping in the Baltic Sea and move towards policy objectives especially on EU and global level. The report describes the assessment of 20 selected policy options that focus on different environmental pressures from shipping: GHG and air pollutant emissions (SO_X, NO_X, PM), water emissions (including invasive species and water pollutants such as heavy metals), underwater noise and physical impacts. The assessment includes different steps of stakeholder engagement process. The policy options are taking into account different types of policy instruments, e.g. financial support, emission standards, trading, taxes and charges (or fees). The evaluation is based on a developed multidimensional assessment framework which includes eight assessment criteria (political implementability, acceptance & feasibility, scientific knowledge & uncertainty, technological & innovation potential, environmental and health outcomes, efficiency, distributional effects, synergies & tradeoffs). As part of the policy option's assessment, their potential effect on different environmental pressures and on human health and ecosystem services such as commercial fishing or recreation and tourism is analysed. It includes impacts on the natural environment as well as social impacts. The result is a semi-quantitative and participatory multi-criteria assessment. It should be used to provide a knowledge base and decision support for decision and policy makers on different geographical scales. The results can support the identification and prioritisation of policy options and measures to reduce environmental pressures from shipping activities in the Baltic Sea.

During the last months and years different policy objectives have been adopted for shipping in the Baltic Sea, initiated by global (IMO), EU or national level authorities. Only in April 2018, IMO adopted for the first time a GHG emissions reduction target. The annual GHG emissions from international shipping should be reduced by at least 50% by 2050 compared to 2008 (IMO, 2018). Already in 2011, the European Commission adopted a White Paper: Roadmap to a Single European Transport Area (COM (2011) 144), which formulated a key goal to reduce EU's shipping CO_2 emissions by at least 40% by 2050 compared to 2005 levels (European Commission, 2011). The EU has adopted different Air Quality Standards to address human health impacts. The Air Quality Directive 2008/50/EC (European Parliament and the Council, 2008) includes standards for SO_2, NO_2 and PM air concentrations. Additionally, the EU Marine Strategy Framework Directive (MSFD) (European Commission, 2008) and the EU Water Framework Directive (WFD) (European Parliament and the Council, 2000) are important water related EU regulations. The MSFD represents the environmental pillar of the Integrated Maritime Policy. The aim of the MSFD is to achieve Good Environmental Status (GES) of the EU's marine waters by 2020 and to protect the resource base upon which marine-related economic and social activities depend. The WFD commits Member States to achieve good qualitative and quantitative status of all EU water bodies, including marine waters up to one nautical mile from shore. The aim of the WFD is long-term sustainable water management that is based on high-level protection of aquatic environments. For some types of emissions, shipping activities are the main contributor (e.g. copper emissions into oceans), for other the current share is limited – e.g. shipping contributes to 2.4% of global GHG emissions (IMO, 2014) – but is expected to increase in the future. Therefore, for the implementation of these policy objectives suitable and effective policy instruments are relevant to incentivize emission reduction measures in the shipping sector.

The aim of the research project BONUS SHEBA is to assess the environmental pressures from shipping in the Baltic Sea area and the ultimate impacts on human well being. The assessments of the environmental pressures from shipping are focused on emissions to air (Work Package 2), emissions/discharges to water (Work Package 3) and underwater noise (Work Package 4). Based on the results of these work packages and additional information and data, an integrated assessment of shipping pressures on ecosystem services and human health is implemented (Work Package 5). One part of this assessment is the evaluation of policy instruments to reduce costs of environmental degradation and impacts on human health. Current policy and socioeconomic drivers affecting shipping and other vessels in the Baltic Sea region were analysed in the SHEBA Deliverable 1.1 ‘Drivers for the shipping sector’ (Boteler et al., 2015). The SHEBA Deliverable 5.2 ‘Report on ecosystem services linked to shipping in the Baltic’ provides a 'baseline' of key policy and socioeconomic drivers against which potential future changes affecting vessel activity can be assessed (Tröltzsch et al., 2017). This report analyses new policy instruments and their environmental and socio-economic outcomes and can guide future decision making processes.

The assessment is based on the DPSIR (Driver-Pressure-State-Impact-Response) framework, which was adapted in SHEBA Deliverable 5.1 to the Baltic Sea and shipping (Hassellöv et al., 2016). The DPSIR was created in SHEBA as a framework to understand and ultimately assess the linkages from the drivers of shipping in the Baltic Sea to its effects on ecosystem services and human well being. This framework was built on an existing framework and adjusted to assess the impacts and changes from shipping on ecosystem services under different conditions. Drivers of change are understood as anthropogenic activities that may have an effect on the environment, including indirect drivers, direct drivers, and their subsystems as shown in the figure below (Figure 1). Pressures describe how the driver and subsystems link to the environment. The pressures are characterised as a certain emission, discharge or load in the environment such as level of copper in the water. The state represents the condition of the ecosystem. It can be divided between concentrations or intensity of pressures in the environment (e.g. the concentration of a certain substance such as copper) (State Level 1) and the accumulation of several individual substances could then lead to further changes such as loss of species of algae, birds or fish (State Level 2). The change of state of the environment is then leading to impacts understood as effects on ecosystem services. Impact Level 1 summarizes effects on intermediate ecosystem services e.g. supporting ecosystem services such as maintaining nursery population and habitats. Impact Level 2 are impacts on final ecosystem services which affect human well being (i.e. beneficiaries) such as changes in recreational potential, food production and genetic resources. Within the SHEBA analytical framework, responses refer to all possible actions or reactions by society, economic actors and governments to address and cope with drivers, pressures, changes in state and impacts. Responses incorporate all possible strategies, such as societal adaption to new conditions, economic responses, as well as policies and instruments to reduce or mitigate pressures. However, the focus is on policy options designed to improve the environmental performance of shipping.

Figure 1 The DPSIR framework for shipping in the Baltic Sea region

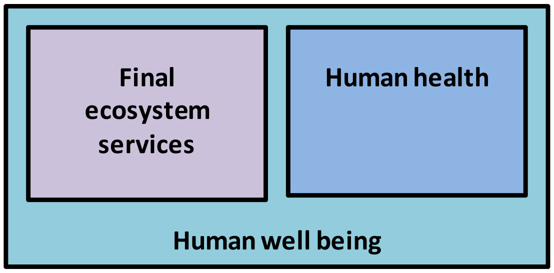


Source: Hasselöv et al. (2016); Tröltzsch et al. (2017).

SHEBA Deliverable 1.1 explained the drivers relevant within this framework. The SHEBA deliverable D5.2 describes the pressures, state and impacts of the adapted DPSIR. This report Deliverable 5.3 covers responses and policy instruments.

In the SHEBA Delivable 5.2 the assessment approach for the effects on human well being was developed (Tröltzsch et al., 2017). SHEBA measures the direct influences by shipping on welfare and further well being (see Figure 2). The assessment of human well being in SHEBA is based on the delivery of final ecosystem services and human health.

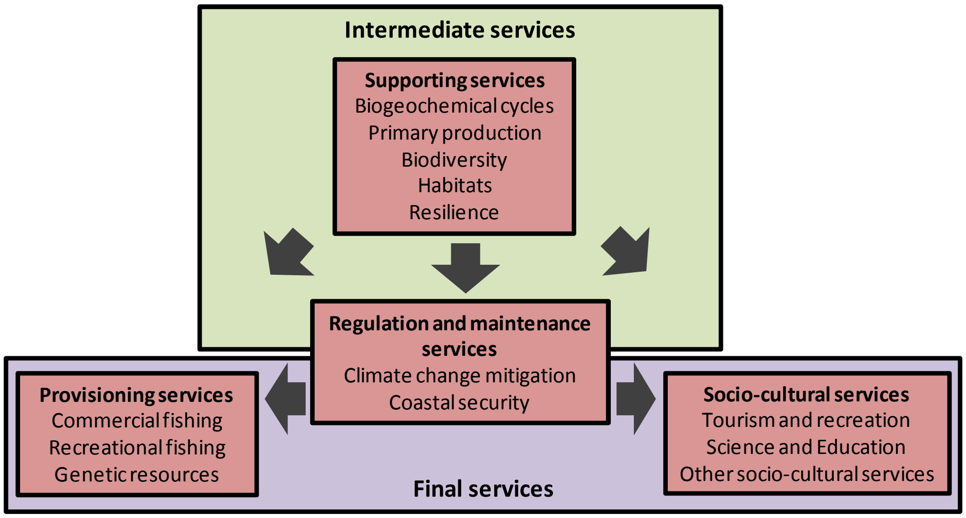
Figure 2 Assessment components of human well being



Source: Tröltzsch et al. (2017).

Ecosystem services are defined as the final outputs or products from ecosystems that are directly consumed, used (actively or passively) or enjoyed by people, and the ecosystem structures (or components), processes and functions underpinning them (see Fisher et al., 2009; Haines-Young & Potschin, 2013; Maes et al., 2013; EEA, 2015). Provisioning services (e.g. commercial fisheries), regulating and maintenance services (e.g. coastal protection) or socio-cultural values (e.g. recreation and tourism) are understood as final ecosystem services. Further examples of final ecosystem services can be found in Figure 3. The ecosystem services approach is a way to integrate into assessments how functioning ecosystems support societal welfare (i.e. human well being) which is otherwise left out of the analysis. Not fully including ecosystem services can potentially lead to undervalue their importance for society and not adequately integrating these services into political decision making processes as well as resulting measures and instruments.

Figure 3 Examples for marine ecosystem services in the Baltic Sea



Source: Tröltzsch et al. (2017), based on EEA (2015); HELCOM (2010); Ahtiainen & Öhman (2013); CICES (2013); Millennium Ecosystem Assessment (2005).

In Chapter 2, the overall approach including the stakeholder engagement, the selection of the policy options and the developed assessment framework are explained. The assessments results are presented in Chapter 3, which includes the feedback of the implemented stakeholder process and short summaries of the assessed policy options, including the results of the multi-criteria analysis. In chapter 4, the report’s results are briefly summarized and conclusions are drawn. Part II of the report includes the assessment factsheets for each of the policy options, which contain more information per option and assessment criteria including corresponding literature resources. Part II can be useful for readers looking for in-depth information.

2 Approach

Within the context of SHEBA, available or possible "Responses" are defined in 'D5.1 Report on the analytical framework for assessment of shipping and harbours in the Baltic Sea' (Hassellöv et al., 2015). Responses refer to all possible actions or reactions by society, economic actors and governments to address and cope with drivers, pressures, changes in state and impacts. These may include responses by the private sector as well as broader social responses from the public. Responses incorporate all possible strategies, such as societal adaption to new conditions (e.g. reducing car use in response to global climate change), economic responses (e.g. slow steaming to reduce costs when fuel prices go up), as well as policies (e.g. international targets for CO_2) and instruments (e.g. taxes on fuel use) to reduce or mitigate pressures. Those who are "responding" include policy makers, public authorities, economic actors (e.g. private companies), scientists as well as individuals and society. Hence, the following types of responses exist: social response, economic response, technology and policy, which include economic instruments and regulation. Nevertheless, in an effort to conduct a more in-depth assessment, there is a need to focus on a limited range of responses. In the assessment of this report, we focus on policy options initiated by public authorities to support and incentivize the mentioned variety of possible responses. We also take into account initiatives of private actors such as ports – in the past port authorities have been mainly public bodies but now partially transforming to privately managed institutions.

To initiate reduction of environmental pressures different types of policy instrument can be used, e.g. fees, taxes, trading systems, direct financial support such as subsidies and information sharing. All these have advantages and disadvantages that have to be taken into account, see following Table 1.

Table 1 Types of policy instruments

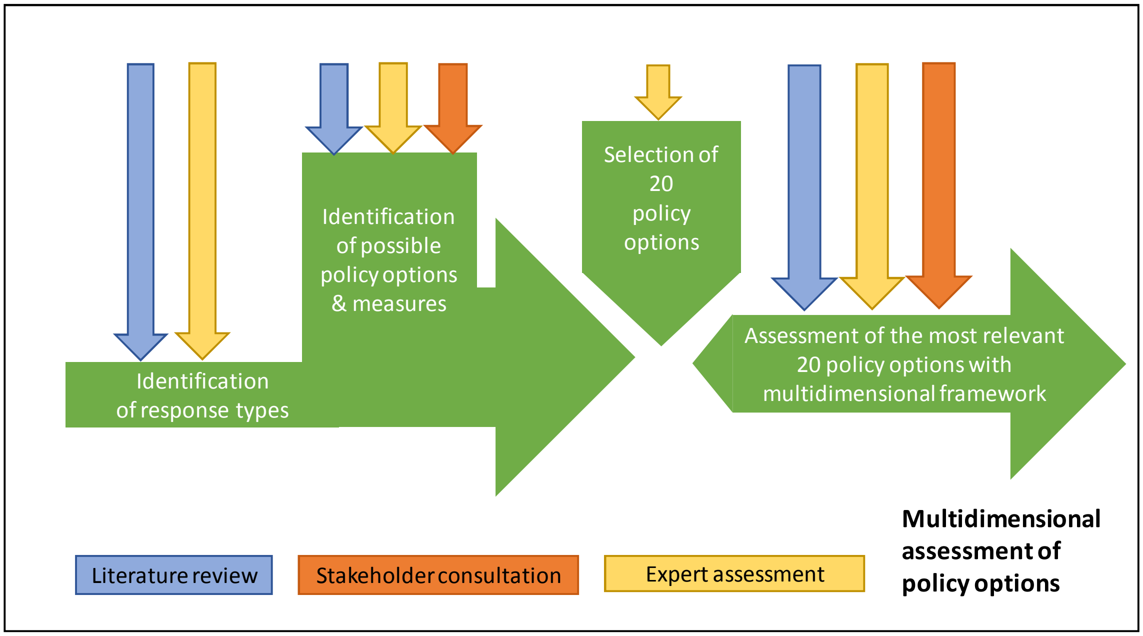
Type of policy instrument	Definition	Advantages	Disadvantages
Direct funding (e.g. subisidies / research funding)	Payments from government bodies	- Very targeted - Can be easily tailored to specific policy objective - Frequently used	- Bears risk of market distortion and mismanagement - Effectiveness depends on programme design, less certain
Taxes	Compulsory payment to the fiscal authority for a behaviour that leads to the degradation of the environment	- Can directly address the failure of markets to take environmental impacts into account - Choice of technology, enables low cost solutions	- Effectiveness depends on ability to set tax at a level that induces behavioural change
Charges / fees / dues	Compulsory payment to the competent body for a service	- Charges proportional to pollution	- Behavioural effect depends on set level of charge - Monitoring data must be available -Monitoring and enforcement costly
Standards / limits via regulation	Legal requirements, set quantitative limit on pollutants/emissions	- Creating incentives for innovation and establish favourable framework - Emission levels set directly	- Takes time to be implemented - Can create unnecessary burden

Type of policy instrument	Definition	Advantages	Disadvantages
			- Enforcement necessary - Effectiveness depends on set level of standard / limit
Tradable permits / certificates	Exchange of rights or entitlements	- Emission cap can be set directly - Flexible in design, also over time - Innovation potential - Choice of technology, enables low cost solutions	- Effectiveness depends on emissions cap, participation and compliance
Cooperation	Negotiated voluntary arrangement between parties to adopt agreed practices or targets	- Often politically popular - Raise awareness	- Requires administrative resources - Clearset targets are necessary to include - Often limited effect
Information provision	Supports actors to make better-informed choices	- Can be easily combined with other policies to increase effect - Potentially low cost	- Effectiveness depends on how target groups use the information - Indirect effect

Source: Declámara et al. (2013); IPCC (2007); OECD (2011).

The assessment approach of this report involves literature review, stakeholder consultation as well as expert assessments (see Figure 4). Based on the by literature and experts identified response types a literature review was used to identify a ‘long list’ of policy options and measures which was enriched with inputs from stakeholders and experts. After the selection of 20 policy options (‘short list’) the developed multidimensional assessment framework was used to evaluate the 20 selected policy options. The approach will be described in detail in the next subchapters.

Figure 4 Approach of policy options' assessment



Source: Authors.

2.1 Stakeholder consultation

The main objective of the stakeholder consultation was the integration of stakeholder feedback in the development of the assessed policy options and in the assessment process. The stakeholder engagement integrated a variety of views in the selection and assessment of the policy options. Three different components were part of the stakeholder consultation: (1) discussions at the SHEBA first stakeholder meeting in Hamburg, (2) discussion during second SHEBA stakeholder meeting in Tallinn and (3) Web-survey on assessment of policy options.

2.1.1 First SHEBA Stakeholder meeting in Hamburg

The first SHEBA stakeholder meeting was held on 29th and 30th September 2015 in Hamburg. The main objective regarding WP5 was to discuss success and challenges of existing environmental policies and instruments for shipping, expected future policies and instruments (at global, EU and Baltic level).

For the discussion a World Café format was chosen. The following questions were included in the different table discussions.

WP5 session 1: The Current Policy Mix

- How successful (i.e. ensuring some level of marine environment protection) have existing shipping policies been designed, implemented and enforced to date (e.g. MARPOL)? Which barriers and success factors do you see in the current policy framework?
- What indirect effects does the current policy framework lead to (e.g. increased operational costs, or creation of new environmental concerns)?
- Do you think it is realistic to meet the GHG reduction target of 40-50% by 2050 in the shipping sector as defined in the EU White Paper on transport?

WP5 session 2: The Future of Shipping Policy (focus on international and EU policy)

- Do you expect to have more or less stringent environmental regulations in the future? In regard to which environmental concerns (e.g. underwater noise, GHG emissions, water emissions, invasive species, hull bio-fouling)?
- Do you have a preference for future policy measures for shipping? Traditional command and control (regulation) vs economic policy instruments?
- Which instruments fit well together? Which do not fit so well together, might cause issues/challenges? Which policy measures or types/mixes of measures do you consider most cost-effective for the shipping industry?

WP5 session 3: Shipping in the Baltic

- What policy developments for shipping do you expect to take place in the Baltic Region in the future (i.e. 2030, 2040)?
- What suggestions on the current shipping political framework do you suggest for the future in the Baltic? E.g. better investments in reception/fueling stations in ports, increased coordination between governing bodies, reduction on any gaps in coverage, better coordination among Member States, implementation of MSP for the region, the establishment of an inter-organizational regulating body.
- How will the Baltic, as a Particularly Sensitive Sea Area, handle a potential increase in shipping?
    - How might this influence other environmental factors?
    - How might this affect interaction with other sectors in the Baltic?
- Do you consider the shipping sector in the Baltic to be an innovator or laggard in regard to the use of new technologies to comply with environmental standards?
- Do you consider policies/instruments from other regions to be valuable for the Baltic Sea?

The results of the discussions were included in the selection of policy options assessed in this report.

2.1.2 Second SHEBA Stakeholder meeting in Tallinn

The second SHEBA stakeholder meeting was held on 12th and 13th October 2016 in Tallinn.

For the socioeconomic analysis, stakeholders were consulted regarding their expertise on potential changes to relevant pressures, the state of the environment as well as human well being (including ecosystem services) during the workshop.

Workshop participants filled out a questionnaire. In the questionnaire they indicated if they expect that pressures, changes to the environment and impacts to human well being (i.e. ecosystem services) are increasing, stagnating or decreasing until 2030 and ranked the different items according to their relevance.

The participants presented the answers and discussed among them. Stakeholders were selected and invited based on their knowledge and expertise of the overlapping issues (e.g. shipping, conservation, policy). The participating stakeholders came from public research institutions, public information agencies and maritime authorities. The results were included in the work of Deliverable 5.2, to support the analysis of effects from shipping on human well being (including ecosystem services and human health) (Tröltzsch et al., 2017). And therefore, they are background and input for the policy options' assessment in this D5.3 report.

2.1.3 Web-survey for assessment of policy options

In order to enrich and validate the integrated assessment of policy options by the SHEBA team with stakeholder perspectives, a web-survey was designed, with the goal to obtain more information on the stakeholder's own weighting of assessment criteria. Due to time restrictions (and to keep the number of survey participants dropping out of the survey before completion as low as possible), the web-survey was designed to last approximately 15 minutes. Therefore, stakeholders were only asked to evaluate the 20 policy options against three of the eight assessment criteria, before being asked to rank all eight criteria and to create their ideal mix of six out of the 20 policy options (via drag & drop).

The three assessment criteria selected for the web-survey from the list of eight criteria, were chosen based on where stakeholder input was considered to be most valuable, and which criteria appeared most relevant for the stakeholder target group. The following three criteria were therefore included in the web-survey:

- political implementability (i.e. the fit with the current institutional settings and existing policy instruments)
- acceptance and feasibility (i.e. the the support from the society, including shipping industry, individual ports, governmental institutions, NGOs)
- positive effects on environment and health (the change of environmental and health pressures, e.g. different emissions, which are targeted by the policy options)

Subsequently, assessment criteria and policy options were rephrased in a commonly understandable language so as to address a broad stakeholder base from various types of backgrounds. A web-survey was designed based on the open access software lime survey. The survey contained a total of nine questions. Note, however that questions five, six and seven required survey participants to analyse 20 policy options against one criterion each: The first two questions were dedicated to obtaining background information of the survey participants regarding the type of affiliation and the country the interviewee was located in. The following two questions concerned general opinions of the participants on the current environmental status of the Baltic Sea and the importance of the environmental impact of shipping on the Baltic Sea. As a next step, the survey participants were asked to assess each of the 20 SHEBA policy options regarding their "political implementability"[1], by moving a slider on a scale from one (very low) to one hundred (very high). The same procedure was repeated for "acceptance and feasibility"[2] and the "strength of the positive effects on environment and health"[3]. Subsequently, participants were asked to rank the eight criteria used in the SHEBA project for the integrative assessment of policy options according to their relative importance, and they were asked to enter other/new criteria if they found that any particular criterion was missing in the list. Finally, the survey participants were asked to create an ideal policy mix of a maximum of six policy measures, which complemented or enhanced each other best. This had to be done by selecting a

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[1] Political implementability describes the fit with the current institutional settings and existing policy instruments.

[2] Acceptance and feasibility can be described as the support from the society (including shipping industry, individual ports, governmental institutions, NGOs).

[3] Environmental and health effects describe the change of environmental and health pressures (e.g. different emissions) which are targeted by the policies.

combination of policy measures from the pool of 20 policy options assessed in SHEBA, and by dragging and dropping these six into a specific box. Participants were then given the chance to provide reasons for their pick.

The survey was tested and adapted internally with the help of two test respondents. The web-survey finally went online in mid-March and continued until mid-May 2018. It was sent to a number of previously identified, existing mailing lists in the scientific and policy network of SHEBA, and email-reminders were sent around twice within a timeframe considered appropriate. Stakeholders who had attended SHEBA workshops and events in the past were addressed separately with a targeted email. Furthermore, the link to the survey was distributed among the partners of the SHEBA consortium, and the advisory board, with an invitation to pass on the questionnaire within their network. The survey targeted on public authorities, harbours, private businesses in the field of shipping, NGOs, research institutions & universities, including the SHEBA advisory board.

By the end of this period, a total of 63 stakeholders had responded to the questionnaire, and 14 had continued to fill it in until the last question. The most participants came from Sweden (21), followed by Germany (9), Finland (4) and Poland (3), and individual answers from further countries i.e. Belgium, Denmark, Estonia and Lithuania. A graphical overview can be found in Figure 6. The most responses came from public authorities (13), science (11), businesses (8) and NGOs (7), see also Figure 7.

The number of answers per question varies between 17 and 26. Considering this outcome and due to the low sample size, for the evaluation of the web-survey in excel, only simple statistical analysis (average, standard deviation, etc.) were used. Only in the case of the results of the policy mix question, a hierarchical cluster analysis was conducted in the statistical programme “R” to identify trends and to be able to spot whether two policy options appeared particularly often together in a policy mix. The software calculates a "distance" between two options, based on the frequency with which they are mentioned together, and displays this in a tree diagram. However, in this case, the robustness of such a hierarchical cluster analysis should not be overestimated, considering the low amount of mixes composed (14).

Figure 5 Screenshot from limesurvey: Assessment of policy options 1-4 regarding their political implementability. Definitions and further explanation of specific terms is provided when mouse is hovered over respective words.

Policy evaluation (1/3)

What is your opinion on the political implementability of the listed policy options? Political implementability describes the fit with the current institutional settings and existing policy instruments

#1 Sea grass protection: Restrictions on number of boats mooring in certain areas and better enforcement 64

#2 Speed regulation: Zoning and maximal speed (Baltic-wide) 26

#3 Excluding the noisiest ships / limits on average noise level 45

#4 Promoting biocide-free anti-fouling paint and alternatives (research funding, financial support for 64

Source: Authors.

2.2 Identifying and selection of policy options

The identification of policy options was based at first on a screening of literature, webpages, and other information material. The search included the SHEBA reports, grey and scientific literature, webpages and newsletters. Grey literature included e.g. published reports by public bodies (national governments, European Commission), industry associations, companies, NGOs or consultancies. Additionally, the stakeholder inputs from the two SHEBA stakeholder meetings (Hamburg and Tallinn, see chapter 2.1) were utilised.

A 'long list' of policy options and measures has been prepared based on the search. The 'long list' contained 85 options. Six selection criteria were used to further select a 'short list' of 20 policy options to be assessed (see Table 2). The selection criteria are based on the environmental priorities of shipping as well as practicalities of the assessment, such as available information. The suggested 'short list' of 20 options was circulated within the SHEBA Work Package leads, their feedback and additions were incorporated. A second round of feedback was gathered during a SHEBA project workshop.

Table 2 Selection criteria for policy options

Selection criteria	**Explanation**
Relevant for Baltic wide implementation	Implementable global, EU or Baltic-wide, transfer potential from one location to another, not already implemented on level of Baltic
Environmental pressures from shipping that have the biggest impact on human well being	Air: NO_X, PM (especially in ports), CO_2, SO_X (acidification) Water: non-indigenous species, oil spills, nutrients Noise: underwater noise Physical impacts (Prioritization is based on results from SHEBA Deliverable 5.2, Tröltzsch et al., 2017)
Coverage of a variety of pressures	Different pressures should be targeted with the policy options
Coverage of different types of policy instruments	Different policy instruments types such as regulation (standards/limits), market-based, direct funding, etc. should be part of the selected options
Links to relevant policy objectives	Links to e.g. MSFD (GES descriptors), air quality/health policies, climate mitigation policies exist
Information availability	Sufficient information for an assessment are available, e.g. maybe for innovative technical solutions not enough information is published
Expected substantial effect	Option has a certain effect on ecosystem features and functioning, option is not too small scale

Source: Authors.

In the following table the final 20 'short listed' policy options are presented (Table 3).

Table 3 Short listed policy options

Pressure type	**Policy options**
Physical impacts	#1 Sea grass protection: Restrictions on number of boats mooring in certain areas and better enforcement
Noise / emissions to air	#2 Speed regulation: Zoning and maximal speed (Baltic-wide)
Noise	#3 Excluding the noisiest ships / limits on average noise level
Emissions to water	#4 Promoting biocide-free anti-fouling paint and alternatives (research funding, financial support for pilots)
	#5 Reduced limits for biocidal release rate for anti-fouling paints
	#6 Guidance on integration of antifouling paints in river basin management plans (RBMPs) and national marine strategies
	#7 Stricter regulation on scrubber water
Emissions to air	#8 Promoting optimized fossil fuel driven engine and ship design, e.g. stricter energy efficiency standard (EEDI)
	#9 Promoting use of low emission fossil fuels, e.g. LNG
	#10 Promoting use of renewable fuels and energy sources, e.g. biofuels, wind
	#11 Limits on methane slip from LNG engines (due to incomplete combustion)
	#12 Promoting use of electric power for running the engine (battery –driven)
Emissions to air	#13 Promoting shore power in ports
	#14 Green port fees linked to ship emissions/pollutants
	#15 Introduction of national fairway dues (charges) which are linked to ship emissions/pollutants
	#16 Initiatives to simplify procedures in ports, e.g. use of communication tools to adjust speed to arrive in ports
Various	#17 Promote vessel scrapping to reduce environmental impacts of fleets (financial support)
Emissions to air	#18 Establish PM (including black carbon) emission standards for ships
	#19 Implementation of a CO_2-tax for shipping
	#20 Establishing of an emission trading scheme for greenhouse gases from shipping

Source: Authors.

2.3 Developing a multi-dimensional assessment framework

This chapter describes the Multidimensional Assessment Framework (MAF) used to assess policy instruments to reduce environmental and health impacts from shipping in the Baltic Sea. The MAF can be understood as the boundaries and broad set of goals by which to select and finally to assess policy measures. While the primary application of the MAF is to establish the broad goals or expected outcomes by which any new or existing policy options should achieve, this means it is needed to identify relevant criteria by which to assess policy instruments against these goals. The three basic principles of sustainable development, relating to ecology, economy and society, are the guiding principles used in this assessment. Simply put, it is assumed that by creating policies that contribute to improvements in one of these three pillars - while not causing a significant reduction in one or two of the others - makes an overall contribution to human well being.

In order to develop the MAF a literature review was conducted. The review focused on identifying key principles or conditions essential to the primary objective of SHEBA. That is, identifying options to reduce the environmental and health impacts due to shipping in the Baltic Sea in an effort to support an improvement in overall human well being. This therefore also requires identifying secondary objectives which promote enabling conditions to help achieve the primary objective (e.g. consider stakeholder knowledge). By developing and applying a MAF for policy instruments, the goal is also to determine different available pathways by which to reach these objectives. A full review of assessment frameworks can be found in Gómez et al. (2016).

The MAF is separated into three broad categories and explained below. These include enabling conditions, outcome conditions and integrative conditions. Enabling conditions are those factors which are necessary to facilitate the success of policy options. They are in many cases associated with the design or implementation of a policy, and therefore perhaps indirectly related to the outcome. Next are outcome conditions, which relate explicitly to the objectives of policy options and are therefore directly linked to the targets set. Finally, there are integrative conditions, which are cross-cutting considerations and may be linked to the overall design or management approach. It should be kept in mind that all conditions could be considered integrative, and that the separation into these groups is not to create exclusive categories, but merely to provide a means for structuring the assessment and surrounding discussions.

Enabling conditions

- *Political implementability* (Long et al., 2015; Zetland et al., 2011 citing North 1990) – this condition is necessary to identify whether policy instruments are politically feasible and implementable. In an existing governance and institutional setting, institutions are adapted to local conditions and have developed a specific bureaucracy or type of behavior, also due to the various stakeholders participating and potential competing interests. For the assessment to be conducted here for SHEBA it is essential to be aware of the multiple or overlapping institution jurisdiction to address multiple scales from local (e.g. port authorities) to national, regional (Baltic Sea) and international (link to spatial and temporal scales condition) as well as the different competencies and responsibilities of different institutions (e.g. shipping, environment, ports). This includes if the instruments are developed for an appropriate spatial scale such as areas of environmental importance (e.g. fish spawning grounds or mating areas) or distance to human populations (e.g. regarding emissions through ports).
- *Acceptance & feasibility* (Long et al., 2015) – a pre-condition to implementing policy options is that they have sufficient support from or consideration of society (shipping industry, individual ports, governmental institutions, NGOs, associations, etc.). In this sense, it is also important that policy options take into account stakeholder knowledge, societal values, and power relations of local and regional circumstances when considering the design of policy instruments. Those policy options which are co-built or co-designed with stakeholders may have stronger buy-in and ultimately be

easier to implement. At the same time, industry actors may also benefit from adapting to environmental policies, as this may strengthen their reputation amongst stakeholders as being leaders in the industry (Andersson et al., 2015).

- *Apply multi-disciplinary and scientific knowledge, acknowledge uncertainty* (Long et al., 2015; Rouillard et al. 2016) – scientific knowledge is a pre-condition for designing instruments and taking advantage of new opportunities such as from current research. However, by ensuring that scientific knowledge is used when designing or implementing a policy option uncertainty can be identified and therefore potentially integrated into the policy design. In regard to shipping it is important to consider uncertainty, as there may be less scientific knowledge or available assessments for some pressures such as noise (see Deliverable 5.2, Tröltzsch et al,. 2017).

<u>Outcome conditions</u>

- *Technological and innovation potential* – policy options within SHEBA are also assessed and evaluated in regard to whether they promote technological improvements and innovation. This would mean options which build upon advancements in industry (e.g. scrubber technologies, cleaner fuels, etc.) should be considered as such opportunities may unlock further opportunities to reduce pressures from shipping not yet recognised by industry or policy makers.
- *Environmental and health outcomes* (Zetland et al., 2011; Long et al., 2015) – Policy options are targeting certain policy objectives (e.g. encountering climate change impacts, decreased impacts on human health, or support reaching the MSFD's Good Environmental Status). The policy options will be assessed by comparing actual environmental and health outcomes with alternatives (no action or other options, for example) and evaluating positive and negative side effects. Furthermore, policy options which can be monitored or enforced may be more likely to be effective in the long term, especially in the case of shipping where many activities are happening at sea and distant from shores making it historically difficult to enforce policies.
    - *Environmental outcomes* – policy options that can be assessed in regard to the environmental outcomes they produce, such as a reduction in air or water emissions as well as noise levels, are critical. The availability of ecosystem services such as stocks for commercial fishing depends on the conservation of marine ecosystems through policy and management. Those options which target policy goals, in particular the EU Marine Strategy Framework Directive (GES) are particularly relevant for SHEBA. Environmental criteria for establishing improvements in environmental outcomes relate to reductions in pressures (see SHEBA D5.2), quantifiable or qualified, i.e. descriptive.
    - *Health outcomes* – similar to environmental outcomes, policy options should also focus on human health improvements, especially related to air emissions in ports (see SHEBA D5.2). Health criteria should focus on identifiable reductions in pressures such as airborne particles and gases occurring in concentrations which lead to negative impacts on human health such as Particulate Matter (PM) and nitrogen oxide (NO_x) emissions.
- *Efficiency (Economic outcomes)* (Zetland et al., 2011; Barton et al., 2014; McCann et al., 2005) – The option's economic outcomes will be evaluated using a cost-benefit analysis (CBA) principle. It includes a semi-quantitative assessment of negative and positive side-effects, cost savings and transaction costs which are related to the design and implementation of policies. The effects and

benefits are directly linked with the effectiveness criteria on environmental and health outcomes and their assessment will be used as an input to the analysis here.

Integrative conditions

- *Distributional effects* – refers to the distribution of goods and services across different actors and groups (Zetland et al., 2011). Criteria should focus on assessing the distribution across both environmental, economic and social aspects as well as across groups as a result of implementation of policies.
- *Reflect synergies and tradeoffs between ecosystem services* – policy options should also be assessed based on an understanding of the social-ecological system (Gómez et al., 2016). This means considering multiple ecosystem services and health benefits (common pool resources) in order to identify options which create synergies and reduce, or remove, tradeoffs between beneficiaries. Considering the dynamic nature of the social-ecological system may lead to the conclusion of alternative policy options or prioritizations due to a broader understanding of the policy implications for human well being.

The following Table 4 includes a summary of the used assessment criteria.

Table 4 Summary of assessment criteria of Multidimensional Assessment Framework

Conditions	Multidimensional Assessment Framework	Short description
Enabling	Political implementability	This condition is necessary to identify whether policy instruments are politically feasible and implementable. In an existing governance and institutional setting, institutions are adapted to local conditions and have developed a specific bureaucracy or type of behavior, also due to the various stakeholders participating and potential competing interests.
	Acceptance & Feasibility	A pre-condition to implementing policy options is that they have sufficient support from or consideration of society (shipping industry, individual ports, governmental institutions, NGOs, associations, etc.) depending as well on the feasible implementation of the different options. In this sense, it is also important that policy options take into account stakeholder knowledge, societal values, and power relations of local and regional circumstances when considering the design of policy instruments.
	Scientific knowledge and uncertainty	Scientific knowledge is used when designing or implementing a policy option. Uncertainty can be identified and therefore potentially integrated into the policy design. In regard to shipping it is important to consider uncertainty, there may be less scientific knowledge or available assessments for some pressures such as noise.
Outcome	Technological and innovation potential	Policy options are also assessed and evaluated in regard to whether they promote technological improvements and innovation. This would mean options which build upon advancements in industry (e.g. cleaner fuels) should be considered as such opportunities may unlock further opportunities to reduce pressures from shipping not yet recognised by industry or policy makers.
	Environmental and health outcomes	Policy options are targeting certain policy objectives (e.g., encountering climate change impacts, decreased impacts on human health, or support reaching the MSFD good environmental status). The policy options will be assessed by comparing actual environmental and health outcomes with alternatives (no action or other options, for example) and evaluating positive and negative side effects.
	Efficiency (Economic outcomes)	The option’s economic outcomes will be evaluated using a cost-benefit analysis (CBA) principle. The effects and benefits are directly linked with the effectiveness criteria on environmental and health outcomes and their assessment will be used as an input to the analysis here.
Integrative	Distributional effects	Refers to the distribution of goods and services across different actors and groups. Criteria should focus on assessing the distribution across both environmental, economic and social aspects as well as across groups as a result of implementation of policies.
	Synergies and tradeoffs	Policy options should also be assessed based on an understanding of the social-ecological system. This means considering multiple ecosystem services and health benefits (common pool resources) in order to identify options which create synergies and reduce, or remove, tradeoffs between beneficiaries.

Source: Authors.

As already mentioned in Chapter 2.1: Stakeholder consultation two of the eight criteria were assessed by stakeholders via a web-survey (political implementability and acceptance & feasibility). The other criteria were evaluated based on literature review and expert assessment. For the expert assessment a questionnaire was circulated in the project consortium. Experts in the consortium were clustered according to their knowledge to GHG and air pollutant emissions, water emissions, noise emissions and physical impacts. Based on the received filled questionnaires (max. 4 questionnaires were received for the same policy option) a final score was estimated based on an equal weighted approach.

A multi-criteria approach (MCA) was used for the estimation of a score across all assessment criteria per policy option. With help of the MCA the results for assessment criteria with different charactistics (e.g. quantitative and qualitative results) can be estimated. One main advantage of MCA methods is their capability to integrate a diversity of criteria in a multidimensional way. Furthermore, MCA is especially suitable to link with stakeholder interaction, i.e. used with participatory methods. However, MCA is also perceived as a more technocratic approach and depends on the knowledge of participating stakeholders (Geneletti, 2013).

The multidimensional assessment framework has been further operationalised, e.g. developing of key questions, further definition of included cost components, developing of key for scoring. The operationalised assessment framework that is compatible with the MCA scoring approach can befound in Chapter 6.1 Template for options' assessment. The template was used for the assessment of the 20 policy options.

We used the MCA with a weighted approach for the different criteria. The weighting of the criteria was performed by the stakeholders via the web-survey (see Chapter 2.1) and resulted in the weights shown in (Table 5).

Table 5 Summary of weighting used for MCA

Criterion	Stakeholder feedback	Weighting factor
Political implementability	7,12	13%
Acceptance & Feasibility	7,00	13%
Scientific knowledge and uncertainty	7,65	14%
Technological and innovation potential	6,88	12%
Environmental and health outcomes	8,13	15%
Efficiency (economic outcomes)	7,31	13%
Distributional effects	5,73	10%
Synergies and tradeoffs	6,15	11%

Source: Authors.

2.4 Excursus: Methodology for health impacts assessment and valuation

To study the health impacts of air pollution related to the investigated shipping scenarios and their monetary valuation, the Swedish version of the ALPHA-Riskpoll tool (ARP) (Holland et al., 2013; Holland, 2014) has been used. The ARP tool was developed to provide a detailed quantification of benefits of pollution controls in Europe. It has been used extensively for European policy assessments including work on the National Emission Ceilings Directive and the UN/ECE Gothenburg Protocol under the Convention on Long Range Transboundary Air Pollution, directives on air quality including the Clean Air For Europe (CAFE) Directive and others. The tool provides a detailed quantification of effects on health, including various morbidity impacts (on chronic bronchitis, hospital admissions, etc.) and mortality. The ARP version used here is based on recommendations of the HRAPIE project regarding concentration-response functions and is providing full details of the data needed, for example the incidence rates (Holland, 2014). Analysis then continues to monetization of quantified effects.

The health impact assessment in the ARP tool follows a general form:

$$I = C_i \times P_a \times P_r \times R \times CRF$$

Where
I = Impact (e.g. number of cases, days of ill health, etc.)
C_i = Average population weighted concentration for pollutant i
P_a = Fraction of the population within the age group considered (e.g. those aged over 65 years)
P_r = Fraction of the population at risk within this age group (e.g. asthmatics)
R = Incidence rate (e.g. cases per 1000 population at risk)
CRF = Concentration response function (change in incidence per unit concentration for those at risk)

The country-specific population-weighted exposures to PM2.5 and ozone for the impacts of different policy options (based on different developed SHEBA scenarios) were calculated using concentration maps calculated with CMAQ (regional scale) and TAPM (urban scale) models, were overlaid with population maps (reference) and inserted into the AROP tool while CRF and country-specific data on incidence rates, population age structure and population in risk are included in ARP.

Following the advice of an earlier expert group convened by WHO-Europe under the CAFE Programme, the Health Impact Assessment was performed against exposure to ozone and fine particles, considering the acute effects on mortality – as reflected by premature mortality (ozone) – and the longer-term changes in life expectancy (sometimes termed chronic mortality) from particles. The particles considered include primary particulate emissions (emitted directly) and secondary particulates that form in the atmosphere. In line with WHO advice, the analysis treats all particles, irrespective of source and chemical composition, as equally harmful. The outputs are reported as the cumulative years of life lost (YOLL) or cases of premature mortality from PM pollution. For acute mortality from ozone, the analysis quantifies the number of premature deaths.

The health impact with highest monetary value is avoided mortality (fatality), which is valued by either estimating the Value of Statistical Life (VSL) or the Value Of Life Year lost (VOLY). The estimated economic value of these varies in the literature and between methods. The values can also differ between VOLY and VSL due to differences in how many life years that are assumed to be lost when a fatality occurs. We therefore include estimates using both VOLY and VSL based on the NEEDS study (www.needs-project.com, 2006) which is in line with proposal for a new Clean Air Policy Package that the European Commission published on the 18th of December 2013 (European Commission, 2013).

Mid VOLY uses the median VOLY and mid VSL uses the mean VSL from the NEEDS study. In addition, ARP assess uncertainty range including costs based on the low end on the median VOLY estimate from Desaigues et al. (2011) and on the high end on the mean VSL value from OECD (2012).

For other non-fatal health effects (morbidity), the ARP tool uses method based on the CAFE CBA methodology (Holland et al., 2005; Hurley et al., 2005) and response functions developed as part of the EC CAFÉ programme.

Based on the described methodology, the following results have been calculated for the policy options #2 Speed regulation: Zoning and maximal speed (slow steaming), #8: Promoting optimized fossil fuel driven engine and ship design, e.g. stricter energy efficiency standard (EEDI) and #9 Promoting use of low emission fossil fuels, e.g. LNG; for all policy options compared to BAU scenario for the year 2040

Table 6 Evaluation of effects on human health (year 2040)

Policy options	Damage valuation, mid VOLY (M€/year)	Damage valuation, mid VSL (M€/year)	Valuation of lost working days (M€/year)
#2: Slow steaming (SlSt-BAU)	-53	-211	-3
#8: Increased EEDI (BAU-EEDI)	-136	-527	-6
#9: LNG (LNG-BAU)	-89	-356	-4

Source: Authors.

2.5 Excursus: Methodology for estimation of effects of acidification and eutrophication on ecosystems

The effects of acidification and eutrophication can be expressed in general terms as ranging from loss of species (e.g. trout and salmon from rivers and lakes in northern Europe) to more subtle effects, for example the relative abundance of different species in grassland or moorland. Stock at risk data for ecosystem impacts have been collated over a period of many years through the Coordination Center for Effects in the Netherlands. In SHEBA a modelling framework for describing exceedance of critical loads and levels, also included within the CAFÉ cost-benefit analysis methodology (AEAT 2005), has been adopted. Using methods agreed with the CCE (and hence already subject to extensive discussion with ecological experts across Europe) critical loads exceedance for acidification and eutrophication are quantified in terms of:

1. Area in each country where ecosystems are exceeded;

2. Accumulated exceedance of critical loads.

Whilst information from the literature provides insight on the types of effect that may be anticipated, there is a lack of information at the present time for going beyond this. AEAT (2005) states that valuation of these impacts is not yet possible because of limited research in this area that has specific relevance to reductions in air pollutant emissions. ECLAIRE (2015) suggests three different methods for valuation of ecosystem damages. First builds on willingness to pay (WTP) for protection of biodiversity, based on households' WTP for protection of some species in protected sites at risk based on Christie et al. (2006, 2011 and 2012). This methodology has been implemented in the UK to address protected sites but is not possible to implement on entire EU and also consider the unprotected sites. The second methodology uses restoration costs of the lost biodiversity. This methodology has similar limitations as the previous one, limited data on restoration costs are available from Germany and Holland and these needs to be applied on entire EU. This method requires other type of modelling than critical loads. The third approach looks at cost of measures to reduce emissions in a way that the requirement that critical loads in Natura 2000 areas are not exceeded are met at all places. Eclaire (2015) calculates the cost of damage from eutrophication as a cost of reducing the NOx and NH3 emissions from the CLE scenario to the MFTR scenario (per country). It is the first approach which would be compatible with the CL modelling, however, at this moment it is not mature for implementation.

The following results for the above mentioned area in each country where ecosystems are exceeded and accumulated exceedance of critical loads have been estimated for the policy options #2 Speed regulation: Zoning and maximal speed (slow steaming), #8: Promoting optimized fossil fuel driven engine and ship design, e.g. stricter energy efficiency standard (EEDI) and #9 Promoting use of low emission fossil fuels, e.g. LNG; for all policy options compared to BAU scenario for the year 2040.

Table 7 Effects of policy options on acidification and eutrophication of ecosystems (year 2040)

Policy options	**Relative shipping contributions to exceeded area (eco area km^2)**		**Relative shipping contributions to accumulated exceedance (eq/ha/y)**	
	Power	**Linear**	**Power**	**Linear**
#2: Slow steaming (SlSt-BAU)	-0.9%	-1.3%	-1.1%	-1.4%
#8: Increased EEDI (BAU-EEDI)	-2.7%	-3.7%	-3.0%	-3.9%
#9: LNG (LNG-BAU)	-1.4%	-2.1%	-1.7%	-2.3%

Source: Authors.

3 Assessment of potential policy options

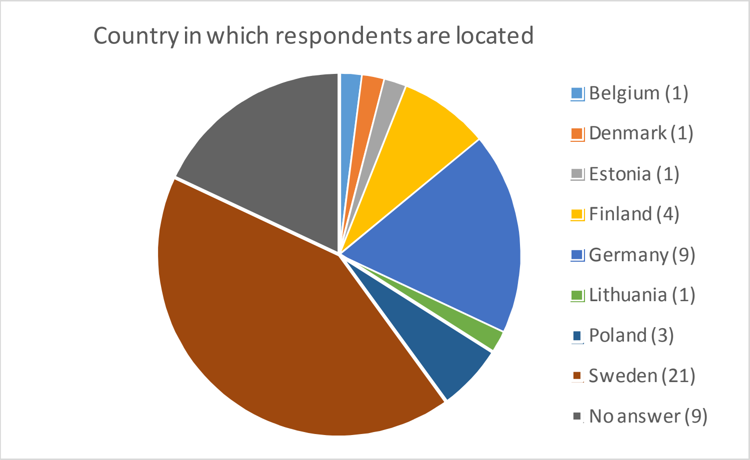
This chaper contains the assessment results for the 20 selected policy options. It starts with the results of the stakeholder consultation via the web-survey. The second subchapter includes a brief summary and all scores for the assessment criteria.

3.1 Stakeholder consultation via web-survey

In total, 63 people filled in the web-based survey, however, only 14 of them answered all questions. Figure 6 and Figure 7 provide an overview of the background of respondents to the web survey. When asked for their country of residence, the majority of the 50 people who responded indicated they were located in Sweden (21) and nine people answered they were located in Germany. Another four people indicated they were working from Finland and three people indicated that they were working from Poland. There was one participant working from Belgium, Denmark, Estonia and Lithuania, respectively, while nine people indicated that they did not want to answer this question.

It can be assumed that the country of residence indicated by respondents is related to the composition of the mailing lists through which the web survey was distributed, since the mailing lists contained particularly many contacts of stakeholders in Sweden and Germany.

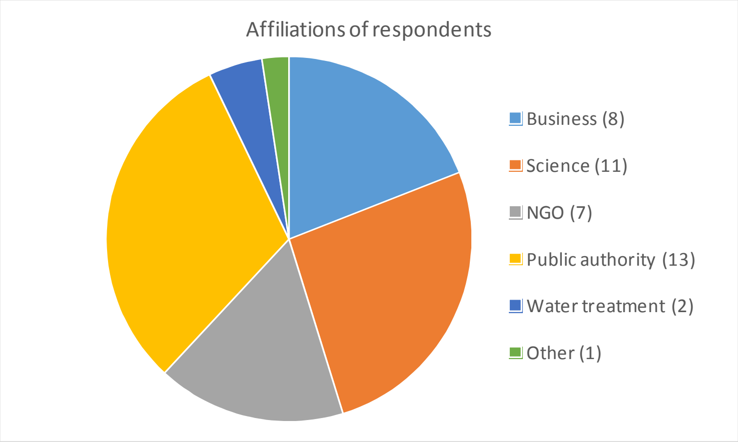
Figure 6 Country of residence of respondents



Source: Authors.

To the next question on which type of affiliation they belonged to, only 42 respondents provided an answer. Of these, the majority (13) work for public authorities, followed by scientific institutes (11), businesses (8) and NGOs (7). Two respondents work at water treatment utilities and one respondent indicated "other".

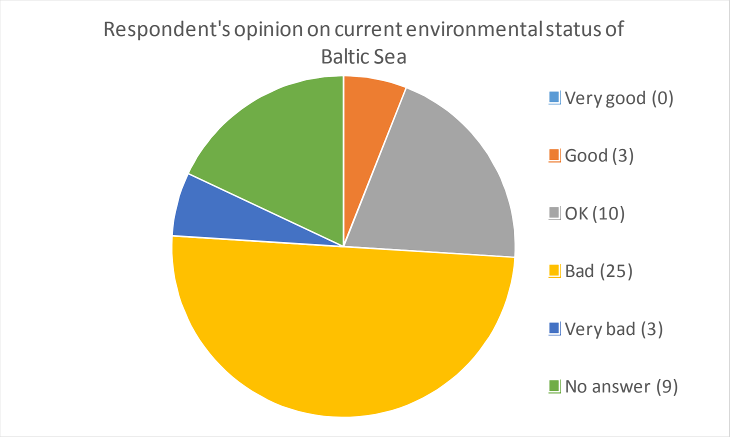
Figure 7 Affiliations of respondents



Source: Authors.

The question regarding their opinion on the current environmental status of the Baltic Sea (see Figure 8) was answered with bad or very bad by a little more than half (28) of the respondents. Nine respondents refrained from answering and 13 described the environmental status of the Baltic Sea as good or OK.

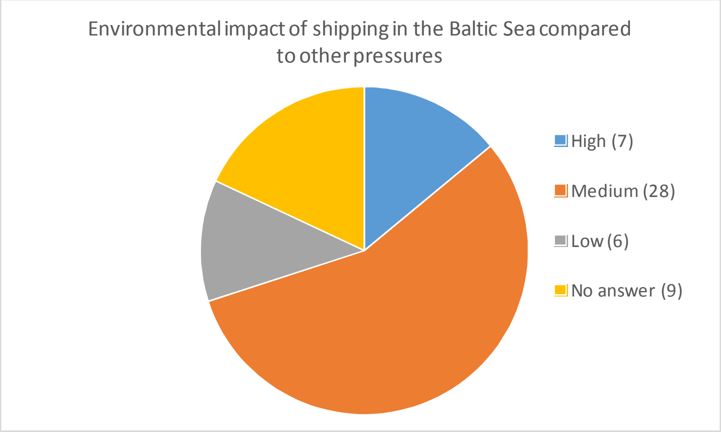
Figure 8 Respondent's opinion on current environmental status of Baltic Sea



Source: Authors.

However, the relative importance of shipping in contributing to the environmental status of the Baltic Sea in comparison to other pressures (see Figure 9) was assessed to be medium or low by the majority (34) of respondents. Only seven respondents concluded that the impact of shipping on the Baltic Sea was relatively high.

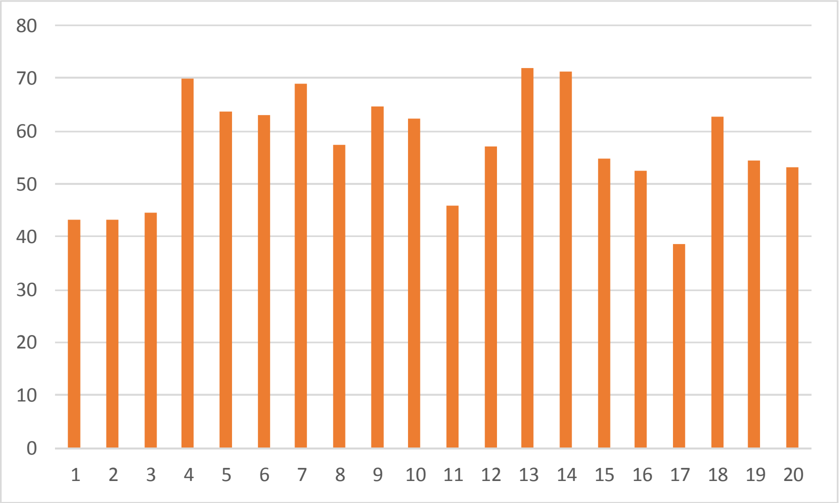
Figure 9 Environmental impact of shipping in the Baltic Sea compared to other pressures



Source: Authors.

In the assessment of policy options regarding their political implementability on a scale from zero to one hundred (see Figure 10), the stakeholders found high political implementability in: the 'promotion of shore power in ports' (#13, average 72), 'green port fees' (#14, average 71) and the 'promotion of biocide-free anti-fouling paint and alternatives' (# 4, average 70). Given that option #13 and #4 consist of promotion and option #14 is already implemented in a number of ports, this assessment seems reasonable. Policy option #17 'Promote vessel scrapping to reduce environmental impacts of fleets' scored lowest in this assessment (average of 39). List of assessed policy options see Table 3.

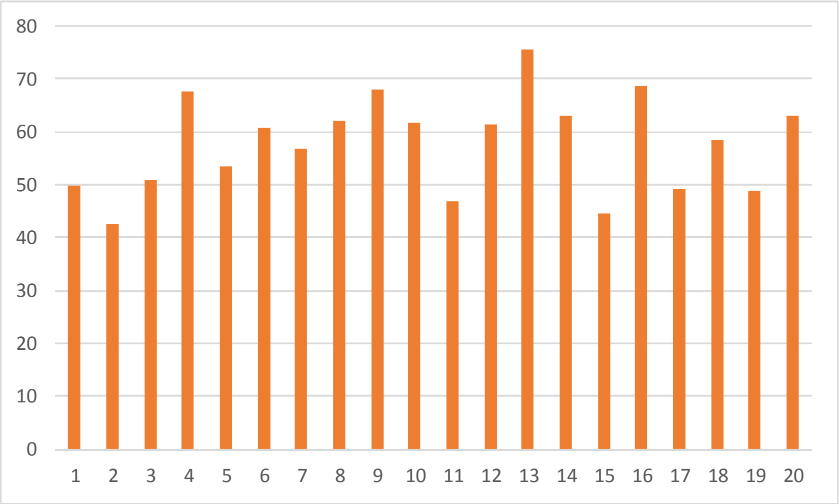
Figure 10 MCA: Political implementability on a scale from 0 – 100



Source: Authors.

Figure 11 shows the assessment of the 20 policy options regarding their acceptance & feasibility. In this assessment, option #13 'promotion of shore power in ports' (average of 76) and #4 'promotion of biocide-free anti-fouling paint and alternatives' (average of 68) scored relativey high again. Option #16 'Initiatives to simplify procedures in ports' scored high (average of 69) as well as #9 'Promoting use of low emission fossil fuels' (average 68). Policy options #2 'Speed regulation' scored lowest (average of 43). Interesting is the difference in assessment of a ‘CO_2-tax for shipping’ (#19) with an average score of 49 and ‘Maritime emission trading scheme’ (#20) with a significant higher average score of 63. List of assessed policy options see Table 3.

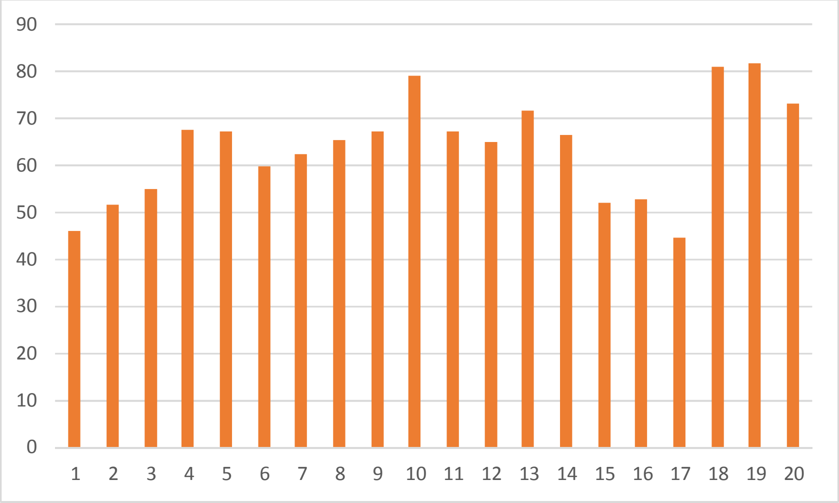
Figure 11 MCA: Acceptance & Feasibility on a scale from 0 - 100



Source: Authors.

When asked to assess the positive environmental and health effects of the 20 policy options on a scale from zero to one hundred, respondents indicated other options than the four that scored highest in the previous questions. This time, the implementation of a ‘CO_2-tax for shipping’ scored highest (#19, average of 82), followed by the ‘establishment of particulate matter (PM) emission standards’ (#18, average of 81) and the ‘promotion of the use of renewable fuels and energy sources’ (#10, average of 79). The policy option with the lowest scoring was the ‘promotion of vessel scrapping to reduce environmental impacts of fleets’ (#17, average of 45). ‘Sea grass protection restricting moorings’ (#1) (average 46) also scored low. This indicates that while political implementability and acceptance & feasibility seem to be linked to each other in the eyes of stakeholders, there seems to be no such positive correlation between the environmental and health outcomes of a policy option and its political implementability and acceptance & feasibility. List of assessed policy options see Table 3.

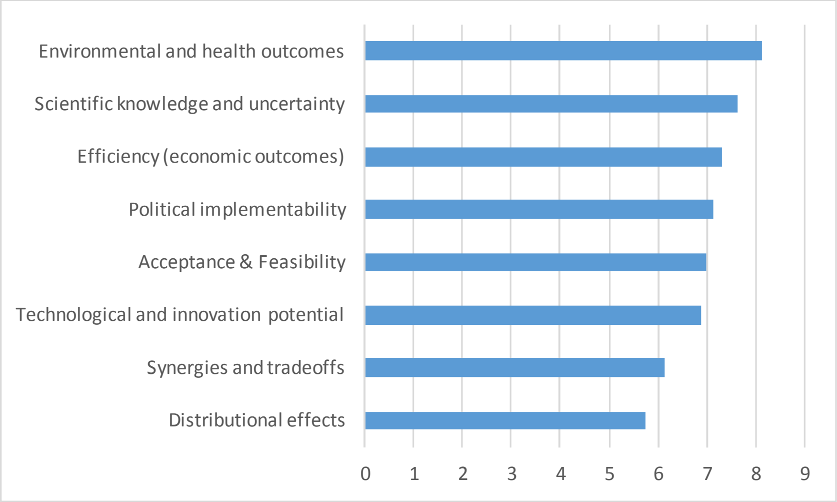
Figure 12 MCA: Strength of positive effect on environment and health outcomes on a scale from 0 – 100



Source: Authors.

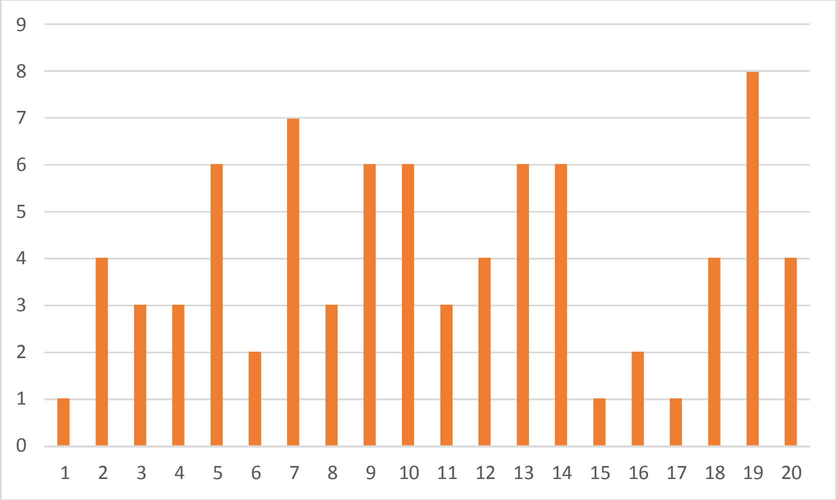
When looking at the ranking by stakeholders of the criteria used in this study (see Figure 13), 'environmental and health outcomes' were seen as most important by stakeholders, and 'political implementability' and 'acceptance & feasibility' only ranked fourth and fifth, respectively. The scoring of policy options regarding these criteria will therefore be assigned a lower weight than the scoring of policy options regarding their environmental and health outcomes.

Figure 13 Average weighting of criteria on a scale from 1-10



Source: Authors.

Figure 14 Number of times policy options were chosen to be included in policy mix of six (14 mixes created)



Source: Authors.

This is also reflected in the amount of stakeholders who chose to include #19 ‘CO_2-tax’ in the policy mix (8 stakeholders out of 14). Nevertheless, the picture is not as clear for the other options which scored relatively high on political implementability, environmental and health outcomes, or acceptability & feasibility (i.e. policy options #4, #10, #13, #14, #16, #18). A hierarchical cluster analysis conducted with the statistical software “R” (Code: d <- dist(x, method = "binary") hc1 <- hclust(d, method = "ward.D") plot(hc1, cex = 0.6, hang = -1)) showed that there is a slight tendency of policy options #4 ‘Promoting biocide-free anti-fouling paint’, #9 ‘Promoting use of low emission fossil fuels’ and #12 ‘Promoting use of electrically powered ships’ to be chosen relatively often together in the policy mixes. Such clustering behavior needs, however, to be interpreted with great care, considering the low sample size, which also makes it very likely for those options mentioned most frequently to end up clustering together. The reasons which stakeholders gave for choosing a particular policy mix were also very diverse, ranging from personal familiarity with the option selected for the mix, a focus on greenhouse gas emissions, or a broad coverage of air and water quality, or a focus on their economic efficiency or on a particular type of measure (e.g. "command and control"). List of assessed policy options see Table 3.

3.2 Summarized assessment results per option

The 20 selected policy options were assessed with a participatory MCA based on the assessment criteria included in SHEBA’s multidimensional assessment framework. The following chapter includes an assessment summary for each policy option, containing a short summary text (general description and highlights) as well as the MCA scores and the rank within the 20 assessed policy options. The full assessment (including references to the used literature sources, etc.) can be found in PART II: In-depth assessment of policy options of this report.

3.2.1 Policy option #1 Sea grass protection: Restrictions on number of boats mooring in certain areas and better enforcement

Ecosystems formed by seagrass beds are estimated to be the largest ocean carbon sinks in the world (Nellemann et al., 2009). Meadows formed by such seagrass are present in most oceans and seas of the world (Green & Short, 2003), with a focus on tropical coasts and temperate regions (Den Hartog

& Kuo, 2006). Their ecological role is crucial for the marine environment and provision of ecosystem services, such as nursery habitats for fish, coastal protection, water purification and carbon sequestration (Hemminga & Duarte, 2000; UNEP/MAP, 2012; Ondiviela et al., 2014).
Shipping has various negative effects on seagrass meadows, which includes 'scarring' due to static moorings and anchors, damages due to boat groundings and propeller contact and boat-related pollution. This policy option is primarily addressing the most severe one: anchoring and mooring. If seagrass areas are not only protected from mooring and anchoring, but also integrated into MPAs, a wider protection could be ensured. Since seagrass areas are large and often located in coastal areas, where harbours are located, such wide protection is unlikely. An EU-wide or general limitation of mooring is regarded as unlikely or difficult to implement. However, a limitation of anchoring and the provision of seagrass-friendly alternatives could be established at local level.

Table 8 Summary: #1 Sea grass protection: Restrictions on number of boats mooring in certain areas and better enforcement

Summary: Policy option #1 Sea grass protection: Restrictions on number of boats mooring in certain areas and better enforcement			
Political implementability	1	Environmental and health outcomes	3
Acceptance & Feasibility	2	Efficiency	4
Scientific knowledge and uncertainty	3	Distributional effects	3
Technological and innovation potential	2	Synergies and tradeoffs	3
		Total score:	2,6
		Rank	17

Source: Authors.

3.2.2 Policy option #2 Speed regulation: Zoning and maximal speed (Baltic-wide)

Vessel operation at high speeds leads to high underwater noise emissions. Noise can affect fish/mammals in many ways, starting from masking of communications (which may lead into difficulties in mating, avoiding predators) to physical symptoms (like temporary or permanent hearing loss) or ultimately, death. The noise levels caused by shipping may lead to changes in migratory patterns or habitat loss and animals may move to less noisy areas. In the long term, this can lead to depletion of fisheries and declining populations. Currently, low noise emissions are not necessarily considered as design criteria for ships.

Slow steaming can be a valid measure to reduce noise emissions from ships. Leaper et al. (2014) concluded, that slow steaming had likely reduced the overall broadband acoustic footprint from observed ships by over 50% due to reduction in mean speeds from 15.6 (sd = 4.2) knots in 2007 to 13.8 (sd = 3.0) knots in 2013.

The largest barrier for the option is the limited knowledge on impacts from noise emissions of ships. There is only very limited measurement data of underwater noise from a small number of research projects; routine monitoring of noise is not done. In addition, further work is required to map out the response of marine life to noise. Currently very little information is available on this topic. It can be assumed that the existing knowledge gap leads to a low rating by stakeholders (on political implementability and acceptance & feasibility). However, speed regulation shows significant synergies with the reduction of GHG and air pollutant emissions. The estimations of the SHEBA project (based on reduced PM and ozone emissions) show a reduction potenial of health impacts between 53 million and 211 million Euro per year for 2040 (compared to BAU, for mid VSL and VOLY).

Table 9 Summary: Policy option #2 Speed regulation: Zoning and maximal speed (Baltic-wide)

Summary: Policy option #2 Speed regulation: Zoning and maximal speed (Baltic-wide)			
Political implementability	1	Environmental and health outcomes	3
Acceptance & Feasibility	1	Efficiency	4
Scientific knowledge and uncertainty	1	Distributional effects	4
Technological and innovation potential	1	Synergies and tradeoffs	4
		Total score:	2,3
		Rank	18

Source: Authors.

3.2.3 Policy option #3 Excluding the noisiest ships / limits on average noise level

Amongst the types of anthropogenic energy that human activities introduce into the marine environment, the most widespread and pervasive type is underwater noise (Van der Graaf et al., 2012). Shipping contributes to long lasting underwater noise; indeed, motorized shipping is “one of the most prominent man-made sources of underwater noise” (Madsen et al., 2006). This policy would address the most relevant sources for ship-related noise, which is the engine operation (loud continuous noise from 10 Hz to 10kHz).

The limits on noise levels could be reached e.g. by hybrid technologies of diesel and electrically powered ships. This policy would require a ranking of all ships after their average noise level. Adressing underwater noise is a crucial challenge to preserve habitats and ensure the provision of ecosystems services. But effectiveness is potentially higher for other options and measures such as reducing shipping speed (Policy option #2 Speed regulation: Zoning and maximal speed (Baltic-wide)) or including noise levels in the design of ship hulls, propellers etc.

Table 10 Summary: Policy option #3 Excluding the noisiest ships / limits on average noise level

Summary: Policy option #3 Excluding the noisiest ships / limits on average noise level			
Political implementability	1	Environmental and health outcomes	2
Acceptance & Feasibility	2	Efficiency	1
Scientific knowledge and uncertainty	1	Distributional effects	4
Technological and innovation potential	4	Synergies and tradeoffs	1
		Total score:	1,9
		Rank	20

Source: Authors.

3.2.4 Policy option #4 Promoting biocide-free anti-fouling paint and alternatives

Having a non-fouled surface is vital for shipping to reduce fuel consumption and CO_2 emissions. The most commonly used method to prevent fouling on ships hulls is to coat the hull with antifouling paints that contain and leach biocides, such as copper oxide. This option aims to reduce the loads of biocides from antifouling coatings to the Baltic Sea by promoting biocide-free antifouling paint and other alternatives (e.g. hull cleaning). Several more environmentally friendly options are commercially available. One example is foul-release coatings that form a non-stick surface on vessel hulls and hinders organisms to attach. Other options are epoxy-based paints in combination with underwater cleaning. With this policy option, biocide free solutions, such as underwater cleaning, are promoted and research fundings of biocide free alternatives are provided. The promotion of biocide-free paints would be feasible at low costs and low resistance of stakeholder groups. However, this alternative has to be effective and cost-effective in order to be applied. This is not the case for all alternatives to biocidal paints. Hence, it is necessary to do further research on these alternatives.

Table 11 Summary: Policy option #4 Promoting biocide-free anti-fouling paint and alternatives

Summary: Policy option #4 Promoting biocide-free anti-fouling paint and alternatives			
Political implementability	5	Environmental and health outcomes	3
Acceptance & Feasibility	4	Efficiency	3
Scientific knowledge and uncertainty	5	Distributional effects	5
Technological and innovation potential	4	Synergies and tradeoffs	1
		Total score:	3,8
		Rank	1

Source: Authors.

3.2.5 Policy option #5 Reduced limits for biocidal release rate for anti-fouling paints

Biocidal components of anti-fouling paints pose a significant threat to ecosystem services and indirectly to human health. Hence, reducing its release would have a direct positive impact. Apparently; the most feasible way to limit the biocidal release of anti-fouling paints today is through the banning of certain chemicals or products. It has not been addressed by any organization yet to measure and control biocidal release in real time. A serious certification and auditing process of applicators could be a strong measure to limit biocidal emission rate as well. The by far major source for copper and zinc emitted by ships are antifouling paints. There are options that lead to low biocidal release rate – down to zero (e.g. by using hull cleaning robots). These options are comparably cost intensive. Hence, new, more cost-effective, options would be needed. However, a significant (10 fold) reduction of copper release can also be achieved by specific paints, without compromising the efficiency of macrofouling. Additionally, current industry practices in the application of paint also play a major role. The release rate of biocidal compounds could be limited by addressing these deficiencies, since it is “the principal” reason why antifouling paints fail to achieve their potential service life (Natural Heritage Trust, 2007). Compared to Policy option #4 Promoting biocide-free anti-fouling paint and alternatives and Policy option #6 Guidance on integration of antifouling paints in river basin management plans (RBMPs) and national marine strategies, this policy is a rather strong measure. By upgrading industry standards and defining good practices and auditing/certificating applicators could play an important part in order to reduce biocidal release, which would entail significant public investment.

Table 12 Summary: Policy option #5: Reduced limits for biocidal release rate of organic biocides for anti-fouling coatings of ships (anti-fouling paints)

Summary: Policy option #5: Reduced limits for biocidal release rate of organic biocides for anti-fouling coatings of ships (anti-fouling paints)			
Political implementability	4	Environmental and health outcomes	5
Acceptance & Feasibility	2	Efficiency	4
Scientific knowledge and uncertainty	2	Distributional effects	4
Technological and innovation potential	4	Synergies and tradeoffs	3
		Total score:	3,5
		Rank	8

Source: Authors.

3.2.6 Policy option #6 Guidance on integration of antifouling paints in river basin management plans (RBMPs) and national marine strategies

Biocidal components of anti-fouling paints pose a significant threat to ecosystem services and indirectly to human health. Hence, reducing its release would have a direct positive impact. Apparently; the most feasible way to limit the biocidal release of anti-fouling paints today is through the banning of certain chemicals or products. Another effective way to reduce the release of biocidal substances is to reduce respective limits (Policy option #5 Reduced limits for biocidal release rate for anti-fouling paints). If reducing limits on a Baltic level is not feasible, including antifouling paint issues in river basin management plans (RBMPs) and/or national marine strategies is potentially suitable to address that challenge effectively. The large advantage is that regulations and processes are already in place. An adjustment could be implemented within the regular review cycles of the RBMPs. This measure requires individual EU countries or institutions to be 'pionieers'. Such integration could be the result of or be aligned with Policy option #4 Promoting biocide-free anti-fouling paint and alternatives.

Table 13 Summary: Policy option #6 Guidance on integration of antifouling paints in river basin management plans (RBMPs) and national marine strategies

Summary: Policy option #6 Guidance on integration of antifouling paints in river basin management plans (RBMPs) and national marine strategies			
Political implementability	4	Environmental and health outcomes	4
Acceptance & Feasibility	3	Efficiency	4
Scientific knowledge and uncertainty	2	Distributional effects	4
Technological and innovation potential	4	Synergies and tradeoffs	3
		Total score:	3,5
		Rank	9

Source: Authors.

3.2.7 Policy option #7 Stricter regulation on scrubber water

Exhaust gas cleaning systems, also known as scrubbers, offer an alternative reduction of emissions of sulphur oxides instead of switching to low sulphur fuel. In its simplest form, so called open loop scrubber, the technology implies that large volumes (on average 45 m^3 MWh^{-1}) of acidified seawater contaminated with metals, nitrates and organic pollutants are released back into the marine environment. Closed loop and hybrid scrubbers, with the ability to switch between open and closed loop, can collect the washwater onboard for treatment in port, however a minor fraction (~0.3m^3 MWh^{-1}) of the washwater may be continuously discharged, so called bleed off. The primary incentive for ship owners to install scrubbers is economic; to reduce costs by burning cheaper, dirtier fuel oil. The potential threats to the marine environment from scrubbers are most pronounced in areas of intense shipping and limited water exchange, e.g. port areas, and during periods of less natural water mixing i.e. late summer months. Increased input of dissolved nitrogen can be of importance in coastal areas already affected by eutrophication. According to the precautionary principle, some European ports and on German inland waterways discharge of scrubber water has been already banned. A policy option of stricter regulation towards use of closed loop scrubbers would likely promote innovation on improved scrubber technology especially on zero discharge modes and could initiate a fuel change to low sulphur fuels.

Table 14 Summary: Policy option #7 Stricter regulation on scrubber water

Summary: Policy option #7 Stricter regulation on scrubber water			
Political implementability	5	Environmental and health outcomes	4
Acceptance & Feasibility	3	Efficiency	3
Scientific knowledge and uncertainty	4	Distributional effects	3
Technological and innovation potential	4	Synergies and tradeoffs	3
		Total score:	3,7
		Rank	3

Source: Authors.

3.2.8 Policy option #8 Promoting optimized fossil fuel driven engine and ship design, e.g. stricter energy efficiency standard (EEDI)

The IMO Energy Efficiency Design Index (EEDI) targets CO_2 emissions from shipping by requiring for all newly built ships from 2013 onwards to meet reduction targets (which increase until 2030) (Rehmatulla et al., 2017).

Hull optimisation is a well known, easily available technique that can be used to reduce main engine power requirement by reducing the resistance offered by the ship's hull to its propulsion. Propeller optimisation can reduce power required by the engine to subsequently lower the EEDI value.

Estimations of the SHEBA project show a substantial potential for reduction of health impacts by implementation of an increased EEDI between 136 and 527 million Euro per year for 2040 (compared to BAU, for mid VSL and VOLY). Lost working days could be reduced by 6 million Euro per year. The estimation is based on reduction of PM and ozone.

Altogether, from ship owners' point of view, hull optimisation seems to be a cost effective option to meet the EEDI regulation as initial investment is low with very short payback time and potential for fuel savings is high. Moreover, there is no sacrifice of basic design parameters such as design speed which is crucial for ship owners from revenue purpose.

Energy efficiency enhancing measures are very heterogenous in their impact. At the same time, often implemented measures have tended to be those that have small energy efficiency gains at the ship level (Rehmatulla et al., 2017).

Table 15 Summary: Policy option #8 Promoting optimized fossil fuel driven engine and ship design, e.g. stricter energy efficiency standard (EEDI)

Summary: Policy option #8 Promoting optimized fossil fuel driven engine and ship design, e.g. stricter energy efficiency standard (EEDI)			
Political implementability	3	Environmental and health outcomes	3
Acceptance & Feasibility	3	Efficiency	3
Scientific knowledge and uncertainty	4	Distributional effects	5
Technological and innovation potential	3	Synergies and tradeoffs	3
		Total score:	3,3
		Rank	11

Source: Authors.

3.2.9 Policy option #9 Promoting use of low emission fossil fuels, e.g. LNG

Low emission shipping fuels will probably be necessary to manage climate change and local pollutants (Gilbert et al., 2018). Several fossil fuels lead to less emissions than heavy fuel oil or marine diesel oil, which both are widely used. Aside of biofuels (such as, biodiesel, straight vegetable oil and bio-LNG), there are several fossil fuels which aim at emitting less sulphur oxides, nitrogen oxides, and particulate matter. Hence, these alternative fuels are expected to provide health benefits beside other environmentally benefical effect, due to avoided emissions. Liquified hydrogen is rather a niche phenomenon. Liquified natural gas (LNG) however, is widely discussed to be the new shipping fuel of choice. LNG is expanding as a new energy technology around the Baltic Sea due to its capacity to fulfill three policy expectations: enhancing energy security, providing low-sulphur bunker fuel, and balancing renewables in the power sector.

The SHEBA project has estimated reduction potential for health impacts by using more LNG driven ships between 89 and 356 million Euro per year for 2040 (compared to BAU, for mid VSL and VOLY). Lost working days could be reduced by 4 million Euro per year. Calculations are based on reductions of PM and ozone.

This policy option would reduce health problems and eutrophication/acidification, but this pathway still uses fossil fuels. Gradually, a shift towards carbon neutral fuel should occur. However, from today's perspective, it looks unrealtistic that shipping will be carbon neutral in the near future. To reach such state, it could be an option to produce hydrogen and methane with excess electricity from renewables sources, such as wind farms. In this case LNG would be an important prerequisite for the introduction of fossil free fuels for ships If bio-LNG or synthetic-LNG or bio-methanol is used, then this becomes more important and it ties in with the policy option #10 (Promoting use of renewable fuels and energy sources, e.g. biofuels, wind).

There are links to Policy option #18 Establish PM (including black carbon) emission standards for ships as BC would be reduced by using LNG as well. Links to Policy option #11 Limits on methane slip from LNG engines (due to incomplete combustion) also exist, since the mitigating effect of LNG potentially is compensated to a big extent, if methane slip is not addressed consequently.

Table 16 Summary: Policy option #9 Promoting use of low emission fossil fuels, e.g. LNG

Summary: Policy option #9 Promoting use of low emission fossil fuels, e.g. LNG			
Political implementability	4	Environmental and health outcomes	3
Acceptance & Feasibility	4	Efficiency	2
Scientific knowledge and uncertainty	5	Distributional effects	4
Technological and innovation potential	3	Synergies and tradeoffs	4
		Total score:	3,6
		Rank	5

Source: Authors.

3.2.10 Policy option #10 Promoting use of renewable fuels and energy sources, e.g. biofuels, wind

For biofuels the current power trains and fuel systems, on board and for distribution, can be used after minor modifications. The problem is both, the high cost of biofuels and the limited availability. Wind has of course been used for thousands of years for ship propulsion. Today the technology has developed but issues remain with speed and reliability. Biofuels are usually categorised as first or second generation. First generation biofuels are produced primarily from agricultural crops such as grains and oil seeds while second generation biofuels are produced from lingo-cellulosic materials such as forest residues. Issues concerning first generation biofuels have been raised since they can create competition for land with food production, they have limited production potential and their environmental performance is questioned.

Using wind energy for shipping is an old concept, which could be revived soon. In this case a complementary use of that wind energy is likely. Power-to-gas concepts could be implemented relatively easy, once the LNG infrastructure is set.

Table 17 Summary: Policy option #10: Promoting use of renewable fuels and energy sources, e.g. biofuels, wind

Summary: Policy option #10: Promoting use of renewable fuels and energy sources, e.g. biofuels, wind			
Political implementability	4	Environmental and health outcomes	3
Acceptance & Feasibility	3	Efficiency	2

Scientific knowledge and uncertainty	4	Distributional effects	4
Technological and innovation potential	5	Synergies and tradeoffs	5
		Total score:	3,7
		Rank	2

Source: Authors.

3.2.11 Policy option #11 Limits on methane slip from LNG engines (due to incomplete combustion)

Engines running on LNG have reduced emissions of several gases (such as SO_X, CO_2) but have higher unburned HC emissions (mainly CH_4), compared to conventional diesel engines. This slip can be significant and can result in a higher climate impact from LNG engines compared with conventional engines. The policy option is a limit on emitted methane for LNG engines (Zetterdahl et al., 2016; Liu et al., 2013; Verbeek & Verbeek, 2015).

For short sea ships, the methane slip has a relatively large share of the ship's GHG emissions, e.g between 16 and 20 % of the total GHG ship emissions (Verbeek & Verbeek, 2015). In the SHEBA project a optimistic LNG scenario has been developed together with stakeholders, in which 25% of the ship engines used in the Baltic Sea run on LNG in the year 2040 (Fridell et al., 2018).

The methane slip could be controlled with improved timing of the injection of the pilot fuel and there is also the possibility for after-treatment which is currently used for truck engines, but not for ship engines. Further technological development and practice-testing will be necessary.

The acceptance and feasibility of the option is evaluated by stakeholders (web survey) with very low which could link to strong resistance in the ship and gas industry, expecting additional costs (research, investment and operational costs) and a barrier for market uptake of LNG ships.

Table 18 Summary: Policy option#11 Limits on methane slip from LNG engines (due to incomplete combustion)

Summary: Policy option#11 Limits on methane slip from LNG engines (due to incomplete combustion)			
Political implementability	2	Environmental and health outcomes	3
Acceptance & Feasibility	1	Efficiency	3
Scientific knowledge and uncertainty	5	Distributional effects	4
Technological and innovation potential	3	Synergies and tradeoffs	2
		Total score (including weighting):	2,9
		Rank	16

Source: Authors.

3.2.12 Policy option #12 Promoting use of electric power for running the engine (battery–driven)

Additional to options such as LNG fueled ships and ships using renewable energy, electric power driven ships could be an option to decrease ship emissions. Ships run by electric power are already existing and suitable for short distances ferry traffic, e.g. the ferry “Ampere” in Norway. A financial incentives programme could support the additional investment costs for battery-driven ships. Operational and maintenance costs are expected to be lower compared to diesel fueled ships, e.g. for the Norwegian ferry Ampere operational cost cuts of 80 % are reported (e.g. Lambert, 2018).

If electric power driven engines are fuelled with renewable energies, GHG and air pollutant emissions including NO_X, SO_X, PM and CO_2 emissions can be reduced substantially. Air emissions are reduced in highly populated port areas and cities. Water emissions as well as oil spills are reduced significantly.

For the Norwegian electric ferry Ampere which is running on renewable energy sources, a CO_2 emission cut of 95 % is reported (e.g. Lambert, 2018). For the switch of additional 127 Norwegian ferries to fully electric or hybrid technology the CO_2 emission reduction is estimated with 300,000 tonnes per year and reduction of NO_X emissions by 8,000 tonnes per year (Viseth, 2016).

The largest shortcoming is the current feasibility only for short distance ferries. Different projects exist that research on ships for longer distances, e.g. including cargo ships going along the coast. Furthermore, the necessary energy charging and storage infrastructure at land needs to be developed. The described support programme could include or be linked with support for the necessary infrastructure in ports.

Table 19 Summary: Policy option #12 Promoting use of electric power for running the engine (battery–driven)

Summary: Policy option #12 Promoting use of electric power for running the engine (battery–driven)			
Political implementability	3	Environmental and health outcomes	3
Acceptance & Feasibility	3	Efficiency	2
Scientific knowledge and uncertainty	4	Distributional effects	5
Technological and innovation potential	4	Synergies and tradeoffs	5
		Total score:	3,6
		Rank	6

Source: Authors.

3.2.13 Policy option #13 Promoting shore power in ports

Most of the emissions in port areas are from ships at berth. In Hamburg, for example, ships alone account for 38 % of the NO_X emissions and 17 % of PM10 emission (BSU Hamburg, 2012). As the installation of shore power equipment is the major investment to use electricity at berth, financial support of upfront investment costs could increase the uptake and installation by ports. With shore power compared to marine diesel NO_X, SO_X and PM emissions in ports and therefore harbour cities can be reduced (ICCT, 2015). A significant reduction of CO_2 emissions will only be reached if electricity from renewable energies or natural gas is used (ICCT, 2015). To increase the environmental and health effects, the financial support could be linked to a minimum share of electricity from renewables. A coupling with differentiated port fees would be suitable. If ships are using shore power during their time at the berth, they have to pay reduced port fees.

Shore power is mainly attractive for ships in frequent traffic to ports, mainly ferries and RoRos, fewer container ships in liner traffic. Also cruise ships have a significant electricity demand also at berth and are encountering an increasing pressure from authorities and customers for use of shore power to reduce GHG emissions. (Winnes et al., 2015) The technology is available, on shore power is installed in several ports in the world, among them Gothenburg (six RoRo berths) and Hamburg but with large upfont investment costs. The results of the stakeholder assessment show a very high score on the political implementability.

ICCT (2015) also assessed cost-effectiveness of shore power (based on 100 % natural gas energy mix) and fuel switching to low sulphur fuel and estimated for the fuel switch a better cost-effectiveness for SO_X and PM (fuel switching does not address NO_X and CO_2 emissions). However, if 100 % renewables are represented in the energy mix, the emission reduction would be by far larger for shore power.

Table 20 Summary: Policy option #13 Promoting shore power in ports

Summary: Policy option #13 Promoting shore power in ports			
Political implementability	5	Environmental and health outcomes	3
Acceptance & Feasibility	5	Efficiency	3
Scientific knowledge and uncertainty	4	Distributional effects	4
Technological and innovation potential	1	Synergies and tradeoffs	4
		Total score:	3,6
		Rank	4

Source: Authors.

3.2.14 Policy option #14 Green port fees linked to ship emissions/pollutants

Green port fees are a market- based strategy to address environmental impacts from the shipping sector. Green port fees are understood as differentiated port fees or dues based on ship emissions (e.g. NO_X, SO_X, GHG emissions), pollutants or other “green” features of the ship, e.g. shore power equipment. Green port fees are already implemented in several ports, including many Swedish ports as well as Riga and Klaipeda. This option aims at reducing different types of negative environmental impacts from shipping. The policy instrument can be designed to address different issues like air pollution, greenhouse gases, emissions to water, noise but also working conditions and others sustainability issues. The incentive schemes are in general established on port level, but also harmonized pan-Baltic port fee systems or worldwide systems are discussed with advantages for shipowners and ports. The stakeholder assessment and also surveys show that green port fees are relatively accepted. But the environmental impacts is described as limited because the reward for green technologies is very limited and easily compensated by savings of well-organized operations and well-managed fleets. To reach significant reductions of emissions and pollutants other policy options need to be taken on international level. Ports can facilitate this process and green port fees could play a role in a larger set of options to support different environmentally friendly practices.

Table 21 Summary: Policy option #14 Green port fees linked to ship emissions/pollutants

Summary: Policy option #14 Green port fees linked to ship emissions/pollutants			
Political implementability	5	Environmental and health outcomes	2
Acceptance & Feasibility	4	Efficiency	3
Scientific knowledge and uncertainty	3	Distributional effects	5
Technological and innovation potential	2	Synergies and tradeoffs	5
		Total score:	3,5
		Rank	7

Source: Authors.

3.2.15 Policy option #15 Introduction of national fairway dues (charges) which are linked to ship emissions/pollutants

National fairway dues or charges paid by ships are used to finance maritime fairways, navigational aid, pilotage, search and rescue operation and ice-breaking. In general, the charges are based on gross tonnage and volume of goods loaded and unloaded in the ports of a country. In many countries the facilities and services are linked to ports, but several EU countries are using national dues, e.g. Sweden and Finland. Environmental impacts can be addressed via the differentiation of the fees according to the emissions and pollutants linked to the individual ships. The design is to establish lower dues for ships with less environmental impacts (emissions/pollutants/etc.) and thus higher dues for more polluting ships. The differentiation can be linked to established indices such as Environmental Ship Index, Clean Shipping Index or Green Award which are summarizing different environmental pressures. To increase environmental effect the fees could be based on sailed distance or fuel consumption and not on number of ports called. For most probably targeted pressures technologies exist. Objective of this policy option is a wider adoption of existing emission abatement technologies.

Different reports say that the incentives to reduce NO_X emissions by the Swedish national fairway dues seem to be too low (SMA, 2013; 2016; Lindé & Vierth, 2018). Furthermore, it was discussed that the discounts in the fairway dues system that was in place till the end of 2017 contributed to a relatively small part of the costs for catalytic equipment with the result of a limited emission reduction (Transport Analysis, 2017; Lindé & Vierth, 2018). A provided example shows that for a large ferry and a Ro-Ro vessel with 50 port calls in Sweden, the fairway fee discount (excluding any refunds) covers 25-35 percent of the additional annual cost for Selective Catalytic Reduction (SCR) systems (including averaged investment and yearly operational costs) (Lindé & Vierth, 2018). Also if there are still uncertainties on the substantial effect of the Swedish national fairway due system, it can be assumed that the fairway dues are supporting the business decisions to reduce NO_X and SO_X emissions which show clear benefits for the society. Therefore, environmentally differentiate fairway dues could be a component in a set of policy options, but they are only partially recommendable if the system has to be newly adopted.

Table 22 Summary: Policy option #15 Introduction of national fairway dues (charges) which are linked to ship emissions/pollutants

Summary: Policy option #15 Introduction of national fairway dues (charges) which are linked to ship emissions/pollutants			
Political implementability	3	Environmental and health outcomes	2
Acceptance & Feasibility	1	Efficiency	3
Scientific knowledge and uncertainty	3	Distributional effects	5
Technological and innovation potential	2	Synergies and tradeoffs	5
		Total score:	2,9
		Rank	15

Source: Authors.

3.2.16 Policy option #16 Initiatives to simplify procedures in ports, e.g. use of communication tools to adjust speed to arrive in ports

Although most emissions from shipping is released on sea, their emissions are most apparent when ships are berthed in ports. Dalsoren et al. (2009) estimate that emissions due to ships' activities in or around ports account for up to 5% of total emissions from navigation, SO_X and NO_X emissions are especially significant. Containerships and tankers are contributing about 85% of these emissions (Merk, 2014).

Beside shore power use in ports, other measures to reduce emissions in ports exist e.g. using global information network and strengthen communications between ports and ship operators on sea to optimize speed and arrival time. As vessels become connected to the global information network via onboard satellite communications, ports can help leverage this additional connectivity by managing arrivals so that if the port is too congested, the vessel knows that it must decrease speed, rather than consume fuel at a more expensive, faster rate, only to then have to continue to consume waiting to dock (FathomShipping, 2013). The policy option could give financial support for research, pilot-testing and market uptake.

The policy option shows on the one side a limited environmental effect, but on the other side is linked to low costs and has a high innovation potential regarding operation of ships. The technologies and therefore the policy option might not be a stand alone measure, but can be easily linked to different other policy options, especially port fees or fairway dues could include a rebate for ships using communication tools for navigating.

Table 23 Summary: Policy option #16 Initiatives to simplify procedures in ports, e.g. use of communication tools to adjust speed to arrive in ports

Summary: Policy option #16 Initiatives to simplify procedures in ports, e.g. use of communication tools to adjust speed to arrive in ports			
Political implementability	3	Environmental and health outcomes	1
Acceptance & Feasibility	4	Efficiency	1
Scientific knowledge and uncertainty	2	Distributional effects	5
Technological and innovation potential	4	Synergies and tradeoffs	5
		Total score:	3,0
		Rank	13

Source: Authors.

3.2.17 Policy option #17 Promote vessel scrapping to reduce environmental impacts of fleets

Supporting instruments for vessel scrapping (so called “scrap and build subsidies”) have the target to promote a technical upgrade of the existing vessel fleet and to reach a more environmentally friendly fleet. These have effects on multiple policy objectives according to technological developments during the last years. Until the year 2017, scrap and build subsidies had been implemented in China, Turkey and Norway with the primary objective of improving fuel efficiency (OECD, 2017). A variety of environmental pressures (GHG emissions, air pollution, noise emissions) would be tackled as technological improvements during the last decades led to adjustments of ship design, engine, etc. A variety of policy objectives could be supported.

The risks of building up overcapacity of vessels through a misallocation of resources without any additional consumer surplus are discussed. Furthermore, the Norwegian scheme resulted in higher maintenance costs for fishing vessels and an increased price for old fishing vessels due to speculation from the private sector (Standal & Sønvisen, 2015). Technical upgrades could be interlinked with other policy options such as scrubber technology implementation that highly benefits from being installed as part of a new vessel.

Table 24 Summary: Policy option #17: Promote vessel scrapping to reduce environmental impacts of fleets

Summary: Policy option #17: Promote vessel scrapping to reduce environmental impacts of fleets (financial support)			
Political implementability	1	Environmental and health outcomes	2
Acceptance & Feasibility	1	Efficiency	2
Scientific knowledge and uncertainty	3	Distributional effects	4
Technological and innovation potential	1	Synergies and tradeoffs	4
		Total score:	2,2
		Rank	19

Source: Authors.

3.2.18 Policy option #18 Establish PM (including black carbon) emission standards for ships

Particulate matter (PM) and black carbon (BC) as one component of fine PM2.5 are contributing to air pollution in coastal cities and areas, and emissions are contributing to global warming effect and the decline of Artic sea ice. Comer et al. (2017) estimate ships were responsible for 0.7% to 1.1% of anthropogenic BC emissions globally in 2015 and for 3.9% to 5.7% of diesel source BC emissions globally in 2015 (Comer et al. 2017, based on Bond et al. 2015).

The implementation of strict PM emission standards including emissions standards for BC in the Baltic Sea could lead to additional emission reductions and would lead to benefits especially for human health in coastal areas. International forums have noticed the need to address the risks of BC and residual fuel and processes and discussions at IMO have already started. Effectiveness and costs for abatement technologies have been analysed e.g. by IMO. The results show that different measures could reach a 50% reduction of BC emissions (e.g. switch to distillate fuels or LNG). Major additional costs would be expected for using scrubbers. More cost-effective technologies are slow steaming or switch to LNG. (Comer et al., 2017; IMO, 2015)

In parallel to a strict emission standard, grants, subsidies or financing tools could be initiated to support ship owners investing in reducing PM and BC (e.g. via cleaner fuels, or control technologies) (see Policy option #8 Promoting optimized fossil fuel driven engine and ship design, e.g. stricter energy efficiency standard (EEDI), Policy option #9 Promoting use of low emission fossil fuels, e.g. LNG, Policy option #10 Promoting use of renewable fuels and energy sources, e.g. biofuels, wind and Policy option #12 Promoting use of electric power for running the engine (battery–driven)).

Table 25 Summary: Policy option #18 Establish PM (including black carbon) emission standards for ships

Summary: Policy option #18 Establish PM (including black carbon) emission standards for ships			
Political implementability	4	Environmental and health outcomes	4
Acceptance & Feasibility	3	Efficiency	3
Scientific knowledge and uncertainty	4	Distributional effects	4
Technological and innovation potential	3	Synergies and tradeoffs	1
		Total score:	3,3
		Rank	12

Source: Authors.

3.2.19 Policy option #19 Implementation of a CO_2-tax for shipping

IMO has agreed (April 2018) that 50% reduction of ship GHG emissions should be achieved by the year 2050. This target is not achievable by improving energy efficiency of ships (EEDI Phases 0-3), but it requires a gradual shift away from fossil fuels. The objective of this policy option is to curb shippings` CO_2 emissions, by internalization of externalities of the polluter by taxation of CO_2 emissions.

Taxation on the marine shipping industry has a strong potential as a measure to reduce GHG emissions. It is assumed that the policy option would incentivize the implementation of cleaner technologies and fuels. Nevertheless, it is considerably uncertain which tax value should be defined and how it should be distributed across countries. However, it should be taken into account that the stakeholder assessment shows a low acceptance & feasibility for this policy option.

Table 26 Summary: Policy option #19 Implementation of a CO_2-tax for shipping

Summary: Policy option #19 Implementation of a CO_2-tax for shipping			
Political implementability	3	Environmental and health outcomes	4
Acceptance & Feasibility	1	Efficiency	3
Scientific knowledge and uncertainty	4	Distributional effects	3
Technological and innovation potential	3	Synergies and tradeoffs	2
		Total score:	2,9
		Rank	14

Source: Authors.

3.2.20 Policy option #20 Establishing of an emission trading scheme for greenhouse gases from shipping

As described for the CO_2-tax, IMO has agreed (April 2018) that 50% reduction of ship GHG emissions should be achieved by year the 2050. For implementation of the objective additional policy options targeting GHG emissions are expected. One instrument would be to include CO_2 emissions in an emission trading scheme (ETS). The actual implementation of an ETS in the shipping sector remains controversial. Some of the critical issues are whether to develop an open ETS or a maritime specific one; that growth will be limited if the supply of allowances is set too small; and the increase of uncertainty on behalf of the shipping industry due to volatile allowance prices (Kosmas & Acciaro, 2017; Koesler et al., 2015).

The stakeholder assessment states a high acceptance & feasibility which may be partially explained with the advantages of a market-based instrument. But the experiences with the integration of the aviation sector in the EU emission trading scheme can act as a barrier.

In general, emission trading systems are linked to substantial transaction costs, mainly for monitoring and reporting CO_2 emissions, therefore existing monitoring procedures should be taken into account as well as the long investment cycles in the shipping sector.

Table 27 Summary: Policy option #20 Establishing of an emission trading scheme for greenhouse gases from shipping

Summary: Policy option #20 Establishing of an emission trading scheme for greenhouse gases from shipping			
Political implementability	3	Environmental and health outcomes	4
Acceptance & Feasibility	4	Efficiency	3
Scientific knowledge and uncertainty	4	Distributional effects	3
Technological and innovation potential	4	Synergies and tradeoffs	2
		Total score:	3,4
		Rank	10

Source: Authors.

3.3 Summary and ranking of options

The following matrices give on overview of the potential effect of the assessed policy options on relevant environmental pressures of shipping (see Table 28) and components of human well being (ecosystem services and human health) (see Table 29). Positive effects - mainly decreases - on a certain pressure or component of human well being are differentiated in slight positive effect (+) and positive effect (++) in the tables. Negative effects – mainly increases - are differentiated in slight negative effect (-) and negative effect (--), no effect is shown with a “O”, not filled cells = uncertain.

Table 28 Potential effect of policy options on environmental pressures of shipping

Policy options	**Emissions to air**				**Emissions to water**			**Noise emissions**	**Physical impacts**
	CO_2	NO_X	SO_X	PM	Non-indigenous species	Contaminants to water	Oil spills	Underwater noise	Anchoring, mooring and movement and ship wakes
#1 Sea grass protection: Restricting mooring	O	O	O	O	O	O	O	O	++
#2 Zoning and maximal speed	+	+	+	+	O	-	-	++	+
#3 Excluding the noisiest ships / limits on average noise level	-	-	-	-	O	O	O	++	O
#4 Promotion and funding research of biocide-free anti-fouling paint	O	O	O	O	-	++	O	O	O
#5 Reduced limits for biocidal release (anti-fouling paints)	O	O	O	O	-	++	O	O	O
#6 Integrating anti-fouling paints in river basin management plans (RBMPs) & national marine strategies	O	O	O	O	-	++	O	O	O
#7 Stricter regulation on scrubber water	+	O	O		O	++	O	O	O
#8 Promoting optimized fossil fuel driven engine and ship design	++	++	++	++	O	O	O	O	O
#9 Promoting use of low emission fossil fuels	+	++	++	++	O	O	++	O	O

#10 Promoting use of renewables	++	O	++	++	O	O	++	++	O
#11 Limits on methane slip from LNG engines	++ (CO$_{2eq}$)	-	O	O	O	O	O	O	O
#12 Promoting electric power for running the engine	++	++	++	++	O	+	++	++	O
#13 Promoting shore power in ports	++	++	++	++	O	O	O	++	O
#14 Green port fees linked to ship emissions/pollutants	++	++	++	++	O	O	O	+	O
#15 National fairway dues linked to ship emissions/pollutants	++	++	++	++	O	O	O	+	O
#16 Simplify port procedures in ports	++	++	++	++	O	O	O	O	O
#17 Promoting vessel scrapping	++	++	++	++	O	O	+	O	O
#18 Establish PM (incl. black carbon) emission standards for ships	+	+	+	++	O	O	O	O	O
#19 Implementation of a CO$_2$-tax for shipping	++	++	++	++	O	O	+	-	O
#20 Establishing of an emission trading scheme for shipping	++	++	++	++	O	O	+	-	O

Key: + = slight positive effect (reduction of emission, pollutant, etc.), ++ = positive effect, - = slight negative effect (increase of emission, pollutant, etc.), - = negative effect, O = no effect, Not filled = uncertain

Source: Authors.

Table 29 Potential effect of policy options on human well being (ecosystem services and human health)

	Effect on human well being							
Policy options	**Commercial fishing**	**Recreational fishing**	**Genetic resources**	**Climate change mitigation**	**Coastal protection**	**Tourism and recreation**	**Other socio - cultural values**	**Human health**
#1 Sea grass protection: Restricting mooring	O	++	O	++	++	O	+	O
#2 Zoning and maximal speed	++	++	+	+	+	++	++	++
#3 Excluding the noisiest ships / limits on average noise level	+	+	+	-	O	+	O	-
#4 Promotion and funding research of biocide-free anti-fouling paint	++	++	++	O	O	+	+	O
#5 Reduced limits for biocidal release (anti-fouling paints)	++	++	++	O	O	+	+	O
#6 Integrating antifouling paints in river basin management plans (RBMPs) & national marine strategies	++	++	++	O	O	+	+	O
#7 Stricter regulation on scrubber water	++	++	+	O	O	+	+	O
#8 Promoting optimized fossil fuel driven engine and ship design	++	++	+	++	O	+	+	+
#9 Promoting use of low emission fossil fuels	++	++	+	+	O	++	++	++
#10 Promoting use of renewables	++	++	+	++	O	++	+	++
#11 Limits on methane slip from LNG engines	O	O	O	++	O	O	O	O
#12 Promoting electric power for running the engine	++	++	O	++	O	++	+	++

#13 Promoting shore power in ports	++	++	O	+	O	++	O	++
#14 Green port fees linked to ship emissions/pollutants	++	++	O	+	O	+	+	++
#15 National fairway dues linked to ship emissions/pollutants	++	++	O	+	O	+	+	++
#16 Simplify port procedures in ports	O	O	O	+	O	O	O	+
#17 Promoting vessel scrapping	+	+	O	O	O	+	O	+
#18 Establish PM (incl. black carbon) emission standards for ships	+	+	O	-	O	+	O	++
#19 Implementation of a CO_2-tax for shipping	++	++	+	++	O	++	+	++
#20 Establishing of an emission trading scheme for shipping	++	++	+	++	O	++	+	++

Key: + = slight positive effect (reduction of emission, pollutant, etc.), ++ = positive effect, - = slight negative effect (increase of emission, pollutant, etc.), - = negative effect, O = no effect

Source: Authors.

The overview shows that some environmental pressures are covered only by a low number of very specific targeted policy options, e.g. physical impacts with option on 'sea gras protection by restriction of moorings' (#1). Also a lower number of policy options is targeting on the reduction of noise emissions, two are more targeted especially on noise (#2 and #3). 'Speed regulation' (#2) has also significant synergies with the reduction of GHG and air pollutant emissions. For Option #12 ('Promotion of battery driven ships') and #13 ('Promotion of shore power in ports') noise reduction is more a side effect beside their core target to reduce GHG and air pollutant emissions with the use of electricity (produced by renewables). Policy option #11 'Limits on methane slip from LNG engines' is also very targeted as it would have a specific effect on methane emissions but it is strongly linked to the acceptance of LNG fueled ships and their potenial to reduce GHG and air pollutant emissions.

Another group of measures are covering a broad variety of environmental pressures, e.g. 'green port fees' (#13), 'national fairway dues' (#14) (both depending on their design) and 'promoting vessel scrapping' (#17). The 'promotion of battery driven ships' (#12) and 'promotion of shore power' (#13) also covers a variety of environemntal pressures, e.g. GHG emissions (if electricity from renewables is used) but as the ships have no large amount of oil on board, oils spills could be reduced as well as other water pollutants stemming from oil fueled engines. Additionally, ships running on electricity are by far less noisy and could be used for ferries running in noise restricted areas (#2) and could grant for exemptions in slow speeding zones (#3).

Not surprisingly, many policy options regarding GHG and air pollutant emissions have effects on a variety of air emissions and pollutants, also if they are initially targeted on one specific gas, such as 'CO_2 tax' (#19) or the 'maritime emission trading scheme' (#20).

As result of the multi-criteria analysis, the ranking of the options according to their total MCA score is shown in the following table (Table 30). The MCA score gives a first orientation on policy options which are more recommendable to implement than others. MCA scores for the policy options can only be interpreted in relation to each other (limited to the same assessment) and have no absolute value.

Table 30 Ranking of policy options (according to total MCA score)

Rank	No.	Policy option
1	#4	Promoting biocide-free anti-fouling paint and alternatives
2	#10	Promoting use of renewable fuels and energy sources, e.g. biofuels, wind
3	#7	Stricter regulation on scrubber water
4	#13	Promoting shore power in ports
5	#9	Promoting use of low emission fossil fuels, e.g. LNG
6	#12	Promoting use of electric power for running the engine (battery–driven ships)
7	#14	Green port fees
8	#5	Reduced limits for biocidal release rate of organic biocides for anti-fouling coatings of ships (anti-fouling paints)
9	#6	Guidance on integration of antifouling paints in river basin management plans of the EU Water Framework Directive and national marine strategies
10	#20	Establishing of an emission trading scheme for greenhouse gases from shipping
11	#8	Promoting optimized fossil fuel driven engine and ship design, e.g. stricter energy efficiency standard (EEDI)
12	#18	Establish particulate matter (PM) emission standards for ships (including black carbon)
13	#16	Initiatives to simplify procedures in ports, e.g. use of communication tools to adjust speed to arrive in ports
14	#19	Implementation of a CO_2-tax for shipping

Rank	No.	Policy option
15	#15	Introduction of national fairway dues (charges) which are linked to ship emissions/pollutants
16	#11	Limits on methane slip from LNG engines (due to incomplete combustion)
17	#1	Sea grass protection: Restrictions on number of boats mooring in certain areas and better enforcement
18	#2	Speed regulation: Zoning and maximal speed (Baltic-wide)
19	#17	Promote vessel scrapping to reduce environmental impacts of fleets
20	#3	Excluding the noisiest ships / limits on average noise level

Source: Authors.

Based on the differences between the total MCA scores the policy options can be categoriesed in four groups (see colour code in previous Table 30). Five policy options (dark green) are ranked highest and show mainly high and very high scores (High range). The second group (light green) contains seven policy options with a similar score (High-Mid range). The assessment results are mid-range with maximum one outlier. A group of another five policy options (Low-Mid range) (light red) shows already several (up to two) low scores but can partially outweight with high scored assessment criteria. And the group with the lowest scores (Low range) (dark red) consists of three policy options that show a majority of low or very low scored criteria and can not outbalance these with the higher assessed criteria.

Interesting is that the highest ranked policy option (‘promoting biocide-free anti-fouling paint and alternatives’ #4) is an option targeted very specifically on the reduction of two related pressures (copper release in the water and non-indigenious species). The option shows a very low score for synergies & tradeoffs but reached for most other criteria high and very high scores. Four of five options ranked two to six are related to a fuel switch to electricity, LNG or renewables (in ports or at sea). Also the ‘stricter regulation of scrubber water’ (#7) is evaluated with a high rank (third rank). All criteria are scored solid between medium and high and the assessment does not result in an outlier for these options.

The further options focusing on water emissions (‘reduced limits for biocidal release rate’ #5 and ‘integration of biocides in WFD and MSFD’ #6) are in a mid-range as well as ‘promoting energy efficient ship design’ (#8) and ‘standards for PM including BC’ (#18). Interesting to see is that the options ‘maritime emission trading scheme’ (#20) is evaluated with higher score than a ‘CO_2-tax’ (#19). This is mainly due to the low score on acceptance & feasibility for the CO_2-tax.

On the lower end of the ranking, the noise related options (‘speed regulation’ #2 and ‘excluding noisiest ships’ #3) and the ‘promoting of vessel scrapping’ (#17) are evaluated. All of them show a very low or low score for the two criteria political implementability and acceptance & feasibility which were assessed by the stakeholders. The options targeting noise emissions additionally show a gap on knowledge base. The partially good evaluation on efficiency (‘speed regulation’ #2) can also not change the relative low total MCA score.

4 Summary and conclusions

Summary of socio-economic assessment

This socio-economic assessment evaluated 20 policy options (out of 85 identified policy options) which potentially reduce environmental pressures from shipping in the Baltic Sea. As a result, these 20 policy options were ranked according to the total score of a multi criteria assessment, which evaluates these options in relation to each other. ‘promoting biocide-free anti-fouling paint and alternatives’ and ‘promoting use of renewable fuels and energy sources’ were the top two options in this ranking, followed by the options ‘stricter regulation of scrubber water’, ‘promoting shore power in ports’ and ‘promoting low emission fossil fuels’. Four of the five highest ranked policy options are rather targeting on financial support and funding of research, pilot testing and market uptake, thriving for change through the promotion of environmentally beneficial behaviour. However, these options target important challenges (biocidal substances and climate change), which result into high environmental and health outcomes. At the same time, the political implementability, acceptance & feasibility and economic efficiency of introducing the policy options are high, while the scientific uncertainties of measuring its impacts are low.

Seven other policies had similar high scores, which are ‘promoting battery driven ships’, ‘green port fees’, ‘reduced limits for biocidal release rate’, ‘guidance on integration on anfifouling paints in river basin management plans or marine strategies’, ‘establishing a maritime emission trading scheme’, ‘promoting energy efficiency’ and ‘emission standards for PM (including BC)’. All these options are ranked high or average, compared to all 20 policy options. These options entail a high innovation potential (e.g. ‘promoting energy efficiency’ and ‘promoting battery driven ships’) or have a high score in political implementability (e.g. ‘promoting low emission fossil fuel’, ‘promoting shore power’, or ‘green port fees’) or environmental and health outcomes (e.g. ‘reducing the release rate of organic biocides for anti-fouling paints’).

‘Simplifying port procedures’, ‘implementing a CO_2 shipping tax’, ‘introducing fairway dues, that are linked to emissions/pollutants’, ‘limiting methane slip from LNG ships’ and ‘restricted mooring linked to seagrass protection’ are rather ranked below average.

‘Regulating shipping speed’, ‘promoting vessel scrapping’ and ‘excluding the noisiest ships’ were ranked at the low end of all 20 policy options. Hence, the options addressing sea grass destruction and underwater noise are scored with low scores – especially in political implementability, scientific uncertainty and acceptance & feasibility. More research is needed to gain knowledge about underwater noise and its impacts. With regards to sea grass, there is knowledge, but relocating mooring areas or shipping lanes to a large extent is unlikely. However, sea grass protection could play a bigger role, when new marine infrastructure is planned and built. Also the policy options that thrive for a renewal of the fleet (‘scrapping and excluding the noisiest ships’) are ranked with low scores. A misallocation of resources without any significant benefits is discussed. Technical upgrades and the characteristics of new boats are rather dependent on standards (and its enforcement). At the same time there are threats of windfall gains by financing the reduction of overcapacities (in the case of promoting scrapping) and scientific uncertainties (in the case of identifying and ranking the noisiest ships).

Synergies and contradictions

Some assessed policy options have an integrative potential covering several policy targets, environmental pressures and components of human well being. ‘Green port fees’ or ‘fairway dues’ differentiated according to air, water and noise emissions and pollutants might not be too powerful as stand-alone instruments but could play a role in combination with other policy options (e.g. standards or taxes). ‘Battery driven ships’ are reducing GHG emissions and as well noise emissions and water emissions such as oil spills.

‘The promotion of renewables’ for example does not only curb CO_2 emissions, but also other (air) pollutants which harm human health and the coastal environment, including NO_X, SO_X or particulate matter. Also ‘decreasing shipping speed’ reduces underwater noise, but also GHG and air pollutant emissions of the ship which is going at a lower speed. At the same time, such options can have systemic effects. If shipping speed would be lowered at the same or increasing demand, more ships would be necessary to transport the same amount of goods, which would compensate the benefits partially or totally. Other adverse systemic effects, of for example ‘promoting renewables’, could occur at land, where e.g. biofuels are produced. In the case of biofuels, these adverse effects could be significant. Other policies are contradicting to policy goals which are also marine-specific. Using hull coatings for example reduces and prevents hull fouling and thus is helpful in reducing frictional resistance and therefore to increase energy efficiency and reduce fuel consumption (IMO, 2011). Since these coating often include biocidal substances, also the introduction of non-indigenous species is reduced. However, these biocidal substances are released into the water, posing the respective ecosystems at risk. As a result, all policies should be seen in interrelation in their respective policy landscape and with other policy goals.

When assessing shipping policies, it is evident that there are still “low hanging fruits”, which would have considerable impacts at low costs, for example ‘promoting low emission fossil fuels’, for which infrastructure is already available in many ports. Other policies are effective, but require considerable efforts of policy making. For example ‘promoting shore power’ or ‘integrating biocidal release rates into river management plans or marine strategies’. Some policies do not only require changes of policy schemes or new institutions, but a paradigm shift, which includes shipping into international up to global agreements. This applies to introducing a carbon tax, a maritime emission trading scheme or including shipping into the UNFCCC process.

Emissions to water- no fear of changes with regards to antifouling paint regulation

With respect to emission to water, most of the discussed policy options aim at reducing the release of biocidal substances from anti-fouling paint. ‘Promoting existing alternative paints and researching for such alternatives’ is assessed to be the most promising policy option, and could prepare or accompany the ‘strengthening of the respective standards’ which was assessed as the option with the highest environmental and health outcomes. If ‘biocidal release standards for antifouling paints’ were strengthened at an international or even global level, following a long-term roadmap, increased research activities and awareness level of alternatives would be the result. Hence, promoting alternatives and (partially) funding respective research activities could support the introduction. Even more effective than strengthening release standards is banning the most toxic substances. Historic evidence shows, that major negative impacts are unlikely to occur: When anti-fouling paints containing organotin tributylin (TBT) were banned, several negative impacts were expected (such as uncontrollable hull fouling; global spreading of non-indigenous species and unknown environmental risks due to an increased usage of alternative biocides) (IMO, 2002). However, alternatives were available and no major economic or ecological issues occurred.

Emissions to air – Accompanying tax or emission trading with direct funding or environmentally differentiated fees

The assessed policy options regarding emissions and pollutants to air focused primarily on GHG and PM (including BC) emissions as policy instruments targeting especially NO_X and SO_X emissions are already adopted for the Baltic Sea. With regards to CO_2 emissions, shipping is contributing to about 2.4% of global CO_2 emissions today (IMO, 2014). Cames et al. (2015) estimated that under business as usual scenario, by 2050 shipping is likely to represent around 17% of global CO_2 emissions. Rehmatulla et al. (2017) identified four solutions to mitigate these emissions, which are almost all addressed by the policy options assessed in SHEBA: improving energy efficiency, using renewables energy, using fuels with lower carbon content or emission reduction technologies, such as scrubbers in combination with carbon capture and storage.

Using carbon capture and storage appears to be a too simplistic, technical solution for a complex challenge. Implementing small changes in the short-term (supported by e.g. promotion of low emission fossil fuels) and systemic changes in the long-term (initiated by a carbon tax or maritime emission trading scheme) are more promising. Direct funding of alternative fuels (in ports and at sea) and improvements on energy efficiency or differentiated fee systems in ports can accompany an introduction phase of a maritime emission trading scheme or a CO_2-tax. A further increase of LNG fueled ships should be combined with a 'stricter regulation of the methane slip' otherwise a significant share of the mitigation effect is compensated by methane emissions.

Noise – Knowledge gaps exist, but synergies with reducing air emissions and pollutants by battery driven ships and change of hull design

Underwater noise is still an underresearched pressure of shipping. Stakeholders and relevant institutions, including the IMO, are aware of its negative impacts, but its extent and parameters are unknown to a large extent. Consequently, it is not clear which policy is the most promising one to curb underwater noise. However, integrating noise effects in the design and retrofitting process of engines, hulls and other relevant shipping parts as well as limiting speed (especially in vulnerable locations) seem to be promising policy options. At the same time, using renewable fuels, especially via battery driven engines, potentially show high synergies with avoiding underwater noise.

Physical impacts – To be included in long term planning of port infrastructure

Physical impacts are widely discussed in combination of sea grass protection, since sea grass beds are important for fish stocks and an effective carbon sink. However, besides the implementation of marine protected areas and the development of maps and apps for leisure boat owners to avoid mooring in sea grass areas, not much is done to avoid adverse effects. At the same time, big ships are concentrated on specific shipping lines and sea grass beds suffer from different pressures, including non-shipping ones. As with other policy options that are ranked with low scores in political implementability and acceptance & feasibility, it is very challenging to change the current infrastructure (in this case ports). However, the adverse effects (in this case physical impacts) should be integrated in future planning and building of such infrastructure.

Policy mix - Considering targeted policy objectives and socio-economic framework

The choice for the implementation of a certain instrument should take into consideration the general advantages and disadvantages of an instrument (see chapter 2). Additionally, it is highly relevant what are the actual policy objectives in the concrete situation, what is the policy and socio-economic framework for implementation, the geographic level, the mainly targeted pressure of the instrument, etc. Depending on the situation, not only high prioritized policy options should be considered, also instruments in mid-range of the ranking can be suitable, especially if implemented in combination with other instruments to compensate weaknesses.

5 Literature

AEAT (2005). Methodology for the Cost-Benefit analysis for CAFE: Volume 1: Overview of Methodology. AEAT/ED51014/ Methodology Issue 4, AEA Technology Environment, Bdg 154 Harwell Business Centre, Didcot, Oxon, OX11 0QJ, United Kingdom.

Ahtiainen, H., Öhman, M. C. (2013). The Baltic Sea and the valuation of marine and coastal ecosystem services - A background paper for the Regional Workshop on the Valuation of Marine and Coastal Ecosystem Services in the Baltic Sea, 7-8 November 2013, Stockholm.

Andersson, K., Brynolf, S., Lindrgen, J.F., Wilewska-Bien, M. (eds.) (2015). Shipping and the Environment, Improving Environmental Performance in Marine Transportation. Springer.

Barton et al. (2014). Technical Brief, Guidelines for multi-scale policy mix assessments, Issue No. 12. PolicyMix FP7-ENV-2009-1: Collaborative project. http://policymix.nina.no/Portals/policymix/Documents/Research%20topics/WP9/D91%20Policymix%20Technical%20Brief%20-%20INTERACTIVE%20PDF%20v1%20_(2).pdf

Bond, T. C., Doherty, S. J., Fahey, D. W., Forster, P. M., Berntsen, T., DeAngelo, B. J.,⋯ Zender, C.S. (2013). Bounding the role of black carbon in the climate system: a scientific assessment. Journal of Geophysics Research, 118(11), 5380‐5552. doi:10. 1002/jgrd.50171

Boteler, B., Tröltzsch, J., Abhold, K., Lago, M., Nguyen, T.T., Roth, E., Fridell, E., Winnes, H., Ytreberg, E., Quante, M., Matthias, V., Jalkanen, J-P., Johansson, L., Piotrow, J., Kowalczyk, U., Vahter, K. and Raudsepp, U. (2015). Drivers for the Shipping Sector. Report (D1.1) as part of the BONUS project SHEBA (Sustainable Shipping and Environment of the Baltic Sea Region).

BSU Hamburg (2012). Luftreinhalteplan für Hamburg. 1. Fortschreibung 2012. Behörde für Stadtentwicklung und Umwelt, Hamburg.

Cames, M., Graichen, J., Siemons, A., Cook, V. (2015). Emission reduction targets for international aviation and shipping, viewed 06 December 2015, http://www.europarl.europa.eu/RegData/etudes/STUD/2015/569964/IPOL_STU(2015)569964_EN.pdf

Christie, M., Hanley, N., Warren, J., Murphy, K., Wright, R., and Hyde, T. (2006). Valuing the diversity of biodiversity. Ecological Economics, Volume 58, Issue 2, June 2006, pages 304 – 317.

Christie, M., Hyde, T., Cooper, R., Fazey, I., Dennis, P., Warren, J., Colombo, S., and Hanley, N. (2011). Economic Valuation of the Benefits of Ecosystem Services Delivered by the UK Biodiversity Action Plan. Final Report to Defra.

Christie, M., Rayment, M. (2012). An economic assessment of the ecosystem service benefits derived from the SSSI biodiversity conservation policy in England and Wales. Ecosystem Services 1, 70–84.

CICES (2013).The Common International Classification of Ecosystem Services (CICES) V4.3' (http://cices.eu/), January 2013, accessed 9 May 2017.

Comer, B., Olmer, N., Mao, X., Roy, B., Rutherford, D. (2017). Black carbon emissions and fuel use in global shipping 2015. ICCT-Report. Washington D.C.

Delacámara, G., Dworak, T., Gómez, CM., Lago, M. Maziotis, A., Rouillard, J., Strosser, P. (2013). EPI-Water Deliverable 5.3: Guidance on the design and development of Economic Policy Instruments in European water policy. EPI-Water - Evaluating Economic Policy Instruments for Sustainable Water Management in Europe.

Den Hartog, C., Kuo, J. (2006). Taxonomy and biogeography of seagrasses. In: Larkum, A.W.D., Orth, R.J., Duarte, C.M. (Eds.), Seagrasses: Biology, Ecology and Conservation. Springer, New York.

Desaigues, B., Ami, D., Bartczak, A. et al. (2011). Economic valuation of air pollution mortality: A 9-country contingent valuation survey of value of a life year (VOLY), Ecological Indicators, Volume 11, Issue 3, 2011, Pages 902-910.

ECLAIRE (2015). D18.4 Scenario analysis to include policy recommendations and advice to other interest groups. Deliverable report of the ECLAIRE FP7 project.

EEA (2015). State of Seas report, EEA Report No 2/2015, Copenhagen, Denmark.

European Commission (2008). Marine Strategy Framework Directive 2008/56/EC of the European Parliament and of the Council.

European Commission (2011). White paper on transport. Roadmap to a single European transport area – Towards a competitive and resource-efficient transport system. Luxembourg: Publications Office of the European Union, https://ec.europa.eu/transport/sites/transport/files/themes/strategies/doc/2011_white_paper/white-paper-illustrated-brochure_en.pdf

European Commission (2013). Proposal for a Directive of the European Parliament and of the Council on the reduction of national emissions of certain atmospheric pollutants and amending Directive 2003/35/EC, COM(2013)920 final. 0443.

European Commission (2014). Guide to Cost-Benefit Analysis of Investment projects. Brussels.

European Parliament and the Council (2000). Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy. Official Journal L 327 , 22/12/2000 P. 0001 – 0073.

European Parliament and the Council (2008). Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe. Official Journal of the European Commission, L 152, 11.6.2008, p. 1–44.

Fisher, B., Turner, R. K., Morling, P. (2009). Defining and classifying ecosystem services for decision making. Ecological economics, 68(3), 643-653.

Fridell, E., Tröltzsch, J., Hasenheit, M., Jalkanen, J.-P., Matthias, V., Eriksson, M. (2018). Sustainable Shipping Scenario. SHEBA Deliverable 1.5. BONUS Research Project.

Geneletti, D. (2013). Multi-criteria analysis. LIAISE Toolbox. http://www.liaise-kit.eu/ia-method/multi-criteria-analysis

Gilbert, P., Walsh, C., Traut, M., Kesieme, U., Pazouki, K., & Murphy, A. (2018). Assessment of full life-cycle air emissions of alternative shipping fuels. Journal of Cleaner Production, 172, 855-866.

Gómez et al. (2016). Developing the AQUACROSS Assessment Framework. Deliverable 3.2, AQUACROSS, European Union's Horizon 2020 Framework Programme for Research and Innovation Grant Agreement No. 642317. http://aquacross.eu/sites/default/files/D3.2_Assessment%20Framework.13012017.pdf

Gray, A., Boehlje, M., Amanor-Boadu, V., & Fulton, J. (2004). Agricultural innovation and new ventures: assessing the commercial potential. American Journal of Agricultural Economics, 86(5), 1322-1329.

Green, E.P., Short, F.T. (Eds.) (2003). World Atlas of Seagrasses. Prepared by the UNEP World Conservation Monitoring Centre. University of California Press, Berkeley, USA, 310p.

Haines-Young, R., Potschin, M. (2013). Common International Classification of Ecosystem Services (CICES): Consultation on Version 4, August-December 2012, EEA Framework Contract No. EEA/IEA/09/003.

Hassellöv, I.-M., Ytreberg, E., Granhag, L., Boteler, B., Tröltzsch, J., Hasenheit, M., Lago, M., Roth, E., Nguyen, T. T. (2016). Report on analytical framework for assessment of shipping and harbours in the Baltic Sea. Report (D5.1) as part of the BONUS project SHEBA (Sustainable Shipping and Environment of the Baltic Sea Region).

HELCOM (2010). Ecosystem Health of the Baltic Sea 2003–2007: HELCOM Initial Holistic Assessment.

Hemminga, M.A., Duarte, C.M. (2000). Seagrass Ecology. Cambridge: Cambridge University Press, 299pp.

Holland, M. et al. (2005). Methodology for the Cost-Benefit Analysis for CAFE: Volume 3: Uncertainty in the CAFE CBA: Methods and First Analysis, http://ec.europa.eu/environment/archives/cafe/activities/pdf/cba_method_vol3.pdf

Holland, M., S. Pye, G. Jones, A. Hunt and Markandya, A. (2013). The Alpha Benefit Assessment Model - EC4MACS Modelling Methodology.

Holland, M. (2014). Implementation of the HRAPIE Recommendations for European Air Pollution CBA work. EMRC report.

Hurley, F., Hunt, A., Cowie, H., Holland, Miller, B., Pye, S. and Watkiss, P. (2005). Development of Methodology for the CBA of the Clean Air For Europe (CAFE) Programme, Volume 2: Health Impact Assessment. http://ec.europa.eu/environment/archives/cafe/pdf/cba_methodology_vol2.pdf, Section 3.3.4.

ICCT (2015). Costs and benefits of shore power at the port of Shenzhen. https://www.theicct.org/publications/costs-and-benefits-shore-power-port-shenzhen

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

International Maritime Organization (IMO) (2015). Investigation of appropriate control measures (abatement technologies) to reduce Black Carbon emissions from international shipping. http://www.imo.org/en/OurWork/Environment/PollutionPrevention/AirPollution/Documents/Air%20pollution/Black%20Carbon.pdf

International Maritime Organization (IMO) (2018). UN body adopts climate change strategy for shipping, Briefing: 13/04/2018, http://www.imo.org/en/MediaCentre/PressBriefings/Pages/06GHGinitialstrategy.aspx

IPPC (2007). Climate Change 2007: Working Group III: Mitigation of Climate Change. https://www.ipcc.ch/publications_and_data/ar4/wg3/en/tssts-ts-13-2-national-policy.html

Koesler, S., M. Achtnicht, J. Köhler. (2015). Course set for a cap? A case study among ship operators on a maritime ETS. Transport Policy 37, 2015, 20–30.

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

Krutilla, K, Krause, R. (2010). Transaction Costs and Environmental Policy: An Assessment Framework and Literature Review. International Review of Environmental and Resource Economics, 2011, vol. 4, issue 3–4, 261-354.

Lambert, F. (2018). All-electric ferry cuts emission by 95% and costs by 80%, brings in 53 additional orders. Feb 3, 2018, https://electrek.co/2018/02/03/all-electric-ferry-cuts-emission-cost/

Leaper, R., Renilson, M., & Ryan, C. (2014). Reducing underwater noise from large commercial ships: Current status and future directions. Journal of Ocean Technology, 9(1).

Lindè, T., I. Vierth (2018). An Evaluation of the Environmentally Differentiated Fairway Dues in Sweden 1998-2017. In: VTI notat 3A-2018. P.1-46. http://vti.diva-portal.org/smash/get/diva2:1186525/FULLTEXT01.pdf

Long, R.D., Charles, A. and Stephenson R.L. (2015). Key principles of ecosystem-based management in Marine Policy Vol 57 pps 53-60 July 2015. http://www.sciencedirect.com/science/article/pii/S0308597X1500024X

Madsen, P. T., Wahlberg, M., Tougaard, J., Lucke, K., Tyack, P. (2006). Wind turbine underwater noise and marine mammals: implications of current knowledge and data needs, Vol. 309: 279–295.

Maes, J., Teller, A., Erhard, M., Liquete, C., Braat, L., Berry, P., Egoh, B., Puydarrieux, P., Fiorina, C., Santos, F., Paracchini, M. L., Keune, H., Wittmer, H., Hauck, J., Fiala, I., Verburg, P. H., Condé, S., Schägner, J. P., San Miguel, J. et al. (2013). Mapping and Assessment of Ecosystems and their Services: An Analytical Framework for Ecosystem Assessments under Action 5 of the EU Biodiversity Strategy to 2020, Publications Office of the European Union, Luxembourg.

McCann, L., Colby, B., Easter, K., Kasterine, A. and Kuperan, K.V. (2005). Transaction cost measurement for evaluating environmental policies. Ecological Economics, 2005, vol. 52, issue 4, 527-542

Millennium Ecosystem Assessment (2005). Ecosystems and Human Well-being: Synthesis. Island Press, Washington, DC.

Natural Heritage Trust (2007). Antifouling performance standards for the Maritime industry. Australian government.

Nellemann, C., Corcoran, E., Duarte, C. M., Valdés, L., De Young, C., Fonseca, L.,Grimsditch, G., (2009). Blue Carbon. A Rapid Response Assessment. United Nations Environment Programme. GRID-Arendal (80p).

OECD (2007). Analysis of selected measures promoting the construction and operation of greener ships. OECD, https://www.oecd.org/sti/ind/analysis-of-measures-promoting-greener-ships.pdf

OECD (2011). Environmental Taxation. A Guide for Policy Makers. https://www.oecd.org/env/tools-evaluation/48164926.pdf

OECD (2012). Mortality Risk Valuation in Environment, Health and Transport Policies, OECD Publishing, Paris, http://dx.doi.org/10.1787/9789264130807-en)

Ondiviela, B., Losada, I.J., Lara, J.L., Maza, M., Galván, C., Bouma, T.J., van Belzen, J. (2014). The role of seagrasses in coastal protection in a changing climate. Coast. Eng. 87, 158–168. http://dx.doi.org/10.1016/j.coastaleng.2013.11.005

Rehmatulla, N., Calleya, J., & Smith, T. (2017). The implementation of technical energy efficiency and CO2 emission reduction measures in shipping. Ocean Engineering, 139, 184-197.

Rouillard, J., et al. (2016) Synergies and Differences Between Biodiversity, Nature, Water, and Marine Environment EU Policies. Deliverable 2.1 AQUACROSS European Union's Horizon 2020 Framework Programme for Research and Innovation Grant Agreement No. 642317. http://aquacross.eu/sites/default/files/D2.1_Synergies%20and%20Differences%20between%20EU%20Policies%20with%20Annexes%2003112016.pdf

Standal, Dag, and Signe Annie Sønvisen (2015). Into the Scrap Iron Business : Transaction Costs for Fl Eet Sustainability in Norway. 62: 213–17.

Swedish Maritime Administration (2013). Utvärdering av miljödifferentierade farledsavgifter för kväveoxider, Norrköping: Swedish Maritime Administration.

Swedish Maritime Administration (2016). Beräknad minskning av emissioner av kväveoxider 2013 och 2014, Norrköping: Swedish Maritime Administration.

Transport Analysis (2017). Miljökonsekvenser av nya farledsavgifter, Stockholm: Transport Analysis.

Tröltzsch, J., Boteler, B., Hasenheit, M., Tien Nguyen, T., Roth, E., Granhag, L., Eriksson, M., Ytreberg, E., Matthias, V., Moldanova, J., Peltonen, H., Pajala, J., Jalkanen J.P., Maljutenko, I. (2017). Report on ecosystem services linked to shipping in the Baltic. Deliverable 5.2, Sustainable Shipping and Environment of the Baltic Sea region (SHEBA), BONUS Research project.

UNEP/MAP (2012). State of the Mediterranean Marine and Coastal Environment, UNEP/MAP – Barcelona Convention, Athens, 32p.

Van der Graaf A. J. , Ainslie M. A., André M., Brensing K., Dalen J., Dekeling R. P. A., Robinson S., Tasker M. L., Thomsen F., Werner S. (2012). European Marine Strategy Framework Directive-Good Environmental Status (MSFD GES): Report of the Technical Subgroup on Underwater noise and other forms of energy.

Verbeek, R. & Verbeek, M. (2015). LNG for trucks and ships: fact analysis: Review of pollutant and GHG emissions. Final. TNO report. Delft.

Viseth, E. (2016). Battery Ferries smashes diesel on profitability. July 22, 2016, http://www.pbes.com/2016/07/22/battery-ferries-smashes-diesel-profitability/

Winnes, H., Styhre, L., Fridell, E. (2015). Reducing GHG emissions from ships in port areas. Research in Transportation Business & Management 17 (2015) 73–82.

Zetland, D., Weikard, H.P. et al. (2011). Overall Assessment Framework, Evaluating Economic Policy Instruments for Sustainable Water Management. Deliverable no.: D2.1 5 July 2011.

Zetterdahl, M. (2016). Particle Emissions from Ships: Measurements on Exhausts from Different Marine Fuels. PhD Thesis, Chalmers University of Technology

6 PART II: In-depth assessment of policy options

6.1 Template for options' assessment

Multidimensional Assessment Framework	*Modes of Assessment (i.e. key questions, indicators, scores for MCA)*
Description of policy option	Short description of policy option: • objectives • impacts to be curbed • design • technologies/implementation • existing examples
Political implementability	Which political/administrative scale is targeted by the policy option? (local, national, Baltic, EU, global) Do institutions need to be changed or new institutions established due to introduction of policy option? Is the policy option flexible? (Zetland & Weikart, 2011; Barton et al., 2014) Scoring based on stakeholder assessment (web survey) (see chapter 2.1.3 and 3.1) Score 1-5; 1 = very difficult to implement, 2 = difficult to implement, 3 = medium, 4= easy to implement, 5 = very easy to implement
Acceptance & Feasibility	Are there essential social barriers to implement the policy option? Are there stakeholder groups which are hindering the implementation of the policy option? Is a policy option accepted as the "lesser evil" as a stricter or less preferred option can be avoided? (Zetland & Weikart, 2011) Scoring based on stakeholder assessment (web survey) (see chapter 2.1.3 and 3.1) Score 1-5; 1 = very low acceptance and feasibility, 2 = low acceptance and feasibility, 3 = medium acceptance and feasibility, 4= high acceptance and feasibility, 5 = very high acceptance and feasibility
Scientific knowledge and uncertainty	Uncertainties are evaluated qualitatively by expert judgment. To gather the different uncertainties the following assessment steps can be helpful. 

<table>
<tr><th>Multidimensional Assessment Framework</th><th>Modes of Assessment
(i.e. key questions, indicators, scores for MCA)</th></tr>
<tr><td></td><td>Guiding question:
How robust, reliable and easy to use are the measurements/assessments linked to the policy option?
Score: 1-5, 1 = very high uncertainties, 2 = = high uncertainties, 3 = medium uncertainties, 4= low uncertainties, 5 = very low uncertainties in all assessment steps</td></tr>
<tr><td>Technological and innovation potential</td><td>Guiding questions:
- Is the implementation of the option based on available and tested technologies? Is it necessary to develop new technologies?
- Is the option directly aimed at providing incentives for technological change (e.g. subsidy for implementing battery-driven ferries) (innovation is also an objective of the option)?
- Is the option indirectly promoting innovative technologies (e.g. market prices)?
(Zetland & Weikart, 2011; Gray et al., 2004)
Score 1-5: 1 = very low innovation potential, 2 = low innovation potential, 3 = medium innovation potential, 4= high innovation potential, 5 = very high innovation potential</td></tr>
<tr><td>Environmental and health outcomes</td><td>1) Effect on pressures:
- List potential effects of policy option on pressures
- Key: Positive effect, slight positive effect, no effect, slight negative effect, negative effect
<table>
<tr><th colspan="2">Pressure</th><th>Description of expected impact of option on pressures</th></tr>
<tr><td rowspan="4">Emissions to air</td><td>CO_2</td><td>No effect</td></tr>
<tr><td>NO_X</td><td>Positive effect</td></tr>
<tr><td>SO_X</td><td>Positive effect</td></tr>
<tr><td>PM /BC</td><td>No effect</td></tr>
<tr><td rowspan="3">Emissions to water</td><td>Non-indigenous species</td><td>No effect</td></tr>
<tr><td>Contaminants to water</td><td>Slight negative effect</td></tr>
<tr><td>Oil spills</td><td>No effect</td></tr>
<tr><td>Noise emissions</td><td>Underwater noise</td><td>No effect</td></tr>
</table>
</td></tr>
</table>

Multidimensional Assessment Framework	***Modes of Assessment (i.e. key questions, indicators, scores for MCA)***

Physical impacts	Anchoring, mooring and movement and ship wakes	*No effect*

2) Effect on human well being:

- List potential effect of option on ecosystem services (based on components of human well being which were discussed as relevant in SHEBA D5.2 (Tröltzsch et al., 2017) and list of pressures develop above)

- Key: *Positive effect, slight positive effect, no effect, slight negative effect, negative effect*

Human well being	**Ecosystem services**	**Description of effect on ecosystem services**
Commercial fishing	Cod, sprat, herring, salmon and seafood	*No effect*
Recreational fishing	Cod, sprat, herring, salmon and seafood)	*No effect*
Genetic resources	Genetic variation of species	*Slight positive effect*
Climate change mitigation	Capacity of sea to absorb CO_2 (i.e. seagrass meadows)	*No effect*
Coastal protection	Capacity of sea to protect coastline, sediments, avoid erosion (i.e. seagrass meadows)	*No effect*
Tourism and recreation	Swimming, beach activities	*No effect*
Other socio-cultural services	Heritage, inspiration, local and regional species	*No effect*
Human health	Clean air	*Positive effect*

- Links to existing policies and their policy targets (e.g. GES-descriptors (MSFD), WFD, Air quality, Climate policy)

- Impact assessment for policy option (e.g. reduced CO_2-emissions, water pollutants, etc.)

  - How high are the relevant emissions/contaminants/etc. currently and expected to increase in the upcoming years (e.g. in the SHEBA BAU-scenario)?
  - What is the impact of the policy option on a BAU-scenario? Does any other SHEBA-scenario exist (e.g. LNG scenario, slow steaming) for which reduction of emission/pollutant have been estimated?
  - Did any additional articles or studies covered effects?

Multidimensional Assessment Framework	*Modes of Assessment (i.e. key questions, indicators, scores for MCA)*
	Score 1-5: 1 = very low positive effects, 2 = low positive effect, 3 = medium positive effects, 4 = high positive effects, 5: very high positive effects
Efficiency (Economic outcomes)	**Costs:** Including transaction costs as well as investments and maintenance costs (Barton et al, 2014; Zetland & Weikart, 2011) **Transaction costs:** Transaction costs (Krutilla & Krause, 2010) examine "TCs relate to the creation, implementation and operation of environmental policies." It can be differentiated between ex-ante TCs, e.g. negotiating and ex-post TCs (e.g. monitoring costs). According to the typology of McCann et al. (2005) TCs can be differentiated between: research & providing information, design & implementation, support & administration, monitoring, enforcement. Additionally, TCs occur in different phases of the establishing of policy options: development, implementation, established program. Scoring based on a summary of all phases where TCs are occurring. **Investment and maintenance costs** - Initial investment costs includes the capital costs of all the fixed assets (e.g. ship components, equipment, machinery, etc.) and non-fixed assets (e.g. start up and technical costs such as design/planning, project management and technical assistance, etc.). Cost breakdown over the years of life-time. - Maintenance costs include ongoing costs for maintaining the new or upgraded service/technologies, can include e.g. material needed for maintenance and repair of assets, labour costs, fuel, energy. (European Commission 2014) Score 1-5: 1 = very low transaction and inv. and maintenance costs, 2 = low transaction and inv. and maintenance costs, 3 = medium transaction and inv. and maintenance costs, 4 = high transaction and inv. and maintenance costs, 5 = very high inv. and maintenance costs **Benefits:** Economic evaluation of certain benefit components as far as available in literature **Comparison between costs and benefits:** Estimation of Benefit-cost ratio based on the scores for costs and environmental outcomes: 1) evaluation environmental outcomes/cost-ratio, 2) transferring of these ratio into efficiency score of 1-5 Score 1-5: 1 = very low efficiency, 2 = low efficiency, 3 = medium efficiency, 4 = high efficiency, 5: very high efficiency
Distributional effects	Distributional consequences regarding the implementation of the policy option should be analysed. Stiglitz Commission (2009) describe different components of well-being: material living standards (income, consumption, wealth), health, education, personal activities including work, political voice and governance, social con-

Multidimensional Assessment Framework	***Modes of Assessment (i.e. key questions, indicators, scores for MCA)***
	nections and relationships, environment, insecurity (economic and physical) (citation according to Zetland & Weikart, 2011). People with higher income should cover higher share of costs (Barton et al., 2014). Description of stakeholder groups which are affected by the policy options (winners and losers), including economic effects and non-economic effects (social effects), increase/decrease of inequalities Score: 1-5: 1 = many groups loose, existing inequalities will potentially increase, 2 = several groups loose, existing inequalities will potentially increase slightly, 3 = no effects, 4 = several groups benefit positively, no negative effects, inequalities will potentially decrease slightly, 5 = many groups benefit positively, no negative effects, inequalities will potentially decrease
Synergies and tradeoffs	- Does the option reduce different pressures? Are their contradictory effects on other pressures? (Zetland & Weikart 2011) -Does the option have a positive effect on a variety of ecosystem services? Are there any conflicts leading to negative effects on ecosystem services? Score 1-5: 1= minor synergies, major conflicts, 2 = minor synergies, minor conflicts, 3 = no synergies, no conflicts, 4 = major synergies, low conflicts, 5=major synergies, no conflicts

Summary
(max ¾ page, summarizing highlights of assessment, summary is included in the main text of the deliverable)

Summary table

Summary: Policy option XX	
Political implementability	Environmental and health outcomes
Acceptance & Feasibility	Efficiency
Scientific knowledge and uncertainty	Distributional effects
Technological and innovation potential	Synergies and tradeoffs
	Total score:
	Rank

Multidimensional Assessment Framework	***Modes of Assessment (i.e. key questions, indicators, scores for MCA)***

References:

Barton et al. (2014). Technical Brief, Guidelines for multi-scale policy mix assessments, Issue No. 12. PolicyMix FP7-ENV-2009-1: Collaborative project. http://policymix.nina.no/Portals/policymix/Documents/Research%20topics/WP9/D91%20Policymix%20Technical%20Brief%20-%20INTERACTIVE%20PDF%20v1%20_(2).pdf

European Commission (2014). Guide to Cost-Benefit Analysis of Investment projects. Brussels.

Gray, A., Boehlje, M., Amanor-Boadu, V., & Fulton, J. (2004). Agricultural innovation and new ventures: assessing the commercial potential. American Journal of Agricultural Economics, 86(5), 1322-1329.

Krutilla, K, Krause, R. (2010). Transaction Costs and Environmental Policy: An Assessment Framework and Literature Review. International Review of Environmental and Resource Economics, 2011, vol. 4, issue 3–4, 261-354.

McCann, L., Colby, B., Easter, K., Kasterine, A. and Kuperan, K.V. (2005). Transaction cost measurement for evaluating environmental policies. Ecological Economics, 2005, vol. 52, issue 4, 527-542

Zetland, D., Weikard, H.P. et al. (2011). Overall Assessment Framework, Evaluating Economic Policy Instruments for Sustainable Water Management. Deliverable no.: D2.1 5 July 2011.

6.2 In-depth assessment results for the different policy options

6.2.1 #1 Sea grass protection: Restrictions on number of boats mooring in certain areas and better enforcement

Assessment criteria	*Assessment results*
Description of policy option	Seagrass meadows are important marine habitats that provide ecosystem services such as nursery habitats for fish, coastal protection, water purification and carbon sequestration (Hemminga & Duarte, 2000; Short et al., 2011; UNEP/MAP, 2012; Ondiviela et al., 2014). Anchoring affects seagrass negatively (Collins et al., 2010; Francour et al., 1999; Milazzo et al., 2004; Montefalcone et al., 2008), which applies not only to leisure boats, but also very much to large boats (> 50 m) (Deter et al., 2017). To ensure mooring ships are not damaging seagrass areas, these areas are protected, while alternative mooring areas are provided. **Objectives** To protect seagrass beds from damage. **Impacts to be curbed** Positive impacts on carbon sequestration, water purification, habitat quality and coastal protection (Larkum et al., 2006). **Design** In seagrass-free location, anchoring areas are created, while anchoring is prohibited in seagrass areas. **Technologies/implementation** Maps which indicate where seagrass areas and alternative mooring spots are located, are provided by local and port authorities. Additionally, local, national and EU authorities promote different application to identify seagrass (especially for leisure boat owners), such as Donia[4] or SeagrassSpotter[5]. **Existing examples** Different port and local authorities or other organisations provide seagrass-friendly mooring opportunities (e.g. in Torbay, UK[6]). Until now, there is no EU-wide regulation dedicated to the protection of seagrass with respect to mooring.
Political implementability	**Which political/administrative scale is targeted by the policy option?** Local, national, Baltic, EU **Do institutions need to be changed or new institutions established due to introduction of policy option?**

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[4] http://www.donia.fr/en

[5] https://seagrassspotter.org/

[6] https://www.countryside-trust.org.uk/news/details/Eco-mooring

6.2.1 #1 Sea grass protection: Restrictions on number of boats mooring in certain areas and better enforcement

(stakeholder)	Once the policy (prohibiting damaging seagrass areas) is in place, it is up to existing (most local) authorities to monitor and provide seagrass-friendly alternatives. **Is the policy option flexible?** Yes. **Score from stakeholders (survey): very low (1)**
Acceptance & Feasibility (stakeholder)	Are there essential social barriers to implement the policy option? **Ship owners:** - opposed to additional costs (due to technologies, slightly changing routes) **NGOs:** **-** potentially opposing to a concentration of ships at no-seagrass mooring areas - potentially opposing changing routes of ships and logistics (due to new mooring areas) - welcoming all the positive impacts on carbon sequestration, habitat quality, coastal protection and water purification **Coastal communities** - potentially opposing to a concentration of ships at no-seagrass mooring areas - welcoming the direct positive impacts (mostly on habitat quality, coastal protection and partly water purification) **Score from stakeholders (survey): low (2)**
Scientific knowledge and uncertainty	**Measurement of Pressure** Feasible but costly to measure the pressure at low uncertainties (remote sensing would need to be merged with field data, local level assessment (data and maps). **Impact assessment / Socio-economic evaluation** It is challenging but possible to assess the environmental impacts and socio-economic implications of the different mooring activities and forms on sea-grass (which are also impacted by other pressures). **Score: medium (3)**
Technological and innovation potential	Tested and available technologies are existing. However, more efficient, new technologies might be required, especially on application which can be used to identifiy seagrass areas. But at the same time, this policy option is not directly incentifizing research or development. **Score: low (2)**
Environmental and health outcomes	1) **Effects on pressures:**

6.2.1 #1 Sea grass protection: Restrictions on number of boats mooring in certain areas and better enforcement

Pressure		Description of expected impact of option on pressures (Increase/Decrease/no effect, brief description if needed)
Emissions to air	CO_2	*No effect*
	NO_X	*No effect*
	SO_X	*No effect*
	PM /BC	*No effect*
Emissions to water	Non-indigenous species	*No effect*
	Contaminants to water	*No effect*
	Oil spills	*No effect*
Noise emissions	Underwater noise	*No effect*
Physical impacts	Anchoring, mooring and movement and ship wakes	*Positive effect (decrease disturbance of seagrass beds due to anchoring)*

2) Effects on human well being:

Human well being	Ecosystem services	Description of effect on ecosystem services (positive, negative, no effect, e.g. with arrows)
Commercial fishing	Cod, sprat, herring, salmon and seafood	*No significant effect*
Recreational fishing	Cod, sprat, herring, salmon and seafood	*Positive effect (fish stocks benefits from seagrass protection)*
Genetic resources	Genetic variation of species	*No effect*
Climate change mitigation	Capacity of sea to absorb CO_2 (i.e. seagrass meadows)	*Positive effect (increased carbon sequestration)*
Coastal protection	Capacity of sea to protect coastline, sediments, avoid erosion (i.e. seagrass meadows)	*Positive effect (increased coastal protection by seagrass beds)*
Tourism and recreation	Swimming, beach activities	*No effect*
Other socio-cultural services	Heritage, inspiration, local and regional species	*Slightly positive effect (preservation of seagrass beds)*
Human health	Clean air	*No effect*

Major effects on human well-being are expected for coastal protection due to less destroying of coastal vegetation. Coastal vegetation is as well important as habitat

6.2.1 #1 Sea grass protection: Restrictions on number of boats mooring in certain areas and better enforcement

	for nurseries, refuges and foraging areas for a variety of fish species there could be local impacts on fish stocks with effects on recreational fishing. **Links to existing policies and their policy targets** - EU Habitats Directive recognises the importance of seagrass meadows - EU Water Framework Directive recognises the importance of seagrass meadows - Marine protected areas (MPAs) have been set up to help ensure seagrass protection **Impact assessment for policy option** The policy can support the reduction of impacts to seagrass meadows. The effect is depending on size of areas included and local implementation. With this policy only a part of ship-related pressures on seagrass is addressed ('scarring' due to static moorings and anchors) (Cullen-Unsworth & Unsworth, 2016). Further damages due to boat groundings and propeller contact are only addressed, if the seagrass areas are not only excluded from anchoring, but generally protected. Boat-related pollution is not addressed. **Score**: **medium effect (3)**
Efficiency (Economic outcomes) (Ecologic/SDU)	**Transaction costs** The transaction costs are relatively high, since seagrass meadows (which are not static) have to be mapped, as well as areas where anchoring is encouraged. Furthermore, strict enforcement is necessary. **Investment and maintenance costs** Mooring infrastructure needs to be provided/build. **Score cost: low costs (1)** **Benefits** Acording to Campagne et al. (2015), the economic value of goods and benefits provided by Posidonia oceanica in the Mediterranean sea ranges between 25.3 million and 45.9 million Euro per year which equates to 283–513 Euro per hectar and year. These goods and benefitted include the use as material and bioindicator, wastewater treatment, protection from coastal erosion, fishery contribution, carbone sequestration and knowledge contribution. It is also estimated that the present economic value of carbon storage and sequestration capacity of Baltic Sea eelgrass meadows is between 1.7 and 12 % out of the global seagrass blue carbon value (Rohr et al., 2016). For the Chesapeake Bay (USA), a study estimated net economic benefit to Virginia hard-shell blue crab fishermen of full seagrass restoration to be about US$1.8 million per year (Anderson, 1989). **Score: high efficiency (4)**

6.2.1 #1 Sea grass protection: Restrictions on number of boats mooring in certain areas and better enforcement

Distributional effects (Ecologic/SDU)	Shipowners have additional costs; public or private port authorities have to invest with effects on public budgets. **Score: medium (3)**
Synergies and tradeoffs (Ecologic/SDU)	**Pressures:** The option focuses on the decrease of one pressure which is physical impacts (1). No negative effects are assessed (if shipping routes are not lengthened significantly) **Human well being:** Positive effects are assessed for: recreational fishing locally at the coastline and coastal protection (2). No negative effects are assessed. **Score: (almost) no synergies, no conflicts (3)**

Summary

Ecosystems formed by seagrass beds are estimated to be the largest ocean carbon sinks in the world (Nellemann et al., 2009). Meadows formed by such seagrass are present in most oceans and seas of the world (Green & Short, 2003), with a focus on tropical coasts and temperate regions (Den Hartog & Kuo, 2006). Their ecological role is crucial for the marine environment and provision of ecosystem services, such as nursery habitats for fish, coastal protection, water purification and carbon sequestration (Hemminga & Duarte, 2000; UNEP/MAP, 2012; Ondiviela et al., 2014).

Shipping has various negative effects on seagrass meadows, which includes 'scarring' due to static moorings and anchors, damages due to boat groundings and propeller contact and boat-related pollution. This policy option is primarily addressing the most severe one: anchoring and mooring. If seagrass areas are not only protected from mooring and anchoring, but also integrated into MPAs, a wider protection could be ensured. Since seagrass areas are large and often located in coastal areas, where harbours are located, such wide protection is unlikely. An EU-wide or general limitation of mooring is regarded as unlikely or difficult to implement. However, a limitation of anchoring and the provision of seagrass-friendly alternatives could be established at local level.

Summary table

Summary: Policy option #1 Sea grass protection: Restrictions on number of boats mooring in certain areas and better enforcement			
Political implementability	1	Environmental and health outcomes	3
Acceptance & Feasibility	2	Efficiency	4
Scientific knowledge and uncertainty	3	Distributional effects	3
Technological and innovation potential	2	Synergies and tradeoffs	3
		Total score:	2,6
		Rank	17

6.2.1 #1 Sea grass protection: Restrictions on number of boats mooring in certain areas and better enforcement

References:

Anderson, E. E. (1989). Economic Benefits of Habitat Restoration: Seagrass and the Virginia Hard-Shell Blue Crab Fishery. North American Journal of Fisheries Management, 9(2), 140-149.

Campagne, C. S., Salles, J. M., Boissery, P., & Deter, J. (2015). The seagrass Posidonia oceanica: ecosystem services identification and economic evaluation of goods and benefits. Marine pollution bulletin, 97(1-2), 391-400.

Collins, K. J., Suonpää, A. M., Mallinson, J. J. (2010). The impacts of anchoring and mooring in seagrass, Stud-land Bay, Dorset, UK. Underwater Technology, 29(3), 117-123.

Cullen-Unsworth, L. C., & Unsworth, R. K. (2016). Strategies to enhance the resilience of the world's seagrass meadows. Journal of Applied Ecology, 53(4), 967-972.

Den Hartog, C., Kuo, J. (2006). Taxonomy and biogeography of seagrasses. In: Larkum, A.W.D., Orth, R.J., Duarte, C.M. (Eds.), Seagrasses: Biology, Ecology and Conservation. Springer, New York

Francour P, Ganteaume A and Poulain M. (1999). Effects of boat anchoring in Posidonia oceanica seagrass beds in the Port-Cros National Park (north-western Mediterranean Sea). Aquatic Conservation: Marine and Freshwater Ecosystems 9: 391-400.

Green, E.P., Short, F.T. (Eds.) 2003. World Atlas of Seagrasses. Prepared by the UNEP World Conservation Monitoring Centre. University of California Press, Berkeley, USA, 310p

Hemminga, M.A., Duarte, C.M. (2000). Seagrass Ecology. Cambridge: Cambridge University Press, 299pp.

Larkum AWD., Orth RJ., Duarte CM. (eds.) (2006). Seagrasses: Biology, Ecology and Conservation. Dordrecht, Netherlands: Springer, 691pp.

Milazzo M., Badalamenti F, Ceccherelli G., Chemelloa R. (2004). Boat anchoring on Posidonia oceanica beds in a marine protected area (Italy, western Mediterranean): effect of anchor types in different anchoring stages. Journal of Experimental Marine Biology and Ecology 299: 51-62.

Montefalcone, M., Chiantore, M., Lanzone, A., Morri, C., Albertelli, G., Bianchi, C.N. (2008). BACI design re-veals the decline of the seagrass Posidonia oceanica induced by anchoring. Marine Pollution Bulletin 56: 1637-1645.

Nellemann, C., Corcoran, E., Duarte, C. M., Valdés, L., De Young, C., Fonseca, L.,Grimsditch, G. (2009). Blue Carbon. A Rapid Response Assessment. United Nations Environment Programme. GRID-Arendal (80p).

Ondiviela, B., Losada, I.J., Lara, J.L., Maza, M., Galván, C., Bouma, T.J., van Belzen, J. (2014). The role of seagrasses in coastal protection in a changing climate. Coast. Eng. 87, 158–168. http://dx.doi.org/10.1016/j.coastaleng.2013.11.005

Rohr, M., E., Bostrom, C., Canal-Vergés, P., Holmer, M. (2016). Blue carbon stocks in Baltic Sea eelgrass (Zostera marina) meadows. Biogeosciences, 13(22), 6139.

6.2.1 #1 Sea grass protection: Restrictions on number of boats mooring in certain areas and better enforcement

UNEP/MAP (2012). State of the Mediterranean Marine and Coastal Environment, UNEP/MAP – Barcelona Convention, Athens, 32p.

6.2.2 #2 Speed regulation: Zoning and maximal speed (Baltic-wide)

Assessment criteria	*Assessment results*
Description of policy option	Vessel operation at high speeds leads to high underwarter noise emissions. Little is known about the impacts, but the consensus is that the noise levels are increasing. Noise can affect fish/mammals in many ways, starting from masking of communications (which may lead into difficulties in mating, avoiding predators) to physical symptoms (like temporary or permanent hearing loss) or ultimately, death. The noise levels caused by shipping may lead to changes in migratory patterns or habitat loss and animals may move to less noisy areas. In the long term, this can lead to depletion of fisheries and declining populations. Currently, low noise emissions are not necessarily considered as design criteria for ships. **Objectives**: The objective of this policy is to curb shipping noise, reduce fuel consumption and emissions by introducing maximal speeds and zoning. **Impacts to be curbed** Decreasing noise from shipping. Decrease vessel fuel consumption and emissions. **Design** Maximal speeds for ships (Baltic-wide) and stricter speed limitations are introduced in zones which are criticale.g. for fish or mammal polulations. **Technologies/implementation** Ships using fixed pitch propellers change their speed by adjusting its rotational speeds; this applies to most of the global fleet. Vessels using controllable pitch propellers change the blade angle to alter their speed. Therefore, a speed regulation should address final shipping speed; to incorporate both ways to change shipping speed. **Existing examples** Speed limits already exist in Stockholm archipelago area, which can be used as precedence.

6.2.2 #2 Speed regulation: Zoning and maximal speed (Baltic-wide)

Political implementability	**Political/administrative scale targeted by the policy:** - Baltic countries (national law) - Baltic region (Helcom/EU) **Do institutions need to be changed?** - no additional institutions are necessary. - there is real time data of ships, their speed can be monitored rather easily (e.g. vessel satellite navigation equipment could be used). - institutions would need additional ressources for monitoring and enforcement (strict enforcement would be necessary). - additional monitoring schemes for underwater noise would ne necessary. Changes in vessel operational speed could be tested with a limited number of ships. This would link with the slow steaming scenario. **Score from stakeholders (survey): very low policy implementability (1)**
Acceptance & Feasibility	**Ship owners:** - opposed to additional costs (less goods could be transported in the same time) - opposed to additional regulation (especially if there is a lack of knowledge) - welcoming lower costs for fuel - welcoming long-term schemes & policy focuses **NGOs:** - opposing, in case more ships are needed for transporting the same amount of people and goods, due to slow steaming - welcoming the noise reducing effects **Coastal communities** - welcoming the side effects (positive effects on recreational fishing, tourism etc.) - opposing slower marine transport (esp. if fast ferries are affected and passenger embarking/disembarking) **Score from stakeholders (survey): very low acceptance & feasability (1)**
Scientific knowledge and uncertainty	There is only very limited measurement data of underwater noise from a small number of research projects; routine monitoring of noise is not done. In addition, further work is required to map out the response of marine life to noise. Currently very little information is available on this topic. Further, species-specific population/habitat maps are needed to assess the impacts of noise on marine life. These maps do not cover all relevant species at the Baltic Sea scale. **Score: very high uncertainties (1)**
Technological and innovation potential	An adjustment of ship operation is immediately possible. No technological change is necessary. **Score: very low technological potential (1)**

6.2.2 #2 Speed regulation: Zoning and maximal speed (Baltic-wide)

Environmental and health outcomes

1) Effects on pressures:

Pressure		Description of expected impact of option on pressures (Increase/Decrease/no effect, brief description if needed)
Emissions to air	CO_2	*Positive effect (Decrease) per ship; potentially negative effect for the overall emissions (in case of more ships)*
	NO_X	*Positive effect (Decrease) per ship; potentially negative effect for the overall emissions (in case of more ships)*
	SO_X	*Positive effect (Decrease) per ship; potentially negative effect for the overall emissions (in case of more ships)*
	PM /BC	*Positive effect (Decrease) per ship; potentially negative effect for the overall emissions (in case of more ships) or increased emissions from old vessels.*
Emissions to water	Non-indigenous species	*No effect; potentially negative effect for the overall emissions (in case of more ships)*
	Contaminants to water	*Slight negative effect (ships trip duration is longer)*
	Oil spills	*Slight negative effect (ships trip duration is longer)*
Noise emissions	Underwater noise	*Positive effect*
Physical impacts	Anchoring, mooring and movement and ship wakes	*Slight positive effect (lower ship wakes)*

(Slow steaming may lead to increase in emissions of some pollutants, like CO (Johansson et al., 2013).

2) Effects on human well being:

Human well being	Ecosystem services	Description of effect on ecosystem services (positive, negative, no effect, e.g. with arrows)
Commercial fishing	Cod, sprat, herring, salmon and seafood	*Positive effect (due to reduction of noise and air emissions)*
Recreational fishing	Cod, sprat, herring, salmon and seafood)	*Positive effect (due to reduction of noise and air emissions)*
Genetic resources	Genetic variation of species	*Slight positive effect (due to reduction of air emissions)*
Climate change mitigation	Capacity of sea to absorb CO_2 (i.e. seagrass meadows)	*Positive effect (due to reduction of air emissions)*
Coastal protection	Capacity of sea to protect coastline, sediments, avoid erosion (i.e. seagrass meadows)	*Slight positive effect (lower ship wakes)*

6.2.2 #2 Speed regulation: Zoning and maximal speed (Baltic-wide)

Tourism and recreation	Swimming, beach activities	*Positive effect (due to reduction of noise and air emissions)*
Other socio-cultural services	Heritage, inspiration, local and regional species	*Positive effect (noise and air emissions)*
Human health	Clean air	*Positive effect (air emissions)*

Due to reduction of air emissions slight effects on all ecosystem services and human health are expected, mainly for human health, fishing and tourism and recreation. For commercial and recreational fishing positive effects are expected due to lower noise levels, but as noise impacts of shipping on fish species are still less researched the significance of the effect needs to be discussed.

Links to existing policies and their policy targets

- At the IMO, a statement declaring that underwater noise should decrease at a rate of 3 dB/decade, however that is not a binding target, but a recommendation (see the International Maritime Organization's (IMO) "Code on noise levels on board ships" by the Maritime Safety Committee (MSC) (IMO, 2012)
- MSFD Descriptor 11 on Underwater Noise and other forms of energy

Impact assessment for policy option

- In the SHEBA-BAU scenario until 2040: an increasing trend on noise emissions is expected as number of ships are increasing and, no policy to limit noise emissions is in place. In the BAU scenario noise emissions from shipping are expected to grow in similar magnitude as other emissions.
- The slow steaming scenario developed in SHEBA is linked to this option. The SHEBA slow steaming scenario assumed a 10% reduced average cruising speed, total transport work remains constant. For the year 2040, the CO_{2eq} emissions are 1.9 Mtonne lower than in the BAU scenario. Regarding emissions of air pollutants the slow steaming scenario shows lower emissions than the BAU. Water contaminants are expected to increase due to more operating ships (Fridell et al., 2018).

- Leaper et al. (2014) analysed slow steaming practices since 2007. The slow steaming showed an observed reduction in mean speeds from 15.6 (sd = 4.2) knots in 2007 to 13.8 (sd = 3.0) knots in 2013 – analysed for ships transiting the major shipping route in the eastern Mediterranean. They "estimated that slow steaming in the last five years has likely reduced the overall broadband acoustic footprint from these ships by over 50%." (Leaper et al., 2014).

Score: medium positive effect (3)

Efficiency

Transaction costs:

Transaction costs are limited. Monitoring and enforcement need to be in place, but can be based on vessel satellite navigation equipment.

Investment and maintenance costs

6.2.2 #2 Speed regulation: Zoning and maximal speed (Baltic-wide)

	For reducing speed, for ship owners no further investments for new technologies are necessary. But fuel consumption will be reduced, linking to lower fuel costs. **Score: very low costs (1)** **Benefits:** Estimations of the SHEBA project (based on reduced PM and ozone emissions) show a reduction potenial of health impacts for mid-VOLY with 53 million Euros per year for 2040, compared to the BAU scenario and 211 million Euro per year for 2040 (compared to BAU) for mid VSL. Lost working days could be reduced by 3 million Euro per year. The contribution of shipping on the area in which critical loads are exceeded could be reduced by 0.9 and 1.3% (see for more information chapter 2.4 and 2.5). Travelling a distance of 24000 nautica miles, decreasing speed from a usual speed of 25 nm/h to 20 nm/h, for a fuel oil price of 700 $, a 8000 TEU container vessel could save 2,550 tons of fuel oil resulting, which equal to financial savings of 1,785,000 $ (Fathom, 2014). Fuel saving: With 10% speed reduction (if vessel operates with speeds larger than 10 knots) fuel savings may be 9.4%. With 30% reduction in speed, savings can be 20.7%. It should be noted that largest savings can be achieved with vehicle carriers, containerships, reefers, RoRo/RoPax and Cruise vessels. (Johansson et al., 2013) Passenger vessel schedules are such that most embark/disembark operations happen during daytime. If less trips are done because of relaxed schedules, potential loss of revenue may occur. This might not be critical for cargo traffic, but will reflect first to passenger traffic. **Score: high efficiency (4)**
Distributional effects	Probably low distributional effect **Score: low distributional effect (4)**
Synergies and tradeoffs	**Pressures:** Primarily, the option has positive effects on underwater noise and air emissions (especially CO_2, NO_X, but also SO_X, PM). No major, direct negative effects are assessed. However, since slower ships have higher ship trip durations, slightly negative impacts on emissions to water (e.g. release of anti-fouling paint) could be expected, as well as slight increase of CO emissions as a result of operating engines outside their usual load range. Additionally, negative impacts would arise in case of slow steaming leading to more ships in the Baltic Sea. However, this is very much linked to the global economic situation too. **Human well being:** Positive effects are assessed for: Commercial fishing, recrea-

6.2.2 #2 Speed regulation: Zoning and maximal speed (Baltic-wide)

	tional fishing, genetic resources (slight), climate change mitigation, tourism & recreation, other socio-cultural services (slight), human health. No negative effects are assessed. **Score: minor synergies, no conflict (4)**

Summary

Vessel operation at high speeds leads to high underwater noise emissions. Noise can affect fish/mammals in many ways, starting from masking of communications (which may lead into difficulties in mating, avoiding predators) to physical symptoms (like temporary or permanent hearing loss) or ultimately, death. The noise levels caused by shipping may lead to changes in migratory patterns or habitat loss and animals may move to less noisy areas. In the long term, this can lead to depletion of fisheries and declining populations. Currently, low noise emissions are not necessarily considered as design criteria for ships.

Slow steaming can be a valid measure to reduce noise emissions from ships. Leaper et al. (2014) concluded, that slow steaming had likely reduced the overall broadband acoustic footprint from observed ships by over 50% due to reduction in mean speeds from 15.6 (sd = 4.2) knots in 2007 to 13.8 (sd = 3.0) knots in 2013.

The largest barrier for the option is the limited knowledge on impacts from noise emissions of ships. There is only very limited measurement data of underwater noise from a small number of research projects; routine monitoring of noise is not done. In addition, further work is required to map out the response of marine life to noise. Currently very little information is available on this topic. It can be assumed that the existing knowledge gap leads to a low rating by stakeholders (on political implementability and acceptance & feasibility). However, speed regulation shows significant synergies with the reduction of GHG and air pollutant emissions. The estimations of the SHEBA project (based on reduced PM and ozone emissions) show a reduction potenial of health impacts between 53 million and 211 million Euro per year for 2040 (compared to BAU).

Summary table

Summary: Policy option #2 Speed regulation: Zoning and maximal speed (Baltic-wide)			
Political implementability	1	Environmental and health outcomes	3
Acceptance & Feasibility	1	Efficiency	4
Scientific knowledge and uncertainty	1	Distributional effects	4
Technological and innovation potential	1	Synergies and tradeoffs	4
		Total score:	2,3
		Rank	18

6.2.2 #2 Speed regulation: Zoning and maximal speed (Baltic-wide)

References:

Faber, J. F., Huigen, T., & Nelissen, D. (2017). Regulating Speed: a Short-term Measure to Reduce Maritime GHG Emissions. CE Delft.

Fathom (2014). Ship performance management, edition 2014

Fridell, E., Tröltzsch, J., Hasenheit, M., Jalkanen, J.-P., Matthias, V., Eriksson, M. (2018). Sustainable Shipping Scenario. SHEBA Deliverable 1.5. BONUS Research Project

IMO (2012). Resolution MSC.337 (91) (adopted on 30 November2012), ADOPTION OF THE CODE ON NOISE LEVELS ON BOARD SHIPS, http://www.imo.org/en/KnowledgeCentre/IndexofIMOResolutions/Documents/MSC%20-%20Maritime%20Safety/337(91).pdf

Johansson, L., Jalkanen, J.-P., Kalli, J., Kukkonen, J. (2013). The evolution of shipping emissions and the costs of regulation changes in the northern EU area. Atmospheric Chemistry and Physics, 13(22), 11375-11389, https://doi.org/10.5194/acp-13-11375-2013.

Leaper, R., Renilson, M., & Ryan, C. (2014). Reducing underwater noise from large commercial ships: Current status and future directions. *Journal of Ocean Technology*, *9*(1).

McKenna, M. F., Ross, D., Wiggins, S. M., & Hildebrand, J. A. (2012). Underwater radiated noise from modern commercial ships. The Journal of the Acoustical Society of America, 131(1), 92-103.

6.2.3 #3 Excluding the noisiest ships / limits on average noise level

Assessment criteria	*Assessment results*
Description of policy option	Vessel operation at high speeds lead to high underwarter noise emissions. Little is known of the impacts, but the consensus is that the noise levels are increasing. Noise can affect fish/mammals in many ways, starting from masking of communications (which may lead into difficulties in mating, avoiding predators) to physical symptoms (like temporary or permanent hearing loss) or ultimately, death. The noise levels caused by shipping may lead to changes in migratory patterns or habitat loss and animals may move to less noisy areas. In the long term, this can lead to depletion of fisheries and declining populations. Currently, low noise emissions are not necessarily considered as design criteria for ships. Under this policy option, avoiding underwater noise by a noise-sensitive ship design would be mandatory. Phasing out fast vessels with mechanical power transmission and reduction gearboxes and replacing them with vessels equipped with diesel-electric powertrains. **Objectives**: The objective of this policy is to curb shipping noise by excluding the loudest ships and limiting the average noise levels. **Impacts to be curbed** Decreasing noise from shipping. **Design** It is mandatory for ships to have a certain maximum noise level in order to enter the Baltic Sea area. Ships will be ranked after their noise emissions, by putting ship type and engine into perspective (leaving out shipping speed and other noise sources, such as pumps sonar or echo). Changes in vessel operational speed could be tested with a handful of ships. **Technologies/implementation** Underwater noise from shipping has different sources. The most relevant one are linked to the shippings` engine (apart of the general design of the ship). Hence, most of the technologies that aim at curbing underwater noise are likely to be linked to the ships` engine (including introduction of diesel-electric vessels with modern engines to reduce noise from mechanical power transmission).
Political implementability	**Political/administrative scale targeted by the policy:** - Baltic countries (national law) - Baltic region (Helcom/EU) **Do instituions need to be changed?** - no additional institutions are necessary - there is real time data of ships, their speed can be monitored rather easily by institutions

6.2.3 #3 Excluding the noisiest ships / limits on average noise level

	- implementing institution would need additional ressources to enforce the policy - additional monitoring schemes for underwater noise would ne necessary **Score from stakeholders (survey): low policy implementability (1)**
Acceptance & Feasibility	**Ship owners:** - opposed to additional costs (for renewing the fleet) - opposed to additional regulation (especially if there is a lack of knowledge) - co-benefit: the new, less noisy ships might be more efficient - welcoming long-term schemes & policy focuses **NGOs:** - potentially critizing the resource use and scrapping issues related to excluding the noisiest ships - welcoming the noise reducing effects **Coastal communities** - welcoming the side effects (positive effects on recreational fishing, tourism etc.) - opposing slower marine transport (esp. if fast ferries are affected) **Score from stakeholders (survey): low-medium acceptance & feasability (2)**
Scientific knowledge and uncertainty	There is only very limited measurement data of underwater noise from a small number of research projects; routine monitoring of noise is not done. In addition, further work is required to map out the response of marine life to noise. Currently very little information is available on this topic. Further, species-specific population/habitat maps are needed to assess the impacts of noise on marine life. These maps do not cover all relevant species at the Baltic Sea scale. **Score: very high uncertainties (1)**
Technological and innovation potential	There is a high technological potential: If the policy it setting targets, but leaving open to ship designers and owners how to reach the, research and development in differente areas would be supported – indluding development of adapted engines, hybrid technologies (diesel-electric) or new ship hull designs. At the same time, systematic measurements of underwater noise are needed. This concerns both shipbuilding industry and the governments conducting routine environmental monitoring. Significant amount of new research is needed, because the studies made for civilian purposes are at their infancy. Hence, this topic is very little researched and requires further attention. It is probable that once the groundwork is done, innovations may be achieved at a later stage. **Score: high technological potential (4)**
Environmental and	**1) Effects on pressures:**

6.2.3 #3 Excluding the noisiest ships / limits on average noise level

health outcomes

Pressure		Description of expected impact of option on pressures (Increase/Decrease/no effect, brief description if needed)
Emissions to air	CO_2	*Slight negative effect (slight increase) in case of ship design changes)*
	NO_X	*Slight negative effect (slight increase) in case of ship design changes)*
	SO_X	*Slight negative effect (slight increase) in case of ship design changes)*
	PM /BC	*Slight negative effect (slight increase) in case of ship design changes)*
Emissions to water	Non-indigenous species	*No effect*
	Contaminants to water	*No effect*
	Oil spills	*No effect*
Noise emissions	Underwater noise	*Positive effect (decrease) in case of ship design changes)*
Physical impacts	Anchoring, mooring and movement and ship wakes	*No effect*

2) Effects on human well being:

Human well being	Ecosystem services	Description of effect on ecosystem services (positive, negative, no effect, e.g. with arrows)
Commercial fishing	Cod, sprat, herring, salmon and seafood	*Positive effect (by noise reduction), slightly negative effect (by air emissions)*
Recreational fishing	Cod, sprat, herring, salmon and seafood)	*Positive effect (by noise reduction), slightly negative effect (by air emissions)*
Genetic resources	Genetic variation of species	*No effect*
Climate change mitigation	Capacity of sea to absorb CO_2 (i.e. seagrass meadows)	*Slightly negative effect (by air emissions)*
Coastal protection	Capacity of sea to protect coastline, sediments, avoid erosion (i.e. seagrass meadows)	*No effect*
Tourism and recreation	Swimming, beach activities	*Positive effect (by noise reduction), slightly negative effect (by air emissions)*
Other socio-cultural services	Heritage, inspiration, local and regional species	*Positive effect (by noise reduction), slightly negative effect (by air emissions)*
Human health	Clean air	*Slightly negative effect (by air emissions)*

6.2.3 #3 Excluding the noisiest ships / limits on average noise level

Increasing air emissions will have slightly negative effects on all components of human well being, significance can vary between the different services, also due to importance of shipping as pressure compared to other e.g. land-based pressure. Positive effects are assessed for commercial and recreation fishing, tourism&recreation and other socio-cultural services due to a reduced noise levels.

Links to existing policies and their policy targets

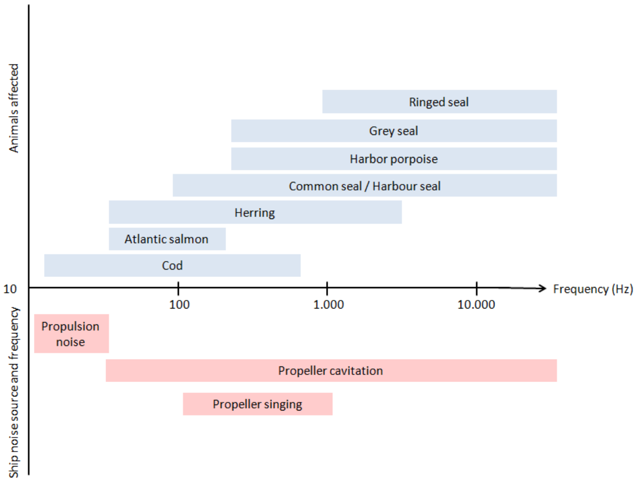
- At the IMO, a statement declaring that underwater noise should decrease at a rate of 3 dB/decade, but that is not a binding target, but a recommendation (see the International Maritime Organization's (IMO) "Code on noise levels on board ships" by the Maritime Safety Committee (MSC

- MSFD Descriptor 11 on Underwater Noise and other forms of energy

Impact assessment for policy option

- In the SHEBA-BAU scenario until 2040: an increasing trend on noise emissions is expected as number of ships are increasing and, no policy to limit noise emissions is in place (Annual traffic growth factors are applied to emitted noise energy, no mitigation scenarios applied).

- Short term continuous noise (30 minutes) to recorded noise from small vessels has been shown to already increase cortisol levels in fish (Wysocki et al., 2006). This increases stress levels for the fish, potentially impacts stocks and catches. Long-term continuous exposure (2 hours) from noise from small boats and ferries can additionally lead to hearing impairment and masking of natural communication between species (Scholik & Yan 2001; Vasconcelos et al., 2007). Furthermore, vessel noise potentially alter mammal and fish behaviour by provoking avoidance reactions (including altering swimming speed and direction) and altering schooling behaviour (Engås et al., 1995; 1998; Sarà et al., 2007).



Source: based on Chapman & Sand, 1974; Enger, 1967; Kastak & Schusterman, 1996; Nedwell, 2004; Madsen et al., 2006; Ridgway & Joyce, 1975; Terhune & Ronald, 1975

6.2.3 #3 Excluding the noisiest ships / limits on average noise level

	There is a tradeoff between propeller noise and efficiency (Carlton, 2010). Propeller efficiency improvements will lead to noisier designs. There are mandatory design requirements for energy efficiency in place, but no requirements to reduce noise emissions. Due to the energy efficiency requirements noise emissions will continue to increase if limits do not exist. **Score: low positive effect (2)**
Efficiency (Economic outcomes)	**Transaction costs:** There are costs to define which ships are the noisiest. But transaction costs are limited. **Investment and maintenance costs** High investment costs for exchanging the loudest ships. For ferries hybrid technologies (diesel-electric) could be used which are less noisy. They have larger upfront investments but lower maintenance and operational costs (see for more details policy option #12). **Score: high costs (4)** **Benefits:** Economic benefits due to decreased noise are existent, but difficult to assess. A full assessment of underwater noise is difficult and not feasible, missing essential parts like species specific habitat maps, dose-response functions and noise propagation results for the whole of the Baltic Sea region. For improved water quality and reduced noise and litter with links to habitats (supporting services) and reduction in eutrophication, Östberg et al. (2012) estimated between EUR 19 and 54 per person per year for Sweden with a willingness to pay approach. Noise is in the study only one included aspect. **Score: very low efficiency (1)**
Distributional effects	Uncertain, probably low distributional effect **Score: low distributional effect (4)**
Synergies and tradeoffs	**Pressures:** The option has positive effects on underwater noise. But negative effects on air emissions (CO_2, NO_X, SO_X, PM) are possible. **Human well being:** Positive effects are assessed for: Commercial fishing, recreational fishing, tourism & recreation, socio-cultural services (slight) (4). Negative effects are assessed for a number of components of human well being: Commercial fishing, recreational fishing, climate change mitigation, tourism & recreation, socio-cultural services (slight) and human health (6). **Score: minor synergies, conflicts (1)**

6.2.3 #3 Excluding the noisiest ships / limits on average noise level

Summary

Amongst the types of anthropogenic energy that human activities introduce into the marine environment, the most widespread and pervasive type is underwater noise (Van der Graaf et al., 2012). Shipping contributes to long lasting underwater noise; indeed, motorized shipping is "one of the most prominent man-made sources of underwater noise" (Madsen et al., 2006). This policy would address the most relevant sources for ship-related noise, which is the engine operation (loud continuous noise from 10 Hz to 10kHz).

The limits on noise levels could be reached e.g. by hybrid technologies of diesel and electrically powered ships. This policy would require a ranking of all ships after their average noise level. Adressing underwater noise is a crucial challenge to preserve habitats and ensure the provision of ecosystems services. But effectiveness is potentially higher for other options and measures such as reducing shipping speed (Policy option #2 Speed regulation: Zoning and maximal speed (Baltic-wide) or including noise levels in the design of ship hulls, propellers etc.

Summary table

Summary: Policy option #3 Excluding the noisiest ships / limits on average noise level			
Political implementability	1	Environmental and health outcomes	2
Acceptance & Feasibility	2	Efficiency	1
Scientific knowledge and uncertainty	1	Distributional effects	4
Technological and innovation potential	4	Synergies and tradeoffs	1
		Total score:	1,9
		Rank	20

References:

Carlton, J. (2010). Marine Propellers and Propulsion, Third Edit., Elsevier Ltd, Oxford, UK., 2010

Chapman, C. J., Sand, O. (1974). Field studies of hearing in two species of flatfish Pleuronectes platessa (L.) and Limanda limanda (L.)(Family Pleuronectidae). Comparative Biochemistry and Physiology Part A: Physiolo-gy, 47(1), 371-385.

Engås, A., Misund, O. A., Soldal, A. V., Horvei, B., Solstad, A. (1995). Reactions of penned herring and cod to playback of original, frequency-filtered and time-smoothed vessel sound. Fisheries Research, 22(3), 243-254.

Engås, A., Haugland, E. K., Øvredal, J. T. (1998). Reactions of cod (Gadus morhua L.) in the pre-vessel zone to an approaching trawler under different light conditions. Hydrobiologia, 371, 199-206.

Enger, P. (1967). Hearing in herring. Comp. Biochem. Physiol., 22:527-538.

IMO (1981). A.343(IX) Recommendation on methods of measuring noise levels at listening posts,

6.2.3 #3 Excluding the noisiest ships / limits on average noise level

resolution A.468(XII) Code on Noise Levels on Board Ships, and resolution MSC.337(91) Code on Noise Levels on Board Ships.

Kastak, D., Schusterman, R. J. (1996). Temporary threshold shift in a harbor seal (Phoca vitulina). The Journal of the Acoustical Society of America, 100(3), 1905-1908.

Madsen, P. T., Wahlberg, M., Tougaard, J., Lucke, K., Tyack, P. (2006). Wind turbine underwater noise and marine mammals: implications of current knowledge and data needs, Vol. 309: 279–295.

Nedwell, J.R., Edwards, B., Turnpenny, A.W.H., Gordon, J. (2004). Fish and Marine Mammal Audiograms: A summary of available information. Subacoustech Report ref: 534R0214. http://www.subacoustech.com/wp-content/uploads/534R0214.pdf .

Östberg, K., Hasselström, L., Håkansson, C. (2012). Non-market valuation of the coastal environment—uniting political aims, ecological and economic knowledge. Journal of Environmental Management, 110: 166–178.

Ridgway, S.H. & Joyce, P.L. (1975). Studies on seal brain by radiotelemetry. Rapp. P.-v. Reun. Cons. Int. Explor. Mer, 169, 81-91.

Sarà, G., Dean, J. M. , D'Amato, D., Buscaino, G., Oliveri, A., Genovese, S., Ferro, S., Buffa, G.,Lo Martire, M., Mazzola S. (2007). Effect of boat noise on the behaviour of bluefin tuna Thunnus thynnus in the Mediterra-nean Sea, Marine Ecology Progress Series Vol. 331 (February 16 2007), pp. 243-253.

Terhune, J. M., Ronald, K. (1975). Underwater hearing sensitivity of two ringed seals (Pusa hispida). Canadian Journal of Zoology, 53(3), 227-231.

Scholik, A. R., & Yan, H. Y. (2002). Effects of boat engine noise on the auditory sensitivity of the fathead min-now, Pimephales promelas. Environmental Biology of Fishes, 63(2), 203-209.

Van der Graaf A. J. , Ainslie M. A., André M., Brensing K., Dalen J., Dekeling R. P. A., Robinson S., Tasker M. L., Thomsen F., Werner S. (2012). European Marine Strategy Framework Directive-Good Environmental Status (MSFD GES): Report of the Technical Subgroup on Underwater noise and other forms of energy.

Vasconcelos, R.O., Amorin, M.C.P., Ladlich, F. (2007). Effects of ship noise on the detectability of communica-tion signals in the Lusitanian toadfish. Journal of Experimental Biology, 2007 210:2104-2112; doi:10.1242/jeb.0004317.

Wysocki, A., S., Ladich, L., E. (2004). Noise emission during the first powerboat race in an Alpine lake and potential impact on fish communities. J. Acoust. Soc. Am., 116: 3789–3797. Andersen, S. 1970. Auditory sensitivity of the harbour porpoise phocoena phocoena. In: Pilleri, G. (Ed) Investigations on cetacea, Vol II. Institute of Brain Anatomy, Bern, Switzerland, p 255-259.

6.2.4 #4 Promoting biocide-free anti-fouling paint and alternatives (research funding, financial support for pilots)

Assessment criteria	*Assessment results*
Description of policy option	For economic reasons, underwater ship parts must be kept relatively smooth in order to reduce drag resistance and thus minimise fuel consumption (Abbot et al., 2000; Champ, 2000). Anti-fouling paint is also used to reduce the transport of non-indiginous species. **Objectives** Promoting existing and researching new biocide-free paint. **Impacts to be curbed** Negative impacts from biocide paints should be decreased. **Design** Research grants are provided for the research and development of biocide-free paints. Existing biocide-paints are further researched, and also promoted by different authorities. **Technologies/implementation** Several more environmentally friendly options are commercially available. One example is foul-release coatings that form a non-stick surface on vessel hulls and makes it difficult for fouling organisms to attach. Other options are epoxy-based paints in combination with underwater cleaning. But research on biocide-free anti-fouling paint and alternative solutions is a challenging task and resource-intensive. **Existing examples** Numerous anti-fouling paints claim to be more friendly to the environment, compared to average anti-fouling paints. However, it is argued whether these paints can keep their promises in practice (Karlsson & Eklund, 2004).
Political implementability	**Which political/administrative scale is targeted by the policy option?** National, Baltic, EU, (best case but unlikely: global) **Do institutions need to be changed or new institutions established due to introduction of policy option?** Research institutions and local/national/international bodies that could promore biocide-free paints are in place. **Is the policy option flexible?** This policy option could be adapted to the different paints and standards. **Score from stakeholders (survey): very high (5)**
Acceptance & Feasibility	There are no specific barriers to this policy option. However, ship owners as well as private leisure boat owners are skeptical about the effectiveness of biocide-free antifouling paint. At the same time, stakeholders from policy and science might be skeptical to research the “perfect, effective but non-toxic paint”, which was not

6.2.4 #4 Promoting biocide-free anti-fouling paint and alternatives (research funding, financial support for pilots)

<table>
<tr><td></td><td>found yet – despite considerable efforts.
Ship owners:
- opposed to additional costs for different paints
- welcoming the provision of information
- welcoming long-term policy schemes to plan accordingly
NGOs:
- maybe opposing to increased threat through non-indigenous species (if there is one)
- welcoming all positive effects on biodiversity etc.
Coastal communities
- welcoming all positive effects on biodiversity etc.
Scoring based on stakeholder assessment (web survey)

Score from stakeholders (survey): high (4)</td></tr>
<tr><td>Scientific knowledge and uncertainty)</td><td>Measurement of Pressure
- Release of copper from paints is common scientific knowledge. Biocide-free paints are good to assess as substances are excluded.
Impact assessment
- A clear linkage between biocide-free coatings, underwater cleaning, etc. and a lower emission of copper can be seen. Negative effects of copper on aquatic ecosystems and human health is studied and relative sound. (e.g. Alkesh & Bharat, 2015; Solomon, 2009)
Socio-economic evaluation
The assessment of the socio-economic effects of avoided release of biocidal substances is challenging but feasible.

Score: very low uncertainties (5)</td></tr>
<tr><td>Technological and innovation potential</td><td>Besides the promotion of existing alternatives to non-biocidal paints, this policy is focused on research and development. Several more environmentally friendly options are commercially available, e.g. combination of epoxy-based paints in combination with underwater cleaning. However, there is still a high innovation potential.

Score: high (4)</td></tr>
<tr><td>Environmental and health outcomes</td><td>1) Effect on pressures:
<table>
<tr><th colspan="2">Pressure</th><th>Description of expected impact of option on pressures (Increase/Decrease/no effect, brief description if needed)</th></tr>
<tr><td rowspan="4">Emissions to air</td><td>CO_2</td><td><i>No effect</i></td></tr>
<tr><td>NO_X</td><td><i>No effect</i></td></tr>
<tr><td>SO_X</td><td><i>No effect</i></td></tr>
<tr><td>PM /BC</td><td><i>No effect</i></td></tr>
<tr><td>Em is- sio ns</td><td>Non-indigenous species</td><td><i>Slight negative effect (May increase)</i></td></tr>
</table></td></tr>
</table>

6.2.4 #4 Promoting biocide-free anti-fouling paint and alternatives (research funding, financial support for pilots)

	Contaminants to water	*Positive effect (Decrease of biocides, increase particles in the water, if ship hull washing will be released to the surrounding water)*
	Oil spills	*No effect*
Noise emissions	Underwater noise	*No effect*
Physical impacts	Anchoring, mooring and movement and ship wakes	*No effect*

2) Effects on human well being:

Human well being	**Ecosystem services**	**Description of effect on ecosystem services (positive, negative, no effect, e.g. with arrows)**
Commercial fishing	Cod, sprat, herring, salmon and seafood	*Positive effect, maybe negative effects due to non-indigenious species*
Recreational fishing	Cod, sprat, herring, salmon and seafood)	*Positive effect, maybe negative effects due to non-indigenious species*
Genetic resources	Genetic variation of species	*Positive effect, maybe negative effects due to non-indigenious species*
Climate change mitigation	Capacity of sea to absorb CO_2 (i.e. seagrass meadows)	*No effect*
Coastal protection	Capacity of sea to protect coastline, sediments, avoid erosion (i.e. seagrass meadows)	*No effect*
Tourism and recreation	Swimming, beach activities	*Positive effect, maybe negative effects due to non-indigenious species*
Other socio-cultural services	Heritage, inspiration, local and regional species	*Positive effect, maybe negative effects due to non-indigenious species*
Human health	Clean air	*No effect*

All ecosystem services are expected to be affected positive due to reduced emission of biocides. Maybe some ecosystem services are affected negatively by an increase of non-indigenious species.

Links to existing policies and their policy targets

- MSFD, GES descriptor 8 (Concentrations of contaminants give no effects)
- MSFD, GES descriptor 9 (Contaminants in seafood are below safe levels)

Impact assessment for policy option

6.2.4 #4 Promoting biocide-free anti-fouling paint and alternatives (research funding, financial support for pilots)

The following figure from the SHEBA project shows that almost all by ships emitted copper has it source in antifouling paints, as well as a major part of zinc.

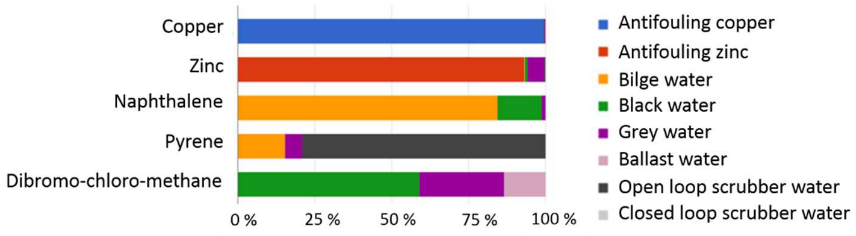


Figure: Distribution of the contaminants over the shipping emission sources. Source: Fridell et al., (2018).

In the SHEBA project calculated the copper load from shipping was estimated with approximately 280 tons copper released from antifouling paints coated on ships to the Baltic Sea annually (SHEBA, 2017). SHEBA scenario: No emission to water scenario has a Cu load of 276 ton in year 2030 as compared to BAU which during the same year has a Cu load of 309 ton. In the no emission to water scenario it is assumed that ships spending more than 50 percent of their time in the Baltic Sea don not use biocidal coatings. However, as most traffic in the Baltic Sea spend more than 50 % of their time outside of the Baltic Sea the reduction in copper load is not that high in the no emission to water scenario (SHEBA, 2017). The size of the areas for which the copper and zinc emissions from shipping lead to concentrations above the EQS values are estimated in SHEBA as well. The area where the EQS values for zinc are exceeded is small, only a few square kilometers. The area where the EQS values for copper is exceeded increase from 431 km^2 in 2012 to 526 km^2 in 2040 (in the BAU scenario). The *No emissions to water* scenario decrease the area to 379 km^2, but the scrubber scenarios do not show any effect compared to *BAU* 2040 (Fridell et al., 2018).

Score: medium effect (3) (if hull cleaning on biocide free coatings would be used)

Efficiency (Economic outcomes)

Transaction costs: low (promotion programme, regularly used instrument)

Investment costs:

The process of developing and testing new coating paints for ships is a long one, typically requiring from 5 to 8 years to reach the market, including the time needed to get a new biocide registered, e.g. with the EPA in the US. Furthermore, it can take biocide manufacturing companies as much as $5 million in testing before products can be industrialized by paint companies (Seidel, 2017).

Score costs: low costs (2) (if products are ready, low costs or almost no additional costs, but products need to be developed for large scale use)

Benefits:

“It is estimated that antifouling coatings provide the shipping industry with annual

6.2.4 #4 Promoting biocide-free anti-fouling paint and alternatives (research funding, financial support for pilots)

	fuel savings of $60 billion and reduced emissions of 384 million tonnes and 3.6 million tonnes, respectively for carbon dioxide and sulphur dioxide per annum" (Moura Bordado, 2014). This means that anti-fouling systems represent a benefit both for ship-owners in terms of (mostly) fuel consumption savings and for society since air emissions are decreased. AkzoNobel claims to have saved $3 billion on fuel and 32 million tons of CO_2 to shippers by using AkzoNobel's biocide-free marine coatings since their technology was introduced two decades ago. These numbers were calculated by comparing the fuel saving performance of their technology, called Intersleek, with each vessel's previous hull coating system. They estimated fuel cost at $300 per ton (Environmental Leader, 2017). Furthermore, they have partnered with Maersk Line to reduce carbon emissions per container shipped by 10%. There are research from private companies and public institutions that face the issue of biocide releasing types of fouling. There are promising products such as LEAF, FOUL-X-SPEL or an environmentally friendly coating developed by the University of Kiel and Phi-Stone AG, which won the Global Marine Technology Entrepreneurship Competition in 2017 (Kiel University, 2017). **Score: high efficiency (4)**
Distributional effects	*Ship owners:* Supports ship owners as pilot testing, with research funding, etc. leading to reduced costs (-) *Population*: No direct financial effects on population (0) **Score: very low distributional effect (5)**
Synergies and tradeoffs	**Pressures:** The option can have positive effects on water contaminants, especially reduction of biocides (1). Slight negative effects might be expected from non-indigenious species, if e.g. hull cleaning is not performed properly. **Human well being:** Positive effects are assessed for: Commercial fishing, recreational fishing, genetic resources (slight), tourism & recreation, other socio-cultural services (slight) (5). For all of them slight negative effects are assessed from non-indigenious species. **Score: minor synergies, conflicts (1)**

Summary

Having a non-fouled surface is vital for shipping to reduce fuel consumption and CO_2 emissions. The most commonly used method to prevent fouling on ships hulls is to coat the hull with antifouling paints that contain and leach biocides, such as copper oxide. This option aims to reduce the loads of biocides from antifouling coatings to the Baltic Sea by promoting biocide-free antifouling paint and other alternatives (e.g. hull cleaning). Several more environmentally friendly options are commercially available. One example is foul-release coatings that form a non-stick surface on vessel hulls and hinders organisms to attach. Other options are epoxy-based paints in combination with under-

6.2.4 #4 Promoting biocide-free anti-fouling paint and alternatives (research funding, financial support for pilots)

water cleaning. With this policy option, biocide free solutions, such as underwater cleaning, are promoted and research fundings of biocide free alternatives are provided. The promotion of biocide-free paints would be feasible at low costs and low resistance of stakeholder groups. However, this alternative has to be effective and cost-effective in order to be applied. This is not the case for all alternatives to biocidal paints. Hence, it is necessary to do further research on these alternatives.

Summary table

Summary: Policy option #4 Promoting biocide-free anti-fouling paint and alternatives			
Political implementability	5	Environmental and health outcomes	3
Acceptance & Feasibility	4	Efficiency	3
Scientific knowledge and uncertainty	5	Distributional effects	5
Technological and innovation potential	4	Synergies and tradeoffs	1
		Total score:	3,8
		Rank	1

References:

Abbot, A., Arnold, P.D.W., Milne, A (2000). Sci. Total Environ. 258, 5.Christen K. (1999). IMO will ban the use of a popular biocide. Environ Sci Technol. 1999 Jan 1;33(1). Available online at: https://pubs.acs.org/doi/pdfplus/10.1021/es992609%2B [14/05/2018]

Alkesh, S. I.; Bharat, V. M. (2015). Relative study of copper toxicity on aquatic life and human health. In: Journal of Environmental Research and Development. Vol. 9, No. 3A, Jan-March 2015.

Champ, M.A. (2000). Sci. Total Environ. 258, 21.

Department of Pesticide Regulation (DPR) (2015). List of copper-based antifoulants paints by leach rate category.

Environmental Leader (2017). AkzoNobel, Maersk Line Partner to Reduce Shipping Carbon Emissions. Available online at: https://www.environmentalleader.com/2017/03/akzonobel-maersk-line-partner-reduce-shipping-carbon-emissions/ [10/05/2018].

Fridell, E., Tröltzsch, J., Hasenheit, M., Jalkanen, J.-P., Matthias, V., Eriksson, M. (2018). Sustainable Shipping Scenario. SHEBA Deliverable 1.5. BONUS Research Project.

HELCOM (2011). The Fifth Baltic Sea Pollution Load Compilation (PLC-5) Balt. Sea Environ. Proc. No. 128

International Maritime Organization (IMO) (2002). Anti-fouling Systems.

International Maritime Organization (IMO) (2018). Anti-fouling systems. Available online at: http://www.imo.org/en/OurWork/Environment/Anti-foulingSystems/Pages/Default.aspx [13/05/2018]

6.2.4 #4 Promoting biocide-free anti-fouling paint and alternatives (research funding, financial support for pilots)

Karlsson, J., & Eklund, B. (2004). New biocide-free anti-fouling paints are toxic. Marine Pollution Bulletin, 49(5-6), 456-464.

Kiel University (2017). From the lab on to the ship: environmentally-friendly removal of biofouling. Available online at: http://www.uni-kiel.de/pressemeldungen/index.php?pmid=2017-383-biofouling&lang=en [13/05/2018]

Lagerström, M., J. F. Lindgren, A. Holmqvist, M. Dahlström, and E. Ytreberg. 2018. In situ release rates of Cu and Zn from commercial antifouling paints at different salinities. Marine Pollution Bulletin 127:289-296.

LEAF (2015). Project Final Report.

Moura Bordado, João Carlos (2014). FOUL-X-SPEL Project Final Report.

Natural Heritage Trust (2007). Antifouling performance standards for the Maritime industry. Australian government.

Sanchirico, J., A. Cochran & P. Merson (2002). Marine Protected Areas: Economic and Social Implications.

Seidel, James (2017). Regulations and Technology Change Antifouling Paints. Available online at: https://www.sailmagazine.com/diy/regulations-technology-change-antifouling-paints [12/05/2018].

SHEBA (2017): WP1 scenario development, Technial note.

Solomon, F. (2009). Impacts of Copper on Aquatic Ecosystems and Human Health. In: Mining.com, January 2009, 25-28.

The BoatYard’s (2015). Bottom Paint Recommendations – 2015.

Vishnoi, A. & Park, K. (2017). A New Coat of Paint Is Rocking the Global Shipping Industry. Available online at: https://www.bloomberg.com/news/features/2017-06-26/an-environmental-push-is-rocking-the-global-shipping-industry [12/05/2018].

WikiGreen (2016). Commercial shipping: 1 million tons of biocides released into oceans every year. Available online at: http://wikigreen.net/one-shipping-giant-can-release-10000-tons-of-biocides-into-oceans-every-year/ [12/05/2018].

Ytreberg, E., Lagerström M, Holmqvist, A., Eklund, B., Elwing, H., Dahlström, M., Dahl, P., Dahlström M. (2017). A novel XRF method to measure environmental release of copper and zinc from antifouling paints. Environmental Pollution 225:490-496.

6.2.5 #5 Reduced limits for biocidal release rate for anti-fouling paints

Assessment criteria	*Assessment results*
Description of policy option	The most commonly used method to prevent fouling on ships hulls is to coat the hull with antifouling paints that contain and leach biocides, such as copper oxide. Today, several water bodies in Baltic countries or the Baltic Sea itself have copper concentration exceeding the environmental quality standard (EQS) value. Hence, there is a need to develop, test and apply biocide-free paints. **Objectives** This option aims to reduce the loads of biocides from antifouling coatings by limiting the allowed release rates of biocides to the Baltic. This measure would promote the research of other non-biocidal technologies. **Impacts to be curbed** Negative impacts from harmful substances, especially copper, from anti-fouling paint are meant to be curbed. **Design** For existing paints leach rates have been already assessed (see below), further assessments might be necessary, in case they show a biocidal release rate above the set threshold (limit), they are banned after a certain period of transition. In order to approve new paints, they have to show biocidal release rates lower than the set threshold. **Technologies/implementation** The methods for determinging the release rate biocides from antifouling paints are: Ketchum method, ASTM/ISO standard method, US Navy/dome method and CEPE/mass-balance calculation method. Several environmentally friendly options are commercially available. One example is foul-release coatings that form a non-stick surface on vessel hulls and makes it difficult for fouling organisms to attach. Other options are epoxy-based paints in combination with underwater cleaning. But research on biocide-free anti-fouling paint and alternative solutions is a challenging task and resource-intensive.
Political implementability	This policy should be implemented at Baltic or EU level. Global level would be preferably, but this is unlikely to happen. At the same time, concensus about technologies and monitoring schemes has to be achieved. There is no need for new institutions, but existing institutions need more competences. Leach rates are already assessed and used for classification today. For example, the Department of Pesticide Regulation (DPR) from California (US) divides coatings into three categories: - Category I: Products with a leach rate below or equal to (≤) 9.5 µg/cm2/day - Category II: Products with a leach rate below or equal to (≤) 13.4 and above (>) 9.5 µg/cm2/day - Category III: Products with a leach rate above (>) 13.4 µg/cm2/day (DPR, 2015) The policy option is partly flexible, as the thresholds can be adapted. However, new potentially critical substances are not covered by this policy by default.

6.2.5 #5 Reduced limits for biocidal release rate for anti-fouling paints

Score from stakeholders (survey): high (4)

Acceptance & Feasibility

There is a wide consensus between the stakeholders that the release of anti-fouling paint need to be limited. However, currently the approach used the most is banning certain substances, such as tributylin (TBT) by the IMO (IMO, 2002; IMO, 2018). In terms of reducing the limits of biocidal rate, an intense discussion about the best way to assess the biocidal release rate, the selection of substances being monitored and ways to monitor would be expected.

Ship owners:
- opposed to additional costs
- welcoming this policy as a policy frame
- welcoming that the policy is open with regards to the technology being used to achieve a low biocidal release rate

NGOs:
- Criticizing that no total ban is aimed for (e.g. by cleaning hulls with underwater robots)
- welcoming this policy as an important step to curb the release of environmentally harmful substances

Coastal communities
- welcoming lower concentration of harmful substances
- opposed to additional costs for local ship owners

Score from stakeholders (survey): low (2)

Scientific knowledge and uncertainty

Despite the methodological challenges: Assessing the biocidal release rate for different anti-fouling paints is feasible. However, the sedimentation of the harmful substances pose additional challenges when trying to link release rates with the substances concentration. In addition, the links between concentrations of harmful substances and their quantitatve impacts on human well-being (including ecosystem services and human health) are not conclusively clarified yet.

Score: low (2)

Technological and innovation potential

This policy option is indirectly promoting innovative technologies, since anti-fouling paints that do not meet the requirements are restricted, new innovative paints that do, have a comparative economic advantage. Several more environmentally friendly options are commercially available, e.g. combination of epoxy-based paints in combination with underwater cleaning. However, there is still a high innovation potential.

Score: high (4)

Environmental and health outcomes

1) **Effects on pressures:**

Pressure		Expected impact
Emissions to air	CO_2	*No effect*
	NO_X	*No effect*
	SO_X	*No effect*

	PM /BC	*No effect*
Emissions to water	Non-indigenous species	*Slight negative effect (may increase)*
	Contaminants to water	*Positive effect (Decrease of biocides, increase particles in the water, if ship hull washing will be released to the surrounding water)*
	Oil spills	*No effect*
Noise emissions	Underwater noise	*No effect*
Physical impacts	Anchoring, mooring and movement and ship wakes	*No effect*

2) Effects on human well being:

Human well being	**Ecosystem services**	**Effects on human well being**
Commercial fishing	Cod, sprat, herring, salmon and seafood	*Positive effect (due to biocides, indigenious species)*
Recreational fishing	Cod, sprat, herring, salmon and seafood)	*Positive effect (due to biocides, indigenious species)*
Genetic resources	Genetic variation of species	*Positive effect (due to biocides, indigenious species)*
Climate change mitigation	Capacity of sea to absorb CO_2 (i.e. seagrass meadows)	*No effect*
Coastal protection	Capacity of sea to protect coastline, sediments, avoid erosion (i.e. seagrass meadows)	*No effect*
Tourism and recreation	Swimming, beach activities	*Positive effect (due to biocides, indigenious species)*
Other socio-cultural services	Heritage, inspiration, local and regional species	*Positive effect (due to biocides, indigenious species)*
Human health	Clean air	*No effect*

In the SHEBA project, the release rate data from almost 200 commercially available antifouling coatings were assessed (Eriksson et al., 2017). Internationally, the average release rate of copper is 24.5 µg/cm/d. In recent studies by Ytreberg et al (2017) and Lagerström et al (2018) both the efficacy of different coatings to prevent biofouling in the Baltic Sea as well as their biocidal release rate were assessed. The results showed that coatings with release rates as low as 2.1 µg/cm/d prevented macrofouling. Also the EU BONUS CHANGE project (Lagerström et. al., 2018; Ytreberg et al., 2017) has investigated what release rates of copper that are necessary to prevent biofouling. Measures limiting the copper influx, such reducing the

6.2.5 #5 Reduced limits for biocidal release rate for anti-fouling paints

	limits for biocidal release rate, are expected to have positive impacts on the ecosystem services and indirectly on human health (since the concentrations of harmful substances in fish would be lower). There could be a slightly negative impact on ecosystem services, due to a higher spread and influx of non-indigenous species – this is highly linked to the question which solution is chosen to remain under the introduced limits for biocidal release rates. **Links to existing policies and their policy targets** - MSFD, GES descriptor 8 (Concentrations of contaminants give no effects) - MSFD, GES descriptor 9 (Contaminants in seafood are below safe levels) - Antifouling paints are in EU regulated via the Biocidal Products Regulation (*BPR*, Regulation (EU) 528/2012). **Impact assessment of policy option** The effects of anti-fouling paint are significant. Waterborne copper input to the Baltic Sea, exluding copper input from antifouling paints are estimated to be 886 tons per year (HELCOM, 2011). In the SHEBA project it is estimated that approximately 280 tons copper being emitted from antifouling paints to the Baltic Sea annually (SHEBA, 2017). More information on relevance of copper and zinc from antifouling paints and possible reduction, can be found in chapter on policy option: *#4 Promoting biocide-free anti-fouling paint and alternatives (research funding, financial support for pilots).* **Score: high effect (5)**
Efficiency (Economic)	**Transaction costs** Transaction costs are limited. Responsible public authorities are in place. Categorization scheme of paints are available. **Investment and maintenance costs** There is no major investment in new equipment required when changing anti-fouling paints, so the main cost would be the price difference between products. For recreational vessels, the approximate retail price for the less-harmful paints range from \$285 - \$315/gal compared to about \$220/gal for traditional copper bottom paint, based on the DPR categories (The BoatYard's, 2015). More relevant information can be found in chapter on policy option: *#4 Promoting biocide-free anti-fouling paint and alternatives (research funding, financial support for pilots).* **Score: low costs (2)** **Benefits** Sanchirico et al. (2002) claimed that a precise calculation of the costs and benefits from Marine Protected Areas in dollar terms is not feasible. Still, the benefits perceived from banning TBT have been reflected on the preservation of marine life. After measures to ban TBT used on yatchs and other small vessels were taken in France, England and the US during the 1980s, dramatic recovery of marine life was

6.2.5 #5 Reduced limits for biocidal release rate for anti-fouling paints

	perceived: "The incidence of imposex [the tendency of marine snails to develop masculine characteristics] has decreased, the abundance of dogwhelks [a common marine snail] has increased and the levels of TBT in tissues has down in these animals" (Christen, 1999). Those are the kind of benefits expected when prohibiting harmful chemicals on fouling paints. Anti-fouling systems have many benefits: direct fuel savings by keeping ships' hull clean of fouling organisms; extends dry-lock interval, when anti-fouling systems provide several years of use; increase vessel availability since it does not have to spend too much time in dry lock (IMO, 2002). There is no question that their use is necessary, although the release rate of biocidals should be limited in order to decrease their environmental negative impact. More relevant information can be found in chapter on policy option: *#4 Promoting biocide-free anti-fouling paint and alternatives (research funding, financial support for pilots).* **Score: high efficiency (4)**
Distributional effects	Many IMO delegates argue that the "polluter pays" principle should apply, which would mean the shipping industry should pay the cost of not contaminating the marine environment. In any case, in the long run "any costs are likely to be passed on to the consumer", (IMO, 2002). However, these effects would be neglible. **Score: low distributional effects (4)**
Synergies and tradeoffs	**Pressures:** The option can have positive effects on water contaminants, especially reduction of biocides. Slight positive effects might be expected from non-indigenious species. (2) **Human well-being:** Positive effects are assessed for commercial fishing, recreational fishing, genetic resources (slight), tourism & recreation, other socio-cultural services (slight) (5). **Score: no synergies, no conflicts (3)**

Summary

Biocidal components of anti-fouling paints pose a significant threat to ecosystem services and indirectly to human health. Hence, reducing its release would have a direct positive impact. Apparently; the most feasible way to limit the biocidal release of anti-fouling paints today is through the banning of certain chemicals or products. It has not been addressed by any organization yet to measure and control biocidal release in real time. A serious certification and auditing process of applicators could be a strong measure to limit biocidal emission rate as well. The by far major source for copper and zinc emitted by ships are antifouling paints. There are options that lead to low biocidal release rate – down to zero (e.g. by using hull cleaning robots). These options are comparably cost intensive. Hence, new, more cost-effective, options would be needed. However, a significant (10 fold) reduction of copper release can also be achieved by specific paints, without compromising the efficiency of macrofouling. Additionally, current industry practices in the application of paint also play a major role. The release rate of biocidal compounds could be limited by addressing these deficiencies, since it is “the principal” reason why antifouling paints fail to achieve their potential service life (Natural Heritage Trust, 2007). Compared to #4 Promoting biocide-free anti-fouling paint and alternatives (research funding, financial support for pilots) and #6 Guidance on integration of antifouling paints in river basin management plans (RBMPs) and national marine strategies, this policy is a rather strong measure. By upgrading industry standards and defining good practices and auditing/certificating applicators could play an important part in order to reduce biocidal release, which would entail significant public investment.

Summary table

Summary: Policy option #5: Reduced limits for biocidal release rate of organic biocides for anti-fouling coatings of ships (anti-fouling paints)			
Political implementability	4	Environmental and health outcomes	5
Acceptance & Feasibility	2	Efficiency	4
Scientific knowledge and uncertainty	2	Distributional effects	4
Technological and innovation potential	4	Synergies and tradeoffs	3
		Total score:	3,5
		Rank	8

References:

Christen K. (1999). IMO will ban the use of a popular biocide. Environ Sci Technol. 1999 Jan 1;33(1). Available online at: https://pubs.acs.org/doi/pdfplus/10.1021/es992609%2B [14/05/2018]

Department of Pesticide Regulation (DPR). (2015). List of copper-based antifoulants paints by leach rate category.

Environmental Leader. (2017). AkzoNobel, Maersk Line Partner to Reduce Shipping Carbon Emissions. Available online at: https://www.environmentalleader.com/2017/03/akzonobel-maersk-line-partner-reduce-shipping-carbon-emissions/ [10/05/2018].

HELCOM (2011). The Fifth Baltic Sea Pollution Load Compilation (PLC-5) Balt. Sea Environ. Proc. No. 128

International Maritime Organization (IMO). (2002). Anti-fouling Systems. http://www.imo.org/en/OurWork/Environment/Anti-foulingSystems/Documents/FOULING2003.pdf [10/05/2018].

International Maritime Organization (IMO) (2018). Anti-fouling systems. Available online at: http://www.imo.org/en/OurWork/Environment/Anti-foulingSystems/Pages/Default.aspx [13/05/2018]

Kiel University (2017). From the lab on to the ship: environmentally-friendly removal of biofouling. Available online at: http://www.uni-kiel.de/pressemeldungen/index.php?pmid=2017-383-

6.2.5 #5 Reduced limits for biocidal release rate for anti-fouling paints

biofouling&lang=en [13/05/2018]

Lagerström, M., J. F. Lindgren, A. Holmqvist, M. Dahlström, and E. Ytreberg (2018). In situ release rates of Cu and Zn from com-mercial antifouling paints at different salinities. Marine Pollution Bulletin 127:289-296.

LEAF (2015). Project Final Report.

Moura Bordado, João Carlos (2014). FOUL-X-SPEL Project Final Report.

Natural Heritage Trust (2007). Antifouling performance standards for the Maritime industry. Australian government.

Sanchirico, J., A. Cochran & P. Merson (2002). Marine Protected Areas: Economic and Social Implications.

Eriksson, M., Jalkanen, J.-P., Magnusson, K., Ytreberg, E., Granhag, L. (2017): Water pollution inventory and load factors, SHEBA deliverable 3.3.

Seidel, James (2017). Regulations and Technology Change Antifouling Paints. Available online at: https://www.sailmagazine.com/diy/regulations-technology-change-antifouling-paints [12/05/2018].

SHEBA (2017): WP1 scenario development, Technial note.

The BoatYard’s (2015). Bottom Paint Recommendations – 2015.

Vishnoi, A. & Park, K. (2017). A New Coat of Paint Is Rocking the Global Shipping Industry. Available online at: https://www.bloomberg.com/news/features/2017-06-26/an-environmental-push-is-rocking-the-global-shipping-industry [12/05/2018].

WikiGreen (2016). Commercial shipping: 1 million tons of biocides released into oceans every year. Available online at: http://wikigreen.net/one-shipping-giant-can-release-10000-tons-of-biocides-into-oceans-every-year/ [12/05/2018].

Ytreberg, E., Lagerström M, Holmqvist, A., Eklund, B., Elwing, H., Dahlström, M., Dahl, P., Dahlström M. (2017). A novel XRF method to measure environmental release of copper and zinc from antifouling paints. Environmental Pollution 225:490-496.

6.2.6 #6 Guidance on integration of antifouling paints in river basin management plans (RBMPs) and national marine strategies

Assessment criteria	*Assessment results*
Description of policy option	The most commonly used method to prevent fouling on ships hulls is to coat the hull with antifouling paints that contain and leach biocides, such as copper oxide. Preventing fouling is necessary to reduce drag resistance and thus minimise fuel consumption (Abbot et al., 2000; Champ, 2000). **Objectives** Adressing biocidal release in river basin management plans (RBMPs). **Impacts to be curbed** The biocidal release reate and respective negative impacts especially of copper should be curbed. **Design** RBMPs and national marine strategies should include stricter limits on biocidal release rates of paints or require biocidal-free paints. **Technologies/implementation** Several more environmentally friendly options are commercially available. One example is foul-release coatings that form a non-stick surface on vessel hulls and makes it difficult for fouling organisms to attach. Other options are epoxy-based paints in combination with underwater cleaning. But research on biocide-free antifouling paint and alternative solutions is a challenging task and resource-intensive. **Existing examples** Gibraltar River Basin Management Plan 2015–2021 (mainly TBT)[7]
Political implementability	**Which political/administrative scale is targeted by the policy option?** The guidelines could be prepared on EU level (European Commission) or the Baltic level (HELCOM). **Do institutions need to be changed or new institutions established due to introduction of policy option?** No additional institutions are necessary. **Is the policy option flexible?** Limits and standards can be changed only when the respective RBMP or national marine strategy is amended. **Score from stakeholders (survey): high (4)**

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[7] https://www.gibraltar.gov.gi/new/sites/default/files/HMGoG_Documents/Gibraltar_River_Basin_Management_Plan_Public_Consultation_Main_Report.pdf

6.2.6 #6 Guidance on integration of antifouling paints in river basin management plans (RBMPs) and national marine strategies

<table>
<tr><td>Acceptance & Feasibility</td><td>There is a wide consensus between the stakeholders that the release of anti-fouling paint need to be limited. However, currently the approach used the most is banning certain substances, such as tributylin (TBT) by the IMO (IMO, 2002; IMO, 2018). In terms of reducing the limits of biocidal rate, an intense discussion about the best way to assess the biocidal release rate, the selection of substances being monitored and ways to monitor would be to be expected.
Ship owners:
- opposed to additional costs
- welcoming this policy as a policy frame
- welcoming that the policy is open with regards to the technology being used to achieve a low biocidal release rate
NGOs:
- Criticizing that soft approach is used and no total ban is aimed for (e.g. by cleaning hulls with underwater robots etc.)
- welcoming any action to curb the release of environmentally harmful substances
Coastal communities
- welcoming lower concentration of harmful substances
- opposed to additional costs for local ship owners
Score from stakeholders (survey): medium (3)</td></tr>
<tr><td>Scientific knowledge and uncertainty</td><td>A clear linkage between biocide-free coatings, underwater cleaning, etc. and a lower emission of copper can be seen. Negative effects of copper on aquatic ecosystems and human health is studied and relative sound (e.g. Alkesh & Bharat, 2015; Solomon, 2009). However, the sedimentation of the harmful substances pose additional challenges when trying to link release rates with the substances concentration. In addition, the links between concentrations of harmful substances and their quantitative impacts on human well-being (including ecosystem services and human health) are not conclusively clarified yet.
Score: low (2)</td></tr>
<tr><td>Technological and innovation potential</td><td>This policy option is indirectly promoting innovative technologies, since anti-fouling paints that do not meet the requirements of the adjusted RBMPs or national marine strategies will not be used anymore. New innovative paints that do, have a comparative economic advantage.
Score: high (4)</td></tr>
<tr><td>Environmental and</td><td>1) Effect on pressures:
<table>
<tr><th>Pressure</th><th>Description of expected impact of option on pressures (Increase/Decrease/no effect, brief description if needed)</th></tr>
</table>
</td></tr>
</table>

6.2.6 #6 Guidance on integration of antifouling paints in river basin management plans (RBMPs) and national marine strategies

health outcomes	**Emissions to air**	CO_2	*No effect*
		NO_X	*No effect*
		SO_X	*No effect*
		PM /BC	*No effect*
	Emissions to water	Non-indigenous species	*Slight negative effect (may increase)*
		Contaminants to water	*Positive effect (Decrease of biocides, increase particles in the water, if ship hull washing will be released to the surrounding water)*
		Oil spills	*No effect*
	Noise emissions	Underwater noise	*No effect*
	Physical impacts	Anchoring, mooring and movement and ship wakes	*No effect*

2) Effect on human well being:

Human well being	Ecosystem services	Description of effect on ecosystem services (positive, negative, no effect, e.g. with arrows)
Commercial fishing	Cod, sprat, herring, salmon and seafood	*Positive effect (due to biocides, indigenious species)*
Recreational fishing	Cod, sprat, herring, salmon and seafood)	*Positive effect (due to biocides, indigenious species)*
Genetic resources	Genetic variation of species	*Positive effect (due to biocides, indigenious species)*
Climate change mitigation	Capacity of sea to absorb CO_2 (i.e. seagrass meadows)	*No effect*
Coastal protection	Capacity of sea to protect coastline, sediments, avoid erosion (i.e. seagrass meadows)	*No effect*
Tourism and recreation	Swimming, beach activities	*Positive effect (due to biocides, indigenious species)*
Other socio-cultural services	Heritage, inspiration, local and regional species	*Positive effect (due to biocides, indigenious species)*
Human health	Clean air	*No effect*

In the SHEBA project, the release rate data from almost 200 commercially available antifouling coatings were assessed (Eriksson et al., 2017). Internationally, the average release rate of copper is 24.5 µg/cm/d. In recent studies by Ytreberg et al.

6.2.6 #6 Guidance on integration of antifouling paints in river basin management plans (RBMPs) and national marine strategies

	(2017) and Lagerström et al. (2018) both the efficacy of different coatings to prevent biofouling in the Baltic Sea as well as their biocidal release rate were assessed. The results showed that coatings with release rates as low as 2.1 µg/cm/d prevented macrofouling. The EU BONUS CHANGE project (Lagerström et. al., 2018; Ytreberg et al., 2017) has also investigated what release rates of copper are necessary to prevent biofouling. The effects of anti-fouling paint are significant. Waterborne copper input to the Baltic Sea, exluding copper input from antifouling paints are estimated to be 886 tons per year (HELCOM, 2011). Additionally, to this influx, there are approximately 280 tons copper being emitted from antifouling paints to the Baltic Sea annually (SHEBA, 2017). Measures limiting this influx, such reducing the limits for biocidal release rate, are expected to have positive impacts on the ecosystem services and indirectly on human health (since the concentrations of harmful substances in fish would be lower). There could be a slightly negative impact on ecosystem services, due to a higher spread and influx of non-indigenous species – this is highly linked to the question which solution is chosen to remain under the introduced limits for biocidal release rates. **Links to existing policies and their policy targets** - MSFD, GES descriptor 8 (Concentrations of contaminants give no effects) - MSFD, GES descriptor 9 (Contaminants in seafood are below safe levels) - Antifouling paints are in EU regulated via the Biocidal Products Regulation (*BPR*, Regulation (EU) 528/2012). **Score: high effect (4)**
Efficiency (Economic outcomes))	**Transaction costs:** costs for preparation of guidance is limited, resources needed for integration in RBMPs, but would be linked to regular review/update process – additional costs limited, monitoring mechanisms via WFD already in place **Investment and maintenance costs:** additional costs for recreational boats: For recreational vessels, the approximate retail price for the less-harmful paints range from $285 - $315/gal compared to about $220/gal for traditional copper bottom paint, based on the DPR categories (The BoatYard's, 2015). More relevant information can be found in chapter on policy option: *#4 Promoting biocide-free anti-fouling paint and alternatives (research funding, financial support for pilots).* **Score costs: low costs (2)** **Benefits:** Sanchirico et al. (2002) claimed that a precise calculation of the costs and benefits from Marine Protected Areas in dollar terms is not feasible. Still, the benefits perceived from banning TBT have been reflected on the preservation of marine life. After measures to ban TBT used on yatchs and other small vessels were taken in France, England and the US during the 1980s, dramatic recovery of marine life was

6.2.6 #6 Guidance on integration of antifouling paints in river basin management plans (RBMPs) and national marine strategies

	perceived: “"The incidence of imposex [the tendency of marine snails to develop masculine characteristics] has decreased, the abundance of dogwhelks [a common marine snail] has increased and the levels of TBT in tissues has down in these animals" (Christen, 1999). Those are the kind of benefits expected when prohibiting harmful chemicals on fouling paints. More relevant information can be found in chapter on policy option: *#4 Promoting biocide-free anti-fouling paint and alternatives (research funding, financial support for pilots).* **Score: high efficiency (4)**
Distributional effects	Many delegates argue that the “polluter pays” principle should apply, which would mean the shipping industry should pay the cost of not contaminating the marine environment. In any case, in the long run “any costs are likely to be passed on to the consumer”, (IMO, 2002). However, these effects would be neglible. **Score: low distributional effects (4)**
Synergies and tradeoffs	**Pressures:** The option can have positive effects on water contaminants, especially reduction of biocides. Slight negative effects might be expected from non-indigenious species. (1) **Human well being:** Positive effects are assessed for: Commercial fishing, recreational fishing, genetic resources (slight), tourism & recreation, other socio-cultural services (slight) (5). **Score: minor synergies, minor conflicts (3)**

Summary

Biocidal components of anti-fouling paints pose a significant threat to ecosystem services and indirectly to human health. Hence, reducing its release would have a direct positive impact. Apparently; the most feasible way to limit the biocidal release of anti-fouling paints today is through the banning of certain chemicals or products. Another effective way to reduce the release of biocidal substances is to reduce respective limits (#5 Reduced limits for biocidal release rate for anti-fouling paints). If reducing limits on a Baltic level is not feasible, including antifouling paint issues in river basin management plans (RBMPs) and/or national marine strategies is potentially suitable to address that challenge effectively. The large advantage is that regulations and processes are already in place. An adjustment could be implemented within the regular review cycles of the RBMPs. This measure requires individual EU countries or institutions to be ‘pioneers’. Such integration could be the result of or be aligned with #4 Promoting biocide-free anti-fouling paint and alternatives (research funding, financial support for pilots).

6.2.6 #6 Guidance on integration of antifouling paints in river basin management plans (RBMPs) and national marine strategies

Summary table

Summary: Policy option #6 Guidance on integration of antifouling paints in river basin management plans (RBMPs) and national marine strategies			
Political implementability	4	Environmental and health outcomes	4
Acceptance & Feasibility	3	Efficiency	4
Scientific knowledge and uncertainty	2	Distributional effects	4
Technological and innovation potential	4	Synergies and tradeoffs	3
		Total score:	3,5
		Rank	9

References:

Abbot, A., Arnold, P.D.W., Milne, A. (2000). Cost-benefit analysis of the use of TBT: The case for a treatment approach. Science of the total environment. 258, 5-19.

Alkesh, S., Bharat M., V. (2015). Relative study of copper toxicity on aquatic life and human health. Journal of Environmental Research And Development Vol. 9 No. 3A, January-March 2015.

Champ, M.A. (2000). A review of organotin regulatory strategies, pending actions, related costs and benefits. Science of the total environment. 258, 21-71.

Christen K. (1999). IMO will ban the use of a popular biocide. Environ Sci Technol. 1999 Jan 1;33(1). Available online at: https://pubs.acs.org/doi/pdfplus/10.1021/es992609%2B [14/05/2018]

Eriksson, M., Jalkanen, J.-P., Magnusson, K., Ytreberg, E., Granhag, L. (2017): Water pollution inventory and load factors, SHEBA deliverable 3.3.

HELCOM (2011). The Fifth Baltic Sea Pollution Load Compilation (PLC-5) Balt. Sea Environ. Proc. No. 128

International Maritime Organization (IMO). (2002). Anti-fouling Systems. http://www.imo.org/en/OurWork/Environment/Anti-foulingSystems/Documents/FOULING2003.pdf [10/05/2018].

International Maritime Organization (IMO) (2018). Anti-fouling systems. Available online at: http://www.imo.org/en/OurWork/Environment/Anti-foulingSystems/Pages/Default.aspx [13/05/2018]

Lagerström, M., J. F. Lindgren, A. Holmqvist, M. Dahlström, and E. Ytreberg (2018). In situ release rates of Cu and Zn from com-mercial antifouling paints at different salinities. Marine Pollution Bulletin 127:289-296.

Sanchirico, J., A. Cochran & P. Merson (2002). Marine Protected Areas: Economic and Social

6.2.6 #6 Guidance on integration of antifouling paints in river basin management plans (RBMPs) and national marine strategies

Implications.

SHEBA (2017): WP1 scenario development, Technial note.

Solomon, F. (2009). Impacts of Copper on Aquatic Ecosystems and Human Health. MINING.com, January 2009.

The BoatYard's (2015). Bottom Paint Recommendations – 2015.

Ytreberg, E., Lagerström M, Holmqvist, A., Eklund, B., Elwing, H., Dahlström, M., Dahl, P., Dahlström M. (2017). A novel XRF method to measure environmental release of copper and zinc from antifouling paints. Environmental Pollution 225:490-496.

6.2.7 #7 Stricter regulation on scrubber water

Assessment criteria	*Assessment results*
Description of policy option	Scrubbers are used to reduce primarily sulphur emissions to air from shipping. Depending on the used systems (open-/closed scrubbers) the scrubber water including resulting pollutants, eutrophying and acidifying substances, is emitted to the Baltic Sea (open-loop scrubber). Closed loop and hybrid scrubbers, with the ability to switch between open and closed loop, can collect the washwater onboard for treatment in port, however a minor fraction of the washwater may be continuously discharged, so called bleed off. Studies show that annual averages on pollutants concentrations are below current environmental quality standards (EQS) for marine waters, but taking into account seasonal changes in hydrographic conditions effects are probably (Hassellöv et al., 2013). Furthermore, cumulative effects have not been assessed and in ports levels can slightly exceed EQS depending on local conditions (Kjølholt et al., 2012). While there are regulations for atmospheric emission of SOx, there are no mandatory regulations concerning the properties of the scrubber water (Turner et al., 2018). Based on the precautionary principle, scrubbers with minimal emission to water (dry, closed wet scrubbers) should be used and resulting pollutants in scrubber water should be stricter regulated to avoid impact on aquatic ecosystems (Lange et al., 2014). **Objectives** To reduce the release of pollutants via scrubber water. **Impacts to be curbed** Negative impacts on the marine environment via scrubber water shall be avoided. **Design** The release of scrubber water is strictly limited or prohibited. **Technologies/implementation** Implementation is possible via existing closed-loop scrubbers (especially in zero discharge mode). The discharge infrastructure in harbours needs to be established. Furthermore, a fuel change to low sulphur fuels is possible. **Existing examples** There are guidelines for scrubber water discharge, stating that the seawater pH at 4 m from the discharge point should not be less than 6.5 (HELCOM, 2016).
Political implementability	“Taking into account the international character of shipping and in order to avoid the creation of economic disadvantages on the global market for national port locations, international regulations are always preferable to those at European, national and local levels. To avoid competitive disadvantages a large-scale adoption of the

6.2.7 #7 Stricter regulation on scrubber water	
	same rules is the most desirable. To achieve this, ports should seek economic interaction at the international level and look to strengthen cooperation within the marine conventions OSPAR, HELCOM and Trilateral Wadden Sea Cooperation (TWC)" (Lange et al., 2014). **Do institutions need to be changed or new institutions established due to introduction of policy option? Is the policy option flexible?** There is no need for new institutions, but some procedures have to be developed or adapted (e.g. for monitoring). This policy option is flexible, since limits and standards can be adapted. **Score from stakeholders (survey): very high (5)**
Acceptance & Feasibility	**Ship owners:** - opposed to additional costs **-** welcoming long-term policy schemes **NGOs:** **-** welcoming the reduction of acidific substances - encouraging strict limits **Coastal communities** - welcoming the reduction of acidific substances **Score from stakeholders (survey): medium (3)**
Scientific knowledge and uncertainty	**Measurement of Pressure / impact assessment / socio-economic evaluation** The pollutant concentration in scrubber water has been analysed as well as impacts on current environmental quality standards (EQS) for marine waters (Kjølholt et al., 2012). "The knowledge about the environmental impact of scrubbers and scrubber effluents is still insufficient. The reviewed assessments found no consistent account of the composition of washwater constituents. There are questions which remain unanswered" (Lange et al., 2014). Nevertheless, there is increasing evidence from recent studies and analyses that the wash-water contains poly-aromatic hydrocarbons (PAH) and heavy metals in larger quantities than initially thought. The discharge of pollutants from open loop scrubbers could lead to potential negative long term impacts especially on coastal waters. Germany has prohibited scrubber washwater discharges in inland rivers and certain ports, including the Kiel Canal. Belgium has prevented discharging within three nautical miles off its coast (den Boer & 't Hoen, 2015; European Commission, 2016). Therefore, it can be assumed that stricter scrubber regulation with less discharge of hazardous substances into marine environment would lead to less degradation of marine environment. **Score*:* low uncertainties (4)**

6.2.7 #7 Stricter regulation on scrubber water

Technological and innovation potential

There is a high innovation potential, since ship owners would require new technologies, which need to be (further) developed, especially for feasible systems with zero discharge mode also usable for medium to long distance traffic and as well investments in fuel change to low sulphur fuels (e.g. MGO, LNG).

Score: high innovation potential (4)

Environmental and health outcomes

1) Effects on pressures:

Pressure		**Description of expected impact of option on pressures (Increase/Decrease/no effect, brief description if needed)**
Emissions to air	CO_2	*Positive effect (increased uptake of CO_2, if acidification is low)*
	NO_X	*No effect*
	SO_X	*No effect*
	PM /BC	*Not enough data available to conclude*
Emissions to water	Non-indigenous species	*No effect*
	Contaminants to water	*Positive effect (Decrease of copper, nutrients, and acidification, decrase of particles, including BC (Black Carbon) in the water)*
	Oil spills	*No effect*
Noise emissions	Underwater noise	*No effect*
Physical impacts	Anchoring, mooring and movement and ship wakes	*No effect*

2) Effects on human well being:

Human well being	**Ecosystem services**	**Description of effect on ecosystem services (positive, negative, no effect, e.g. with arrows)**
Commercial fishing	Cod, sprat, herring, salmon and seafood	*Positive effect, reduced acidification, eutrophication and contaminants affecting water quality and indirectly affecting fish stocks, food web and biodiversity*
Recreational fishing	Cod, sprat, herring, salmon and seafood)	*Positive effect, reduced acidification, eutrophication and contaminants affecting water quality and indirectly affecting fish stocks, food web and biodiversity*
Genetic resources	Genetic variation of species	*Slight positive effect*

6.2.7 #7 Stricter regulation on scrubber water

Climate change mitigation	Capacity of sea to absorb CO_2 (i.e. seagrass meadows)	*No effect*
Coastal protection	Capacity of sea to protect coastline, sediments, avoid erosion (i.e. seagrass meadows)	*No effect*
Tourism and recreation	Swimming, beach activities	*Positive effect*
Other socio-cultural services	Heritage, inspiration, local and regional species	*Positive effect*
Human health	Clean air	*No effect*

All ecosystem services are expected to be affected positive due to reduced emission of copper, nutrients and less acidification - especially those which are locates closely to shipping lanes (since pressures by scrubbing water are concentrated here (Turner et al., 2018). Also with a decreasing deposition of strong acids an increasing CO_2 uptake can be expected (due to increased pH and alkalinity) (Turner et al., 2018)

Links to existing policies and their policy targets

- MSFD, GES descriptor 7 (Permanent alteration of hydrographical conditions does not adversely affect the ecosystem)
- MSFD, GES descriptor 8 (Concentrations of contaminants give no effects)
- MSFD, GES descriptor 9 (Contaminants in seafood are below safe levels)

Impact assessment for policy option

The data from scrubbers are variable, i.e. the uncertainties are large, but using the figures from IMO Gesamp (Marine Environment Protection Committee, 2008) and the calculations in SHEBA (2017) for a BAU-scenario for the year 2030 with only open loop scrubbers would result in a tenfold increase in copper release from scrubbers; 52 tons per year, whereas use of only closed loop scrubbers would result in a decrease from 5 (BAU 2030) to below 2 tons copper per year.

Score: high positive effects (4) (not the single largest source of copper to the Baltic Sea, but could have severe effects on regional/local level (e.g. coastal areas and portals) in case of large scale use of scrubbers)

Efficiency (Economic outcomes)

Transaction costs:

If the enacted policy would dictate the prohibition of any effluent emission from scrubbers, the transaction costs will consist on the establishment, monitoring and reporting of the installed equipment and its proper functionality. Accountability of proper waste management of scrubber water effluent would add considerable costs to both the overviewing authorities and the ship-owners.

Investment and maintenance costs

Costs for closed loop scrubbers are higher than open loop scrubbers. Installation costs for closed loop scrubbers can reach 350-400 €/per installed KW, compared to

6.2.7 #7 Stricter regulation on scrubber water

	150-200 €/per installed KW for open loop systems. Higher maintenance costs including costs for disposal are expected as well (den Boer & 't Hoen, 2015). If regulation prohibits the utilization of open loop systems, additional costs of investments on closed systems will be followed by variable maintenance costs from collection, transportation and possible treatment of the waste dependent on the availability of waste treatment services. These additional costs are expected to be absorbed by the private sector (Kjølholt et al., 2012). A study by TRAFI shows, that investment costs for complying with the revised MARPOL Annex VI and the new EU Sulphur Directive would be lower for ships using MGO (low sulphur fuel) compared to a ships using HFO and the installation of closed loop scrubbers. Maintenance costs per year are estimated higher for MGO fuelled ships (Bácher & Albrecht, 2013). **Scoring costs: medium costs (3)** **Benefits:** As described by the projections of (Gallego-urrea et al., 2018) slugger water discharge from open-loop systems are expected to highly contribute to the eutrophication of the Baltic sea. Therefore, strict regulations that overview both atmospheric emissions and liquid effluents are necessary to manage the adequate implementation of scrubber technology as a cost efficient solution for reducing the environmental impact of the shipping industry. **Score: medium efficiency (3)**
Distributional effects	Ship owners: Additional costs for installation and maintenance. In comparison to Population, there are no direct financial effect, indirect: very slight increase of shipped goods (not significant) **Score: medium distributional effect (3)**
Synergies and tradeoffs	**Pressures:** The option can have positive effects on water contaminants, especially reduction of copper and nutrients. (1) No negative effects are assessed. **Human well being:** Positive effects are assessed for: Commercial fishing, recreational fishing, genetic resources (slight), tourism & recreation, other socio-cultural services (slight) (5). **Score: (almost) no synergies, no conflicts (3)**

Summary

Exhaust gas cleaning systems, also known as scrubbers, offer an alternative reduction of emissions of sulphur oxides instead of switching to low sulphur fuel. In its simplest form, so called open loop scrubber, the technology implies that large volumes (on average 45 m^3 MWh^{-1}) of acidified seawater contaminated with metals, nitrates and organic pollutants are released back into the marine environment. Closed loop and hybrid scrubbers, with the ability to switch between open and closed loop, can collect the washwater onboard for treatment in port, however a minor fraction (~0.3m^3

6.2.7 #7 Stricter regulation on scrubber water

MWh^{-1}) of the washwater may be continuously discharged, so called bleed off. The primary incentive for ship owners to install scrubbers is economic; to reduce costs by burning cheaper, dirtier fuel oil. The potential threats to the marine environment from scrubbers are most pronounced in areas of intense shipping and limited water exchange, e.g. port areas, and during periods of less natural water mixing i.e. late summer months. Increased input of dissolved nitrogen can be of importance in coastal areas already affected by eutrophication. According to the precautionary principle, some European ports and on German inland waterways discharge of scrubber water has been already banned. A policy option of stricter regulation towards use of closed loop scrubbers would likely promote innovation on improved scrubber technology especially on zero discharge modes and could initiate a fuel change to low sulphur fuels.

Summary table

Summary: Policy option #7 Stricter regulation on scrubber water			
Political implementability	5	Environmental and health outcomes	4
Acceptance & Feasibility	3	Efficiency	3
Scientific knowledge and uncertainty	4	Distributional effects	3
Technological and innovation potential	4	Synergies and tradeoffs	3
		Total score:	3,7
		Rank	3

References:

Bácher, H., Albrecht, P. (2013). Evaluating the costs arising from new maritime environmental regulations. Trafi publications 24/2013, Helsinki.

den Boer, E., 't Hoen, M. (2015). Scrubbers – An economic and ecological assessment. Prepared for NABU.

European Commission (2016). Commission's views on the discharge of scrubber wash water and the updated table summarising the position of Member States on the acceptability of discharges of scrubber wash water -Agenda item 6.C ESSF of 26/1/201. Brussels 18/01/2016.Gallego-urrea, Alberto et al. (2018). “The Potential Future Contribution of Shipping to Acidification of the Baltic Sea.” : 368–78.

Hassellöv, I.-M., D. R. Turner, A. Lauer, and J. J. Corbett (2013). Shipping contributes to ocean acidification, Geophys. Res. Lett., 40, 2731–2736, doi: 10.1002/grl.50521.

HELCOM (2016). HELCOM countries submit Baltic Sea NECA application to IMO. Retrieved from http://www.helcom.fi/news/Pages/HELCOM-countries-will-submit-Baltic-Sea-NECA-application-to-IMO.aspx.

Kjølholt, J., Aakre, S., Jürgensen, C., Lauridsen, J. (2012). Assessment of possible impacts of scrubber water discharges on the marine environment. Danish Environmental Protection Agency.

6.2.7 #7 Stricter regulation on scrubber water

Copenhagen.

Lange, B., Markus, T., Helfst, P. (2014). Impacts of scrubbers on the environmental situation in ports and coastal waters. Federal Environment Agency (Germany), Texte 65/2015.

IMO (2008). MARINE ENVIRONMENT PROTECTION COMMITTEE, 58th session, Agenda item 23, MEPC 58/23, 16 October 2008. ANNEX 16, RESPONSE TO GESAMP REGARDING EGCS INTERIM WASHWATER GUIDELINES.

SHEBA (2017). WP1 scenario development, Technical note.

Turner, D. R., Edman, M., Gallego-Urrea, J. A., Claremar, B., Hassellöv, I. M., Omstedt, A., & Rutgersson, A. (2018). The potential future contribution of shipping to acidification of the Baltic Sea. Ambio, 47(3), 368-378.

6.2.8 #8 Promoting optimized fossil fuel driven engine and ship design, e.g. stricter energy efficiency standard (EEDI)

Assessment criteria	*Assessment results*
Description of policy option	The IMO Energy Efficiency Design Index (EEDI) target CO_2 emissions from shipping by requiring for all newly built ships from 2013 onwards to meet reduction targets (which increase until 2030) (Rehmatulla et al., 2017). Hull optimisation is a well known, easily available technique that can be used to reduce main engine power requirements by reducing the resistance offered by the ship's hull to its propulsion. Propeller optimisation can reduce the power required by the engine to subsequently lower the EEDI value. **Objectives** The objective is to save energy in order to limit the emissions of greenhouse gases (and other pollutants). **Impacts to be curbed** Climate change and negative effects from other emissions. **Design** Measures that enhance energy efficiency, such as enforcing stricter EEDI standards and funding research and development activities that aim at optimizing the energy efficiency of a ship. **Technologies/implementation** Engine or rudder related optimization or resistance reducing measures **Existing examples**

6.2.8 #8 Promoting optimized fossil fuel driven engine and ship design, e.g. stricter energy efficiency standard (EEDI)

	Ships retrofitting their technologies
Political implementability	**Which political/administrative scale is targeted by the policy option?** Baltic, EU, global **Do institutions need to be changed or new institutions established due to introduction of policy option?** No. **Is the policy option flexible?** Yes, the standards applied can be changed. **Score from stakeholders (survey): Medium (3)**
Acceptance & Feasibility	**Ship owners:** - opposed to additional costs for retrofitting - welcoming long-term policy schemes **NGOs:** - opposing small changes of efficiency standards, while big changes (e.g. LNG) are avoided - welcoming reduced emissions **Coastal communities** - welcoming the side-effects of reduced emissions **Score from stakeholders (survey): medium (3)**
Scientific knowledge and uncertainty)	**Measurement of Pressure** - It is not challenging to assess the (avoided) emissions **Impact assessment** - Impacts of different features of ship design, propulsion, etc. are analysed. Uncertainties remain, but generally they are manageable. **Socio-economic evaluation** - Estimating the socio-economic impacts of (avoided) air emissions has the most uncertainties. However, such assessment is still feasible. **Score: low uncertainties (4)**
Technological and innovation potential	Many possible measures ares based on already tested technologies to make ships more efficient. Fuel savings might be reached by improved hull designs, optimized operations etc., new types of propulsion (e.g. modern wind driven ships). However, it might be necessary to develop new technologies for larger energy savings in the future. **Score: medium innovation potential (3)**
Environmental and	**1) Effect on pressures:**

6.2.8 #8 Promoting optimized fossil fuel driven engine and ship design, e.g. stricter energy efficiency standard (EEDI)

health outcomes)

Pressure		Description of expected impact of option on pressures (Increase/Decrease/no effect, brief description if needed)
Emissions to air	CO_2	*Significant positive effect (decrease)*
	NO_X	*Significant positive effect (decrease)*
	SO_X	*Significant positive effect (decrease)*
	PM /BC	*Significant positive effect (decrease)*
Emissions to water	Non-indigenous species	*No effect*
	Contaminants to water	*No effect*
	Oil spills	*No effect*
Noise emissions	Underwater noise	*No effect (Will be influenced by the ship and propeller design, however, it is unclear in which direction)*
Physical impacts	Anchoring, mooring and movement and ship wakes	*No effect (Ship wakes might be lower when ship hulls are designed differently)*

2) Effects on human well being:

Human well being	Ecosystem services	Description of effect on ecosystem services (positive, negative, no effect, e.g. with arrows)
Commercial fishing	Cod, sprat, herring, salmon and seafood	*Positive effect (due to air emissions), unclear/potential for negative effect (due to underwater noise)*
Recreational fishing	Cod, sprat, herring, salmon and seafood)	*Positive effect (due to air emissions), unclear/potential for negative effect (due to underwater noise)*
Genetic resources	Genetic variation of species	*Slight positive effect (due to air emissions)*
Climate change mitigation	Capacity of sea to absorb CO_2 (i.e. seagrass meadows)	*Positive effect (due to air emissions)*
Coastal protection	Capacity of sea to protect coastline, sediments, avoid erosion (i.e. seagrass meadows)	*No effect (ship wakes might be lower when ship hulls are designed differently, but uncertain)*
Tourism and recreation	Swimming, beach activities	*Positive effect (due to air emissions), unclear/ potential fro negative effect (due to underwater noise)*
Other socio-cultural services	Heritage, inspiration, local and regional species	*Positive effect (due to air emissions), unclear/ potential fro negative effect (due to underwater noise)*
Human health	Clean air	*Positive effect (due to air emissions)*

6.2.8 #8 Promoting optimized fossil fuel driven engine and ship design, e.g. stricter energy efficiency standard (EEDI)

Due to reduced air emissions all components of human well being are positively affected by this option. Negative effects for commercial and recreational fishing, tourism&recreation and other socio-cultral services are expected in case the underwater noise would increase.

Links to existing policies and their policy targets

- Fuel consumption reduction is announced by IMO at the latest MEPC April 2018.
- Ship Energy Efficiency Management Plan (SEEMP) target CO_2 emissions from shipping (Rehmatulla et al., 2017)

Impact assessment for policy option

- BAU is the SHEBA scenario with the highest efficiency increase and the highest reductions in air pollutant and GHG emissions. The BAU includes a more ambitious efficiency increase than EEDI. The following figure shows the reduction of NO_2 concentrations caused by NO_X emission reductions between an implementation of the current EEDI and a more ambitious efficiency scenario (SHEBA BAU-scenario) for the year 2040.

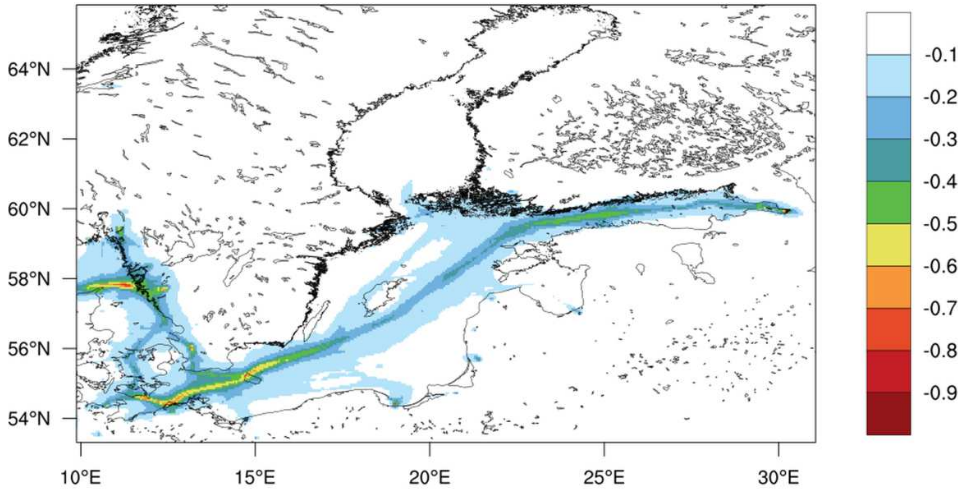

Figure 15 Reduction of NO_2 concentrations (in ppbV) in the Baltic Sea region in 2040 for an efficiency increase according to the SHEBA BAU scenario compared to the less ambitious SHEBA EEDI scenario.

Source: Matthias Karl, HZG. The map is based on data produced for SHEBA Deliverable 2.5.

Score: medium effect (3) (Beneficial overall, since shipping's contribution to all anthropogenic GHG emissions are about 3%, which is not insignificant for one single sector)

Efficiency (Economic outcomes)

Transaction costs: limited, as for promotion programmes routines are established, such instruments have been used already

Investment and maintenance costs: Increase of investment costs are expected but these will be offset by projected fuel savings (International Council for Clean Transportation, 2011). Jain (2012) reviewed cost estimates for increasing energy efficiency of ships. Investing in ship design including tank trials etc. is requested and it

6.2.8 #8 Promoting optimized fossil fuel driven engine and ship design, e.g. stricter energy efficiency standard (EEDI)

also includes costs associated with building the optimised ship (IMO, 2011). It is applicable to all ship types and gives an EEDI reduction potential of maximum 9% depending on the ship type (Wartsila, 2008). The cost of optimising the hull shape is in the range of US$ 50,000 to US$ 200,000 (Skjølsvik et al., 2000). Main advantages for ship owners when considering this option are the fuel savings and a short payback time of less than a year (Wartsila, 2008). Other research shows, that a 11,350dwt Ro-Ro case ship revealed hull optimisation costs of about 0.1 million Euros (US$ 120,000) which resulted in a fuel saving of about 740 tonnes per annum. The EEDI benefit was 2% which resulted into 5% reduction in power requirement or 0.35 knots speed increase at the same engine power (Deltamarin Ltd, 2009). As explained above, frictional resistance is influenced by the roughness of the ship's hull; it is thus important to make the hull surface as smooth as possible in order to reduce the power required by the ship to move and subsequently to lower the EEDI value. The abatement potential of air lubrication is in the range of 10-15% for tanker and bulkers and 5-9% for container vessels. Costs are expected to be 2-3% of the price of a conventional newly built vessel without air lubrication system (IMO, 2011). Payback time for this system is medium in the range of 5-6 years (Wartsila, 2008). Altogether, air lubrication technique has high potential of reducing the EEDI. It has some constraints regarding its applicability to ship types and payback time is little higher than other techniques with medium initial investment. From ship owners' point of view, this can be a good option to meet the EEDI regulations. Air resistance is normally a relatively small component of the total resistance offered by the ship (Molland et al., 2011), however, for ships with large superstructures operating at relatively high speeds aerodynamic drag can contribute more than 10% to the total ship resistance in a strong headwind (Lloyd'sRegister, 2012). There is thus a potential for reducing power consumption by carrying out systematic streamlining of the superstructure. It is found that the rounding of sharp corners can lead to a reduced air resistance of commercial ships in the order of 15% to 20% (Molland et al., 2011). For large ships operating at relatively high speed, potential for reduction in power consumption of 2-5% is estimated depending on the size of the superstructure and the area of operation (Kollamthodi et al., 2008). Also for other ships a certain potential for reduction in power consumption in the order of 1-2% is estimated (Kollamthodi et al., 2008). Optimisation of propeller in conjunction with rudder design has a potential of improving fuel efficiency by 2 to 6% with medium payback time (Wartsila, 2008). This technique is available in the market and is applicable to tankers, containers and Ro-Ro ships (IMO, 2011). According to the report submitted by Deltamarin Ltd to EMSA (Deltamarin Ltd, 2009) research conducted on 11,350 dwt Ro-Ro case ship showed that propeller and rudder optimisation costs about 0.25 million euros (300,000 US$) and results in the fuel saving of about 740 tonnes per annum with EEDI benefit of 2% which resulted into 5% reduction in power requirement or 0.35 knots speed increase at same engine power.

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	Score cost: medium costs (3) **Benefits: (see also above)** Estimations of the SHEBA project (based on reduced PM and ozone emissions) show a reduction potential of health impacts for mid-VOLY with 136 million Euros per year for 2040, compared to the BAU scenario and 527 million Euro per year for 2040 (compared to BAU) for mid VSL. Lost working days could be reduced by 6 million Euro per year. The contribution of shipping on the area in which critical loads are exceeded could be reduced by 2.7 and 3.7% with the policy option compared to BAU (see for more information chapter 2.4 and 2.5). "If implemented on schedule, the EEDI is estimated to save $52 billion in fuel costs and prevent 263 million tons of CO_2 emissions each year (over business as usual) by 2030." (International Council for Clean Transportation, 2011). **Score: medium efficiency (3)**
Distributional effects	Ship owners have to take higher costs for building of new ships. But fuel savings should offset additional costs. Population: No financial effects expected. **Score: low distributional effects (5)**
Synergies and tradeoffs	**Pressures:** The option can have positive effects on air emissions (CO_2, NO_X, SO_X, PM). Slight positive effects might be expected from physical impacts. Impact on underwater noise is unclear. (5, 2 types of pressures) **Human well being:** Positive effects are assessed for: Commercial fishing, recreational fishing, genetic resources (slight), climate change mitigation, tourism & recreation, other socio-cultural services (slight), human health (7). **Score: significant synergies, unclear/potential for conflicts (3)**

Summary

The IMO Energy Efficiency Design Index (EEDI) targets CO_2 emissions from shipping by requiring for all newly built ships from 2013 onwards to meet reduction targets (which increase until 2030) (Rehmatulla et al., 2017).

Hull optimisation is a well known, easily available technique that can be used to reduce main engine power requirement by reducing the resistance offered by the ship's hull to its propulsion. Propeller optimisation can reduce power required by the engine to subsequently lower the EEDI value.

Estimations of the SHEBA project show a substantial potential for reduction of health impacts by implementation of an increased EEDI between 136 and 527 million Euro per year for 2040 (compared

6.2.8 #8 Promoting optimized fossil fuel driven engine and ship design, e.g. stricter energy efficiency standard (EEDI)

to BAU, for mid VSL and VOLY). Lost working days could be reduced by 6 million Euro per year. The estimation is based on reduction of PM and ozone.

Altogether, from ship owners’ point of view, hull optimisation seems to be a cost effective option to meet the EEDI regulation as initial investment is low with very short payback time and potential for fuel savings is high. Moreover, there is no sacrifice of basic design parameters such as design speed which is crucial for ship owners from revenue purpose.

Energy efficiency enhancing measures are very heterogenous in their impact. At the same time, often implemented measures have tended to be those that have small energy efficiency gains at the ship level (Rehmatulla et al., 2017).

Summary table

Summary: Policy option #8 Promoting optimized fossil fuel driven engine and ship design, e.g. stricter energy efficiency standard (EEDI)			
Political implementability	3	Environmental and health outcomes	3
Acceptance & Feasibility	3	Efficiency	3
Scientific knowledge and uncertainty	4	Distributional effects	5
Technological and innovation potential	3	Synergies and tradeoffs	3
		Total score:	3,3
		Rank	11

References:

Deltamarin Ltd. (2009) Report on EEDI Tests and Trials for EMSA, Deltamarin Ltd.

IMO (2011). Reduction of GHG emissions from ships Marginal Abatement Costs and Cost effectiveness of Energy-Efficiency Measures (MEPC62/INF.7).

International Council for Clean Transportation (2011). Policy Update 15: The Energy Efficiency Design Index (EEDI) for New Ships. 3 Oct 2011.

Jain, K.P. (2012). Impacts of Energy Efficiency Design Index. Newcastle University.

Kollamthodi, S., C. Brannigan, M. Harfoot, I. Skinner, C. Whall, L. Lavric, R. Noden, et al. (2008). Greenhouse Gas Emissions from Shipping: Trends, Projections and Abatement Potential. AEA Energy.

Lloyd’s Register (2012). Implementing the Energy Efficiency Design Index (EEDI) – Guidance for owners, operators and shipyards.

Molland, A.F., Turnock, S.R., Hudson, D.A. (2011). Ship Resistance and Propulsion: Practical Estimation of Ship Propulsive Power. Cambridge University Press.

6.2.8 #8 Promoting optimized fossil fuel driven engine and ship design, e.g. stricter energy efficiency standard (EEDI)

Skjølsvik, K.O., Andersen, A.B., Corbett, J.J., Skjelvik, J.M. (2000). Study of Greenhouse Gas Emissions from Ships. Trondheim.

Rehmatulla, N., Calleya, J., & Smith, T. (2017). The implementation of technical energy efficiency and CO2 emission reduction measures in shipping. Ocean Engineering, 139, 184-197.

Wartsila (2008). Boosting Energy Efficiency. Energy Efficiency Catalogue/Ship Power R&D. Wartsila.

6.2.9 #9 Promoting use of low emission fossil fuels, e.g. LNG

Assessment criteria	*Assessment results*
Description of policy option	Low emission shipping fuels are necessary to manage climate change and local pollutants (Gilbert et al., 2018). Several fossil fuels lead to less emissions than heavy fuel oil or marine diesel oil, which both are widely used. Asides of biofuels (such as , biodiesel, straight vegetable oil and bio-LNG), there are several fossil fuels which aim at emitting less sulphur oxides, nitrogen oxides, and particulate matter, as well as greenhouse gases. Hence, these alternative fuels are expected to provide health benefits beside other environmentally benefical effect, due to avoided emissions. Liquified hydrogen is rather a niche phenomenon. Liquified natural gas (LNG) however, is widely discussed to be the new shipping fuel of choice. LNG is expanding as a new energy technology around the Baltic due to its capacity to fulfill three policy expectations: enhancing energy security, providing low-sulphur bunker fuel, and balancing renewables in the power sector. **Objectives** LNG technologies should spread and make the use of this lower emission fossil fuel more likely. **Impacts to be curbed** Reduction of GHG and air pollutants emissions **Design** Ships fueled with low emission fossil fuels are being promoted by financial support e.g. subisides, funding research and development, besides providing information about these alternatives (especially for LNG). The programme could be combined with financial tools for investments in LNG infrastructure (e.g. special loan programmes). **Technologies/implementation** New built ships would run on other fuel types such as LNG or methane. **Existing examples** Gas fuelled ships is a measure to reduce NO_X emissions from ships, and such ships operating in Norwegian waters has gained support from the Norwegian NO_X fund to cover additional investments cost compared to diesel operation. (SINTEF 2017)
Political implementability	**Which political/administrative scale is targeted by the policy option?** Baltic, EU, global **Do institutions need to be changed or new institutions established due to introduction of policy option?** There is no need for new institutions, but new public funds for the promotion activities would be needed. **Is the policy option flexible?** This policy options can be extended and adjusted easily.

6.2.9 #9 Promoting use of low emission fossil fuels, e.g. LNG

Score from stakeholders (survey): high (4)

Acceptance & Feasibility

Ship owners:

- opposed to additional costs and feasibility (ship owners fear that they cannot bunker LNG everywhere in the world.)
- LNG bunkering requires international standards how to do this.(Ship owners fear several stadnards aside)
- welcoming a long-term policy frame

NGOs:

- opposing, since LNG is a fossil fuel and global warming will not be (significantly) reduced with LNG if the methane slip problem won't be solved.
- welcoming the reduction of air pollution

Coastal communities:

- welcoming the side-effects of lower emissions, which result in health benefits and beneficial environmental impacts.

Score from stakeholders (survey): high (4)

Scientific knowledge and uncertainty

Measurement of Pressure

- The impact of LNG can be measured relatively easily based on emission factors

Impact assessment / Socio-economic evaluation

- The impacts of (avoided) shipping emissions can be assessed without many uncertainties
- There is a sound and regularly used methodology for health impacts of air pollution.

Score: very low uncertainty (5)

Technological and innovation potential

LNG and methanol are already used as fuels in big ships. However, LNG and methanol driven engines need improvements. Methane slip needs to be minimized. (see #11 Limits on methane slip from LNG engines (due to incomplete combustion). LNG bunkering network needs to be extended further, i.e. LNG needs to be made available in more ports. Incentives for LNG and methanol bunkering structure might be useful.

Score: medium innovation potential (3)

Environmental and health outcomes

1) **Effects on pressures**

Pressure		**Description of expected impact of option on pressures (Increase/Decrease/no effect, brief description if needed)**
Emissions to air	CO_2	*Slight positive effect (decrease) (but negative effect: more emissions of methane and on CO2eqv)*
	NO_X	*Significant positive effect (decrease)*
	SO_X	*Very significant positive effect (decrease)*
	PM	*Very significant positive effect (decrease)*
Emissions to water	Non-indigenous species	*No effect*
	Contaminants to water	*No effect*

6.2.9 #9 Promoting use of low emission fossil fuels, e.g. LNG

	Oil spills	*Positive effect (avoided, ships do not use oil anymore)*
Noise emissions	Underwater noise	*No effect (might be influenced when engines are more silently operated)*
Physical impacts	Anchoring, mooring and movement and ship wakes	*No effect*

2) Effects on human well being:

Human well being	**Ecosystem services**	**Description of effect on ecosystem services (positive, negative, no effect, e.g. with arrows)**
Commercial fishing	Cod, sprat, herring, salmon and seafood	*Positive effect (due to CO_2, NO_X, SO_X, oil spills, noise)*
Recreational fishing	Cod, sprat, herring, salmon and seafood)	*Positive effect (due to CO_2, NO_X, SO_X, oil spills, noise)*
Genetic resources	Genetic variation of species	*Slight positive effect (CO_2)*
Climate change mitigation	Capacity of sea to absorb CO_2 (i.e. seagrass meadows)	*Slight positive effect (CO_2), negative effects (methane)*
Coastal protection	Capacity of sea to protect coastline, sediments, avoid erosion (i.e. seagrass meadows)	*No effect*
Tourism and recreation	Swimming, beach activities	*Positive effect (due to CO_2, NO_X, SO_X, oil spills, noise)*
Other socio-cultural services	Heritage, inspiration, local and regional species	*Positive effect (due to CO_2, NO_X, SO_X, oil spills)*
Human health	Clean air	*Positive effect (due to NO_X, SO_X, PM)*

The largest effect is expected on human health. But also ecosystem services such as commercial and recreational fishing and tourism and recreation are positively affected. Slight positive effect due to reduced CO_2 emissions can be expected for several additional ecosystem services, but it needs to be discussed if methane emissions (methane slip) would outweight these positive effects.

Links to existing policies and their policy targets

Links to Air Quality Directive and possibly climate targets (IMO, EU level)

6.2.9 #9 Promoting use of low emission fossil fuels, e.g. LNG

Impact assessment for policy option

- A certain fraction of LNG, following current trends, is included in SHEBA-BAU scenario, it includes a fraction of 10% of the ships using LNG. (Fridell et al., 2018)

- There is a SHEBA LNG scenario for 2040 for the emission, but there were no specific chemistry transport model runs done in SHEBA. The LNG scenario assumes 26.5 % of the ships going on LNG instead of 10 % in BAU. This results in lower emissions of N_2O, HC, CO and SO_2 in the order of 30%, for NO_X 22 % less and CO_{2eq} will be reduced by 1.8%. (Fridell et al., 2018)

- Assuming a large implementation of LNG as fuel will results in (compared with BAU) significantly lower emissions of particles and sulphur dioxide but higher emissions of methane.

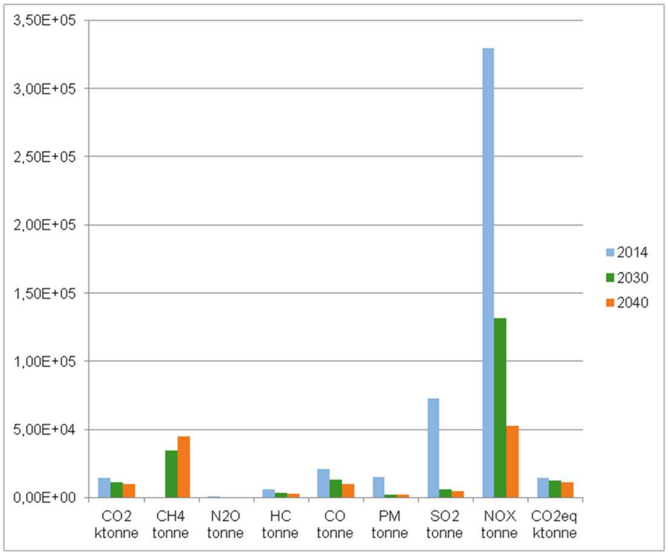


Figure 16 Figure emissions to air on SHEBA LNG scenario, which assumes 26.5% of ships going on LNG

Source: Fridell et al. (2018).

- The following emission and concentration maps show the implication of compliance with the NECA rules in the North Sea in case the Emission Control Area (ECA) for nitrogen oxide emissions would have been in force since 2016. In the scenarios for 2030, all regulations given in MARPOL Annex VI are in force, i.e. the sulfur limit in ECAs (0.1%S) and the NECA rules for new builts apply. In the ECA-LNG 16 scenario it has been assumed that ships use LNG instead of catalysts in order to comply with the NECA rules. Selective catalytic reduction (SCR) is used in the ECA-SCR 16 scenario. It is assumed that in 2030 about 6,000 ships (approx. 30 %) sailing in the North Sea run on LNG, preferably those that sail most of the time in ECAs.

6.2.9 #9 Promoting use of low emission fossil fuels, e.g. LNG

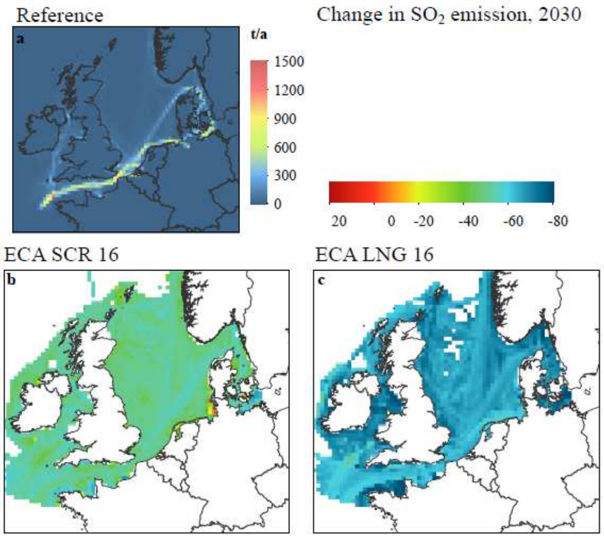


Figure 17 SO_2 emissions from ships (a) annual totals in t per grid cell of 24 x 24km^2. Emission changes for scenarios (b) ECA SCR 16 and (c) ECA LNG 16 for 2030. No values are shown in grid boxes where the SO_2 emissions from ships were below 0.5 t per year per grid cell of 24 x 24 km^2.

Source: Matthias et al. (2016).

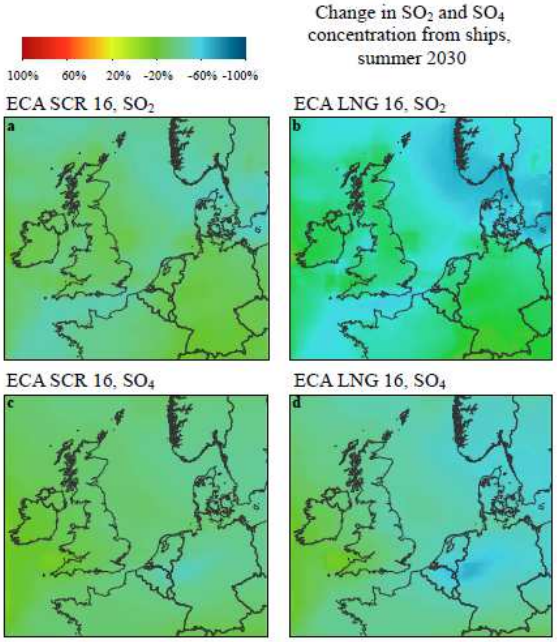
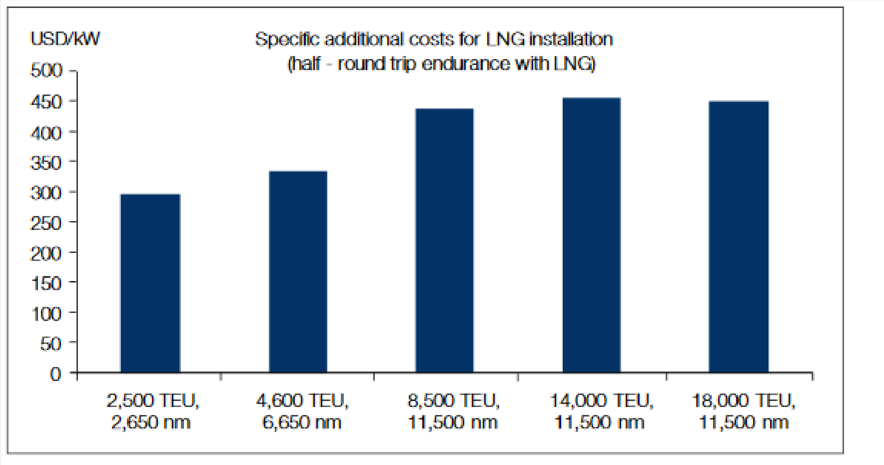


Figure 18 Change in the contribution of shipping to the total (a and b) SO_2 and (c and d) SO4 concentration in summer (JJA) 2030 for scenarios ECA SCR 16 (left) and ECA LNG 16 (right) in relation to concentrations in 2011.

Source: Matthias et al. (2016).

Score: medium effect (3) (in case methane slip is very low)

6.2.9 #9 Promoting use of low emission fossil fuels, e.g. LNG

Efficiency (Economic outcomes)	**Transaction costs:** Transaction costs are limited for a promotion program. **Investment and maintenance costs**  *Fig. 7: Specific additional costs for LNG installation for various ship sizes* 300-500 USD/KW specific additional costs, Source: MAN (o.d.) **Score costs: high (4)** **Benefits:** Estimations of the SHEBA project show a potential for reduction of health impacts (based on reduced PM and ozone emissions) for mid-VOLY with 89 million Euros per year for 2040, compared to the BAU scenario and 356 million Euro per year for 2040 (compared to BAU) for mid VSL. Lost working days could be reduced by -4 million Euro per year. The contribution of shipping on the area in which critical loads are exceeded could be reduced by 1.4 and 2.1% with the policy option compared to BAU (see for more information chapter 2.4 and 2.5). Shindell et al. (2018) have estimated, that eliminating of most fossil-fuel-related emissions lead to significant co-benefits. The human health benefits of the reductions by 180 GtC (for reaching the 2 °C to 1.5 °C scenario, without negative emissions) would lead to 153 ± 43 million fewer premature deaths worldwide (more than a million premature deaths would be prevented in metropolitan areas in Asia and Africa, and >200,000 in individual urban areas on every inhabited continent except Australia). More relevant information can be found in the sections on policy option: #19 Implementation of a CO_2-tax for shipping and #20 Establishing of an emission trading scheme for greenhouse gases from shipping. **Score: low efficiency (2)**

6.2.9 #9 Promoting use of low emission fossil fuels, e.g. LNG

Distributional effects	Effects: higher costs for ship owners, slightly increase of prices for goods. Overall, the distributional effects are limited. **Score: low (4)**
Synergies and tradeoffs	**Pressures:** The option can have positive effects on air emissions (CO_2, NO_X, SO_X, PM). There are further effects on reduced number of oil spills, and might influence underwater noise. (6, 3 types of pressures). Negative effects are expected by increased emission of methane. **Human well being:** Positive effects are assessed for: Commercial fishing, recreational fishing, genetic resources (slight), climate change mitigation, tourism & recreation, other socio-cultural services (slight), human health (7). For climate change mitigation also negative effects by methane are expected. **Score: major synergies, low conflicts (4)**

Summary

Low emission shipping fuels will probably be necessary to manage climate change and local pollutants (Gilbert et al., 2018). Several fossil fuels lead to less emissions than heavy fuel oil or marine diesel oil, which both are widely used. Aside of biofuels (such as, biodiesel, straight vegetable oil and bio-LNG), there are several fossil fuels which aim at emitting less sulphur oxides, nitrogen oxides, and particulate matter. Hence, these alternative fuels are expected to provide health benefits beside other environmentally benefical effect, due to avoided emissions. Liquified hydrogen is rather a niche phenomenon. Liquified natural gas (LNG) however, is widely discussed to be the new shipping fuel of choice. LNG is expanding as a new energy technology around the Baltic Sea due to its capacity to fulfill three policy expectations: enhancing energy security, providing low-sulphur bunker fuel, and balancing renewables in the power sector.

The SHEBA project has estimated reduction potential for health impacts by using more LNG driven ships between 89 and 356 million Euro per year for 2040 (compared to BAU, for mid VSL and VOLY). Lost working days could be reduced by 4 million Euro per year. Calculations are based on reductions of PM and ozone.

This policy option would reduce health problems and eutrophication/acidification, but this pathway still uses fossil fuels. Gradually, a shift towards carbon neutral fuel should occur. However, from today's perspective, it looks unrealistic that shipping will be carbon neutral in the near future. To reach such state, it could be an option to produce hydrogen and methane with excess electricity from renewables sources, such as wind farms. In this case LNG would be an important prerequisite for the introduction of fossil free fuels for ships If bio-LNG or synthetic-LNG or bio-methanol is used, then this becomes more important and it ties in with the policy option #10 (Promoting use of renewable fuels and energy sources, e.g. biofuels, wind).

6.2.9 #9 Promoting use of low emission fossil fuels, e.g. LNG

There are links #18 Establish PM (including black carbon) emission standards for ships as BC would be reduced by using LNG as well. Links to #11 Limits on methane slip from LNG engines (due to incomplete combustion) also exist, since the mitigating effect of LNG potentially is compensated to a big extent, if methane slip is not addressed consequently.

Summary table

Summary: Policy option #9 Promoting use of low emission fossil fuels, e.g. LNG			
Political implementability	4	Environmental and health outcomes	3
Acceptance & Feasibility	4	Efficiency	2
Scientific knowledge and uncertainty	5	Distributional effects	4
Technological and innovation potential	3	Synergies and tradeoffs	4
		Total score:	3,6
		Rank	5

References:

Fridell, E., Tröltzsch, J., Hasenheit, M., Jalkanen, J.-P., Matthias, V., Eriksson, M. (2018). Sustainable Shipping Scenario. SHEBA Deliverable 1.5. BONUS Research Project

Gritsenko, D. (2018). Explaining choices in Energy infrastructure development as a network of adjacent action situations: The case of LNG in the Baltic Sea region. Energy Policy, 112, 74-83.

Gilbert, P., Walsh, C., Traut, M., Kesieme, U., Pazouki, K., & Murphy, A. (2018). Assessment of full life-cycle air emissions of alternative shipping fuels. Journal of Cleaner Production, 172, 855-866.

MAN (o.d.) Costs and Benefits of LNG as Ship Fuel for Container Vessels. https://marine.mandieselturbo.com/docs/librariesprovider6/technical-papers/costs-and-benefits-of-lng.pdf?sfvrsn=18

Matthias, V.; Aulinger, A.; Backes, A.; Bieser, J.; Geyer, B.; Quante, M. and Zeretzke, M. (2016). The impact of shipping emissions on air pollution in the Greater North Sea region. Part II: Scenarios for 2030, Atmos. Chem. Phys. 16, 759-776.

Shindell, D., Faluvegi, G., Seltzer, K., & Shindell, C. (2018). Quantified, localized health benefits of accelerated carbon dioxide emissions reductions. Nature climate change, 8(4), 291.

6.2.10 #10 Promoting use of renewable fuels and energy sources, e.g. biofuels, wind

Assessment criteria	*Assessment results*
Description of policy option	**Objectives**: The objective of this policy is to foster the use of renewable fuels in the shipping sector. **Impacts to be curbed** Decreasing GHG emissions, by decreasing (fossil) fuel use. Side-effect: Decreasing SO_X emissions **Design** Renewable fuels are supported by funding research and innovation activities, related to the development of renewable fuel technologies for shipping **Technologies/implementation** Potential renewable energy sources for shipping include - wind (e.g. Soft sails, fixed wings, rotors, kites and conventional wind turbines), solar photovoltaics or super capacitors charged with renewables, biofuels, wave energy and hydrogen.
Political implementability	**Political/administrative scale targeted by the policy:** - Baltic countries (national research spending schemes) - Baltic region (BONUS) - EU (H2020/EU funding) **Do instituions need to be changed?** - no, but funding schemes need to be adapted/extend - such schemes might be part of future policies that aim at reducing GHG on a national level or specifically in the shipping sector **Score from stakeholders (survey): high policy implementability (4)**
Acceptance & Feasibility	**Ship owners:** - opposed to additional costs (especially since LNG is cheaper (Bengtsson et al., 2012)) - welcoming long-term schemes & policy focuses **NGOs:** - opposing partly to biofuels (negative side-effects) - welcoming the initiative to increase the use of renewables **Coastal communities** - welcoming the side effects (reduced emissions of NO_X, SO_X, PM etc.) **Score from stakeholders (survey): medium acceptance & feasability (3)**
Scientific knowledge and uncertainty	CO_2 emissions from ships are fairly well known and methods for both measuring and modeling exits. Methods to calculate the reduced emissions from biofuels are available and can be established for wind-power. Climate impacts of increasing CO_2 levels are well known and political consensus for the need to act exists.

6.2.10 #10 Promoting use of renewable fuels and energy sources, e.g. biofuels, wind

Score: high scientific knowledge (4)

Technological and innovation potential

Modern technologies of using wind power for ships are available, but still under development. Hence the innovation potential is high – also are investment and development costs (IRENA, 2015) Powertrains for biofuels are available. Blending can be made in present equipment. It is argued that second generation biofuels can avoid many of the concerns facing first generation biofuels, but they still face economical and technical challenges (Carriquiry et al., 2011; Havlık et al., 2011; Naik et al., 2010). Power to gas technologies could be an option to use excess renable energy on land in order to provide energy for shipping.

Score: high technological potential (5)

Environmental and health outcomes

1) Effects on pressures:

Pressure		Expected impact
Emissions to air	CO_2	*Positive effect (Decrease)*
	NO_X	*No effect*
	SO_X	*Positive effect (Decrease)*
	PM	*Positive effect (Decrease)*
Emissions to water	Non-indigenous species	*No effect*
	Contaminants to water	*No effect*
	Oil spills	*Positive effect (Decrease) (depending on the renewable energy being used) (IRENA, 2015)*
Noise emissions	Underwater noise	*Positive effect (Decrease) (depending on the renewable energy being used (IRENA, 2015))*
Physical impacts	Anchoring, mooring and movement and ship wakes	*No effect*

2) Effects on human well being:

Human well being	Ecosystem services	Effects on human well being
Commercial fishing	Cod, sprat, herring, salmon and seafood	*Positive effect (CO_2, SO_X, reduced noise, oil spills, depending on renewable energy)*
Recreational fishing	Cod, sprat, herring, salmon and seafood)	*Positive effect (CO_2, SO_X, reduced noise, oil spills, depending on renewable energy)*
Genetic resources	Genetic variation of species	*Slight positive effect*
Climate change mitigation	Capacity of sea to absorb CO_2 (i.e. seagrass meadows)	*Positive effect (reduced CO_2, SO_X)*

6.2.10 #10 Promoting use of renewable fuels and energy sources, e.g. biofuels, wind

Coastal protection	Capacity of sea to protect coastline, sediments, avoid erosion (i.e. seagrass meadows)	*No effect*
Tourism and recreation	Swimming, beach activities	*Positive effect (reduced emissions of NO$_X$, SO$_X$, oil spills – depending on renewable energy)*
Other socio-cultural services	Heritage, inspiration, local and regional species	*Slight positive effect (less oil spills – depending on renewable energy)*
Human health	Clean air	*Positive effect (NO$_X$, SO, PM, in coastal areas and on-bord) (IRENA, 2015))*

Links to existing policies and their policy targets
- UNFCCC climate targets
- EU transport white book (target: reduction of 40%, if feasible 50 %, by 2050 compared to 2005 levels (EU, 2011))
- IMO MEPC72 (target: reduction of 50% by 2050 (IMO, 2018). This target is not achievable by improving energy efficiency of ships (EEDI Phases 0-3), but it requires a gradual shift away from fossil fuels. Energy efficient designs are barely able negate the annual growth of GHG emissions from ships is the growth is less than 1.4%/year.)

Impact assessment for policy option
- Small effect in relation to SHEBA BAU (depends on penetration)
- The SHEBA *SSP1* scenarios implies efficiency gains and/or introduction of renewable fuels with a rate of 2-2.5% per year depending on ship type. To go from SHEBA *BAU* in 2040 to *SSP1* in 2040 about 4.7 Mtonne of CO$_{2eq}$ needs to be removed from shipping in the Baltic Sea. If all RoRo and RoPax ships would switch to renewable fuels or electricity this would cover 3.8 Mtonne. If no auxiliary engines use fossil fuel would mean a reduction with about 2.5 Mtonne. Tankers transporting fossil fuels account for about 1.1 Mtonne in *BAU* for 2040 (Fridell et al, 2018).

Score: medium effect (3) [Developments with renewable fuels stretch beyond the shipping sector. This pathway may involve all modes of transport, not just ships]

Efficiency (Economic outcomes)

Transaction cost:
- research costs (what should be financed): medium
- design & implementation costs: low
- monitoring the finance schemen: low-medium

Investment and maintance costs:

Soft-sails

B9 Shipping & Fair Transport BV Ecoliner: construction & maintenance costs between 10-15% of total asset costs,(IRENA, 2015).

Fixed wing sails technology

OCIUS Technology Ltd. shows an estimated return on investment of between one and two years at 2013 fuel prices (IRENA, 2015). Oceanfoil has modelled an estimated payback period of 15-18 months for its new wingsail design. The University of Tokyo projected that for its 60 000 gross tonnage (IRENA, 2015). UT Wind Challengers could achieve shorter payback times

6.2.10 #10 Promoting use of renewable fuels and energy sources, e.g. biofuels, wind

than kites and rotors based on simplified economic assumptions (IRENA, 2015).

Kite-assisted sailing

Kite-assisted technologies (like the MS Beluga Skysails system) is thought to have a higher maintenance and servicing cost compared to other wind technologies. Recent studies under the EffShip programme have modelled savings using fixed-wing, rotor and kite auxiliaries for a Panamax (EffShip, 2013a). (Traut et al., 2014) and comparisons for rotor and kite fitted ships on transatlantic runs.

Econmic - Direct	**Economic – Indirect**
Significant fuel costs reduction	Increased resilience (fuel stocks)
Increased stability and security in energy prices and supply	Potential to revitalise uneconomical routes (danger: rebound effect)
Reduction in wear and tear, increased stability	Stimulation for new and existing industries
Maintenance of resale and chartering value	Shake up/ increase of competition in the energy supply chain
Potential for reduced port fees and local/ regional levies	Reduction of wider economic impact of emissions on health
	Eligible for market-based mechanisms
	Eco-branding (Marketing)

Source: based on IRENA, 2015.

Score costs: high costs (4)

Benefits

Soft-sails

B9 Shipping & Fair Transport BV Ecoliner: 60% fuel savings, significant reductions in main engine and propeller wear, cleaner fuel compliance costs and possible future emissions trading levies (IRENA, 2015).

Fixed wing sails technology

OCIUS Technology Ltd. reported 5-100% fuel savings depending on the application. By retrofitting opening wing sails to a motor-sail, without altering the primary propulsion system of a modern tanker or bulker, ship operators can expect 20-25% fuel savings on cross-equator shipping routes and 30-40% on same-hemisphere shipping routes (IRENA, 2015). Oceanfoil has modelled a fuel saving of 20%. The University of Tokyo projected that for its 60 000 gross tonnage (IRENA, 2015). UT Wind Challenger, fuel costs could be reduced by as much as one-third. The EffSail, developed from the EffShip project, has been modelled to show that, under certain conditions, savings in fuel use of up to 40% could be achieved (IRENA, 2015).

Kite-assisted sailing

The MS Beluga Skysails system saved 10-15% of fuel on selected passages. However, annual savings in consumption on most routes is on the order of 5.5%, as determined by the EU-funded Life project WINTECC. Propulsive savings can only be realised with wind

6.2.10 #10 Promoting use of renewable fuels and energy sources, e.g. biofuels, wind	
	coming from the beam to the aft (back) of the ship (IRENA, 2015; Fagerlund & Ramne, 2013; Traut et al., 2014) **Score: low efficiency (2)**
Distributional effects	Uncertain, probably low distributional effect **Score: low distributional effect (4)**
Synergies and tradeoffs	**Pressures:** The option can have effects on a variety of different pressures: air emissions (CO_2, SO_X), oil spills, underwater noise (6, 3 types of pressures). Negative effects might occur if biofuels are widely used. **Human well being:** Positive effects are assessed for: Commercial fishing, recreational fishing, genetic resources (slight), climate change mitigation, tourism & recreation, other socio-cultural services (slight), human health (7). No negative effects are assessed. **Score: major synergies, no conflicts (except for biofuels) (5)**

Summary

For biofuels the current power trains and fuel systems, on board and for distribution, can be used after minor modifications. The problem is both, the high cost of biofuels and the limited availability. Wind has of course been used for thousands of years for ship propulsion. Today the technology has developed but issues remain with speed and reliability. Biofuels are usually categorised as first or second generation. First generation biofuels are produced primarily from agricultural crops such as grains and oil seeds while second generation biofuels are produced from lingo-cellulosic materials such as forest residues. Issues concerning first generation biofuels have been raised since they can create competition for land with food production, they have limited production potential and their environmental performance is questioned.

Using wind energy for shipping is an old concept, which could be revived soon. In this case a complementary use of that wind energy is likely. Power-to-gas concepts could be implemented relatively easy, once the LNG infrastructure is set.

Summary table

Summary: Policy option #10: Promoting use of renewable fuels and energy sources, e.g. biofuels, wind			
Political implementability	4	Environmental and health outcomes	3
Acceptance & Feasibility	3	Efficiency	2
Scientific knowledge and uncertainty	4	Distributional effects	4
Technological and innovation potential	5	Synergies and tradeoffs	5
		Total score:	3,7
		Rank	2

6.2.10 #10 Promoting use of renewable fuels and energy sources, e.g. biofuels, wind

References:

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

Carriquiry, M.A., Du, X., Timilsina, G.R. (2011). Second generation biofuels: economics and policies. Energy Policy 39, 4222–4234

European Commission (EU) (2011). White paper on transport, https://ec.europa.eu/transport/sites/transport/files/themes/strategies/doc/2011_white_paper/white-paper-illustrated-brochure_en.pdf

Fagerlund, P., & Ramne, B. (2013). Effship Project: summary and conclusions. WP9 Final Reporting and Dissemination.

Fridell, E., Tröltzsch, J., Hasenheit, M., Jalkanen, J.-P., Matthias, V., Eriksson, M. (2018). Sustainable Shipping Scenario. SHEBA Deliverable 1.5. BONUS Research Project

Havlík, P., Schneider, U.A., Schmid, E., Böttcher, H., Fritz, S., Skalský, R., Aoki, K., Cara, S.D., Kindermann, G., Kraxner, F., Leduc, S., McCallum, I., Mosnier, A., Sauer, T., Obersteiner, M. (2011). Global land-use implications of first and second generation biofuel targets. Energy Policy 39, 5690–5702.

International Maritime Organization (IMO) (2018). UN body adopts climate change strategy for shipping, Briefing: 13/04/2018, http://www.imo.org/en/MediaCentre/PressBriefings/Pages/06GHGinitialstrategy.aspx

Naik, S.N., Goud, V.V., Rout, P.K., Dalai, A.K. (2010). Production of first and second generation biofuels: a comprehensive review. Renewable and Sustainable Energy Reviews 14, 578–597.

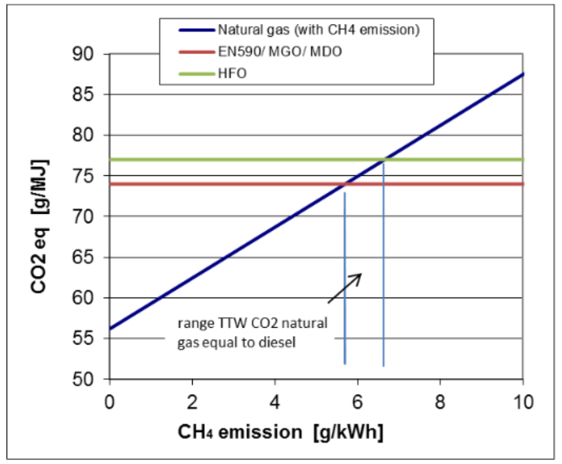
IRENA (2015). Renewable Energy Options for Shipping – Technology Brief, http://repository.usp.ac.fj/7923/1/Shipping-Web-150dpi.pdf

Rehmatulla , N., T. Smith and P. Wrobel (2013). Implementation Barriers to Low Carbon Shipping. In Low Carbon Shipping Conference. London, 2013.

Traut, M. et al.(2014). Propulsive power contribution of a kite and a Flettner rotor on selected shipping routes. Applied Energy, pp. 362–372.

UNFCCC (2018). World Nations Agree to At Least Halve Shipping Emissions by 2050, https://unfccc.int/news/world-nations-agree-to-at-least-halve-shipping-emissions-by-2050

6.2.11 #11 Limits on methane slip from LNG engines (due to incomplete combustion)

Assessment criteria	*Assessment results*
Description of policy option	Engines running on LNG have reduced emissions of several gases (such as NO_X, SO_X, CO_2) but have higher unburned HC emissions (mainly CH_4), compared to conventional diesel engines. This slip can be significant and can result in a higher climate impact from LNG engines compared with conventional engines. The policy option is a limit on emitted methane for LNG engines. **Objectives** This option aims at reducing the slip of methane from LNG-engines. By December 2016 approximately 120 gas fuelled ships were in operation worldwide (SINTEF 2017) **Impacts to be curbed** Ship engines running on LNG have reduced emissions of several gases (such as NO_X, SO_X, CO_2). Compared to conventional diesel engines they have higher unburned HC emissions. From the unburned HC emission 90% is methane. (Zetterdahl et al., 2016; Liu et al., 2013). The methane slip from the combustion of ships is estimated with an average of 31 g CH_4/kg LNG (SINTEF, 2017). A TNO report (Verbeek & Verbeek, 2015) says most gas engines emit around 4.5 g methane/kWh[8]. The figure below shows a comparison of greenhouse gas (CO_2 equivalent) emissions between a diesel and natural gas engines as a function of methane emissions of the gas engine. The graph shows, that with a methane emission of approximately 6 g/kWh, the GHG emission of a diesel and gas engines is equal.  Source: Verbeek & Verbeek (2015) For short sea ships, the methane slip has a relatively large share of the ship's GHG emissions, e.g. between 16 and 20 % of the total GHG emissions. For different configurations the GHG emissions of LNG fueled ships are not lower than MGO or HFO

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[8] The methane emissions could go down to 0.2 g methane per kWh for gas engines with direct injection.

6.2.11 #11 Limits on methane slip from LNG engines (due to incomplete combustion)

	burned engines (Verbeek & Verbeek 2015). To preserve the climate benefits of using LNG instead of heavy fuel oil, it is critical to limit the methane slip (Brynolf et al., 2013; Burel et al., 2013). **Design** The policy instrument should be designed as an emission limit. The limit should not be too low also in an introduction phase due to the long lifetime of ships. **Technologies/implementation** There are engine types with low slip (which are producing more NO_X emissions) and methane slip could be controlled with improved timing of the injection of the pilot fuel (Sahoo et al., 2009). There is also the possibility for after-treatment, such as oxidation catalysts but the systems have not been used for ships so far (Anderson et al., 2015; Zetterdahl et al., 2016; Hussain et al., 2015; SINTEF, 2017). **Existing examples** Currently no requirements to methane slip from gas engines are implemented. But methane is already regulated for road traffic, e.g. within EURO VI for trucks.
Political implementability	IMO (global level) would be a suitable level and institution to implement an emission regulation on methane slip. Expert forums, including the IMO, the European Sustainable Shipping Forum and the Society for Gas as a Marine Fuel are already discussing the issue of methane slip (Anderson et al., 2015) The limit can be adjusted step-by-step. A time path could be developed together with companies (Verbeek & Verbeek, 2015). If setting the emission limit it should be taken into account that ships have a long lifetime, nevertheless can the stepwise strengthening of the option be a design possibility. **Score from stakeholders (survey): low (2)**
Acceptance & Feasibility	**Ship owners:** - opposed to additional costs **NGOs:** - welcoming the limit as it is sthrengthening combating climate change **Coastal communities** - welcoming mitigation of climate change, but difficult to differentiate between diversity of mitigation activities **Other: gas industry** - Resistance among the gas-industry would be expected as it could be a barrier for market uptake of LNG ships. **Score from stakeholders (survey): very low (1)**
Scientific knowledge	**Measurement of Pressure:** The slip of methane from engines can be measured. **Impact assessment, Socio-economic evaluation:** Scientific basis is quite sound, as climate effect (GHG equivalent) of methane is established. **Score: very low uncertainty (5)**

6.2.11 #11 Limits on methane slip from LNG engines (due to incomplete combustion)

<table>
<tr><td>and uncertainty</td><td></td></tr>
<tr><td>Technological and innovation potential</td><td>There are engine types with low slip on the market but they are emitting more NO_X emissions than engines with higher methane slip. Further technological development would likely come following the introduction of this policy option. For ambitous targets a combination with an after-treatment system would be necessary. Further development of after-treatment systems is needed although the technology exists for road traffic but has not been used for ships. (Hussain et al., 2015; SINTEF, 2017)
The instrument (emission regulation) is not primarily targeting innovation but has a clear link to technological development to reach the emission limit.
Score: medium innovation potential (3)</td></tr>
<tr><td>Environmental and health outcomes</td><td>1) Effect on pressures
<table>
<tr><th colspan="2">Pressure</th><th>Description of expected impact of option on pressures (Increase/Decrease/no effect, brief description if needed)</th></tr>
<tr><td rowspan="4">Emissions to air</td><td>CO_2</td><td><i>No effect on CO_2 emissions but effect on methane and therefore on CO_2equivalent</i></td></tr>
<tr><td>NO_X</td><td><i>Slight negative effect (increase)</i></td></tr>
<tr><td>SO_X</td><td><i>No efect</i></td></tr>
<tr><td>PM /BC</td><td><i>No effect</i></td></tr>
<tr><td rowspan="3">Emissions to water</td><td>Non-indigenous species</td><td><i>No effect</i></td></tr>
<tr><td>Contaminants to water</td><td><i>No effect</i></td></tr>
<tr><td>Oil spills</td><td><i>No effect</i></td></tr>
<tr><td>Noise emissions</td><td>Underwater noise</td><td><i>No effect</i></td></tr>
<tr><td>Physical impacts</td><td>Anchoring, mooring and movement and ship wakes</td><td><i>No effect</i></td></tr>
</table>
2) Effect on human well being:
<table>
<tr><th>Human well being</th><th>Ecosystem services</th><th>Description of effect on ecosystem services (positive, negative, no effect, e.g. with arrows)</th></tr>
<tr><td>Commercial fishing</td><td>Cod, sprat, herring, salmon and seafood</td><td><i>No effect</i></td></tr>
<tr><td>Recreational fishing</td><td>Cod, sprat, herring, salmon and seafood)</td><td><i>No effect</i></td></tr>
</table></td></tr>
</table>

6.2.11 #11 Limits on methane slip from LNG engines (due to incomplete combustion)

Genetic resources	Genetic variation of species	*No effect*
Climate change mitigation	Capacity of sea to absorb CO_2 (i.e. seagrass meadows)	*Positive effect (methane reduced)*
Coastal protection	Capacity of sea to protect coastline, sediments, avoid erosion (i.e. seagrass meadows)	*No effect*
Tourism and recreation	Swimming, beach activities	*No effect*
Other socio-cultural services	Heritage, inspiration, local and regional species	*No effect*
Human health	Clean air	*No effect*

Links to existing policies and their policy targets

- UNFCCC climate targets

- EU transport white book (target: reduction of 40%, if feasible 50 %, by 2050 compared to 2005 levels (EU, 2011))

- IMO MEPC72 (target: reduction of 50% by 2050 (IMO, 2018).

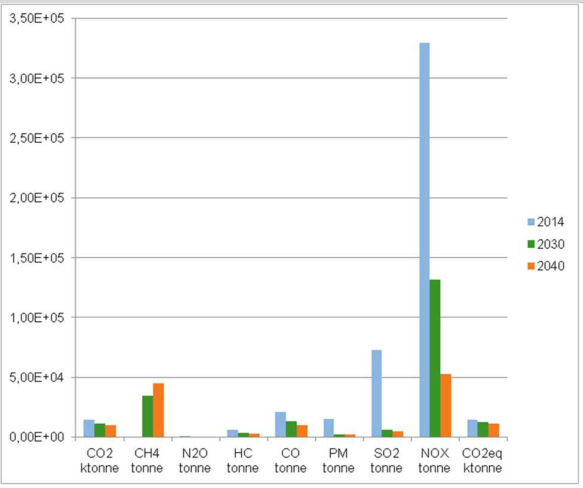
Impact assessment for policy option

- Small effect in relation to BAU (depends on penetration)

- SHEBA-Scenario on effects of option: SHEBA-SSP1 scenario, SHEBA LNG scenario

- The methane slip of the upstream activities is approximately 1.9 g CH_4/kg LNG, and from the combustion 23.04 g CH_4/kg LNG (Bengtsson et al., 2012). For the combustion SINTEF (2017) estimated between 23 and 41 g CH_4/kg LNG, with an average of 31 g CH_4/kg LNG. An emission regulation linked to the combustion process could limit methane emissions. The effect would increase in line with the use of LNG as ship fuel. In the BAU scenario in the SHEBA project it is estimated that 10% of the ships use LNG in the year 2040 which was the lower 10-percentile of an elicitation exercise implemented with stakeholder and experts in the SHEBA project. The most probable value was used in another scenario especially focusing on LNG: with an increase to 25 % of the ships use LNG. The figure below shows the increase of methane emissions from the year 2014 to 2030 and 2040 which is dedicated to the increase to 25 % use of engines with LNG in the year 2040. These emissions could be decreased with policy option #11 substantially. (Fridell et al., 2018)

6.2.11 #11 Limits on methane slip from LNG engines (due to incomplete combustion)

	 Source: Fridell et al (2018). **Score: medium effect (3)**
Efficiency (Economic outcomes)	**Transaction costs:** Limited as processes are not new, similar instruments exist at IMO-level. Monitoring & enforcement is necessary, but measurements can be implemented. **Investment and maintenance costs:** If stricter regulations should apply, which could not be handled by primary measures, a methane reduction catalyst would be required. To the knowledge of the author such catalyst need further development to achieve high methane conversion ratio and long term efficiency, and are not considered to be commercially available for ship application with low methane slip concentration. This will add investment and operation cost for the LPDF and LBSI gas engine concepts. (SINTEF, 2017) **Score cost: medium costs (3)** **Benefits:** The main environmental and social benefit is combating climate change and decreasing effects of changing climate. The greenhouse effect of methane is well known; nevertheless methane slip has only a minor contribution at climate change in general. **Score: medium efficiency (3)**
Distributional effects	*Ship owners* are affected by the regulation as further investments in technological developments are necessary. (+) *Population especially vulnerable to climate impacts* worldwide is benefitting from positive effects such as reduced climate change. No direct financial effects on population, limited indirect effect through increased transport costs (0).

6.2.11 #11 Limits on methane slip from LNG engines (due to incomplete combustion)

	Score: low distributional effect (4)
Synergies and tradeoffs	**Pressures:** The option will have an effect on methane emissions (1). NO_X emissions could increase. **Human well being:** Positive effects are assessed for: Commercial fishing, recreational fishing, climate change mitigation (slight) and tourism & recreation (4). No negative effects are assessed. **Score: (almost) no synergies, low conflicts (2)**

Summary

Engines running on LNG have reduced emissions of several gases (such as SO_X, CO_2) but have higher unburned HC emissions (mainly CH_4), compared to conventional diesel engines. This slip can be significant and can result in a higher climate impact from LNG engines compared with conventional engines. The policy option is a limit on emitted methane for LNG engines (Zetterdahl et al., 2016; Liu et al., 2013; Verbeek & Verbeek, 2015).

For short sea ships, the methane slip has a relatively large share of the ship's GHG emissions, e.g between 16 and 20 % of the total GHG ship emissions (Verbeek & Verbeek, 2015). In the SHEBA project a optimistic LNG scenario has been developed together with stakeholders, in which 25% of the ship engines used in the Baltic Sea run on LNG in the year 2040 (Fridell et al., 2018).

The methane slip could be controlled with improved timing of the injection of the pilot fuel and there is also the possibility for after-treatment which is currently used for truck engines, but not for ship engines. Further technological development and practice-testing will be necessary.

The acceptance and feasibility of the option is evaluated by stakeholders (web survey) with very low which could link to strong resistance in the ship and gas industry, expecting additional costs (research, investment and operational costs) and a barrier for market uptake of LNG ships.

Summary table

Summary: Policy option#11 Limits on methane slip from LNG engines (due to incomplete combustion)			
Political implementability	2	Environmental and health outcomes	3
Acceptance & Feasibility	1	Efficiency	3
Scientific knowledge and uncertainty	5	Distributional effects	4
Technological and innovation potential	3	Synergies and tradeoffs	2
		Total score (including weighting):	2,9
		Rank	16

References:

6.2.11 #11 Limits on methane slip from LNG engines (due to incomplete combustion)

Anderson, M., Salo, K. & Fridell, E. (2015). Particle-and Gaseous Emissions from an LNG Powered Ship. Environmental Science & Technology, 49(20), pp.12568-12575. DOI: 10.1021/acs.est.5b02678

Bengtsson, S., Fridell, E. & Andersson, K. (2012). Enviromental assessment of two pathways towards the use of biofuels in shipping. Energy policy, 44, 451-463.

Brynolf, S., Magnusson, M., Fridell, E. & Andersson, K. (2013). Compliance possibilities for future ECA regulations through the use of abatement technologies or change of fuels. Transport Research Part D: Transport and Environment, 28, 6-18.

Burel, F., Taccani, R. & Zuliani, N. (2013). Improving sustainability of maritime transport through utilization of Liquefied Natural Gas (LNG) for propulsion. Energy, 57, 412-420.

European Commission (EU) (2011). White paper on transport, https://ec.europa.eu/transport/sites/transport/files/themes/strategies/doc/2011_white_paper/white-paper-illustrated-brochure_en.pdf

Fridell, E., Tröltzsch, J., Hasenheit, M., Jalkanen, J.-P., Matthias, V., Eriksson, M. (2018). Sustainable Shipping Scenario. SHEBA Deliverable 1.5. BONUS Research Project.

Liu, J., Yang, F., Wang, H., Ouyang, M. & Hao, S. (2013). Effects of pilot fuel quantity on the emissions characteristics of a CNG/diesel dual fuel engine with optimized pilot injection timing. Applied Energy, 110, 201-206.

Hussain, M., Deorosola, F. A., Russo, N., Fino, D. & Pirone, R. (2015). Abatement of CH4 emitted by CNG vehicles using Pd-SBA-15 and Pd-KIT-6 catalysts. Fuel, 149, 2-7.

International Maritime Organization (IMO) (2018). UN body adopts climate change strategy for shipping, Briefing: 13/04/2018, http://www.imo.org/en/MediaCentre/PressBriefings/Pages/06GHGinitialstrategy.aspx

Sahoo, B. B., Sahoo, N. & Saha, U. K. (2009). Effect of engine parameters and type of gaseous fuel on the performance of dual-fuel gas diesel engines—A critical review. Renewable and Sustainable Energy Reviews, 13, 1151-1184.

Verbeek, R. & Verbeek, M. (2015). LNG for trucks and ships: fact analysis: Review of pollutant and GHG emissions. Final. TNO report. Delft.

Zetterdahl, M. (2016). Particle Emissions from Ships: Measurements on Exhausts from Different Marine Fuels. PhD Thesis, Chalmers University of Technology.

6.2.12 #12 Promoting use of electric power for running the engine (battery –driven)

Assessment criteria	*Assessment results*
Description of policy option	Additional to options such as LNG fueled ships and ships using renewable energy, electric power driven ships could be an option to decrease ship emissions. Ships run by electric power are already existing and suitable for short distances ferry traffic, e.g. the ferry "Ampere" in Norway. A financial support programme could support the additional investment costs for battery-driven ships. **Objectives** This option has the aim to increase the number of battery-driven ships, to increase experiences and technological development especially concerning battery development. Furthermore, it could increase market take-up and penetration. **Impacts to be curbed** If electric power driven engines are fuelled with renewable energies, air pollution and GHG and air pollutant emissions including NO_X, SO_X, PM and CO_2 emissions can be reduced substantially. Air emissions are reduced in highly populated port areas and cities. Water emissions are as well reduced significantly, e.g. no scrubber water, cleaner bilge water will be emitted. Large oil spills are not anymore possible with this ship type, as no larger amount of oil is on board. **Design** Promotional programme supports the investment into battery driven ships with financial support. Research driven and innovative concepts can especially be supported, e.g. zero emission. Clear emission targets to reach for the ferries should be included. A further limiting factor is the existing electric charging infrastructure, therefore also a coupling with support on charging infrastructure in ports is possible. **Technologies/implementation** The option is technology specific supporting electric power driven ships. One example is the ferry "Ampere" operated by Norled in Norway. **Existing examples** Different research projects are funding further development of zero emissions electric ferries (E-Ferry project, PILOT-E project). In Norway, different financial support mechanisms exist which can support investment on electric ferries, e.g. Enova and the NO_X fund for environmental investments (DNV GL, 2018). For example, Enova supported the construction of the first autonomous and fully-electrical zero-emission container ship in the world with 14 mio. EUR (Invest in Norway n.d.). Enova also allocated NOK 480 mio. for electric charging infrastructure for ferries in different counties in Norway (ENERGY FACTS NORWAY, 2018).
Political implementability	**Which political/administrative scale is targeted by the policy option?** The option could be established at EU, Baltic or national level. **Do institutions need to be changed or new institutions established due to introduction of policy option? Is the policy option flexible?**

6.2.12 #12 Promoting use of electric power for running the engine (battery –driven)

Public institutions for management of support programmes exist already. Flexibility of the instrument is high.

Score from stakeholders (survey): medium (3)

Acceptance & Feasibility

Ship owners:

- would be supported by additional investment costs for environmental friendly technology

NGOs:

- potentially welcoming support of electric driven ferries, a variety of benefits for local citizens (e.g. noise)

Coastal communities

- welcoming the benefits and side-effects (air quality improvement, noise reduction, increase of comfort)

Score from stakeholders (survey): medium (3)

Scientific knowledge and uncertainty

Measurement of Pressure

- emissions are based on local/regional mix of energy sources for electricity production – in general needs to be measured individually per ship/ferry, could be based on national energy mix

Impact assessment/Socio-economic evaluation

- Assessments are in place for certain emissions, e.g. NO_X, PM emissions in local communities/port cities

Score : low uncertainty (4)

Technological and innovation potential

Battery driven ships exist and are operated for short distance ferry traffic (e.g. “Ampere” operated by Norled in Norway). The technology exists for short distances but most likely needs further development for longer distances. This mostly concerns new developments in energy storage, i.e. batteries. This can also expand beyond the shipping sector. There is still significant potential for technological development. The option can directly support innovative concepts.

Score: high innovation potential (4)

Environmental and health outcomes

1) **Effects on pressures:**

Pressure		**Description of expected impact of option on pressures (Increase/Decrease/no effect, brief description if needed)**
Emissions to air	CO_2	*Significant positive effect (decrease) on certain routes, but potential for international long distance shipping limited*
	NO_X	*Significant positive effect (decrease)*
	SO_X	*Significant positive effect (decrease)*
	PM /BC	*Significant positive effect (decrease)*
Emissions	Non-indigenous species	*No effect*

6.2.12 #12 Promoting use of electric power for running the engine (battery –driven)

	Contaminants to water	*Slight positive effect (compared to diesel fuelled ships)t*
	Oil spills	*Positive effect (no oil on board)*
Noise emissions	Underwater noise	*Positive effect (engine is more quite)*
Physical impacts	Anchoring, mooring and movement and ship wakes	*No effect*

2) Effects on human well being:

Human well being	**Ecosystem services**	**Description of effect on ecosystem services (positive, negative, no effect, e.g. with arrows)**
Commercial fishing	Cod, sprat, herring, salmon and seafood	*Positive effect (air emissions, oil spills, contaminant, noise)*
Recreational fishing	Cod, sprat, herring, salmon and seafood)	*Positive effect (air emissions, oil spills, contaminants, noise)*
Genetic resources	Genetic variation of species	*No effect*
Climate change mitigation	Capacity of sea to absorb CO$_2$ (i.e. seagrass meadows)	*Positive effect (air emissions, contaminants)*
Coastal protection	Capacity of sea to protect coastline, sediments, avoid erosion (i.e. seagrass meadows)	*No effect*
Tourism and recreation	Swimming, beach activities	*Positive effect (air emissions, oil spills, contaminants, noise)*
Other socio-cultural services	Heritage, inspiration, local and regional species	*Slight positive effect (air emissions, oil spills, contaminants, noise)*
Human health	Clean air	*Positive effect (SO$_X$, NO$_X$, PM)*

For this option the assessment shows positive effects for many components of human well being due to expected less air and water emissions as well as reduced number of oil spills. The effects on human health can be linked to less air emissions.

Links to existing policies and their policy targets

- UNFCCC climate targets

- EU transport white book (target: reduction of 40%, if feasible 50 %, by 2050 compared to 2005 levels (EU, 2011))

6.2.12 #12 Promoting use of electric power for running the engine (battery –driven)

<table>
<tr>
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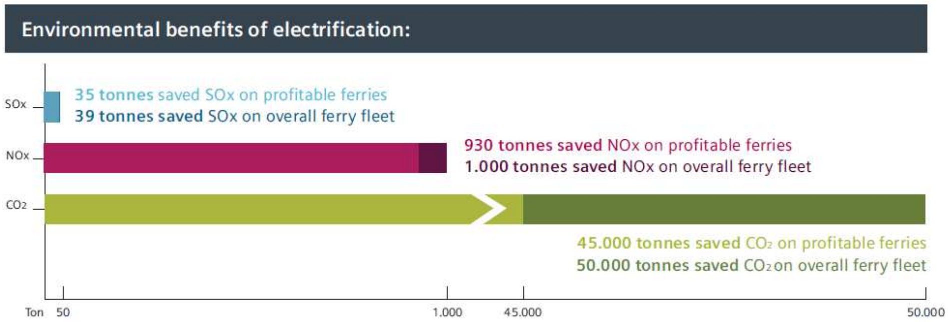
- IMO MEPC72 (target: reduction of 50% by 2050 (IMO, 2018). This target is not achievable by improving energy efficiency of ships (EEDI Phases 0-3), but it requires a gradual shift away from fossil fuels.

Impact assessment for policy option

- For the Norwegian electric ferry Ampere which is running on renewable energy sources, a CO_2 emission cut of 95 % is reported (e.g. Lambert, 2018).
- A study by Bellona & Siemens (2015) analyses that of the 180 ferries operating in Norway, 84 ferries could be switch to fully electric operated, 43 ferries could be switched to hybrid technology. Switch of these ferries would lead to a CO_2 emissions reduction of 300,000 tonnes per year and reduction of NO_X emissions by 8,000 tonnes per year (Viseth, 2016).
- In Denmark the electrification of 30 out of 52 ferries would be profitable and 5 ferries could profitably switched to hybrid technology which would mean a reduction of CO_2 emissions by 45.000 tonnes per year, NO_X could be reduced by 930 tonnes per year and SO_X emissions by 35 tonnes per year, see also figure below (Siemens, 2016).



Source: Siemens (2016).

- The policy option could partially support the realization of the emissions reductions estimated. It would support the higher upfront investment costs which are mentioned as one major barrier for green solutions, analysed by a DNV survey of 23 shipowners (DNV GL, 2014; Gagatsi et al., 2016). The policy option could speed up the market uptake; also with support for establishing the necessary infrastructure in the harbours.

Score: medium effect (3), because effects especially for short distance ferries
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<td>**Efficiency (Economic outcomes)**</td>
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Transaction costs:

For promotion program no significant additional transaction costs are expected.

Investment and maintenance costs

For electric driven ferries upfront investment costs are higher compared to diesel fuelled ferries, but maintenance and operational costs are substantially lower. For the Norwegian ferry Ampere operational cost cuts of 80 % are reported (e.g. Lambert 2018).
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6.2.12 #12 Promoting use of electric power for running the engine (battery –driven)

	The total cost of a switch of 84 Norwegian ferries to fully electric driven and 43 Norwegian ferries to hybrid technology is estimated with NOK 3.5 billion (including infrastructure and charging solutions), but the savings of operational and maintenance costs will be approximately NOK 700 million per year. Additional investments by electric power will thus be repaid within 5 years because of lower costs for fuel and maintenance (life of a ferry is 30-40 years) (Viseth, 2016; Bellona & Siemens, 2015). The required investments for a switch of 39 Danish ferries to electrical propulsion are approximately DKK 420 million higher than for an investment in the same number of diesel ferries. For the substitution of the 39 electrical ferries maintenance and operational costs are estimated with DKK 81 million per year lower than for the diesel fueled ferries (Siemens, 2016). **Score costs: medium (3)** **Benefits:** A variety of benefits are occurring. Human health impacts especially in coastal cities, as NO_X and SO_X pollution could be reduced significantly (Siemens, 2016). The comfort for passengers would increase due to reduced noise emissions and vibrations. Relevant for staff at the ships, dangerous substances and fumes are eliminated too. (Gagatsi et al., 2016; Siemens, 2016). **Score: medium efficiency (3)**
Distributional effects	Positive effects for coastal communities, lower prices for ferry travels possible – positive effects on public budgets, private travelers, cargo tranports **Score: very low (5)**
Synergies and tradeoffs	**Pressures:** The option can have effects on a variety of different pressures: air emissions (CO_2, NO_X, SO_X, PM), water contaminants, oil spills, underwater noise (7, 3 types of pressures). No negative effects are assessed. **Human well being:** Positive effects are assessed for: Commercial fishing, recreational fishing, genetic resources (slight), climate change mitigation, tourism & recreation, other socio-cultural services (slight) and human health (7). No negative effects are assessed. **Score: major synergies, no conflicts (5)**

Summary

Additional to options such as LNG fueled ships and ships using renewable energy, electric power driven ships could be an option to decrease ship emissions. Ships run by electric power are already existing and suitable for short distances ferry traffic, e.g. the ferry “Ampere” in Norway. A financial incentives programme could support the additional investment costs for battery-driven ships. Operational and maintenance costs are expected to be lower compared to diesel fueled ships, e.g. for the Norwegian ferry Ampere operational cost cuts of 80 % are reported (e.g. Lambert, 2018).

6.2.12 #12 Promoting use of electric power for running the engine (battery –driven)

If electric power driven engines are fuelled with renewable energies, GHG and air pollutant emissions including NO_X, SO_X, PM and CO_2 emissions can be reduced substantially. Air emissions are reduced in highly populated port areas and cities. Water emissions as well as oil spills are reduced significantly.

For the Norwegian electric ferry Ampere which is running on renewable energy sources, a CO_2 emission cut of 95 % is reported (e.g. Lambert, 2018). For the switch of additional 127 Norwegian ferries to fully electric or hybrid technology the CO_2 emission reduction is estimated with 300,000 tonnes per year and reduction of NO_X emissions by 8,000 tonnes per year (Viseth, 2016).

The largest shortcoming is the current feasibility only for short distance ferries. Different projects exist that research on ships for longer distances, e.g. including cargo ships going along the coast. Furthermore, the necessary energy charging and storage infrastructure at land needs to be developed. The described support programme could include or be linked with support for the necessary infrastructure in ports.

Summary table

Summary: Policy option #12 Promoting use of electric power for running the engine (battery – driven)			
Political implementability	3	Environmental and health outcomes	3
Acceptance & Feasibility	3	Efficiency	3
Scientific knowledge and uncertainty	4	Distributional effects	5
Technological and innovation potential	4	Synergies and tradeoffs	5
		Total score:	3,6
		Rank	6

References:

Bellona & Siemens (2015). Syv av ti ferger er lønnsomme med ELEKTRISK DRIFT – en mulighetsstudie. Oslo, http://network.bellona.org/content/uploads/sites/2/2015/08/Batteriferger.pdf

DNV GL (2014). Alternative Fuel For Shipping, Strategic Research & Innovation, Position Paper.

DNV GL (2018). Electric ferries on the rise. https://www.dnvgl.com/article/electric-ferries-on-the-rise-117783

ENERGY FACTS NORWAY (2018). ENOVA. https://energifaktanorge.no/en/et-baerekraftig-og-sikkert-energisystem/enova/

European Commission (EU) (2011). White paper on transport, https://ec.europa.eu/transport/sites/transport/files/themes/strategies/doc/2011_white_pape

6.2.12 #12 Promoting use of electric power for running the engine (battery –driven)

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Gagatsi, E., Estrup, T., Halatsis, A. (2016). Exploring the potentials of electrical waterborne transport in Europe: the E-ferry concept. Transportation Research Procedia 14 (2016) 1571 – 1580.

International Maritime Organization (IMO) (2018). UN body adopts climate change strategy for shipping, Briefing: 13/04/2018, http://www.imo.org/en/MediaCentre/PressBriefings/Pages/06GHGinitialstrategy.aspx

Invest in Norway (n.d.). Norway – unique location for battery development and production. https://www.innovasjonnorge.no/contentassets/d3e3d93be72a4c6d910b7c16c8c08633/battery-teaser.pdf

Lambert, F. (2018). All-electric ferry cuts emission by 95% and costs by 80%, brings in 53 additional orders. Feb 3, 2018, https://electrek.co/2018/02/03/all-electric-ferry-cuts-emission-cost/

Siemens (2016). Electrification of Denmark's ferry fleet. Ballerup.

Viseth, E. (2016). Battery Ferries smashes diesel on profitability. July 22, 2016, http://www.pbes.com/2016/07/22/battery-ferries-smashes-diesel-profitability/

6.2.13 #13 Promoting shore power in ports

Assessment criteria	*Assessment results*
Description of policy option	Most of the emissions in port areas are from ships at berth. In Hamburg, for example, ships alone account for 38 % of the NO_X emissions and 17 % of PM10 emission (BSU Hamburg, 2012). As the installation of shore power equipment is the major investment to use electricity at the berth, financial support of upfront investment costs could increase the uptake and installation by ports. A significant reduction of CO_2 emissions will only be reached if electricity from renewable energies is used. Shore power is mainly attractive for ships in frequent traffic to ports, mainly ferries and RoRos, fewer container ships in liner traffic. Also for cruise ships there is an increasing pressure from authorities and customers for use of shore power to reduce GHG emissions. (Winnes et al., 2015) **Objectives** Increase number of ports with shore power equipment installed, support of market uptake of infrastructure including large investment costs **Impacts to be curbed** Reduction of CO_2, NO_X, SO_X and PM emissions in ports and therefore harbour cities **Design** Promotional programme supports the investment in shore power equipment in ports with financial support. Information could be prepared on harbours with shore power

6.2.13 #13 Promoting shore power in ports

	infrastructure. To increase the environmental and health effects, the financial support could be linked to a minimum share of electricity from renewables. **Technologies/implementation** Shore power shifts electrical generation from a ship's onboard generators, driven by auxiliary engines, to a source on shore, usually the electrical grid. On shore power is installed in several ports in the world, among them Gothenburg and Hamburg. New developments include non-stationary electricity generating systems like the LNG driven power barge in the port of Hamburg.
Political implementability	**Which political/administrative scale is targeted by the policy option** National, Baltic, EU or global level suitable. A level beyond national level would be recommendable as a significant number of international ports installed with the equipment would incentivize investments by ship owners. **Do institutions need to be changed or new institutions established due to introduction of policy option? Is the policy option flexible?** Suitable (public) institutions are in place. Option can be extended in time and volume if further demand exists. **Score from stakeholders (survey): very high (5)**
Acceptance & Feasibility	**Ship owners:** - not directly linked additional costs - for ships which have already on board equipment for on shore power – welcoming of more ports with suitable infrastructure can be assumed. **NGOs:** - welcoming of support programme is assumed, especially if it could be linked with renewable energy sources **Coastal communities** - welcoming the side-effects especially better air quality, less noise in the harbour areas **Score from stakeholders (survey): very high (5)**
Scientific knowledge and uncertainty	**Measurement of Pressure** Methodologies for estimation of GHG and air pollutant emissions are well established. The reduction effect can be calculated based on local/regional or national mix of energy. **Impact assessment / Socio-economic evaluation** Methodologies for impact assessment for air and GHG emissions are available and quite sound. Sound and regularly used methodology for health impacts of air pollution, remaining methodological issues on ecosystem services assessment **Score: high (4)**

6.2.13 #13 Promoting shore power in ports

Technological and innovation potential

The technology is available, on shore power is installed in several ports in the world, among them Gothenburg (six RoRo berths) and Hamburg. New developments include non-stationary electricity generating systems like the LNG driven power barge in the port of Hamburg. Incentives are necessary to promote the installation, because they are not fully economically viable. Therefore, the option should not focus on technological development but on market uptake.

Score: very low innovation potential (1) (technology exists, market uptake is necessary)

Environmental and health outcomes

1) Effects on pressures:

Pressure		**Description of expected impact of option on pressures (Increase/Decrease/no effect, brief description if needed)**
Emissions to air	CO$_2$	*Significant positive effect (decrease) if electricity is produced by renewables*
	NO$_X$	*Significant positive effect (decrease), especially locally in port cities and harbour areas*
	SO$_X$	*Significant positive effect (decrease), especially locally in port cities and harbour areas*
	PM /BC	*Significant positive effect (decrease), especially locally in port cities and harbour areas*
Emissions to water	Non-indigenous species	*No effect*
	Contaminants to water	*No effect*
	Oil spills	*No effect*
Noise emissions	Underwater noise	*Positive effect (Reduced in ports, AUX engines are switched off)*
Physical impacts	Anchoring, mooring and movement and ship wakes	*No effect*

2) Effect on human well being:

Human well being	**Ecosystem services**	**Description of effect on ecosystem services (positive, negative, no effect, e.g. with arrows)**
Commercial fishing	Cod, sprat, herring, salmon and seafood	*Positive effect (NO$_X$, SO$_X$, CO$_2$ – if electricity from renewables is used, noise)*
Recreational fishing	Cod, sprat, herring, salmon and seafood	*Positive effect (NO$_X$, SO$_X$, CO$_2$ – if electricity from renewables is used, noise)*
Genetic resources	Genetic variation of species	*No effect*

6.2.13 #13 Promoting shore power in ports

Climate change mitigation	Capacity of sea to absorb CO_2 (i.e. seagrass meadows)	*Slight positive effect (if the electricity stems from renewables)*
Coastal protection	Capacity of sea to protect coastline, sediments, avoid erosion (i.e. seagrass meadows)	*No effect*
Tourism and recreation	Swimming, beach activities	*Positive effect (NO_X, SO_X, CO_2 – if electricity from renewables is used)*
Other socio-cultural services	Heritage, inspiration, local and regional species	*No effect*
Human health	Clean air	*Positive effect (NO_X, SO_X, PM)*

Positive effects by less emitted CO_2, NO_X, SO_X and PM are expected for commercial and recreation fishing, tourism & recreation and human health. As emission reduction is very local no further width spread effects are expected. Furthermore, significant effects can only be expected if the used electricity is produced by renewables.

Links to existing policies and their policy targets

- IMO MEPC72 (target: reduction of 50% by 2050) (IMO, 2018).

- The European Air Quality Directive 2008/50/EC sets limits for e.g. for SO_X and NO_X, the one -hour limit for sulphur dioxide is at 350 µg/m which may not be exceeded more than 24 times a year, the daily limit of 125µg/m may not be exceeded more than three times a year; the European-wide one-hour limit for NO of 200 µg/m3 which may not be exceeded more than 18 times a year. Accompanying this, the limit per year is a daily average of 40 µg/m. For PM10: the average value is limited at 40 µg/m³ (per year) and the daily average value of 50 µg/m³ may not be exceeded on more than 35 days per year. For PM2.5, the the average value is limited at 25 µg/m³ (per year) and (EC 2008; EC 2018).

Impact assessment for policy option

- According to SHEBA BAU scenario, most of the emissions in port areas are from ships at berth. In Gothenburg for example ships contribute several µg/m³ to the NO_2 concentrations downwind of the port (see SHEBA D2.4). In other ports, the contribution is in a similar magnitude, however the affected areas are not as populated as in Gothenburg.
- In Hambug, for example, ships alone account for 38 % of the NO_X emissions and 17% of PM10 emission (BSU Hamburg, 2012), which could be reduced by on shore power significantly.
- The SHEBA project developed an on shore power supply (OPS) scenario for Gothenburg for the year 2040, results for the OPS scenario and the SHEBA-BAU scenario see in the figure below

6.2.13 #13 Promoting shore power in ports

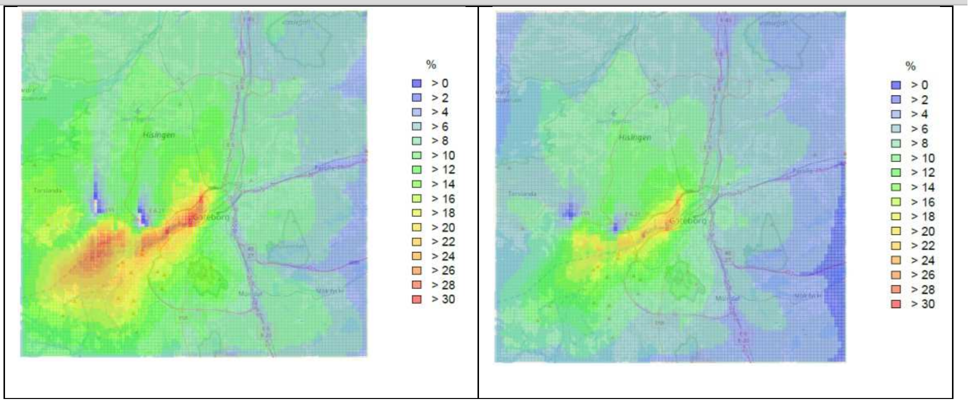


Figure 19 Realtive contribution of shipping to the NO2 concentrations in Gothenburg for the BAU 2040 scenario. Left: Without onshore power supply. Right: With onshore power supply for ships at berth.

Source: Martin Ramacher, HZG. The maps are based on data produced for SHEBA Deliverable 2.4.

- For the establishment of a shore power facility for cruise ships in the habour of Copenhagen emissions reductions are estimated with 46,000 to 117,000 t of CO_2 emissions, 910 to 2,350 t NO_X emissions, 15 to 38 t Particles and 9 to 24 t SO_X emissions over 30 years (2016-2046) (City & Port Development, 2015).

- ICCT (2015) calculated emissions reduction for shore power compared to running the engine at marine diesels (see figure below). For SO_X and NO_X significant emissions reductions are calculated. For CO_2 emissions the results are heavily depending on the used energy mix. It is assumed that energy mix for shore power used in the year 2020 is 100% natural gas, which also leads to almost 40% reduction of CO_2 emissions.

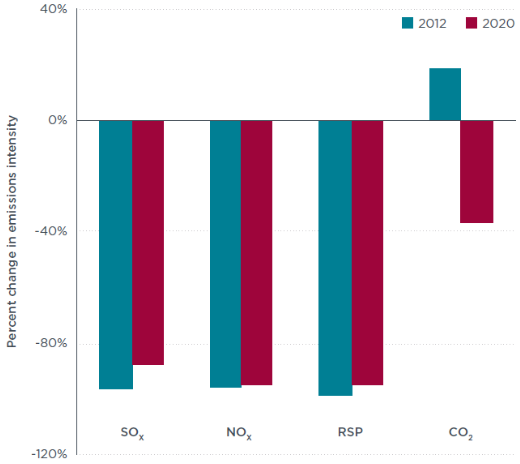


Figure 20 Emissions reduction by switching from marine diesels to electricity via shore power for the port of Shenzhen

Source: ICCT (2015).

Score: medium effects (3)

6.2.13 #13 Promoting shore power in ports

Efficiency (Economic outcomes)	**Transaction costs:** Promotion program costs limited additional transaction costs. **Investment and maintenance costs** Environ (2004) and CARB (2007) estimated that the cost to modify a ship to receive onshore power ranges from USD 500,000 to USD 2 million. ICCT (2015) calculated based on data provided by Environ, that the average cost for the capital investment is around USD 172 per TEU capacity. Based on information provided by various ports, CARB (2007) estimated the investement cost to modify each berth at a terminal to be about USD 5 million. Additional maintenance costs might be possible, ICCT (2015) assumed annual operational and maintenance costs of 12% of total capital investment in shoreside infrastructure. Depending on the individual port, costs for upgrades of electrical infrastructure outside of the port could be possible (CARB, 2007). City & Port Development (2015) published a technical report for establishment of shore power for cruise ships in the harbour of Copenhagen. The total investment for establishment was calculated with DKK 74.8 million. They state that public development grants would be necessary to support the investment as the income can not cover all costs. However, BPO (2016) summarized that initial problems with the shore power technology have been resolved and it is much more mature and affordable than it was a few years ago. The investment costs decreased substantially due to the availability of prefabricated assemblies and system standardization **Score costs: medium (3)** **Benefits:** ICCT (2015) and CARB (2007) developed a cost-effectiveness analysis including costs into infrastructure but as well additional investment costs for ship owners. ICCT (2015) estimated that the average costs of reducing one tonne of pollutants through onshore power at the Port of Shenzhen. The costs of reducing one tonne of NO_X, PM, SO_X and CO_2 are close to USD 56,000, USD 1.4 million, USD 290,000, and USD 2,300 respectively. ICCT (2015) also analyse the cost-effectiveness of fuel switching to low sulphur fuel and estimated for the fuel switch a better cost-effectiveness for SO_X and PM (fuel switching does not address NO_X and CO_2 emissions). They summarize that fuel switching is compared to on shore power cheaper and technologically less challenging. Vaishnav et al. (2016) used two integrated assessment models to quantify the benefits of reducing the emissions of NO_X, SO_2, PM2.5, and CO_2 that would occur if shore power were used at U.S. ports. Depending on the social costs of pollution assumed,

6.2.13 #13 Promoting shore power in ports	
	an air quality benefit of USD 70-150 million per year could be achieved by retrofitting a quarter to two-thirds of all vessels that call at U.S. ports. It would assume that many ships need to be equipped to receive shore power. (Vaishnav et al., 2016) **Score: medium efficiency (3)**
Distributional effects	Shipowners have to take additional costs, public or private port authorities have to invest with effects on public budgets **Score: low (4)**
Synergies and tradeoffs	**Pressures:** The option can have effects on air emissions (CO_2, NO_X, SO_X, PM), especially close to harbor areas and underwater noise (5, 2 types of pressures). No negative effects are assessed. **Human well being:** Positive effects are assessed for: Commercial fishing, recreational fishing, tourism & recreation, human health (4). No negative effects are assessed. **Score: minor synergies, no conflicts (4)**

Summary

Most of the emissions in port areas are from ships at berth. In Hamburg, for example, ships alone account for 38% of the NO_X emissions and 17% of PM10 emission (BSU Hamburg, 2012). As the installation of shore power equipment is the major investment to use electricity at berth, financial support of upfront investment costs could increase the uptake and installation by ports. With shore power compared to marine diesel NO_X, SO_X and PM emissions in ports and therefore harbour cities can be reduced (ICCT, 2015). A significant reduction of CO_2 emissions will only be reached if electricity from renewable energies or natural gas is used (ICCT, 2015). To increase the environmental and health effects, the financial support could be linked to a minimum share of electricity from renewables. A coupling with differentiated port fees would be suitable. If ships are using shore power during their time at the berth, they have to pay reduced port fees.

Shore power is mainly attractive for ships in frequent traffic to ports, mainly ferries and RoRos, fewer container ships in liner traffic. Also cruise ships have a significant electricity demand also at berth and are encountering an increasing pressure from authorities and customers for use of shore power to reduce GHG emissions. (Winnes et al., 2015) The technology is available, on shore power is installed in several ports in the world, among them Gothenburg (six RoRo berths) and Hamburg but with large upfont investment costs. The results of the stakeholder assessment show a very high score on the political implementability.

ICCT (2015) also assessed cost-effectiveness of shore power (based on 100 % natural gas energy mix) and fuel switching to low sulphur fuel and estimated for the fuel switch a better cost-effectiveness for SO_X and PM (fuel switching does not address NO_X and CO_2 emissions). However, if 100% renewables are represented in the energy mix, the emission reduction would be by far larger for shore power.

6.2.13 #13 Promoting shore power in ports

Summary table

Summary: Policy option #13 Promoting shore power in ports			
Political implementability	5	Environmental and health outcomes	3
Acceptance & Feasibility	5	Efficiency	3
Scientific knowledge and uncertainty	4	Distributional effects	4
Technological and innovation potential	1	Synergies and tradeoffs	4
		Total score:	3,6
		Rank	4

References:

Baltic Ports Organization (BPO) (2016). The Baltic Sea as a model region for green ports and maritime transport. Gdynia. http://www.bpoports.com/BPC/Helsinki/BPO_report_internet-final.pdf

BSU Hamburg (2012). Luftreinhalteplan für Hamburg. 1. Fortschreibung 2012. Behörde für Stadtentwicklung und Umwelt, Hamburg.

California Air Resources Board (CARB) (2007). Technical Support Document: Initial Statement of Reasons for the Proposed Rulemaking. Retrieved from http://www.arb.ca.gov/regact/2007/shorepwr07/tsd.pdf

City & Port Development, CMP, City of Copenhagen (2015). Options for establishing shore power for cruise in port of Copenhagen Nordhavn. Copenhagen. https://www.danskehavne.dk/wp-content/uploads/2015/12/GP-CMP-Shoreside-Report.pdf

EC (2008). Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe. Official Journal of the European Commission, L 152, 11.6.2008, p. 1–44.

EC (2018). Air Quality Standards. http://ec.europa.eu/environment/air/quality/standards.htm

Environ International Corp. (2004). Cold ironing cost effectiveness study. Port of Long Beach. Retrieved from http://www.polb.com/civica/filebank/blobdload.asp?BlobID=7718

ICCT (2015). Costs and benefits of shore power at the port of Shenzhen. https://www.theicct.org/publications/costs-and-benefits-shore-power-port-shenzhen

International Maritime Organization (IMO) (2018). UN body adopts climate change strategy for shipping, Briefing: 13/04/2018, http://www.imo.org/en/MediaCentre/PressBriefings/Pages/06GHGinitialstrategy.aspx

6.2.13 #13 Promoting shore power in ports

Vaishnav, P., Fischbeck, P.S., Morgan, M.G., Corbett, J.J. (2016). Shore Power for Vessels Calling at U.S. Ports: Benefits and Costs. Environmental Science & Technology. 2016 Feb 2;50(3):1102-10. doi: 10.1021/acs.est.5b04860.

Winnes, H., Styhre, L., Fridell, E. (2015). Reducing GHG emissions from ships in port areas. Research in Transportation Business & Management 17 (2015) 73–82.

6.2.14 #14 Green port fees linked to ship emissions/pollutants

Assessment criteria	*Assessment results*
Description of policy option	Green port fees are a market- based strategy to address environmental impacts from the shipping sector. Green port fees are understood as differentiated port fees or dues based on ship emissions (e.g. NO_X, SO_X, GHG emissions), pollutants or other “green” features of the ship, e.g. shore power equipment. Green port fees are already implemented in several ports, including many Swedish ports as well as Riga and Klaipeda. **Objectives** Reductions of emissions and pollutants are reached by setting financial incentives via rebates or rewards on port fees **Impacts to be curbed** This option aims at reducing different types of negative environmental impacts from shipping. The policy instrument can be designed to address different issues like air pollution, greenhouse gases, emissions to water, noise but also working conditions and others sustainability issues. **Design** The design is a reduction of fees for ships with less environmental impacts (emissions/pollutants/etc.) and thus a higher fee for more polluting ships. The rebates are often measured based on established indices such as Environmental Ship Index, Clean Shipping Index or Green Award which are summarizing different environmental pressures. A harmonized approach by multiple ports could have benefits for ports and shipowners. **Technologies/implementation** For the different emissions a variety of suitable technologies are available, see the other pressure-specific policy options discussed in this report. **Existing examples**

6.2.14 #14 Green port fees linked to ship emissions/pollutants

Many examples of ports with differentiated fees exist, see Appendix I. Sweden is one of the major examples in Europe. The voluntary differentiation in port dues was implemented 1998 in Sweden (Han, 2010; Lindé, 2018). 30 of the 52 ports in Sweden impose environmentally differentiated port dues by the year 2006. (Wilmsmeier, 2012). A study of global ports found that 79% are rebates for differentiating their fees (Wang, 2014).

Different voluntary ship rating systems are used as basis for the rebates:

- Environmental Ship Index (ESI)
- Blue Angle
- Green Award
- Clean Ship Index (CSI)
- Right ship

Very common is the ESI, Green Award is also very common and CSI is also used (European Commission, 2017).

Political implementability

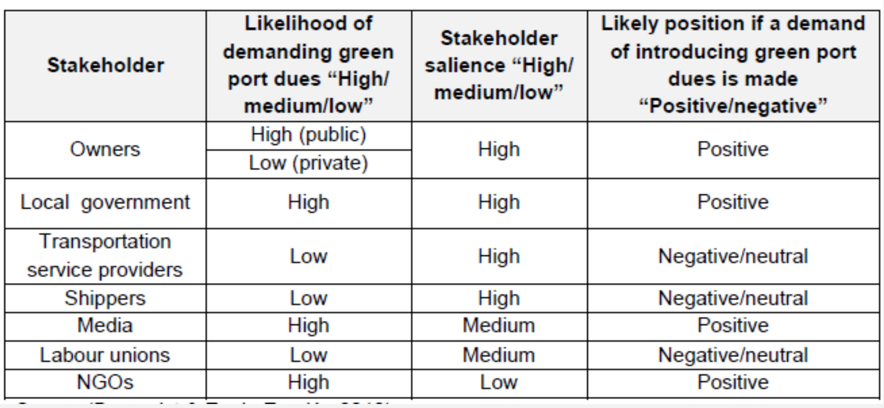
These fees are implemented at local level (port level). Also pan-Baltic port fee systems or worldwide systems are discussed (Katila 2013).

Score from stakeholders (survey): very high (5)

Acceptance & Feasibility

Bergqvist & Egels-Zanden (2012) summarized the assessment of different stakeholders on whether ports are likely to introduce green port dues, see following table.

Table 31 Stakeholder assessment



Stakeholder	Likelihood of demanding green port dues "High/ medium/low"	Stakeholder salience "High/ medium/low"	Likely position if a demand of introducing green port dues is made "Positive/negative"
Owners	High (public) Low (private)	High	Positive
Local government	High	High	Positive
Transportation service providers	Low	High	Negative/neutral
Shippers	Low	High	Negative/neutral
Media	High	Medium	Positive
Labour unions	Low	Medium	Negative/neutral
NGOs	High	Low	Positive

Source: Bergqvist & Egels-Zanden (2012), cited from Wang (2014)

A survey of Swedish ports showed that 20 out of 30 ports responded that the implementation of differentiated port fees has been positive for the business and only one port responded that the effect has been negative (Mellin & Rydher, 2011).

Score from stakeholders (survey): high (4)

6.2.14 #14 Green port fees linked to ship emissions/pollutants

Scientific knowledge and uncertainty

Different knowledge base and uncertainties according to the different covered pressures. There are challenges involved in verification and control.

Score: medium (3)

Technological and innovation potential

Availability of used technology depends on the targeted issues.

Score: low (2)

Environmental and health outcomes

1) **Effects on pressures:**

Pressure		**Description of expected impact of option on pressures (Increase/Decrease/no effect, brief description if needed)**
Emissions to air	CO_2	*Positive effect (decrease (depends on design of instrument (for all pressures))*
	NO_X	*Positive effect (decrease)*
	SO_X	*Positive effect (decrease)*
	PM /BC	*Positive effect (decrease)*
Emissions to water	Non-indigenous species	*No effect*
	Contaminants to water	*No effect (low probability that water emissions will be included)*
	Oil spills	*No effect*
Noise emissions	Underwater noise	*Slight positive effect (decrease, e.g. if shore power is used)*
Physical impacts	Anchoring, mooring and movement and ship wakes	*No effect*

2) **Effects on human well being:**

Human well being	**Ecosystem services**	**Description of effect on ecosystem services (positive, negative, no effect, e.g. with arrows)**
Commercial fishing	Cod, sprat, herring, salmon and seafood	*Positive effect (depending on design of instrument)*
Recreational fishing	Cod, sprat, herring, salmon and seafood	*Positive effect (depending on design of instrument)*
Genetic resources	Genetic variation of species	*No effect*
Climate change mitigation	Capacity of sea to absorb CO_2 (i.e. seagrass meadows)	*Slight positive effect (depending on design of instrument)*

6.2.14 #14 Green port fees linked to ship emissions/pollutants

Coastal protection	Capacity of sea to protect coastline, sediments, avoid erosion (i.e. seagrass meadows)	*No effect*
Tourism and recreation	Swimming, beach activities	*Slight positive effect (depending on design of instrument)*
Other socio-cultural services	Heritage, inspiration, local and regional species	*Slight positive effect (depending on design of instrument)*
Human health	Clean air	*Positive effect (depending on design of instrument)*

The expected effects on human well being are very much depending on the design of the port fees and on which pressures the fee scheme is focusing. Furthermore, the potential for ambitious port fees is critically discussed as these could only be reached if a group of ports would be agree and implement similar ambitious targets and linked fees.

Links to existing policies and their policy targets

Depending on included pressures, e.g. UNFCCC climate targets, IMO MEPC72 decision on shipping green-house gas target (IMO 2018), EU transport white book (European Commission, 2011), MSFD Descriptors 8, 9

Impact assessment for policy option

- Potential effect in relation to BAU (depends on penetration)
- Wang (2014) describes based on interviews with liner shipping companies that they are aware of green incentive schemes but the reward of green incentives is very limited and easily compensated by savings of well-organized operations and well-managed fleets. Wang (2014) concludes that green incentives can only be considered as additional incentive, but it is not essential enough to drive their behavior on improving the efficiency and environmental performance of the vessels. Wang (2014) shows as well that green port fees are not a criterion for decision making in changing port of call. The Green port dues are minor factor behind their decision.
- As for significant emission reductions (e.g. CO_2) stricter policies and regulations related to alternative fuels and ship design need to be taken on an international level, ports can facilitate the process e.g. by implementation of green differentatiated port fees (Winnes et al., 2015)

Score: low effect (2)

Efficiency

Transaction costs:

Extra administration costs and efforts are expected for the ports, as these have to develop and manage the schemes. A harmonized approach for multiple ports on major shipping routes could create benefits for both ports and ships owners. Ports could develop a more consistent approach (Becqué et al., 2018).

Investment and maintenance costs:

Deepening on design of instrument, see other policy options

6.2.14 #14 Green port fees linked to ship emissions/pollutants

	Score costs: high (2) (highly depending on design of instruments) **Benefits:** Deepening on design of instrument, see other policy options **Score: medium efficiency (3)**
Distributional effects	Limited distributional effect **Score: very low (5)**
Synergies and tradeoffs	**Pressures:** The option can have effects on all different pressures, depending on how it is designed. (up to 9 groups of pressures). No negative effects are assessed. **Human well being:** Positive effects can be assessed for many components of human well being (depending on the design). It might be limited for genetic resources and coastal protection (6). No negative effects are assessed. **Score: major synergies, no conflicts (5) (but heavily depending on design of option)**

Summary

Green port fees are a market- based strategy to address environmental impacts from the shipping sector. Green port fees are understood as differentiated port fees or dues based on ship emissions (e.g. NO_X, SO_X, GHG emissions), pollutants or other "green" features of the ship, e.g. shore power equipment. Green port fees are already implemented in several ports, including many Swedish ports as well as Riga and Klaipeda. This option aims at reducing different types of negative environmental impacts from shipping. The policy instrument can be designed to address different issues like air pollution, greenhouse gases, emissions to water, noise but also working conditions and others sustainability issues. The incentive schemes are in general established on port level, but also harmonized pan-Baltic port fee systems or worldwide systems are discussed with advantages for shipowners and ports. The stakeholder assessment and also surveys show that green port fees are relatively accepted. But the environmental impacts are described as limited because the reward for green technologies is very limited and easily compensated by savings of well-organized operations and well-managed fleets. To reach significant reductions of emissions and pollutants other policy options need to be taken on international level. Ports can facilitate this process and green port fees could play a role in a larger set of options to support different environmentally friendly practices.

Summary table

Summary: Policy option #14 Green port fees linked to ship emissions/pollutants			
Political implementability	5	Environmental and health outcomes	2
Acceptance & Feasibility	4	Efficiency	3
Scientific knowledge and uncertainty	3	Distributional effects	5

6.2.14 #14 Green port fees linked to ship emissions/pollutants

Technological and innovation potential	2	Synergies and tradeoffs	5
		Total score:	3,5
		Rank	7

References:

Becqué, R., Fung, F., Zhu, Z. (2018). Incentive Schemes for Promoting Green Shipping. NRDC Discussion Paper. Updated in January 2018.

Bergqvist, R. & Egels-Zandén, N. (2012). Green port dues — The case of hinterland transport. Research in Transportation Business & Management, 5, pp.85–91.

European Commission (2011). White paper on transport, https://ec.europa.eu/transport/sites/transport/files/themes/strategies/doc/2011_white_paper/white-paper-illustrated-brochure_en.pdf

European Commission (2017). Study on differentiated port infrastructure charges to promote environmentally friendly maritime transport activities and sustainable transportation. Executive Summary. https://ec.europa.eu/transport/sites/transport/files/2017-06-differentiated-port-infrastructure-charges-exec-summary.pdf

International Maritime Organization (IMO) (2018). UN body adopts climate change strategy for shipping, Briefing: 13/04/2018, http://www.imo.org/en/MediaCentre/PressBriefings/Pages/06GHGinitialstrategy.aspx

Katila, J. (2013). Environmentally differentiated port fees in the Baltic Sea Ports Building a cost-efficient port fee system. In: IFSP 2013. P. 494-502. https://www.polyu.edu.hk/lms/icms/Proceedings/Proceedings%20of%20IFSPA%202013.pdf

Lindè, T., I. Vierth. (2018). An Evaluation of the Environmentally Differentiated Fairway Dues in Sweden 1998- 2017. In: VTI notat 3A-2018. P.1-46. [downloaded 09.05.2018: http://vti.diva-portal.org/smash/get/diva2:1186525/FULLTEXT01.pdf]

Mellin, A., Rydhed, H. (2011). Swedish ports' attitudes towards regulations of shipping sector's emissions of CO2. Maritime Policy and Management, the flagship journal of international shipping and port research. 38:4, 437-450.

Wang, J.-C. (2014). Green Port Pricing - A case study approach. Erasmus University Rotterdam.

Wilmsmeier, G. (2012). Infrastructure charges: Creating incentives to improve environmental performance. Bulleting FAL. Issue No. 309, Number 5/2012.

Winnes, H., Styhre, L., Fridell, E. (2015). Reducing GHG emissions from ships in port areas. Research in Transportation Business & Management 17 (2015) 73–82.

6.2.15 #15 Introduction of national fairway dues (charges) which are linked to ship emissions/pollutants

Assessment criteria	*Assessment results*
Description of policy option	National fairway dues or charges paid by ships are used to finance maritime fairways, navigational aid, pilotage, search and rescue operation and ice-breaking. In general, the charges are based on gross tonnage and volume of goods loaded and unloaded in the ports of a country. In many countries the facilities and services are linked to ports, but several EU countries are using national dues, e.g. Sweden and Finland (Swann, 2002). Environmental impacts can be addressed via the differentiation of the fees according to the emissions and pollutants linked to the individual ships. **Objectives**: Reductions of emissions and pollutants are reached by setting financial incentives via environmentally differentiated national fairway dues **Impacts to be curbed** This option aims at reducing different types of negative environmental impacts from shipping. The policy instrument can be designed to address different issues like air pollution, greenhouse gases, emissions to water, noise but also working conditions and others sustainability issues. **Design** The design is to establish lower dues for ships with less environmental impacts (emissions/pollutants/etc.) and thus higher dues for more polluting ships. The differentiation can be linked to established indices such as Environmental Ship Index, Clean Shipping Index or Green Award which are summarizing different environmental pressures. To increase environmental effect the fees could be based on sailed distance or fuel consumption and not number of called ports. **Technologies/implementation** For the different emissions a variety of suitable technologies are available, see the other pressure-specific policy options discussed in this report. **Examples:** The most prominent example is Sweden. In Sweden, Swedish Maritime Administration (SMA) is responsible for determining and collecting such fees. The size of the vessel, its cargo and its emission of air pollutants shall be considered when determining the fee. Environmentally differentiated fairway dues on SO_X and NO_X existed in Sweden between 1998 and 2017. After the implementation of the International Maritime Organization's stricter SO_X requirements in the Baltic Sea areas in 2015, it was decided to replace the NO_X-differentiated fairway dues from 2018 by a system that comprises several environmental aspects. (Lindé & Vierth, 2018)

6.2.15 #15 Introduction of national fairway dues (charges) which are linked to ship emissions/pollutants

<table>
<tr><td>Political implementability</td><td>National level (for local level differentiation of port fees is suitable, see #14 Green port fees linked to ship emissions/pollutants)

Score from stakeholders (survey): medium (3)</td></tr>
<tr><td>Acceptance & Feasibility</td><td>Shipowners would probably show some resistance as they are expecting high charges for old ships.
The income for ports and countries could be more uncertain.

Score from stakeholders (survey): very low (1)</td></tr>
<tr><td>Scientific knowledge and uncertainty</td><td>Different knowledge base and uncertainties according to the different covered pressures. There are challenges involved in verification and control.

Score: medium (3)</td></tr>
<tr><td>Technological and innovation potential</td><td>Availability of used technology depends on the targeted issues. For most probably targeted pressures technologies exist. Objective of policy option is a wider adoption of existing emission abatement technologies.

Score: low (2)</td></tr>
<tr><td>Environmental and health outcomes (WP2,3,4-partners + Ecologic/SDU)</td><td>1) Effects on pressures:
<table>
<tr><th colspan="2">Pressure</th><th>Description of expected impact of option on pressures (Increase/Decrease/no effect, brief description if needed)</th></tr>
<tr><td rowspan="4">Emissions to air</td><td>CO_2</td><td><i>Positive effect (decrease, depends on design of instrument (for all pressures)</i></td></tr>
<tr><td>NO_X</td><td><i>Positive effect (decrease)</i></td></tr>
<tr><td>SO_X</td><td><i>Positive effect (decrease)</i></td></tr>
<tr><td>PM /BC</td><td><i>Positive effect (decrease)</i></td></tr>
<tr><td rowspan="3">Emissions to water</td><td>Non-indigenous species</td><td><i>No effect</i></td></tr>
<tr><td>Contaminants to water</td><td><i>No effect (low probability that water emissions will be included)</i></td></tr>
<tr><td>Oil spills</td><td><i>No effect</i></td></tr>
<tr><td>Noise emissions</td><td>Underwater noise</td><td><i>Slight positive effect (decrease, e.g. if shore power is used)</i></td></tr>
<tr><td>Physical impacts</td><td>Anchoring, mooring and movement and ship wakes</td><td><i>No effect</i></td></tr>
</table>
</td></tr>
</table>

6.2.15 #15 Introduction of national fairway dues (charges) which are linked to ship emissions/pollutants

2) Effects on human well being:

Human well being	**Ecosystem services**	**Description of effect on ecosystem services (positive, negative, no effect, e.g. with arrows)**
Commercial fishing	Cod, sprat, herring, salmon and seafood	*Positive effect (depending on design of instrument)*
Recreational fishing	Cod, sprat, herring, salmon and seafood	*Positive effect (depending on design of instrument)*
Genetic resources	Genetic variation of species	*No effect*
Climate change mitigation	Capacity of sea to absorb CO_2 (i.e. seagrass meadows)	*Slight positive effect (depending on design of instrument)*
Coastal protection	Capacity of sea to protect coastline, sediments, avoid erosion (i.e. seagrass meadows)	*No effect*
Tourism and recreation	Swimming, beach activities	*Slight positive effect (depending on design of instrument)*
Other socio-cultural services	Heritage, inspiration, local and regional species	*Slight positive effect (depending on design of instrument)*
Human health	Clean air	*Positive effect (depending on design of instrument)*

As for green port fees, positive effects are linked very much to the design of the fairway dues/charges. In general, highest potential is seen for commercial and recreation fishing, tourism&recreation, climate mitigation function and human health

Links to existing policies and their policy targets

- Depending on included pressures, e.g. UNFCCC climate targets, IMO MEPC72 decision on shipping greenhouse gas target (IMO, 2018), EU transport white book (European Commission, 2011),

- MSFD, GES descriptor 8 (Concentrations of contaminants give no effects)

- MSFD, GES descriptor 9 (Contaminants in seafood are below safe levels)

Impact assessment for policy option

- In Sweden, after implementation of SO_X differentiation many ships got SOx certificates during the initial years, it can be assumed that these are not effects of the differentiated dues but ships were already using low-sulphur fuel. After a rapid growth during the first years, the number of vessels with SO_X certificates steadily decreased to 1450 vessels in 2000 to about 500 vessels in 2014. The stricter sulphur regulations by IMO implemented in 2015 seem to reduce SO_X emissions more than the differentiated fairway dues, also due to the fact that they have to be followed by operators and vessels. For NO_X, the number of ships with NO_X reduction certificates increased

6.2.15 #15 Introduction of national fairway dues (charges) which are linked to ship emissions/pollutants

	steadily during the first years but decreased afterwards strongly to 33 vessels in 2016. The decrease might be due to uncertainties of future development of the incentive scheme. However, another main reason for the low numbers of ships interested in NO_X certificates is that investments in new technologies to reduce NO_X emissions are more expensive and involve more risks compare to the switch to low-sulphur fuel to reach the reduction of SO_X emissions. (Lindé & Vierth, 2018) - The SOx emissions in Sweden have decreased steadily in the last decades (Swedish Environmental Protection Agency, 2017b). “The environmentally differentiated fairway dues have contributed to this reduction, but especially since the implementation of stricter sulphur limits in the SECA in 2015 have the emissions of SO_X from the maritime traffic in the Baltic Sea declined substantially.” (Lindé & Vierth, 2018) - Different reports map that the incentives to reduce NOx emissions by the Swedish national fairway dues seem to be too low (SMA, 2013; 2016; Lindé & Vierth, 2018). Furthermore, it was discussed that the discounts in the fairway dues system that was in place till the end of 2017 contributed to a relatively small part of the costs for catalytic equipment with the result of a limited emission reduction (Transport Analysis, 2017; Lindé & Vierth, 2018) **Score: low effect (2)**
Efficiency	**Transaction costs:** The implementation of a national fairway fee system includes additional administrative costs, mainly including the management of the certificates. **Investment and maintenance costs:** Deepening on design of instrument, see other policy options In Sweden, NO_X and SO_X emissions were included in the system. For the reduction of SO_X emissions the main measure is a switch to low sulphur fuel. This requires no adjustments of the engine and can reduce operating problems in the engine. The cost of switching to low sulphur fuel are estimated to be in the range of 4-10.80 SEK per kg SO_X (Kågeson, 1999; Swahn, 2002). The price of reducing SO_X emissions by switching fuel is directly related to the difference between the price for low and high sulphur fuel and will change with changes in this spread (Lindé & Vierth, 2018). A summary of cost estimate for NO_X emission reduction is quite complex, since many influencing factors do exist. Kågeson (1999) estimates the cost of installing a SCR system in an existing ship to be 250,000-400,000 SEK per megawatt depending on vessel type, with additional annual operational and maintenance costs of 18 SEK per MWh. This yields a cost per kg NOx reduced below 6 SEK. A provided example shows that for a large ferry and a Ro-Ro vessel with 50 port calls in Sweden, the fairway fee discount (excluding any refunds) covers 25-35 percent of the additional annual cost for SCR. (Lindé & Vierth, 2018). Transport Analysis (2016) estimates the costs of installing SCR for a life time of 20 years with 0.14-2.6 million SEK for vessels

6.2.15 #15 Introduction of national fairway dues (charges) which are linked to ship emissions/pollutants

	with a power of 1000-25000 kW. Estimations by Lindé & Vierth (2018) compared total annual cost of installing and running SCR and the annual reduction of NO_X. The cost for reducing NO_X emissions was estimated between 2.5 and 6.7 SEK per kg NO_X (varying by vessel type). **Score costs: low (2)** **Benefits/cost-benefits for society:** **SO_X emissions:** Recommended valuation of the socioeconomic cost of **SO_2** is 29 SEK per kg emission (National Swedish valuation guidelines (ASEK), Swedish Transport Administration, 2016), European valuation guidelines provides unit costs for the Baltic Sea of 47.25 SEK (Ricardo, 2014). Lindé & Vierth (2018) assume that 50,000 tonnes less SO_X emissions are emitted by vessels that call at Swedish ports due to the Swedish fairway due scheme, the benefit for society is approximately 1450 million SEK according to Swedish valuation guidelines and approximately 2362 million SEK if the European unit values for the Baltic Sea are applied. The costs for reducing SO_X emissions by 50,000 tonnes would be in the range of 200 to 540 million SEK (based on the values from Kågeson (1999) and Swahn (2002) (see above). The ratio of benefits to costs indicates that benefits to society of reducing SO_X emissions would be approximately 3-17 times larger than the costs (depending on the valuation and estimation). **NO_X emissions:** Benefit of reducing NO_X emissions were estimate between 42.30 SEK per kg NO_X for the Baltic Sea (Ricardo, 2014) and 86 SEK per kg NO_X (Swedish Transport Administration, 2016). Compared to the above mentioned costs of NO_X reduction between 2.5 and 6.7 SEK per kg, the benefit for society of reducing NO_X emissions is more than six times higher than the cost (Lindé & Vierth, 2018) Also if there are still uncertainties on the substantial effect of the Swedish national fairway due system, it can be assumed that the fairway dues are supporting the business decisions to reduce NO_X and SO_X emissions which show clear benefits for the society. **Score: medium efficiency (3)**
Distributional effects	Limited distributional effect **Score: no negative effect (5)**
Synergies and tradeoffs	**Pressures:** The option can have effects on all different pressures, depending on how it is designed. (up to 9, 4 groups). No negative effects are assessed. **Human well being:** Positive effects can be assessed for many components of human well being (depending on the design). It might be limited for genetic resources and coastal protection (6). No negative effects are assessed. **Score: major synergies, no conflicts (5) (but heavily depending on design of option)**

6.2.15 #15 Introduction of national fairway dues (charges) which are linked to ship emissions/pollutants

Summary

National fairway dues or charges paid by ships are used to finance maritime fairways, navigational aid, pilotage, search and rescue operation and ice-breaking. In general, the charges are based on gross tonnage and volume of goods loaded and unloaded in the ports of a country. In many countries the facilities and services are linked to ports, but several EU countries are using national dues, e.g. Sweden and Finland. Environmental impacts can be addressed via the differentiation of the fees according to the emissions and pollutants linked to the individual ships. The design is to establish lower dues for ships with less environmental impacts (emissions/pollutants/etc.) and thus higher dues for more polluting ships. The differentiation can be linked to established indices such as Environmental Ship Index, Clean Shipping Index or Green Award which are summarizing different environmental pressures. To increase environmental effect the fees could be based on sailed distance or fuel consumption and not on number of ports called. For most probably targeted pressures technologies exist. Objective of this policy option is a wider adoption of existing emission abatement technologies.

Different reports say that the incentives to reduce NO_X emissions by the Swedish national fairway dues seem to be too low (SMA, 2013; 2016; Lindé & Vierth, 2018). Furthermore, it was discussed that the discounts in the fairway dues system that was in place till the end of 2017 contributed to a relatively small part of the costs for catalytic equipment with the result of a limited emission reduction (Transport Analysis, 2017; Lindé & Vierth, 2018). A provided example shows that for a large ferry and a Ro-Ro vessel with 50 port calls in Sweden, the fairway fee discount (excluding any refunds) covers 25-35 percent of the additional annual cost for Selective Catalytic Reduction (SCR) systems (including averaged investment and yearly operational costs) (Lindé & Vierth, 2018). Also if there are still uncertainties on the substantial effect of the Swedish national fairway due system, it can be assumed that the fairway dues are supporting the business decisions to reduce NO_X and SO_X emissions which show clear benefits for the society. Therefore, environmentally differentiate fairway dues could be a component in a set of policy options, but they are only partially recommendable if the system has to be newly adopted.

Summary table

Summary: Policy option #15 Introduction of national fairway dues (charges) which are linked to ship emissions/pollutants			
Political implementability	3	Environmental and health outcomes	2
Acceptance & Feasibility	1	Efficiency	3
Scientific knowledge and uncertainty	3	Distributional effects	5
Technological and innovation potential	2	Synergies and tradeoffs	5
		Total score:	2,9
		Rank	15

6.2.15 #15 Introduction of national fairway dues (charges) which are linked to ship emissions/pollutants

References:

European Commission (2011). White paper on transport, https://ec.europa.eu/transport/sites/transport/files/themes/strategies/doc/2011_white_paper/white-paper-illustrated-brochure_en.pdf

International Maritime Organization (IMO) (2018). UN body adopts climate change strategy for shipping, Briefing: 13/04/2018, http://www.imo.org/en/MediaCentre/PressBriefings/Pages/06GHGinitialstrategy.aspx

Kågeson, P. (1999). Economic instruments for reducing emissions from sea transport. T&E 99/07.

Lindè, T., I. Vierth (2018). An Evaluation of the Environmentally Differentiated Fairway Dues in Sweden 1998- 2017. In: VTI notat 3A-2018. P.1-46. http://vti.diva-portal.org/smash/get/diva2:1186525/FULLTEXT01.pdf

Ricardo (2014). Update of the Handbook on External Costs of Transport (Final Report), London: Ricardo-AEA.

Swann, H. (2002).Environmentally differentiated fairway charges in practice—The Swedish experience, https://www.yumpu.com/en/document/view/11468798/environmentally-differentiated-fairway-and-port-charges-in-practice-

Swedish Maritime Administration (2013). Utvärdering av miljödifferentierade farledsavgifter för kväveoxider, Norrköping: Swedish Maritime Administration.

Swedish Maritime Administration (2016). Beräknad minskning av emissioner av kväveoxider 2013 och 2014, Norrköping: Swedish Maritime Administration.

Swedish Transport Administration (2016). Analysmetod och samhällsekonomiska kalkylvärden för transportsektorn: ASEK 6.0, Kapitel 11 Kostnad för luftföroreningar, s.l.: s.n.

Transport Analysis (2017). Miljökonsekvenser av nya farledsavgifter, Stockholm: Transport Analysis.

6.2.16 #16 Initiatives to simplify procedures in ports, e.g. use of communication tools to adjust speed to arrive in ports

Assessment criteria	*Assessment results*
Description of policy option	Although most emissions from shipping are released on sea, their emissions are most apparent when ships are berthed in ports. Dalsoren et al. (2009) estimate that emissions due to ships' activities in or around ports account for up to 5% of total emissions from navigation, SO_X and NO_X emissions are especially significant. Containerships and tankers are contributing about 85% of these emissions (Merk, 2014). Beside shore power use in ports, other measures to reduce emissions in ports exist e.g. using global information network and strengthen communications between ports and ship operators on sea to optimize speed and arrival time. **Objectives** Simplification and optimization of procedures in ports to reduce air emissions/pollutants in port and coastal areas **Impacts to be curbed** Reduction of air emissions and air pollutants **Design** Financial support for developing and pilot-testing of innovative solutions, a rebate on port fees or national fairway dues could be given to ships using e.g. the communication tool. **Technologies/implementation** As vessels become connected to the global information network via onboard satellite communications, ports can help leverage this additional connectivity by managing arrivals so that if the port is too congested, the vessel knows that it must decrease speed, rather than consume fuel at a more expensive, faster rate, only to then have to continue to consume waiting to dock (FathomShipping, 2013).
Political implementability	**Political/administrative scale targeted by the policy:** - Local/national/EU, policy option is suitable for local and national level **Do institutions need to be changed?** - Additional effort can be integrated in work of existing institutions **Score from stakeholders (survey): medium policy implementability (3)**
Acceptance & Feasibility	**Ship owners:** - opposed to very limited amount of additional costs - welcome fuel savings **NGOs:** **-** welcoming the initiative to reduce emissions

6.2.16 #16 Initiatives to simplify procedures in ports, e.g. use of communication tools to adjust speed to arrive in ports

<table>
<tr><td></td><td>- Coastal communities
- welcoming positive effects on human health and the environment

Score from stakeholders (survey): high acceptance & feasability (4)</td></tr>
<tr><td>Scientific knowledge and uncertainty</td><td>Measurement of pressures: Measurement methodologies for relevant are available and sound, additionally emission inventories for ports has been developed.
Impact and Socio-economic assessment: Methodologies and implemented studies e.g. on health impacts of shipping in coastal areas exist.
But it is unclear how much the policy option could contribute to reduction of emissions, as it is linked strongly to the implementation.

Score: high (2)</td></tr>
<tr><td>Technological and innovation potential</td><td>The technology which is needed to cope with this policy option, could lead to new developments at communication, automation/robotics, IT sectors

Score: high technological potential (4)</td></tr>
<tr><td>Environmental and health outcomes</td><td>1) Effects on Pressures
<table>
<tr><th colspan="2">Pressure</th><th>Expected impact</th></tr>
<tr><td rowspan="4">Emissions to air</td><td>CO_2</td><td><i>Positive effect (Decrease)</i></td></tr>
<tr><td>NO_X</td><td><i>Positive effect (Decrease)</i></td></tr>
<tr><td>SO_X</td><td><i>Positive effect (Decrease)</i></td></tr>
<tr><td>PM</td><td><i>Positive effect (Decrease)</i></td></tr>
<tr><td rowspan="3">Emissions to water</td><td>Non-indigenous species</td><td><i>No effect</i></td></tr>
<tr><td>Contaminants to water</td><td><i>No effect</i></td></tr>
<tr><td>Oil spills</td><td><i>No effect</i></td></tr>
<tr><td>Noise emissions</td><td>Underwater noise</td><td><i>No effect</i></td></tr>
<tr><td>Physical impacts</td><td>Anchoring, mooring and movement and ship wakes</td><td><i>No effect</i></td></tr>
</table>
Source: own

2) Effects on Human well being:
<table>
<tr><th>Human well being</th><th>Ecosystem services</th><th>Effects on human well being</th></tr>
<tr><td>Commercial fishing</td><td>Cod, sprat, herring, salmon and seafood</td><td><i>Positive effect (CO_2, NO_X, SO_X reduced)</i></td></tr>
<tr><td>Recreational fishing</td><td>Cod, sprat, herring, salmon and seafood)</td><td><i>Positive effect (CO_2, NO_X, SO_X reduced)</i></td></tr>
</table></td></tr>
</table>

6.2.16 #16 Initiatives to simplify procedures in ports, e.g. use of communication tools to adjust speed to arrive in ports

Genetic resources	Genetic variation of species	*Slight positive effect*
Climate change mitigation	Capacity of sea to absorb CO_2 (i.e. seagrass meadows)	*Positive effect (reduced CO_2, NO_X, SO_X)*
Coastal protection	Capacity of sea to protect coastline, sediments, avoid erosion (i.e. seagrass meadows)	*No effect*
Tourism and recreation	Swimming, beach activities	*Positive effect (CO_2, NO_X, SO_X reduced)*
Other socio-cultural services	Heritage, inspiration, local and regional species	*Slight positive effect*
Human health	Clean air	*Positive effect*

Links to existing policies and their policy targets

- Can contribute to climate mitigation targets (IMO, 2018; EU, 2011) as well as air quality regulation, e.g. European Air Quality Directive 2008/50/EC

Impact assessment for policy option

-Trials were undertaken for the optimized communication and therefore better managed arrivals in ports. The Oil Companies International Marine Forum (OCIMF) and Intertanko show that fuel consumption and subsequent CO_2 emissions, for example, can be reduced by up to 22% (FathomShipping, 2013).

- The effects are very local and limited.

Score: very low effect (1)

Efficiency (Economic outcomes)

Transaction cost:

Costs for implementing the policy option are limited.

Investment and maintance costs:

Technological costs at ports and onboard are expected, upfront investments are rather low compared to more capital intensive investments (such as ships running on other fuels such as LNG or renewables).

Score osts: low costs (2)

Benefits

Shipping emissions have considerable external costs in ports: for NO_X, SO_X and PM emissions (most relevant emissions for local population) almost EUR 12 billion per year are estimated for the 50 largest ports in the OECD. Approximately 230 million people are directly exposed to the emissions in the top 100 world ports in terms of shipping emissions (Merk, 2014). It shows the relevance of shipping emissions in

6.2.16 #16 Initiatives to simplify procedures in ports, e.g. use of communication tools to adjust speed to arrive in ports

	coastal areas, nevertheless the share which can be reduced by the policy option will be limited. **Score: very low efficiency (1)**
Distributional effects	Uncertain, probably low distributional effect. **Score: very low distributional effect (5)**
Synergies and tradeoffs	**Pressures:** The option has primarily an effect on air emissions (CO_2, NO_X, SO_X, PM). Depending on the technologies being applied, also other pressures could be reduces, such as oil spills, underwater noise. However, most of these synergies only would be notable, if major technological changes would be implemented, such as using renewable energies. No negative effects are assessed. **Human well being:** Positive effects are assessed for: Commercial fishing, recreational fishing, genetic resources (slight), climate change mitigation, tourism & recreation, other socio-cultural services (slight), human health. No negative effects are assessed. **Score: major synergies, no conflicts (5)**

Summary

Although most emissions from shipping is released on sea, their emissions are most apparent when ships are berthed in ports. Dalsoren et al. (2009) estimate that emissions due to ships' activities in or around ports account for up to 5% of total emissions from navigation, SO_X and NO_X emissions are especially significant. Containerships and tankers are contributing about 85% of these emissions (Merk, 2014).

Beside shore power use in ports, other measures to reduce emissions in ports exist e.g. using global information network and strengthen communications between ports and ship operators on sea to optimize speed and arrival time. As vessels become connected to the global information network via onboard satellite communications, ports can help leverage this additional connectivity by managing arrivals so that if the port is too congested, the vessel knows that it must decrease speed, rather than consume fuel at a more expensive, faster rate, only to then have to continue to consume waiting to dock (FathomShipping, 2013). The policy option could give financial support for research, pilot-testing and market uptake.

The policy option shows on the one side a limited environmental effect, but on the other side is linked to low costs and has a high innovation potential regarding operation of ships. The technologies and therefore the policy option might not be a stand alone measure, but can be easily linked to different other policy options, especially port fees or fairway dues could include a rebate for ships using communication tools for navigating.

6.2.16 #16 Initiatives to simplify procedures in ports, e.g. use of communication tools to adjust speed to arrive in ports

Summary table

Summary: Policy option #16 Initiatives to simplify procedures in ports, e.g. use of communication tools to adjust speed to arrive in ports			
Political implementability	3	Environmental and health outcomes	1
Acceptance & Feasibility	4	Efficiency	1
Scientific knowledge and uncertainty	2	Distributional effects	5
Technological and innovation potential	4	Synergies and tradeoffs	5
		Total score:	3,0
		Rank	13

References:

Dalsoren, S. et al. (2008). "Update on emissions and environmental impacts from the international fleet of ships; the contribution from major ship types and ports", Atmospheric Chemistry and Physics Discussions, 8, 18323-18384.

European Commission (EU) (2011). White paper on transport, https://ec.europa.eu/transport/sites/transport/files/themes/strategies/doc/2011_white_paper/white-paper-illustrated-brochure_en.pdf

FathomShipping (2013). Port Operators Under Pressure to Reduce Ship Emissions. http://gcaptain.com/ship-emissions-port-operators-under-pressure/

International Maritime Organization (IMO) (2018). UN body adopts climate change strategy for shipping, Briefing: 13/04/2018, http://www.imo.org/en/MediaCentre/PressBriefings/Pages/06GHGinitialstrategy.aspx

Merk, O. (2014). Shipping Emissions in Ports. OECD/ITF, Discussion Paper 2014-20.

6.2.17 #17 Promote vessel scrapping to reduce environmental impacts of fleets (financial support)

Assessment criteria	*Assessment results*
Description of policy option	Supporting instruments for vessel scrapping (so called "scrap and build subsidies") have the target to promote a technical upgrade of the existing vessel fleet and to reach a more environmental friendly fleet. These have effects on multiple policy objectives according to technological developments during the last years. Until the year 2017, Scrap and build subsidies have been implemented in China, Turkey and Norway with the primary objective of improving fuel efficiency (OECD, 2017). **Objectives** Provide financial incentives to decrease environmental burden from shipping by replacing old fleets to new greener vessels under the assumption that new vessels are more energy efficient than old ones **Impacts to be curbed** A variety of environmental pressures (GHG emissions, air pollution, water pollutants, noise emissions) would be tackled as technological improvements during the last decades led to adjustment of ship design, engine, etc. **Design** The financial subsidy could be applied to ships some years (e.g. one to ten years) before they reach the end of their statutory life (with reducing amount of subsidies). **Technologies/implementation** The implementation of any specific new technologies is not objective of the policy option. The target is to promote the technological improvements which are already included in "standard" ship building today. **Examples** Scrap and build subsidies have been implemented in China, Turkey and Norway to improve fuel efficiency. The programs were adopted in China in 2009, in Turkey in 2015 and in Norway in 2016. The Chinese scheme includes (1) a subsidy when vessels are scrapped before their operational expiration dates in approved domestic shipbreaking facilities and (2) the remaining subsidy is giving to the purchase of new vessels (Xing, 2017). The Norwegian scrapping incentivize programs such as de decommissioning scheme in Norway, which incentivizes vessels scrapping through a quota merger system through an obligatory scrapping of one of the two merging vessels (Standal & Sønvisen 2015).
Political implementability	It could be implemented at national or EU level. It can be seen that the existing systems have a bundle of objectives including growth and trade related aspects (e.g. reducing overcapacity, strengthening local shipbuilding industry). Therefore, the reduction of environmental impacts is only partially the motivation for these kind of scheme.

6.2.17 #17 Promote vessel scrapping to reduce environmental impacts of fleets (financial support)

	Score from stakeholders (survey): low (1)
Acceptance & Feasibility	**Shipowners** will probably welcome the scheme, as they get financial support on renewing their fleet. But other effects, such as that Norwegian scheme resulted in higher maintenance costs for fishing vessels and an increased price for old fishing vessels due to speculation from the private sector(Standal and Sønvisen 2015), and including the business support function can lead to strong opposition by **NGOs, fishing communities and small scale fishermen**. Furthermore, a case of potential windfall gains is given. Kalouptsidi (2017) also describes critical issues linked to the Chinese scheme, as the author mentions that results of the scheme are overcapacity of vessels through a misallocation of resources without any additional consumer surplus. **Score from stakeholders (survey): low (1)**
Scientific knowledge and uncertainty	The environmental and socio-economic effect could be only estimated on a case by case basis (comparing scrapped vessel with new built vessel). In general a reduction of emissions and pollutants for some ship types seems to be sound (e.g. for bulkers), but for certain ship types, e.g. tankers, GHG emissions would increase due to double hull provision (OECD, 2007) **Score: medium (3)**
Technological and innovation potential	Limited as existing technologies would be used for new ships. **Score: very low (1)**
Environmental and health outcomes	**1) Effects on pressures:**

Pressure		**Description of expected impact of option on pressures (Increase/Decrease/no effect, brief description if needed)**
Emissions to air	CO_2	*Positive effect (decrease)*
	NO_X	*Positive effect (decrease)*
	SO_X	*Positive effect (decrease)*
	PM /BC	*Positive effect (decrease)*
Emissions to water	Non-indigenous species	*No effect*
	Contaminants to water	*No effect*
	Oil spills	*Slight positive effect*
Noise emissions	Underwater noise	*No effect*

6.2.17 #17 Promote vessel scrapping to reduce environmental impacts of fleets (financial support)

Physical impacts	Anchoring, mooring and movement and ship wakes	*No effect*

2) Effects on human well being:

Human well being	**Ecosystem services**	**Description of effect on ecosystem services (positive, negative, no effect, e.g. with arrows)**
Commercial fishing	Cod, sprat, herring, salmon and seafood	*Slight positive effect (CO_2, NO_X, SO_X), negative effects close to areas where wracks are collected, (Mainly effects are reached some years earlier than with other instruments.)*
Recreational fishing	Cod, sprat, herring, salmon and seafood	*Slight positive effect (CO_2, NO_X, SO_X), negative effects close to areas where wracks are collected. (Mainly effects are reached some years earlier than with other instruments.)*
Genetic resources	Genetic variation of species	*No effect*
Climate change mitigation	Capacity of sea to absorb CO_2 (i.e. seagrass meadows)	*No effect*
Coastal protection	Capacity of sea to protect coastline, sediments, avoid erosion (i.e. seagrass meadows)	*No effect*
Tourism and recreation	Swimming, beach activities	*Slight positive effect (CO_2, NO_X, SO_X) (mainly effects are reached some years earlier than with other instruments.)*
Other socio-cultural services	Heritage, inspiration, local and regional species	*No effect*
Human health	Clean air	*Slight positive effect (NO_X, SO_X, PM) (Mainly effects are reached some years earlier than with other instruments.)*

The effect of promotion of vessel scrapping is an increase of new modern ships with less emissions. Emissions could be descreased rather earlier than targeted by other regulations, e.g. by NECA.

Links to existing policies and their policy targets

A variety of policies could be supported, e.g. UNFCCC climate targets, IMO MEPC72 decision on shipping greenhouse gas target (IMO, 2018), EU transport white book (European Commission 2011)

Impact assessment for policy option

- The policy option could be partially support to reach some of the objectives assumed for the SHEBA scenario *SSP1 – Sustainability* when it is required that older ships are replaced by newer ones. One example is the emissions of NO_X where older ships

6.2.17 #17 Promote vessel scrapping to reduce environmental impacts of fleets (financial support)

would be replaced by newer ones following the Tier III emission limit. In the following figure, it can be seen that a significant decrease of NO_X emissions estimated for the SSP1 – Sustainability scenario in SHEBA.

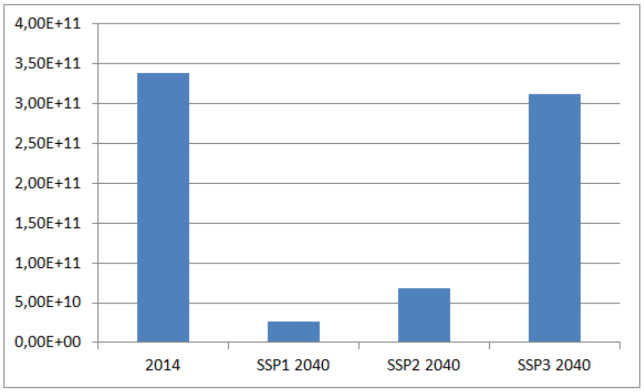


Figure 21 Emissions of NO_X (g) for the Baltic Sea for the SHEBA SSP-scenarios compared with data for 2014

Source: Fridell et al. (2018).

- Discussing the Chinese scrap and build schemes, it has been summarized that the EEDI of vessels built after 2013 has improved due to the EEDI regulation which went into force in 2013. Therefore, OECD (2017) concludes that in general, scrap and build schemes commenced after 2013 are expected to contribute to decreasing CO_2 emission from shipping.

Score: low effect (2)

Efficiency (Economic outcomes)

Transactional costs

The transaction costs would be mainly e.g. on evaluation of life time of vessels, building up of registry, management of application processes and enforcement. As an example, in the case of Norway, after the introduction of scrap-based transferability of fishing quotas was described as a form of additional transaction costs from the vessels owners' point of view. (Standal & Sønvisen 2015)

To reach an impact of the programme and therefore, influence business decisions for very large investments the support scheme has to include a signifincat amount of subsidies.

Investment and maintenance cost

In general, no additional costs are expected, but costs will incurre some years earlier than without the support scheme.

Score costs: medium (3)

Benefits

Depending on the reduction of emissions, etc., benefits which are discussed for the

6.2.17 #17 Promote vessel scrapping to reduce environmental impacts of fleets (financial support)

	other policy options are relevant (see the other policy options in the report, especially GHG and air pollutant emissions). **Score: low efficiency (2)**
Distributional effects	Distributional effects are limited. **Score: low (4)**
Synergies and tradeoffs	**Pressures:** The option can have effects on air emissions (CO_2, NO_X, SO_X, PM). No negative effects are assessed. **Human well being:** Positive effects can be assessed for: commercial fishing (slight), recreational fishing (slight), tourism&recreation (slight) and human health (slight) (4). Locally, negative effects might be expected. **Score: minor synergies, (almost) no conflicts (4)**

Summary

Supporting instruments for vessel scrapping (so called "scrap and build subsidies") have the target to promote a technical upgrade of the existing vessel fleet and to reach a more environmentally friendly fleet. These have effects on multiple policy objectives according to technological developments during the last years. Until the year 2017, scrap and build subsidies had been implemented in China, Turkey and Norway with the primary objective of improving fuel efficiency (OECD, 2017). A variety of environmental pressures (GHG emissions, air pollution, noise emissions) would be tackled as technological improvements during the last decades led to adjustments of ship design, engine, etc. A variety of policy objectives could be supported.

The risks of building up overcapacity of vessels through a misallocation of resources without any additional consumer surplus are discussed. Furthermore, the Norwegian scheme resulted in higher maintenance costs for fishing vessels and an increased price for old fishing vessels due to speculation from the private sector (Standal & Sønvisen, 2015). Technical upgrades could be interlinked with other policy options such as scrubber technology implementation that highly benefits from being installed as part of a new vessel.

Summary table

6.2.17 #17 Promote vessel scrapping to reduce environmental impacts of fleets (financial support)

Summary: Policy option #17: Promote vessel scrapping to reduce environmental impacts of fleets (financial support)			
Political implementability	1	Environmental and health outcomes	2
Acceptance & Feasibility	1	Efficiency	2
Scientific knowledge and uncertainty	3	Distributional effects	4
Technological and innovation potential	1	Synergies and tradeoffs	4
		Total score:	2,2
		Rank	19

References:

European Commission (2011). White paper on transport, https://ec.europa.eu/transport/sites/transport/files/themes/strategies/doc/2011_white_paper/white-paper-illustrated-brochure_en.pdf

Fridell, E., Tröltzsch, J., Hasenheit, M., Jalkanen, J.-P., Matthias, V., Eriksson, M. (2018). Sustainable Shipping Scenario. SHEBA Deliverable 1.5. BONUS Research Project

International Maritime Organization (IMO) (2018). UN body adopts climate change strategy for shipping, Briefing: 13/04/2018, http://www.imo.org/en/MediaCentre/PressBriefings/Pages/06GHGinitialstrategy.aspx

Kalouptsidi, M. (2017). Detection and Impact of Industrial Subsidies: The Case of Chinese Shipbuilding. http://www.restud.com/wp-content/uploads/2017/08/Paper-4-May-2017.pdf

OECD (2017). Analysis of selected measures promoting the construction and operation of greener ships. OECD, https://www.oecd.org/sti/ind/analysis-of-measures-promoting-greener-ships.pdf

OECD (2007). Imbalances in the shipbuilding industry and assessment of polic responses. OECD, https://www.oecd.org/industry/ind/Imbalances_Shipbuilding_Industry.pdf

Standal, Dag, and Signe Annie Sønvisen (2015). Into the Scrap Iron Business : Transaction Costs for Fl Eet Sustainability in Norway. 62: 213–17.

Xing, Wei Shen and Guojing (2017). Study on Status Quo of Shipbreaking Sector and Strategies.

6.2.18 #18 Establish PM (including black carbon) emission standards for ships

Assessment criteria	*Assessment results*
Description of policy option	Different emission standards are already existing. Particulate matter (PM) and black carbon (BC) as one component of fine PM2.5 are contributing to air pollution in coastal cities and areas, and emissions are contributing to global warming effect and the decline of Artic sea ice (Comer et al., 2017). Comer et al. (2017) estimate ships were responsible for 0.7% to 1.1% of anthropogenic BC emissions in 2015 and for 3.9% to 5.7% of diesel source BC emissions in 2015 (Comer et al., 2017, based on Bond et al., 2015). The implementation of strict PM emission standards including emissions standards for BC in the Baltic Sea could lead to additional emission reductions and would lead to benefits especially for human health in coastal areas. **Objectives** Decreasing emissions of particulate matter, including black carbon – mainly to reduce negative health effects, but also to decrease adversal impacts on climate change **Impacts to be curbed** Emissions of PM, including black carbon **Design** A PM and BC emission standard could apply to especially sensitive ecological regions (like coastal waterways), or even include all ships. A PM emission standard could also be included in the Emission Control Area (ECA). **Technologies/implementation** Ship owners and operators could reduce PM and BC emissions by a fuel switch to e.g. LNG or hydrogen and increase of energy efficiency of ships via vessel and engine design changes. Furthermore, after treatment such as exhaust treatment (selective catalyst reduction) or diesel particle filter (used with low sulphur fuels).
Political implementability	International forums have noticed the need to address the risks of BC and residual fuel. IMO developed a definition, measurement method and also investigated on appropriate reduction measures (IMO, 2015; Comer et al., 2017). **Political/administrative scale targeted by the policy:** Global /EU, preferable at global level **Do institutions need to be changed?** no significantly: PM and BC need to be included into the respective monitoring schemes, additional capacities might be necessary **Score from stakeholders (survey): high (4)**

6.2.18 #18 Establish PM (including black carbon) emission standards for ships

<table>
<tr><td>Acceptance & Feasibility</td><td>Shipowners are probably opposing, as clearly additional investments would be necessary to cope with the standards.
Welcoming by other stakeholders, as strict regulation could reduce local air pollution in port cities, etc.

Score from stakeholders (survey): medium (3)</td></tr>
<tr><td>Scientific knowledge and uncertainty</td><td>Measurement of Pressure: Measurement methods have been discussed and agreed by IMO.
Impact assessment / Socio-economic evaluation: Methods for estimation of linkages between PM emissions and human health impacts are well established.

Score: low uncertainty (4)</td></tr>
<tr><td>Technological and innovation potential</td><td>There is currently no big ship equipped with a PM filter that would capture BC and other particles from the exhaust gas. BC emissions could be minimized by switching to LNG as a fuel. Many ships run on LNG and their number is steadily increasing. But as well new filters for ocean going vessels could be developed.
Option could have indirect effect on technological development and innovation if standard would be strict enough.
Score: medium innovation potential (3)</td></tr>
<tr><td>Environmental and health outcomes</td><td>1) Effect on pressures:
<table>
<tr><th colspan="2">Pressure</th><th>Description of expected impact of option on pressures (Increase/Decrease/no effect, brief description if needed)</th></tr>
<tr><td rowspan="4">Emissions to air</td><td>CO_2</td><td><i>Slight negative effect (increase), in case new technology needs energy</i></td></tr>
<tr><td>NO_X</td><td><i>Slight negative effect (increase)</i></td></tr>
<tr><td>SO_X</td><td><i>Slight positive effect (decrease) as sulphur containing particles might be filtered too.</i></td></tr>
<tr><td>PM /BC</td><td><i>Significant decrease</i></td></tr>
<tr><td rowspan="3">Emissions to water</td><td>Non-indigenous species</td><td><i>No effect</i></td></tr>
<tr><td>Contaminants to water</td><td><i>No effect</i></td></tr>
<tr><td>Oil spills</td><td><i>No effect</i></td></tr>
<tr><td>Noise emissions</td><td>Underwater noise</td><td><i>No effect</i></td></tr>
<tr><td>Physical impacts</td><td>Anchoring, mooring and movement and ship wakes</td><td><i>No effect</i></td></tr>
</table>
If scrubbers are used as abatment technology, most particles, including BC (Black Carbon), will end up in the water instead of in the air (open loop system). In a closed</td></tr>
</table>

loop system, particles will be retained in the treatment system, but still the amount of particles discharged to the sea is expected to be substantial.

2) Effects on human well being:

Human well being	Ecosystem services	Description of effect on ecosystem services (positive, negative, no effect, e.g. with arrows)
Commercial fishing	Cod, sprat, herring, salmon and seafood	*Slight positive effect (reduced eutrophication and acidification), slight negative effect (CO_2, NO_X)*
Recreational fishing	Cod, sprat, herring, salmon and seafood)	*Slight positive effect (reduced eutrophication and acidification), slight negative effect (CO_2, NO_X)*
Genetic resources	Genetic variation of species	*No effect*
Climate change mitigation	Capacity of sea to absorb CO_2 (i.e. seagrass meadows)	*Slight negative effect (CO_2)*
Coastal protection	Capacity of sea to protect coastline, sediments, avoid erosion (i.e. seagrass meadows)	*No effect*
Tourism and recreation	Swimming, beach activities	*Slight positive effect (SO_X), slight negative effect (CO_2, NO_X)*
Other socio-cultural services	Heritage, inspiration, local and regional species	*No effect*
Human health	Clean air	*Positive effect (SO_X, PM, in coastal areas and on-bord)*

The by far major component of human well being which is targeted is a positive effect on human health. These benefits are mainly in coastal areas and cities. There might be effects on ecosystem services such as commercial and recreational fishing, tourism&recreation also depending on the technology used to reach the reduction of PM. Negative effects are expected by CO_2 and NO_X, if new (filter) technology needs energy.

Links to existing policies and their policy targets

- The European Air Quality Directive 2008/50/EC sets limits for PM10: the average value is limited at 40 µg/m³ (per year) and the daily average value of 50 µg/m³ may not be exceeded on more than 35 days per year. For PM2.5, the the average value is limited at 25 µg/m³ (per year) (EC, 2008; EC, 2018).
- Climate targets such as reducing GHG emissions of shipping by 50% until 2050 (IMO, 2018) are as well supported.

Impact assessment for policy option

- In the SHEBA BAU scenario PM emissions would decrease from 15 kt to 5 kt (Fridell et al., 2018). BC is only a fraction of this. The potential is to reduce this to almost 0

6.2.18 #18 Establish PM (including black carbon) emission standards for ships

when strict PM emission standards would be implemented.

- The following figure shows the BC reduction potential for shipping in the Baltic Sea area. The figure presents the fraction of BC emissions from ships related to BC in athmospheric PM2.5 in the Baltic sea area (during summer months). During winter months fraction is significant smaller.

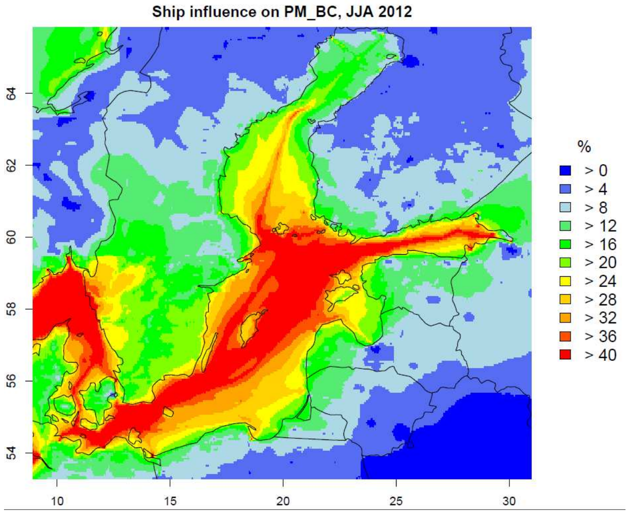


Figure 22 Fraction of shipping related Black Carbon in atmospheric PM2.5. Average value in June/July/August 2012 based on STEAM shipping emissions and CMAQ model calculations.

Source: Volker Matthias, Matthias Karl, HZG. The map is based on data produced for SHEBA Deliverable 2.5.

- Comer et al. (2017) estimated the reduction of BC emissions for different scenarios. They are estimating a drop of about 55 % of emissions for a switch of all ships from residual to distillate fuels. With a switch of half of the ships from oil based fuels to LNG, BC emissions would drop by 47%. A reduction by 27% of BC emissios could be reached if all ships which use residual fuels would use scrubbers. If 50% of distillate fuel consumption was treated with a DPF (diesel particle filter), BC would fall by 42% for that fuel, but total BC emissions from ships would decline only 5%. (Comer et al., 2017)

Score: high effect (4)

Efficiency (Economic outcomes)

Transaction costs

Transaction costs would apply for establishing and management the system, monitoring and enforcement.

Investment and maintenance costs

IMO (2015) estimates annual costs for different abatement technologies, for the example case (14.4 mW aframax tanker). The different abatement technologies are: slow steaming (SSDR), water-in-fuel emulsification (WiFe), switching to liquid natural gas (LNG), diesel particulate filters (DPF), seawater scrubbing (SWS) and freshwater

6.2.18 #18 Establish PM (including black carbon) emission standards for ships

scrubbing (FWS). The results show that some technologies LNG MGO reaches a reduction of costs, mainly fuel switch to LNG, but also slow steaming. Scrubbers add a substantial cost element to existing costs (depending on type of scrubber) (IMO 2015).

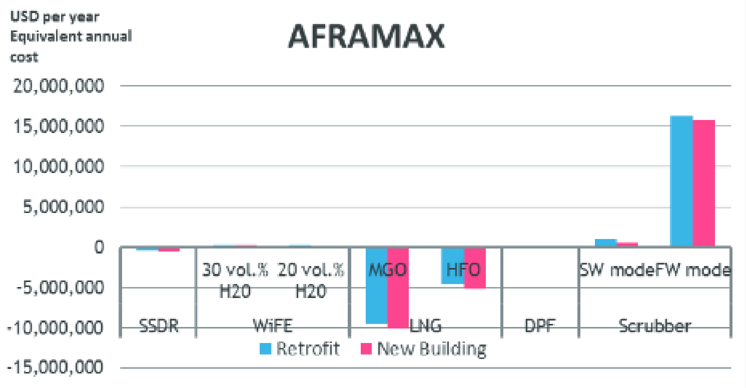


Figure 23 Cost estimates for the technologies (USD/year)

Source: IMO (2015).

Score costs: high (4) (high upfront investment cost are expected for most technologies, but very much depending on used abatement technology)

Benefits / cost-benefits:

The following figure compares the costs for abatement technologies for BC emissions with the reached reduction effect and describes the cost-effectiveness of the measures. LNG MGO describes the option with the best cost-effectiveness (reducing (negative) costs and substantial BC reduction). (IMO 2015)

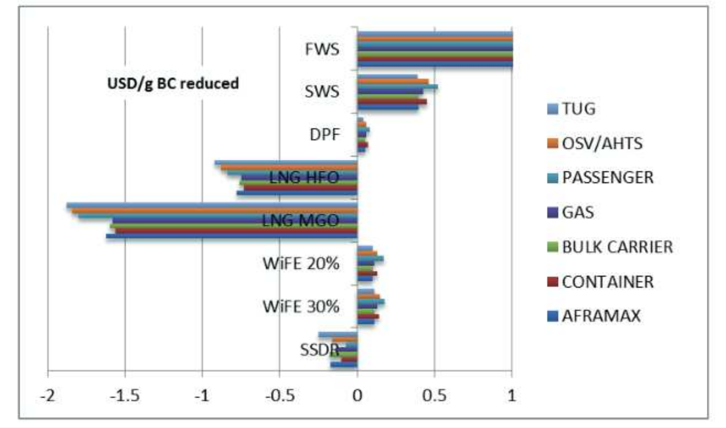


Figure 24: Cost of abatement technologies (in USD per gram reduced BC emissions) over a range of vessels at similar installed effect (10 MW).

Source: IMO (2015).

6.2.18 #18 Establish PM (including black carbon) emission standards for ships

	Score: medium efficiency (3) (depending on used technology by shipowner)
Distributional effects	Distributional effects are limited. **Score: low (4)**
Synergies and tradeoffs	**Pressures:** The option can have positive effects on SO_X and mainly on PM. Slight negative effects might occur for CO_2 and NO_X. **Human well being:** Positive effects can be assessed for: commercial fishing (slight), recreational fishing (slight), climate change mitigation (slight), tourism&recreation (slight) and human health. (4-slight, 1 major). Negative effects might be expected commercial fishing (slight), recreational fishing (slight), climate change mitigation (slight), tourism&recreation (slight). **Score: minor synergies, conflicts (1)**

Summary

Particulate matter (PM) and black carbon (BC) as one component of fine PM2.5 are contributing to air pollution in coastal cities and areas, and emissions are contributing to global warming effect and the decline of Artic sea ice. Comer et al. (2017) estimate ships were responsible for 0.7% to 1.1% of anthropogenic BC emissions globally in 2015 and for 3.9% to 5.7% of diesel source BC emissions globally in 2015 (Comer et al. 2017, based on Bond et al. 2015).

The implementation of strict PM emission standards including emissions standards for BC in the Baltic Sea could lead to additional emission reductions and would lead to benefits especially for human health in coastal areas. International forums have noticed the need to address the risks of BC and residual fuel and processes and discussions at IMO have already started. Effectiveness and costs for abatement technologies have been analysed e.g. by IMO. The results show that different measures could reach a 50% reduction of BC emissions (e.g. switch to distillate fuels or LNG). Major additional costs would be expected for using scrubbers. More cost-effective technologies are slow steaming or switch to LNG. (Comer et al., 2017; IMO, 2015)

In parallel to a strict emission standard, grants, subsidies or financing tools could be initiated to support ship owners investing in reducing PM and BC (e.g. via cleaner fuels, or control technologies) (see #8 Promoting optimized fossil fuel driven engine and ship design, e.g. stricter energy efficiency standard (EEDI), #9 Promoting use of low emission fossil fuels, e.g. LNG, #10 Promoting use of renewable fuels and energy sources, e.g. biofuels, wind and #12 Promoting use of electric power for running the engine (battery –driven)).

6.2.18 #18 Establish PM (including black carbon) emission standards for ships

Summary table

Summary: Policy option #18 Establish PM (including black carbon) emission standards for ships			
Political implementability	4	Environmental and health outcomes	4
Acceptance & Feasibility	3	Efficiency	3
Scientific knowledge and uncertainty	4	Distributional effects	4
Technological and innovation potential	3	Synergies and tradeoffs	1
		Total score:	3,3
		Rank	12

References:

Bond, T. C., Doherty, S. J., Fahey, D. W., Forster, P. M., Berntsen, T., DeAngelo, B. J., Zender, C.S. (2013). Bounding the role of black carbon in the climate system: a scientific assessment. Journal of Geophysics Research, 118(11), 5380‑5552. doi:10. 1002/jgrd.50171

Comer, B., Olmer, N., Mao, X., Roy, B., Rutherford, D. (2017). Black carbon emissions and fuel use in global shipping 2015. ICCT-Report. Washington D.C.

EC (2008). Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe. Official Journal of the European Commission, L 152, 11.6.2008, p. 1–44.

EC (2018). Air Quality Standards. http://ec.europa.eu/environment/air/quality/standards.htm

Fridell, E., Tröltzsch, J., Hasenheit, M., Jalkanen, J.-P., Matthias, V., Eriksson, M. (2018). Sustainable Shipping Scenario. SHEBA Deliverable 1.5. BONUS Research Project

International Maritime Organization (IMO) (2018). UN body adopts climate change strategy for shipping, Briefing: 13/04/2018, http://www.imo.org/en/MediaCentre/PressBriefings/Pages/06GHGinitialstrategy.aspx

IMO (2015). Investigation of appropriate control measures (abatement technologies) to reduce Black Carbon emissions from international shipping. http://www.imo.org/en/OurWork/Environment/PollutionPrevention/AirPollution/Documents/Air%20pollution/Black%20Carbon.pdf

6.2.19 #19 Implementation of a CO_2-tax for shipping

Assessment criteria	*Assessment results*
Description of policy option	IMO has agreed (April 2018) that 50% reduction of ship GHG emissions should be achieved by year 2050. This target is not achievable by improving energy efficiency of ships (EEDI Phases 0-3), but it requires a gradual shift away from fossil fuels. Energy efficient designs are barely able to negate the annual growth of GHG emissions from ships. A CO_2 tax is an economic policy instrument which is already discussed widely. **Objectives**: The objective of this policy is to curb shippings` CO_2 emissions, by making these emissions more expensive for the polluter by integrating this externality with the help of a tax. **Impacts to be curbed** Decreasing GHG emissions **Design** The tax should lead to a significant incentive to curb emmissions. Tax exemptions for certain critical groups are possible. **Technologies/implementation** The instrument is technology free designed, therefore all CO_2 reduction technologies can be used, e.g. fuel switch to distillate fuels, LNG or renewables, increase of energy efficiency via ship design improvements, operational practices such as slow steaming.
Political implementability	**Political/administrative scale targeted by the policy:** - global (IMO) – to avoid carbon leak to non-regulated flag states **Do instituions need to be changed?** - institutions would need additional ressources for registration, monitoring, enforcement **Score from stakeholders (survey): medium (3)**
Acceptance & Feasibility	**Ship owners:** - opposing generally to additional fuel costs, also International Chamber of Shipping (ICS) states a preference for a simple fuel levy (Grey, 2016) - welcoming long-term schemes & policy focuses **NGOs:** - opposing, in case more ships are needed for transporting the same amount of people and goods, due to slow steaming - welcoming the emission reducing effects - welcoming strict regulation with an significant reduction effect **Coastal communities:** - welcoming the side effects (positive effects on recreational fishing, tourism etc.)

6.2.19 #19 Implementation of a CO_2-tax for shipping

<table>
<tr><td></td><td>- opposing slower marine transport (esp. if fast ferries are affected)
Other:
- Resistance at IMO is expected, because currently the implementation method and its details are not defined. Majority at IMO can probably be reached, but BRIC-countries have opposed these initiatives in the past.

Score from stakeholders (survey): very low (1)</td></tr>
<tr><td>Scientific knowledge and uncertainty</td><td>CO_2 emissions from ships are fairly well known and methods both for measuring and modeling exits. Routine reporting at global level is currently implemented at EU (MRV) and at IMO (IMO DCS). Climate impacts of increasing CO_2 levels are well known and political consensus for the need to act exists.

Score: low uncertainties (4)</td></tr>
<tr><td>Technological and innovation potential</td><td>Bunker fuel levy at a global scale has not been tested. It is very likely that strict limits and ambitious reduction targets necessitate significant new research on engine technologies, energy production/storage and alternative fuels.

Score: medium (3)</td></tr>
<tr><td>Environmental and health outcomes</td><td>
1) Effects on pressures
<table>
<tr><th colspan="2">Pressure</th><th>Description of expected impact of option on pressures (Increase/Decrease/no effect, brief description if needed)</th></tr>
<tr><td rowspan="4">Emissions to air</td><td>CO_2</td><td><i>Positive effect (Decrease)</i></td></tr>
<tr><td>NO_X</td><td><i>Positive effect (Decrease)</i></td></tr>
<tr><td>SO_X</td><td><i>Positive effect (Decrease)</i></td></tr>
<tr><td>PM /BC</td><td><i>Positive effect (Decrease)</i></td></tr>
<tr><td rowspan="3">Emissions to water</td><td>Non-indigenous species</td><td><i>No effect</i></td></tr>
<tr><td>Contaminants to water</td><td><i>No effect</i></td></tr>
<tr><td>Oil spills</td><td><i>Slight positive effect (Decrease, especially with non-fossil fuels)</i></td></tr>
<tr><td>Noise emissions</td><td>Underwater noise</td><td><i>Slight negative effect (increase, in case no additional regulation is introduced)</i></td></tr>
<tr><td>Physical impacts</td><td>Anchoring, mooring and movement and ship wakes</td><td><i>No effect</i></td></tr>
</table>
</td></tr>
</table>

6.2.19 #19 Implementation of a CO_2-tax for shipping

2) Effects on human well being:

Human well being	Ecosystem services	Description of effect on ecosystem services (positive, negative, no effect, e.g. with arrows)
Commercial fishing	Cod, sprat, herring, salmon and seafood	*Positive effect (Decrease CO_2, NO_X, SO_X, oil spills), maybe minor negative effect (noise)*
Recreational fishing	Cod, sprat, herring, salmon and seafood)	*Positive effect (Decrease CO_2, NO_X, SO_X, oil spills), maybe minor negative effect (noise)*
Genetic resources	Genetic variation of species	*Slight positive effect (Decrease CO_2, NO_X, SO_X)*
Climate change mitigation	Capacity of sea to absorb CO_2 (i.e. seagrass meadows)	*Positive effect (Decrease CO_2, NO_X, SO_X)*
Coastal protection	Capacity of sea to protect coastline, sediments, avoid erosion (i.e. seagrass meadows)	*No effect*
Tourism and recreation	Swimming, beach activities	*Positive effect (Decrease CO_2, NO_X, SO_X, oil spills), maybe minor negative effect (noise)*
Other socio-cultural services	Heritage, inspiration, local and regional species	*Slight positive effect (Decrease CO_2, NO_X, SO_X, oil spills), maybe minor negative effect (noise)*
Human health	Clean air	*Positive effect (Decrease NO_X, SO_X, PM)*

The option would decrease air emissions especially CO_2 emissions significantly. Therefore, all components of human wellbeing are influenced to a certain degree. Main effects are expected for human health, commercial and recreational fishing, tourism & recreation.

Links to existing policies and their policy targets

- UNFCCC climate targets

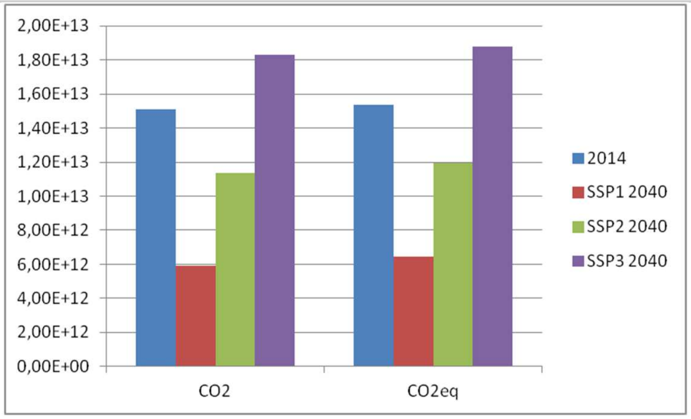
- EU transport white book (target: reduction of 40%, if feasible 50 %, by 2050 compared to 2005 levels (EU, 2011)

- IMO MEPC72 (target: reduction of 50% by 2050 (IMO, 2018). This target is not achievable by improving energy efficiency of ships (EEDI Phases 0-3), but it requires a gradual shift away from fossil fuels. Energy efficient designs are barely able to negate the annual growth of GHG emissions from ships.

Impact assessment for policy option

- The SHEBA SSP1 scenario (sustainability scenario) includes a significant reduction of CO_2 emissions (see figure below, Figure 25). Fridell et al. (2018) summarizes that existing policy instrument can not sufficient to reach these reduction efforts. The CO_2 tax could support reaching this sustainability scenario, e.g. to initiate slow steaming and adoption of LNG.

6.2.19 #19 Implementation of a CO_2-tax for shipping

	 **Figure 25 Emissions to air (in g) for the Baltic Sea for the SHEBA SSP-scenarios compared with data for 2014.** Source: Fridell et al. (2018). **Score: high effect (4)**
Efficiency (Economic outcomes)	**Transaction costs:** Transaction cost will appear for registration procedures, for monitoring and enforcement (but are lower compared to an ETS). **Investment and maintenance costs** Investment costs for reduction of GHG emissions, see different previously assessed options: - #8 Promoting optimized fossil fuel driven engine and ship design, e.g. stricter energy efficiency standard (EEDI), - #9 Promoting use of low emission fossil fuels, e.g. LNG - #10 Promoting use of renewable fuels and energy sources, e.g. biofuels, wind - #12 Promoting use of electric power for running the engine (battery –driven) - #13 Promoting shore power in ports. There are many different studies on the costs and consequences of implementing a CO_2 tax for the marine shipping industry, which inevitably leads to different results. The ICPP has studied the economic potentials for GHG mitigation at different costs for 2030. About 6 GT CO_2-eq could be mitigated involving net benefits (no relevant costs). Furthermore, 13 to 26 GT CO_2-eq can be abated for less than 50 \$/T CO_2-eq[9] and 16-31 GT CO_2-eq for less than 100 \$/T CO_2-eq (Eide et al., 2009). This provides us with reference numbers to compare to other assessments. Furthermore, the International Energy Agency claims that to achieve stabilization at 450 ppm of CO_2, a quota price of \$180 per ton of CO_2 emitted will be required in 2030 (Eide et al., 2009). Eide et al. (2009) agree with the ICPP values and explains that a reduction of 26,9 GT

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[9] $ refers to United State's Dollars

6.2.19 #19 Implementation of a CO_2-tax for shipping

	CO_2-eq in 2030 could be achieved at a cost of 50 $/T CO_2-eq in their optimistic scenario. However, it is possible that that goal might not be achieved even with a 100 $/T CO_2-eq due to contingency in the model. Kosmas & Acciaro (2017) considered the profit reduction that different fuel levies would entail both as a unit-tax per ton of fuel or an as an ad-valorem tax; the latter one leading to higher profit loss. Eskeland & Lindstad (2015) summarize that emission costs for maritime shipping have been indicated at CO_2 price levels of 20 – 50 USD per ton. Eskeland & Lindstad's (2015) estimation indicate that a CO_2 price level of 100 USD per ton will reduce emissions with 10 % in the short term, more in the long term. **Score costs: high costs (4)** **Benefits:** The social benefits of reducing a ton of CO_2 emitted could be measured through the Social Cost of Carbon (SCC), since it has become a standard measure utilized by many different countries and organizations. The establishment of this figure has been quite polemic since it is very sensible to its parameters, especially the discount rate selected. For example, the United States' government bases his estimates on a 3% discount rate, which means a SCC of $40 per metric ton of CO_2 emitted in 2015, with a value expected to increase in future years (Kotchen, 2016). Local differentiated SCC could range from $13 (Eurasia) to $91 (India) when the actual Global SCC is $40. More relevant information can be found in chapter on #9 Promoting use of low emission fossil fuels, e.g. LNG and #20 Establishing of an emission trading scheme for greenhouse gases from shipping. **Score: medium efficiency (3)**
Distributional effects	Kosmas and Acciaro's (2017) work concluded that 90,3% of the extra costs from a theoretical tax would be absorbed by the carriers compared with 9,7% by the consumers. Other studies, such as Wan et al. (2018), also expect a small increase of less than 1% in the commodity's prices. Overall, the impact will probably affect mainly shippers, although there are different opinions on the proportion. However, opinions differ on how this measure should be implemented regarding developed and developing countries, worrying about the possible negative effect on the latter ones. Some member states claim for the incorporation of "the principles of common but differentiated responsibilities" into future possible resolutions (Wan et al., 2018). **Score: medium (3)**
Synergies and	**Pressures:** The option can have positive effects on air emissions (CO_2, NO_X, SO_X, PM). Oil spills could decrease if non-fossul fuels are used. (5, 2 types of pressures). Slight negative effects might be occur for underwater noise.

6.2.19 #19 Implementation of a CO_2-tax for shipping

tradeoffs	**Human well being:** Positive effects can be assessed for: commercial fishing, recreational fishing, genetic resources (slight), climate change mitigation, tourism&recreation, other socio-cultural services (slight) and human health. (7). Negative effects might be expected for several services: commercial fishing (slight), recreational fishing (slight), climate change mitigation (slight), tourism&recreation (slight), other socio-cultural services (slight). **Score: major synergies, conflicts (2)**

Summary

IMO has agreed (April 2018) that 50% reduction of ship GHG emissions should be achieved by the year 2050. This target is not achievable by improving energy efficiency of ships (EEDI Phases 0-3), but it requires a gradual shift away from fossil fuels. The objective of this policy option is to curb shippings` CO_2 emissions, by internalization of externalities of the polluter by taxation of CO_2 emissions.

Taxation on the marine shipping industry has a strong potential as a measure to reduce GHG emissions. It is assumed that the policy option would incentivize the implementation of cleaner technologies and fuels. Nevertheless, it is considerably uncertain which tax value should be defined and how it should be distributed across countries. However, it should be taken into account that the stakeholder assessment shows a low acceptance & feasibility for this policy option.

Summary table

Summary: Policy option #19 Implementation of a CO_2-tax for shipping			
Political implementability	3	Environmental and health outcomes	4
Acceptance & Feasibility	1	Efficiency	3
Scientific knowledge and uncertainty	4	Distributional effects	3
Technological and innovation potential	3	Synergies and tradeoffs	2
		Total score:	2,9
		Rank	14

References:

Eide, M. S., Ø. Endresen, R. Skjong, T. Longva & S. Alvik. (2009). Cost-effectiveness assessment of CO2 reducing measures in shipping. Maritime Policy & Management, Vol. 36, NO. 4, 367-384.

Eskeland, G. S., Lindstad, H. (2015). Environmental taxation in the transport sector. Green Growth Knowledge Platform (GGKP), Third Annual Conference, 29-30 January, 2015.

European Commission (EU) (2011). White paper on transport, https://ec.europa.eu/transport/sites/transport/files/themes/strategies/doc/2011_white_paper/white-paper-illustrated-brochure_en.pdf

Fridell, E., Tröltzsch, J., Hasenheit, M., Jalkanen, J.-P., Matthias, V., Eriksson, M. (2018). Sustainable

6.2.19 #19 Implementation of a CO_2-tax for shipping

Shipping Scenario. SHEBA Deliverable 1.5. BONUS Research Project

Grey, E. (2016). Debating a carbon tax in global shipping. In: Ship technology. https://www.ship-technology.com/features/featuredebating-a-carbon-tax-in-global-shipping-4885856/

International Maritime Organization (IMO) (2018). UN body adopts climate change strategy for shipping, Briefing: 13/04/2018, http://www.imo.org/en/MediaCentre/PressBriefings/Pages/06GHGinitialstrategy.aspx

Kotchen, M. L. (2016). Which social cost of carbon? A theoretical perspective. National Bureau of Economic Research, Cambridge.

Wan, Z., A. el Makhloufic, Y. Chena & J. Tang. (2018). Decarbonizing the international shipping industry: Solutions and policy recommendations. Marine Pollution Bulletin 126, 2018, 428–435.

6.2.20 #20 Establishing of an emission trading scheme for greenhouse gases from shipping

Assessment criteria	*Assessment results*
Description of policy option	IMO has agreed (April 2018) that 50% reduction of ship GHG emissions should be achieved by year 2050. This target is not achievable by improving energy efficiency of ships (EEDI Phases 0-3), but it requires a gradual shift away from fossil fuels. Energy efficient designs are barely able to negate the annual growth of GHG emissions from ships. An Emission trading scheme in the maritime sector could contribute to reaching the CO_2 reduction target. **Objectives**: The objective of this policy is curb shippings` CO_2 emissions, by including these emissions in an emission trading scheme (ETS). **Impacts to be curbed** Decreasing GHG emissions **Design** This ETS is capped, which means every ship owner has a specific amount of emissions permitted. If emissions are saved, the respective emission rights can be sold to those, who need more emission rights than they have. The emission reduction has to been set a priori, making it illegal for ships to operate beyond the allocated emissions and without offsetting (Kosmas & Acciaro, 2017). **Technologies/implementation** The instrument is technology free designed, therefore all CO_2 reduction technologies can be used, e.g. fuel switch to distillate fuels, LNG or renewables, increase of energy efficiency via ship design improvements, operational practices such as slow steaming.
Political implementability	**Political/administrative scale targeted by the policy:** - global (IMO) – to avoid carbon leak to non-regulated flag states **Do institutions need to be changed?** - additional institutions are necessary to built up for design, registration procedures, management of certificates, enforcement, monitoring **Score from stakeholders (survey): medium (3)**
Acceptance & Feasibility	**Ship owners:** - opposing generally to additional policy instruments, but are in favour of market based instruments, but experiences with the integration of aviation sector in EU ETS is a barrier - critical if the ETS applies to the EU only (Safety4Sea, 2017; ECSA, 2017) - opposed to additional costs **-** welcoming long-term schemes & policy focuses

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<table>
<tr><td></td><td>NGOs:
- opposing, in case more ships are needed for transporting the same amount of people and goods, due to slow steaming
- welcoming the environmental and emission reduction effects
Coastal communities:
- welcoming the side effects (positive effects on recreational fishing, tourism etc.)
- opposing slower marine transport (esp. if fast ferries are affected)
Other:
- Resistance at IMO is expected, because currently the implementation method and its details are not defined; and due to the complexity of creating a global ETS.
Further barrier (for different actors): Bad experience of EU ETS on aviation; implemented as unilateral EU initiative.

Score from stakeholders (survey): high (4)</td></tr>
<tr><td>Scientific knowledge and uncertainty</td><td>CO_2 emissions from ships are fairly well known and methods both for measuring and modeling exits. Routine reporting at global level is currently implemented at EU (MRV) and at IMO (IMO DCS, IMO, 2017). Climate impacts of increasing CO_2 levels are well known and political consensus for the need to act exists.

Score: low uncertainties (4)</td></tr>
<tr><td>Technological and innovation potential</td><td>It is very likely that strict limits and ambitious reduction targets necessitate significant new research on engine technologies, energy production/storage and alternative fuels.

Score: high (4)</td></tr>
<tr><td>Environmental and health outcomes</td><td>1) Effect on pressures
<table>
<tr><th colspan="2">Pressure</th><th>Description of expected impact of option on pressures (Increase/Decrease/no effect, brief description if needed)</th></tr>
<tr><td rowspan="4">Emissions to air</td><td>CO_2</td><td><i>Positive effect (Decrease)</i></td></tr>
<tr><td>NO_X</td><td><i>Positive effect (Decrease)</i></td></tr>
<tr><td>SO_X</td><td><i>Positive effect (Decrease)</i></td></tr>
<tr><td>PM /BC</td><td><i>Positive effect (Decrease)</i></td></tr>
<tr><td rowspan="3">Emissions to water</td><td>Non-indigenous species</td><td><i>No effect</i></td></tr>
<tr><td>Contaminants to water</td><td><i>No effect</i></td></tr>
<tr><td>Oil spills</td><td><i>Slight positive effect (decrease, especially with non-fossil fuels)</i></td></tr>
<tr><td>Noise emissions</td><td>Underwater noise</td><td><i>Slight negative effect (increase, in case no additional regulation is introduced)</i></td></tr>
</table></td></tr>
</table>

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Physical impacts	Anchoring, mooring and movement and ship wakes	*No effect*

2) Effects on human well being:

Human well being	Ecosystem services	Description of effect on ecosystem services (positive, negative, no effect, e.g. with arrows)
Commercial fishing	Cod, sprat, herring, salmon and seafood	*Positive effect (CO_2, NO_X, SO_X, oil spills), maybe minor negative effect (noise)*
Recreational fishing	Cod, sprat, herring, salmon and seafood)	*Positive effect (CO_2, NO_X, SO_X, oil spills), maybe minor negative effect (noise)*
Genetic resources	Genetic variation of species	*Slight positive effect (CO_2, NO_X, SO_X)*
Climate change mitigation	Capacity of sea to absorb CO_2 (i.e. seagrass meadows)	*Positive effect (CO_2, NO_X, SO_X)*
Coastal protection	Capacity of sea to protect coastline, sediments, avoid erosion (i.e. seagrass meadows)	*Slight positive effect (CO_2, NO_X, SO_X)*
Tourism and recreation	Swimming, beach activities	*Positive effect (CO_2, NO_X, SO_X, oil spills), maybe minor negative effect (noise)*
Other socio-cultural services	Heritage, inspiration, local and regional species	*Slight positive effect (CO_2, NO_X, SO_X, oil spills), maybe minor negative effect (noise*
Human health	Clean air	*Positive effect (NO_X, SO_X, PM)*

The option would decrease air emissions especially CO_2 emissions significantly. Therefore, all components of human well being are influenced to a certain degree. Main effects are expected for human health, commercial and recreational fishing, tourism & recreation.
Shipping represents less than 3% of the total CO_2 emissions from anthropogenic sources, but must play its part in mitigation efforts.

Links to existing policies and their policy targets

- UNFCCC climate targets
- EU transport white book (target: reduction of 40%, if feasible 50 %, by 2050 compared to 2005 levels (EU, 2011)
- IMO MEPC72 (target: reduction of 50% by 2050 (IMO, 2018). This target is not achievable by improving energy efficiency of ships (EEDI Phases 0-3), but it requires a gradual shift away from fossil fuels.

Impact assessment for policy option

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- ETS with an amibitious cap would have significant effects on GHG emissions from shipping. Different SHEBA scenarios covering potential mitigation measures such as slow steaming or adoption of LNG show a potential reduction of GHG emissions.

- The SHEBA SSP1 scenario (sustainability scenario) includes a significant reduction of CO_2 emissions (see figure below, Figure 256). Fridell et al. (2018) summarizes that existing policy instruments are not sufficient to reach these reduction efforts. The emission trading scheme could support reaching this sustainability scenario, e.g. to initiate slow steaming and adoption of LNG.

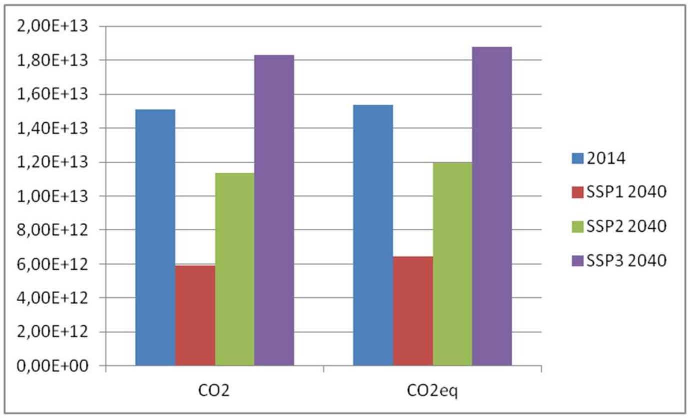

Figure 26 Emissions to air (in g) for the Baltic Sea for the SHEBA SSP-scenarios compared with data for 2014.

Source: Fridell et al. (2018).

- Ben-Hakoun et al. (2016) estimate a reduction potential for an ETS in the maritime transport sector of 84Mt CO_2 for 2020 and 591Mt CO_2 for 2030.

Score: High effect (4)

Efficiency (Economic outcomes)

Transaction costs:

High transaction costs are usually associated with an ETS. These consist mainly of expenditures for monitoring and reporting CO_2 emissions, as well as costs derived from possible trading activities. The ETS needs also a careful design, incuding how it could be linked to existing trading systems. Koesler et al. (2015) performed in-depth interviews in order to identify potential implications of such legislation directly from the parties affected, concluding that “Most operators have already implemented some form of emission reduction targets on a voluntary basis”. Measurement and monitoring: The additional burden for monitoring and reporting is very much dependent upon how much the requirements diverge from the company’s current practices.

Investment and maintenance costs

Investment costs for reduction of GHG emissions, see different previously assessed options:

- #8 Promoting optimized fossil fuel driven engine and ship design, e.g. stricter energy efficiency standard (EEDI),
- #9 Promoting use of low emission fossil fuels, e.g. LNG

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	- #10 Promoting use of renewable fuels and energy sources, e.g. biofuels, wind - #12 Promoting use of electric power for running the engine (battery –driven) - #13 Promoting shore power in ports. **Score costs: high costs (4)** **Benefits** Ben-Hakoun et al. (2016) studied the effectiveness and potential reduction of emissions through a Maritime ETS (METS) mechanism, and selected three periods as reference: 2020, 2025 and 2030. Methodology: first, the socio-economic cost of carbon emissions from seaborne activities were evaluated in both Business as Usual (BAU) and METS state. Then, they studied the relative socio-economic effect with regional segmentation, transportation modes, and the consequences on the shipping industry. They conclude: for General cargo vessels, the potential social cost by international shipping in 2030 is 7.9 billion dollars, and a reduction between 15 and 54% could be achieved through a METS. The reduction potential is approximately 84Mt for 2020 and 591Mt for 2030. Furthermore, container shipping is expected to grow by 400% in 2030 compared to 2010, emitting 1043Mt of carbon and costing 7.62 billion dollars. These emissions could be reduced to approximately 564Mt with the METS (between 15 and 54%). Also, after the implementation of the METS system the potential costs in 2020 and 2025 for container shipping would become 3.01 and 3.72 billion dollars, respectively. More relevant information can be found in chapter on policy option: #9 Promoting use of low emission fossil fuels, e.g. LNG and #19 Implementation of a CO2-tax for shipping. **Score: medium efficiency (3)**
Distributional effects	“Generally speaking, the higher the price elasticity of demand, the smaller the share of additional costs that can be passed on [to the consumers]. However, the shipping industry consists of a set of very different activities and hence various different markets, all having their own structure”, (Koesler et al., 2015). It is worth mentioning that most of the interviewees by Koesler et al. (2015) have the impression that all additional costs will be passed on in the long run to clients and consumers, especially if the regulation is set at a global scale. Increase in cost of shipping is expected to be less then 10%, depending on the price of allowances. The impact on consumer prices is expected to be lower than 1%. (Faber, 2010) **Score: medium (3)**
Synergies and tradeoffs	Pressures: The option can have positive effects on air emissions (CO_2, NO_X, SO_X, PM). Oil spills could decrease if non-fossil fuels are used. (5, 2 types of pressures). Slight negative effects might occur for underwater noise. Human well being: Positive effects can be assessed for: commercial fishing, recrea-

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	tional fishing, genetic resources (slight), climate change mitigation, tourism&recreation, other socio-cultural services (slight) and human health. (7). Negative effects might be expected for several services: commercial fishing (slight), recreational fishing (slight), climate change mitigation (slight), tourism&recreation (slight), other socio-cultural services (slight). **Score: major synergies, conflicts (2)**

Summary

As described for the CO_2-tax, IMO has agreed (April 2018) that 50% reduction of ship GHG emissions should be achieved by year the 2050. For implementation of the objective additional policy options targeting GHG emissions are expected. One instrument would be to include CO_2 emissions in an emission trading scheme (ETS). The actual implementation of an ETS in the shipping sector remains controversial. Some of the critical issues are whether to develop an open ETS or a maritime specific one; that growth will be limited if the supply of allowances is set too small; and the increase of uncertainty on behalf of the shipping industry due to volatile allowance prices (Kosmas & Acciaro, 2017; Koesler et al., 2015).

The stakeholder assessment states a high acceptance & feasibility which may be partially explained with the advantages of a market-based instrument. But the experiences with the integration of the aviation sector in the EU emission trading scheme can act as a barrier.

In general, emission trading systems are linked to substantial transaction costs, mainly for monitoring and reporting CO_2 emissions, therefore existing monitoring procedures should be taken into account as well as the long investment cycles in the shipping sector.

Summary table

Summary: Policy option #20 Establishing of an emission trading scheme for greenhouse gases from shipping			
Political implementability	3	Environmental and health outcomes	4
Acceptance & Feasibility	4	Efficiency	3
Scientific knowledge and uncertainty	4	Distributional effects	3
Technological and innovation potential	4	Synergies and tradeoffs	2
		Total score:	3,4
		Rank	10

References:

Ben-Hakoun, E., M. Shechter & Y. Hayuth. (2016). Economic evaluation of the environmental impact of shipping from the perspective of CO2 emissions. Journal of Shipping and Trade, 2016, 1:5

ECSA (2017). Shipping does not belong in EU Emission Trading Scheme. February 15, 2017,

6.2.20 #20 Establishing of an emission trading scheme for greenhouse gases from shipping

http://www.ecsa.eu/news/shipping-does-not-belong-eu-emission-trading-scheme

European Commission (EU) (2011). White paper on transport, https://ec.europa.eu/transport/sites/transport/files/themes/strategies/doc/2011_white_paper/white-paper-illustrated-brochure_en.pdf

Faber, J., Markowska, A., Eyring, V., Cionni, I., Selstad, E. (2010). A Global Maritime Emissions Trading System. Design and Impacts on the Shipping Sector, Countries and Regions. CE Delft.

Fridell, E., Tröltzsch, J., Hasenheit, M., Jalkanen, J.-P., Matthias, V., Eriksson, M. (2018). Sustainable Shipping Scenario. SHEBA Deliverable 1.5. BONUS Research Project

International Maritime Organization (IMO) (2017). Data collection system for fuel oil consumption of ships. https://gmn.imo.org/wp-content/uploads/2017/05/Data-collection-system-for-fuel-oil-consumption-of-ships.pdf

International Maritime Organization (IMO) (2018). UN body adopts climate change strategy for shipping, Briefing: 13/04/2018, http://www.imo.org/en/MediaCentre/PressBriefings/Pages/06GHGinitialstrategy.aspx

Koesler, S., M. Achtnicht, J. Köhler. (2015). Course set for a cap? A case study among ship operators on a maritime ETS. Transport Policy 37, 2015, 20–30.

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

Safety4Sea (2017). How ETS could be problem to EU shipping. 06/04/17, https://safety4sea.com/how-emissions-trading-scheme-could-be-problem-to-eu-shipping/ [accessed on 02.06.18]

Shi, Yubing. (2016). Reducing greenhouse gas emissions from international shipping: Is it time to consider market-based measures? Marine Policy 64, 2016, 123–134.

Appendix

Appendix I: #14 Green port fees linked to ship emissions / pollutants – Example

Country and Port		Charge Item	Green Incentive Scheme	Ship Rating System
CA	Port of Prince Rupert	Harbour Dues	Differentiated Tariff	RightShi, ESI, Green Marine, EEDI, Green Award, CSI
CA	Port Metro Vancouver	Harbour Dues	Differentiated Tariff	Shore power, vapour control or recovery system, eligible alternative fuels, eligible alternative technologies (other), ESI, RightShip, CSI, Green Marina, EEDI, Green Award, Ship Classification Society
CA	Port of Montreal	Harbour Fees	Rebate	Green Award
CA	Port of Sept-Iles	Harbour Dues	Rebate	Green Award
U.S.	Port of Long Beach	Dockage	Reward, Rebate	IMO Engine Standard, Vessel Speed Reduction, Shore Power Connection
U.S.	Port of Los Angeles	Dockage	Reward, Rebate	ESI, IMO Engine Standard, Vessel Speed Reduction, technology that reduces Diesel Particulate Matter (DPM) and NOx emissions
U.S.	Port of New York / New Jersey	Reward	Reward	ESI, Vessel Speed Reduction
LV	Free Port of Riga	Port Fee	Rebate	Green Award
LT	Port if Klaipeda	Sanity dues	Rebate	Green Award
BE	Port of Ghent	Tonnage dues	Rebate	ESI, Green Award
BE	Port of Antwerp	Port dues	Rebate	IMO, Engine Standard
BE	Port of Zeebrugge	Tonnage dues	Rebate	ESI
GI	Gibraltar Port	Tonnage dues	Rebate	Green Award
NL	Port of Rotterdam	Port fees	Rebate	ESI, Green Award
NL	Port of Amsterdam	Port fees	Rebate	ESI, Green Award
NL	Tata Steel Ijmuiden Terminals	Port dues	Rebate	ESI
NZ	Port Nelson	Marine Services	Rebate	ESI, Green Award

Country and Port		Charge Item	Green Incentive Scheme	Ship Rating System
SG	Port of Singapore	Port Dues	Rebate	Approved abatement technology or burn clean fuels (sulphur < 1.00% m/m), EEDI, Approved SOx scrubber technology exceeding IMO`s emission requirements
IL	Port of Ashdod	Reward and Additional rate	Additional Rate, Rebate	ESI, Additional sea pollution prevention rates on lighthouse rates
SE	Port of Gothenburg	Port dues	Rebate, Additional Levy	SI, LNG Fuel, Vessels`s structure (double bottom and double sides)
SE	Port of Stockholm	Port fee	Rebate, Reward	LNG-powered Vessel, Nitric Oxide Certificate issued by Swedish Maritime Administration, Shore Power connection
DE	Port of Jadeweser	Port dues	Rebate	ESI
DE	Port of Kiel	Port charge	Rebate	ESI
DE	Port of Rostock	Port dues	Redaction of surcharge	ESI, Marine diesel with a sulphur content of ≤ 0.1% LNG or a technolog leading to equivalent emission levels, Shore Power connection
DE	Niedersachsen Ports	Harbour dues	Rebate	ESI
DE	Port of Bremen	Tonnage changes	Rebate	ESI
DE	Port of Hamburg	Port fees	Rebate	ESI
NO	Port of Oslo	Quay charges	Rebate	ESI
NO	Nowegian Coastal Administration	Pilotage readiness fee	Rebate	ESI
NO	Port of Stavanger	Port fees	Rebate	ESI
NO	Port of Bergen	Harbour fee, Port charge, Wharfage dues	Rebate	ESI, LNG Fuel, Shore Power Connection
FR	Port of Le Havre / Paris / Rouen	Port dues	Rebate	ESI
FR	Atlantic Port La Rochelle	Port fee	Rebate	ESI
PT	Porte de Setúbal	Port dues	Rebate	Green Award Certificate
PT	Porto de Sines	Tariff of port use	Rebate	Green Award Certificate
PT	Portes do Douro e Leixoes	Tariff for port use	Rebate	Green Award Certificate
PT	Porto de Lisboa	Tariff for port use	Rebate	Green Award Certificate
SA	National Ports Authority of South Africa	Port dues	Rebate	Green Award Certificate

Country and Port		Charge Item	Green Incentive Scheme	Ship Rating System
JP	Ort of Tokyo	Port dues	Rebate	ESI
KR	Port of Busan	Port dues	Rebate	ESI
HK	Port of Hong Kong	Port facilities, Light dues	Rebate	ESI, Marine fuel (sulphur < 0.5%), LNG Fuel, Fuel approved by the Director of Environmental Protection, Greener technology, Shore Power Connection
ES	Port of Valencia	Vessel charge	Rebate	LNG Fuel
ES	Port of Algeciras	Vessel rate	Rebate	LNG Fuel